Guidelines for
Managing Salinity in Rural Areas

Contributions and acknowledgements

This document has been prepared by Landscape Management Technical Group – a cross agency group involving the NSW Office of Environment and Heritage and the Catchments Unit, Department of Primary Industries.

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The management actions contained in this document have evolved over a number of years.

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Cover photo: Using vegetation for recharge control adjacent to a salt site in the Cowra area (A. Wooldridge, DPI).

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Overview

This document provides salinity management guidelines to support Hydrogeological Landscape (HGL) classifications carried out in a number of areas across NSW. The guidelines are designed to help land managers identify functions of specific landscapes so they can select appropriate management strategies for salinity and target appropriate and practical management actions to specific areas (facets) identified within each HGL unit.

These guidelines relate specifically to salinity management in rural areas of NSW. While HGL classification can be and has been carried out in urban areas, management for salinity in urban and peri-urban areas is not considered in this document.

In addition to spatial mapping products, HGL classification outputs provide descriptions of individual hydrogeological landscape units including detailed management recommendations. The management areas, functions, management strategies and management actions described in the following pages are listed selectively in the individual HGL descriptions. This document provides the detail and program logic behind them. These guidelines should be read in conjunction with the specific HGL reports and spatial maps compiled for the area of interest in order to identify management areas on the ground.

This guidelines document will be dynamic and will be updated by the experts as they continue to map HGLs throughout NSW. Management options will be reviewed and added to through consultation with extension officers and land managers as they increase their understanding of how to best manage salinity in individual HGL units.

1. Introduction

1.1 Background

Dryland salinity is a serious problem that has affected many parts of Australia for a long time. Salinity is but one challenge among many that needs consideration in a complex environmental system. It is difficult making sound choices without a framework to inform the process; land managers have many decisions to make. The management system outlined in this document bridges the gap between understanding salinity science and effective on-ground management for biodiversity, ecosystem health and agricultural production.

In 2000, after many years of national discussion and concern around the issue of dryland salinity, CSIRO Land and Water released a document, *A Revolution in Land Use*, in which it states:

> "No single land use option will halt the growth of salinity and the loss of native biodiversity in our land and rivers. We need … a suite of novel land uses that are matched to the diverse climate, soils, and hydrological conditions of the basin.
>
> "Devising the optimal placement of these land uses in terms of salinity control, productivity and maintenance of native biodiversity will require a robust understanding of landscape process and ecosystem function, and good maps of landscape properties, particularly salt storage and groundwater flow."

Pinpoint tailoring of appropriate land use for salinity management should be a core objective of natural resource managers and land managers. It is a technique of matching appropriate land use to the best locations for management results that these guidelines and the complimentary hydrogeological landscape reports aim to satisfy.

Since 2000, a number of organisations have devised regional, state and national scale groundwater flow maps to provide broadscale hydrological understanding (Coram, 1998; Coram et al. 2000; Walker et al. 2003). The targeting of beneficial land use to control dryland salinity at specific locations on the ground is the next logical step. Variations in climate, soils, hydrology and salt stores occur down to the property scale. A system that enables land use recommendations to match this property scale variation is required if salinity is to be effectively managed.

1.2 Science and salinity management

Many workers in natural resource disciplines have asked how they can better influence land management decisions or have noted a decline in their influence on public thinking (Nelson 1998). In the *Ecological Principles and Guidelines for Managing the Use of Land*, Dale et al. (2000) found that "potential ecological consequences are not always considered in making decisions regarding land use."

Focus is often divided between scientists and land managers due to scales of operation. Innovations in land science are not necessarily or readily translated to a change in the way land managers do their business (Hulse & Ribe 2000). In many parts of Australia, extension officers help transfer knowledge to landholders, but often disjunct with scientists impedes this transfer. The reasons for this are varied – often the extension officer is too busy to search for new ways to do things unless the need is immediate and apparent. Scientists are often poor extension officers – they might relate well to other academics, but not to land managers. Information presented in journal papers and technical reports is often difficult to translate into on-ground actions appropriate for a particular site.

Environmental systems are complex enough to create challenges in making a management decision system simple enough to implement, but still produce effective results. The science and understanding of how a landscape functions is developing ahead of public perception. Consequently, our understanding about salinity and how to remediate and manage it is more sophisticated than is currently in the public domain.

Many science systems partition aspects of the biophysical world into manageable components. Soil landscapes (Atkinson 1993) link soils to landscapes. Groundwater flow systems (Engelen 1986; Coram 1996) perform a similar function for groundwater hydrology, as do vegetation formations (Keith 2004) for vegetation. Although each of these systems does an excellent job to partition aspects of the biophysical world into readily understandable portions, none of them individually translate into easily understood on-site management actions.

Management actions tend to be site specific, whereas science is often more general due to restrictions in time and resources. Thus, the disjunct between scientists and land managers may be more correctly viewed as a disjunct between an achievable understanding of the natural world and the selection of appropriate on-ground management actions.

The management system outlined in this document sets out a cost-effective method of bridging the gap between understanding salinity science and effective on-ground management for biodiversity, ecosystem health and agricultural production.

1.3 Hydrogeological landscapes

HGLs have been developed to characterise and manage the quality and distribution of water on the surface and within the near-surface zone of the earth. HGLs build on the existing Groundwater Flow System (GFS) framework which was developed largely for salinity management (Coram 1998, Coram et al. 2000, Walker et al. 2003). The GFS framework was largely complied from geological maps, supplemented by hydrological and topographic data. Groundwater flow system map units subdivide the landscape into areas with similar groundwater flow and salinity characteristics.

The HGL concept further develops and improves GFS with the systemic inclusion of landforms, regolith (including soils) and elements of structural geology (Wilford et al. 2008a; Wilford et al. 2010). ‘Hydrogeological’ highlights the important components of water and geology whereas ‘Landscape’ highlights the importance of landforms and regolith to define the hydrological regime. Similar frameworks in North America have used a landscape approach to delineate hydrological systems to manage groundwater and surface water resources (Winter 2001). HGL units accordingly integrate information on lithology, bedrock structure, regolith (including soils), landforms and contained hydrologic systems. A HGL unit is therefore a broad, all-encompassing entity that describes many hydrological parameters including water flow (surface, shallow lateral and groundwater flow), storage and quality that can be used to support a range of natural resource management (NRM) applications including ones for land salinisation.

The process of defining HGLs evolved through studies in the Bet Bet catchment, central Victoria (Wilford et al. 2007) and the Central West catchment in NSW (Wilford et al. 2008b). HGLs are imbedded into a hierarchical mapping system to address the importance of landscape scale, both from a hydrological and management perspective. The rational here is that both hydrologic and management components are intrinsically linked across different scales, e.g. most flow systems are nested within larger ones and most local land management strategies ideally need to be integrated into regional programs and goals (Wilford et al. 2008a).

Environmental systems can be viewed within a landscape as both interlinked and hierarchical. They can, therefore, be defined at different scales and linked to other environmental parameters.

The HGL model is a hierarchical system in which smaller landscape mapping units are nested within larger mapping units. The HGL mapping hierarchy is described in Wilford

(2008a) and is summarised in Table 1. A hierarchical approach to landscape assessment partially overcomes scale issues which restrict other systems. The benefits of an hierarchical approach have been discussed by others, for example, Wright (1996), Wielemaker et al. (2001), Wits and Dorren (2004) and Scott and Pain (2008).

At the local scale, mapping hierarchy uses the link between salinity and landform to interpret the complexity of the landscape by presenting information in terms of readily understood landform features (crests, footslopes, floodplains etc). These can be linked to specific land management actions.

Table 1: Hydrogeological mapping hierarchy (Wilford 2008a).

Level	Hydrogeological landscapes	Characteristic dimensions	Description or defining attributes	Map scale	ASRIS order
1	Division	30 km	Broad physiography, climate and geology	1:10 million	Division
2	Region	10 km	General hydrological areas defined by similar geology, climate & physiography	1:2.5 million	Province
Mapping hiatus Levels above are based on continental scale subdivisions. Levels below are formed by either aggregation or disaggregation of mapping units.					
3	Province	3 km	Landscapes with similar physiography (relief/slope), geology, regolith & climate	1:1 million	Zone
4	Association	1 km	Hydrological groups with similar landform, bedrock & regolith types	1:250 000	District
5	System	300-100 m	Local landform and bedrock types. Includes topo-sequences and catenas	1:100 000 1:25 000	System
Below this level parts of a flow system cell are described					

Level	Hydrogeological landscapes	Characteristic dimensions	Description or defining attributes	Map scale	ASRIS order
6	Facet	30-3 m	Landform/hydrological components. Parts of a topo-sequence/catena (e.g. mid-slope)	1:100 000 1:25 000 1:10 000	Facet
7	site	<10 m (x,y) or >10 m (z)	Hydrological properties, surface condition, borehole description	NA	Site

The original HGL study carried out in the Central West CMA area (Wilford et al. in prep) was a collaboration between Geoscience Australia and the NSW Department of the Environment, Climate Change and Water, with the former providing mapping expertise and the latter land management expertise. This study was the foundation for a program to develop HGLs across NSW, developed by OEH in tandem with the NSW Department of Primary Industries in 2007, to answer the need for a detailed understanding of landscape processes. It has since been rolled out across a number of areas in NSW at regional, local and property scales (Figure 1).

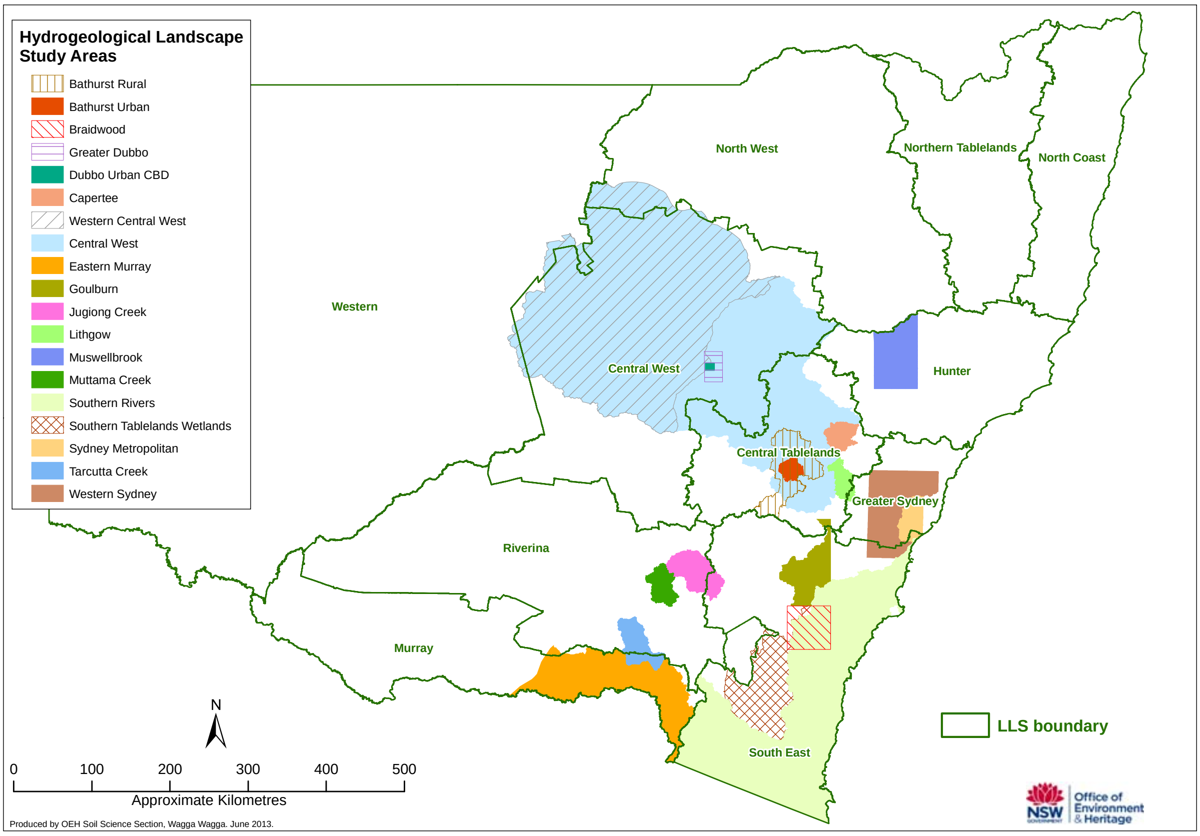

Figure 1: HGL studies areas at a range of scales across NSW as of June 2013.

The HGL program produces maps, cross section profiles and descriptions of differentiated HGL units and compartmentalises landscape facets into discrete management areas. This enables land assessment to target the management of dryland salinity at the appropriate scale. Wherever possible, soil/regolith and stream salinity measurements are used to calibrate and quantify salt load/store and discharge characteristics within each HGL unit.

A study area is divided into HGL units based on ‘like’ biophysical characteristics and ‘like’ salt responses. The biophysical characteristics used to determine an HGL include geology, hydrology, climate, landform, soil and vegetation (Figure 2). Salt responses include salt stores, relative mobility of salt within the landscape, water movement through the landscape, occurrence of dryland salinity, and salt type and salinity level within streams.

Once HGLs or any other landscape understanding models are formulated, a framework is required to bridge the gap between landscape understanding and landscape management. This document sets out the HGL management framework which is continuing to be rolled out across NSW. It describes specific land use management recommendations targeted at specific points in the landscape. This document provides detailed descriptions of the functions, strategies, management actions and high hazard land uses referred to in a range of HGL reports.

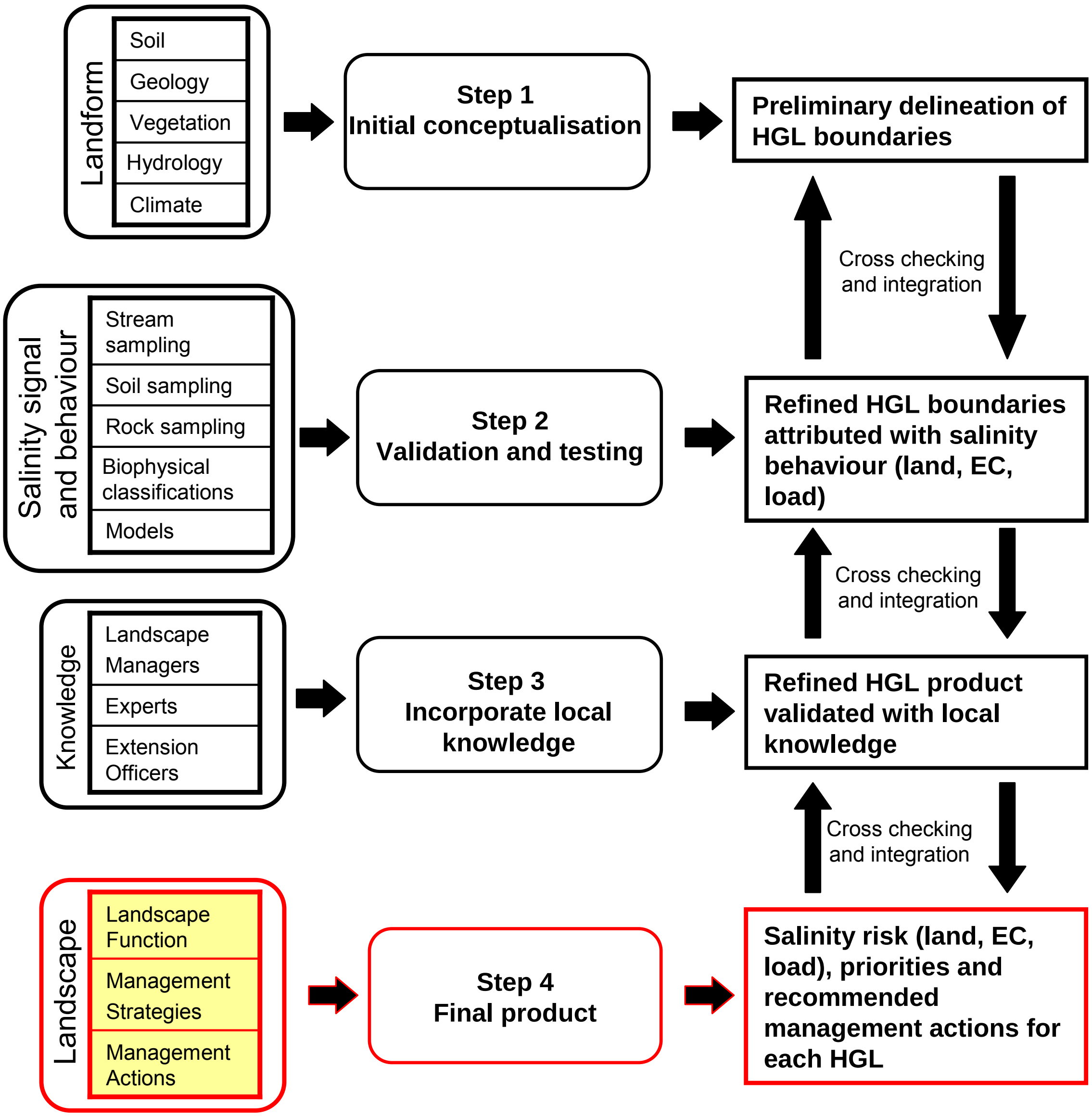

Figure 2: Illustration of the HGL concept. The management system informs Step 4 and is outlined in red.

1.4 Document structure

There are a number of management related components that make up the management structure outlined in this document. They include:

Section 2	Management areas explained in terms of the HGL concept, terminology and conceptual cross sections
Section 3	An overview of the management framework structure including summaries of landscape functions, management strategies and management actions
Section 4	Management strategies are set out in full with assumptions, constraints and the management actions required to deliver on a strategy
Section 5	Management actions are described in detail with groups, aims, opportunities, constraints, logistics design and, where possible, examples
Section 6	In certain circumstances a land use may prove to be highly hazardous for salinity. These potentially hazardous activities are described in terms of scale of impact and potential mitigating actions.

In essence, Sections 2 and 3 describe the building blocks for understanding landscapes characteristics and how these influence salinity manifestation. Sections 4 to 6 detail the program logic that a land manager can use to determine how and why specific management actions will produce positive salinity outcomes.

2. Management areas

Management areas are defined as areas of land within a HGL that can be managed in a uniform manner. They enable the linkage between landscape and targeted management and they operate at the scale of landform facets (crest, upper slopes, footslopes, floodplains etc). For ease of comparison, management areas have been standardised (Table 2).

Table 2: Management areas.

Management area	Description
MA 1	Crest or ridge
MA2	Upper slope – erosional
MA3	Upper slope – colluvial
MA4	Mid slope
MA5	Lower slope – colluvial
MA6	Rises
MA 7	Saline site
MA 8	Structurally controlled saline sites
MA 9	Alluvial plains
MA 10	Alluvial channels

The management area concept allows a complex suite of management actions to be directed to the appropriate part of a landscape. Management areas can be represented spatially on a map, or as a conceptual cross-section (figure 3). The management areas are based in part on terminology used in the *Australian Soil and Land Survey Field Handbook* compiled by the National Committee on Soil and Terrain (NCST 2009).

Where detailed HGL studies are being carried out, extra management areas may be defined to target specific features in the localised landscape.

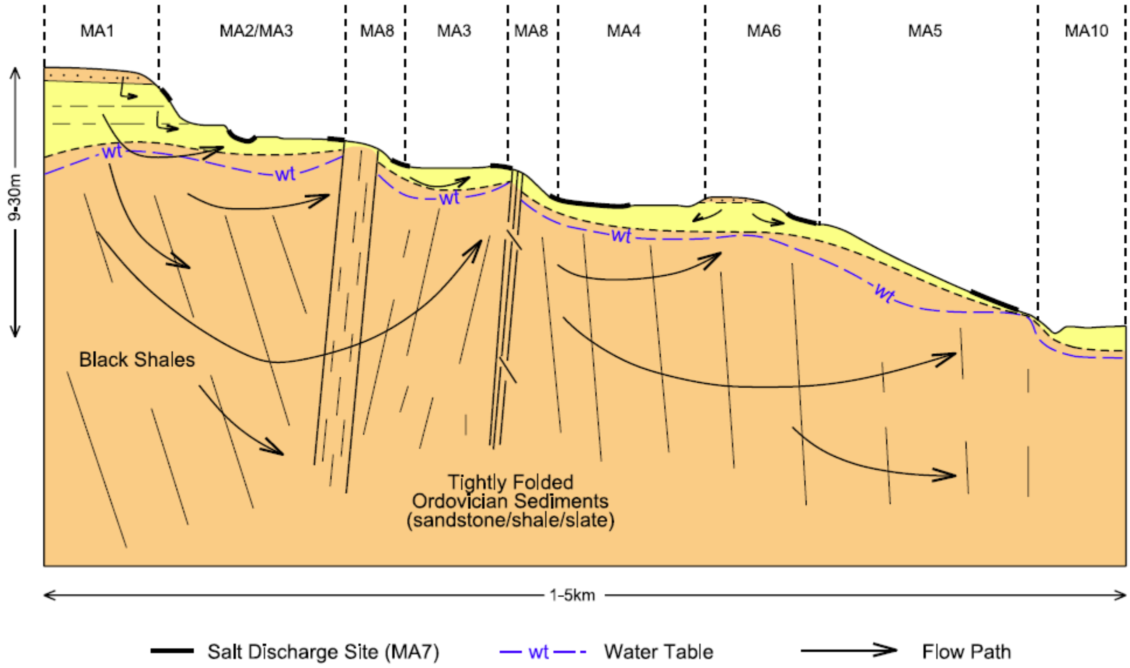

Figure 3: Cross section illustrating a series of management areas across a landscape.

The link between salinity, landforms and other biophysical features makes it possible to manage environments as landscape units. Linking management to landform facets is possible as many biophysical factors, relevant to effective land management, are relatively standard across a facet. These include: slope, climate, soil type, soil depth, lithology, geological structure, rock out crop and landscape limitations.

3. Management framework

3.1 Structure

The management framework provides a way to help assign optimal management actions to discrete parts of the landscape. The framework identifies the relevant landscape function and appropriate management strategy. The location and specific nature of the management actions are then defined at the local scale using management area concepts. The management framework can be applied to most landscape mapping systems. For the purposes of this document, the landscape mapping system is the HGL framework.

The following sequential structure is used in each HGL unit:

landscape function > management strategy > management action

Each of these is discussed below.

Different management actions are applied to different parts of the landscape (management areas). Typically, the landscape function level corresponds with the catchment (greater than or equal to 1:250 000 scale); management strategy corresponds with the landscape (approximately 1:100 000 scale) and management area to the facet (1:10 000 scale or less). Once biophysical characteristics are recognised and organised using this structure the management actions for each management area can be selected (Figure 4).

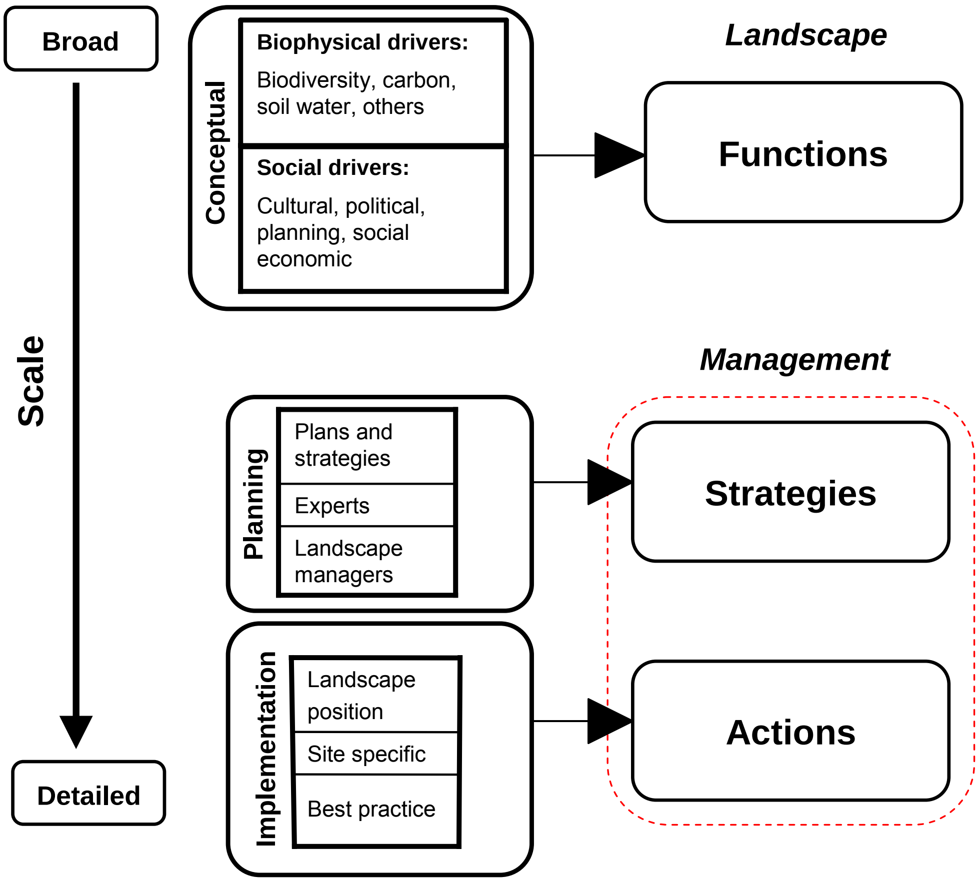

Figure 4: Scale and level of landscape functions and management strategies and actions as used in HGL.

3.2 Landscape function

Landscape function is the highest order within the hierarchical HGL structure. Functions are inherent biophysical characteristics of a landscape which impact upon catchments (Table 3). They will have impacts beyond the HGL. Effective salinity management involves understanding how landscape functions are maintained, improved or degraded. A HGL may provide one or more functions in a catchment.

Table 3: Landscape functions.

Function	Description
A	The landscape provides fresh water runoff as an important water source
B	The landscape provides fresh water runoff as an important dilution flow source
C	The landscape provides important base flows to local streams
D	The landscape generates salt loads which enter the streams and are redistributed in the catchment
E	The landscape receives and stores salt load through irrigation or surface flow
F	The landscape generates high salinity water that doesn't enter local streams

Function	Description
G	The landscape contains important land assets (including infrastructure and high value agricultural land) on which salinity processes impact
H	The landscape contains high hazard for generating sodic and saline sediments
I	The landscape contains high hazard for acid sulfate processes

It is important to understand that application of inappropriate management strategies and actions can negatively impact on landscape function and overall landscape resilience.

3.3 Management strategy

Management strategies are aimed at maintaining or improving landscape functions. One or more strategies may be applicable to any landscape. The 11 salinity management strategies are outlined in Table 4 and discussed in detail in Section 4. Recharge refers to water that percolates through to groundwater. Increased recharge can lead to rising water tables and mobilise salt stored in the soil. Discharge refers to groundwater that is seeping into streams or to the land surface. On the land, it is often expressed as areas of waterlogging. Salt sites may occur as a result of evaporation.

Table 4: Management strategies.

Strategy	Description
Strategy 1	Buffer the salt store – keep it dry and immobile
Strategy 2	Intercept shallow lateral flow and shallow groundwater
Strategy 3	Stop discrete landscape recharge
Strategy 4	Discharge rehabilitation and management
Strategy 5	Increase agricultural production to dry out the landscape and reduce recharge
Strategy 6	Dry out the landscape with diffuse actions over most of the landscape
Strategy 7	Access and use groundwater to change the water balance
Strategy 8	Maximise recharge to dilute water tables and minimise runoff to streams
Strategy 9	Minimise recharge in lower parts of the landscape and maximise runoff to streams
Strategy 10	Maintain or maximise runoff
Strategy 11	Manage and avoid acid sulfate hazards

3.4 Management actions

Management actions deliver management outcomes. Detailed specific management actions are assigned to appropriate management areas, ensuring that the management options are applicable to any given part of the landscape.

The dynamics of a management action may vary. Sometimes the action is very suitable for delivering on a strategy, but unsuited to deliver on a different strategy. Management actions are assessed for suitability and priority for salinity management within the landscape. A management action which is suitable for salinity management in one landscape may be unsuitable or ineffective in another. Combinations of management actions are tailored in accordance with the management strategy objectives. There are more than 50 defined management actions. The list is not exhaustive and new management actions or land management techniques are added as required. New techniques, technologies or discoveries offer new management options. New localities offer new challenges that may require management actions that have not yet been identified.

A background to landscape salinity management is given in Appendix A. Further information on the management of salt affected land is provided in Appendix B.

The management actions shown in Table 5 have been grouped as follows:

- VE Vegetation for ecosystem service
- VP Vegetation for production
- FS Farming systems
- SA Soil ameliorants
- E Engineering
- IS Irrigation systems
- SR Salt land rehabilitation
- AS Acid sulfate hazards.

Each of the management actions is discussed in detail in Section 4.

Table 5: Groups of management actions.

Management action group	Code	Management action
Vegetation for ecosystem service	VE1	Establish and manage blocks of trees to reduce recharge
	VE2	Establish and manage trees to intercept lateral groundwater flow
	VE3	Maintain and improve existing native woody vegetation to reduce discharge
	VE4	Maintain and improve riparian native vegetation to reduce discharge to streams
	VE5	Establish and manage trees that are integrated into farming logistics to reduce recharge
	VE6	Revegetate non-agricultural land with native species to manage recharge
	VE7	Use targeted planting of trees to buffer salt stored in geological layers

Management action group	Code	Management action
Vegetation for production	VP1	Improve grazing management of existing perennial pastures to manage recharge
	VP2	Establish and manage perennial pastures to manage recharge
	VP3	Establish and manage perennial pastures to intercept shallow lateral groundwater flow
	VP4	Maximise agricultural production from pastures by input of additional ameliorants to manage recharge
	VP5	Improve grazing management to improve or maintain native pastures to manage recharge
	VP6	Establish and manage blocks of perennial forage shrubs to manage recharge
	VP7	Establish commercial forestry to manage recharge
	VP8	Establish and manage farm scale forestry integrated into farming logistics to reduce recharge
	VP9	Establish and manage perennial horticulture to manage recharge
Farming systems	FS1	Implement pasture cropping with annual cereals in perennial pastures to manage recharge
	FS2	Maximise agricultural production by using ameliorants in annual cropping systems to manage recharge
	FS3	Implement rotational cropping with a perennial pasture component to manage recharge
	FS4	Implement opportunity cropping with annual crops and green manures to manage recharge
	FS5	Deep rip soil to improve soil structure and manage recharge
	FS6	Implement zero-till farming systems to increase soil water storage, soil water use and to reduce recharge
	FS7	Implement controlled traffic farming systems to increase soil water storage , soil water use and to reduce recharge
	FS8	Implement no-till farming systems to increase soil water storage, soil water use and to reduce recharge

Management action group	Code	Management action
	FS9	Implement reduced-till farming systems to increase soil water storage, soil water use and to reduce recharge
	FS10	Implement direct-drill farming systems to increase soil water storage, soil water use and to reduce recharge
	FS11	Use green manures and manure crops to increase soil water storage, soil water use and to reduce recharge
Soil ameliorants	SA1	Ameliorate soil sodicity by adding gypsum to increase plant water use and reduce recharge
	SA2	Ameliorate soil sodicity by adding lime to increase plant water use, reduce recharge and manage discharge sites
	SA3	Ameliorate soil acidity by adding lime to increase plant water use, reduce recharge and manage discharge sites
	SA4	Improve soil health by applying biological agents to the soil to increase plant water use, reduce recharge and manage discharge sites
	SA5	Improve soil health by applying compost to increase plant water use, reduce recharge and manage discharge sites
Engineering	E1	Use groundwater to supplement or replace surface water for farm stock
	E2	Divert surface water to increase recharge in low lying areas and minimise runoff
	E3	Construct agricultural earthworks to maximise freshwater runoff and reduce recharge in low areas
	E4	Implement groundwater pumping and disposal
	E5	Manage stream flow to create dilution flows in regulated rivers
	E6	Manage flow cycles of rivers to periodically produce dry supply channels and streams
	E7	Install leaky weirs to slow streams and increase freshwater recharge
	E8	Construct diversion banks to connect streams with back plains to increase freshwater recharge

Management action group	Code	Management action
Irrigation systems	IS1	Manage on-farm irrigation to achieve best practice
	IS2	Manage irrigation supply systems to achieve best practice
	IS3	Establish effective effluent disposal systems specific to site conditions
Salt land rehabilitation	SR1	Fence and isolate salt land and discharge areas to promote revegetation
	SR2	Establish and manage salt land pasture systems to improve productivity
	SR3	Establish forestry systems on salt land to improve productivity
	SR4	Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation
	SR5	Establish and manage salt land grazing systems based on forage shrubs to improve productivity
	SR6	Pond water on dry scalds to promote revegetation
	SR7	Reduce animal impact on scalds by providing mineral supplements to stock
	SR8	Mulch sites to reduce evaporation and promote pasture growth
	SR9	Mulch sites using tactical animal impact
Acid sulfate	AS1	Improve or maintain the hydrological regime to keep acid sulfate soil saturated
	AS2	Isolate and improve acid sulfate soil sites

4. Detailed management strategy descriptions

Detailed information about each of the HGL management strategies is presented in this section. It provides the basis for land managers to determine appropriate management actions. This will achieve positive salinity outcomes in the landscapes they are interested in.

The information about each management strategy incorporates the following:

- Assumptions appropriate to the strategy
- Constraints relevant to the strategy
- Management actions appropriate to deliver on the strategy
- Examples of where this strategy is appropriate
- Questions to be considered as a means to 'test' the relevance of the strategy.

Strategy 1	**Buffer the salt store – keep it dry and immobile**

Assumptions for this strategy to be appropriate

- High stores of salt are in discrete places in the landscape
- Discrete salt stores are a low percentage of the overall landscape
- These high salt stores can be identified and targeted for works.

Constraints for this strategy to be appropriate

- Ability of vegetations to reduce water movement and salt mobilisation
- Factors which are limiting to plant growth such as soil type, soil health and climate.

Management actions suitable to deliver on this strategy

- Block plantings of trees or pasture usually low in the landscape
- VE1, VE5, VP2, VP7, VP8, VP9.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Do we know where there are areas of high salt stores in the landscape?
- Are these salt stores important for catchment scale salinity management?
- Can we change the characteristics of vegetation and landscape water use?
- Can we change the characteristics of vegetation and water use to mitigate the negative impacts of the salt store?
- Is lower runoff from this landscape appropriate for catchment water and salinity management?

Strategy 2	**Intercept shallow lateral flow and shallow groundwater**

Assumptions for this strategy to be appropriate

- High proportion of the water which is causing salinity processes is moving laterally
- Groundwater and subsurface flow is shallow – within root zone
- Interception zones can be identified and targeted for works
- No soil or climate limits to water being accessed and used by plants.

Constraints for this strategy to be appropriate

- Reduction in surface water volume may mean increase in stream salt concentration
- Limits to plant growth. What is the vegetation's ability to access and use lateral groundwater?

Management actions suitable to deliver on this strategy

- Interception tree plantings – at least 8 rows wide
- Interception Lucerne planting – at least 100m wide strips
- VE2, VP3, VP7, VP8.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Are salinity processes in this landscape driven by shallow groundwater and/or subsurface lateral flow?
- Do we know where and how to target this shallow groundwater and/or subsurface lateral flow?
- Is the salt derived from this landscape important for catchment scale salinity management?
- Can we design and implement actions to intercept shallow groundwater and/or subsurface lateral flow?
- Is lower runoff from this landscape appropriate for catchment water and salinity management?

Strategy 3	Stop discrete landscape recharge

- Assumptions for this strategy to be appropriate
- High recharge areas exist
- Salt store is diffuse in landscape
- High recharge zones are connected to salt store
- High recharge zones can be identified and targeted for works.

Constraints for this strategy to be appropriate

- Converting available moisture to plant water use will mean less runoff – lower surface water quantity
- Reduction in surface water volume may mean increase in stream salt concentration – lower surface water quality.

Management actions suitable to deliver on this strategy

- Block planting of trees or pastures usually high in the landscape
- Increased level of pasture management on areas with low levels of production – e.g. rocky ridges
- VE1, VE3, VP2.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Do we know where there are high recharge areas in the landscape?
- Are these high recharge areas important for catchment scale salinity management?
- Are these high recharge areas connected to salt stores which are important for catchment scale salinity management?
- Can we change the vegetation and water use characteristics over a large proportion of these high recharge areas?
- Is lower runoff from this landscape appropriate for catchment water and salinity management?

Strategy 4	Discharge rehabilitation and management

Assumptions for this strategy to be appropriate

- Surface or near surface wash off of salt is an important issue
- Land is important or assets are important
- Salt load in streams is NOT an important issue
- Salt concentration in streams is an important issue
- Discharge management will moderate or reduce salt discharge to streams
- Salt affected land will continue to degrade.

Constraints for this strategy to be appropriate

- Limits to plant growth. Soil conditions and climate can be a limiting factor
- Access to site.

Management actions suitable to deliver on this strategy

- Isolate affected area
- Address soil constraints
- Establish vegetation tolerant of waterlogging and salt
- SR1, SR2, SR3, SR4.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Are discharge areas contributing salt to streams?
- Is the salt entering streams from discharge sites important for catchment scale salinity management?
- Is the sediment entering streams from discharge sites important for catchment scale salinity management?
- Can we change the salt or sediment leaving discharge sites through rehabilitation?
- Are land based assets threatened by salinity discharge sites?
- Can we protect land based assets through rehabilitation and management of discharge sites?

Strategy 5	**Increase agricultural production to dry out the landscape and reduce recharge**

Assumptions for this strategy to be appropriate

- Agricultural productivity is the limiting factor for yearly water use
- Seasonal recharge is a major issue
- Diffuse actions over most of the landscape will have a big impact on recharge.

Constraints for this strategy to be appropriate

- Limits to plant growth. Soil conditions and climate can be a limiting factor.

Management actions suitable to deliver on this strategy

- Water efficient production systems
- Changes in techniques, inputs and assessment
- VP2, VP4, FS2, FS3, FS4.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Are there areas where the level of agricultural production is the major driver of deep drainage and salinity processes?
- Do we know where these areas are in the landscape?
- Are these areas important for catchment scale salinity management?
- Can we change water use capacity of vegetation by increasing agricultural production over a large proportion of these areas?
- Is less runoff from this landscape appropriate for downstream catchment water management?
- Is less runoff from this landscape appropriate for downstream catchment salinity management?

Strategy 6	**Dry out the landscape with diffuse actions over most of the landscape**

Assumptions for this strategy to be appropriate

- Plant water use at the landscape scale is the limiting factor for yearly water use
- Seasonal recharge is a major issue
- Soil can be dried out by vegetation to act as a buffer for wetter conditions.

Constraints for this strategy to be appropriate

- Long term recharge and episodic high rainfall may be important
- Soil types may not be able to buffer for wetter conditions.

Management actions suitable to deliver on this strategy

- Vegetation establishment and management
- Improve soil for increased water holding capacity and increased plant growth
- VE1, VE2, VE3, VE5, VE6, VP1, VP2, VP5, VP6, VP7, VP8, VP9, FS1, FS3, FS6.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Are these areas important for catchment scale salinity management?
- Are these diffuse landscape recharge areas connected to salt stores which are important for catchment scale salinity management?
- Can we change the vegetation/water use over a large proportion of these recharge areas?
- Is less runoff from this landscape appropriate for catchment water and salinity management?
- Is less runoff from this landscape appropriate for downstream catchment water management and salinity management?
- Is less runoff from this landscape appropriate for downstream catchment salinity management?

Strategy 7	Access and use groundwater to change the water balance

Assumptions for this strategy to be appropriate

- Relatively small changes in groundwater balance can influence on and off site impacts of the salinity processes
- Farm dams are adding to land salinity
- Surface water is needed as dilution flows.
- Constraints for this strategy to be appropriate
- High cost of infrastructure
- High level understanding of groundwater and landscape required.

Management actions suitable to deliver on this strategy

- Engineering action to complement soil and vegetation actions
- Use shallow groundwater as farm stock supply
- E1.

Example of where this strategy is appropriate

- Ordovician shales and volcanics, particularly where grazing management change is occurring.

Mainly ‘yes’ answers to the following questions would indicate that this is an appropriate strategy.

- Are these areas important for catchment scale salinity management?
- Are these areas important for local scale salinity management?
- Is there a high of understanding of groundwater dynamics in the proposed area?
- Is groundwater suitable for proposed uses – quantity and quality?
- Are vegetation/land management based management actions being applied concurrently?
- Are changes in land management resulting in less surface water runoff for on farm use?
- Is lower runoff from this landscape appropriate for downstream catchment water management and salinity management?
- Is lower runoff from this landscape appropriate for downstream catchment salinity management?

Strategy 8	Maximise recharge to dilute water tables and minimise runoff to streams

Assumptions for this strategy to be appropriate

- Landscape is not important for dilution flows
- Surface water supply is low priority
- Low salt stores in low parts of landscape – low risk of salinity by maximising recharge
- It is possible to direct water out of and back to streams without degrading riparian zone.

Constraints for this strategy to be appropriate

- Increased recharge in alluvial landscape component will increase discharge further down stream
- Alluvial and riparian zone must be perennial woodland/grassland
- Erosion issues at exit and re-entry point of water on stream.

Management actions suitable to deliver on this strategy

- Engineering action to complement soils and vegetation actions
- Directing stream flow to seasonally flood low areas of the landscape
- E2.

Mainly ‘yes’ answers to the following questions would indicate that this is an appropriate strategy.

- Are these areas important for catchment scale salinity management?
- Is salt exiting the landscape through the alluvial plains?
- Do water tables in the alluvial parts of the landscape have low salinity?
- Are water tables in the alluvial parts of the landscape NOT under upward pressure?
- Are we confident that groundwater systems on the alluvial part of the landscape will not mobilise salt stores on or offsite?
- Can we change the vegetation/water use over a large proportion of these recharge areas?
- Are changes to stream flow and less runoff to streams from this landscape appropriate for catchment water and salinity management?

Strategy 9	**Minimise recharge in lower parts of landscape and maximise runoff to streams**

Assumptions for this strategy to be appropriate

- Landscape is important for water supply and dilution flows
- Low lying areas of landscape have salt land outbreaks and erosion
- Low lying areas of landscape have high seasonal recharge and this recharge is an important component of water balance
- It is possible to direct water to streams without degrading the riparian zone.

Constraints for this strategy to be appropriate

- Earthworks are difficult to maintain in waterlogged, saline and sodic environments. These areas are frequently in flow lines and require careful consideration and planning to avoid gully and other forms of erosion
- Tunnelling of earthworks in saline and sodic soils
- Access to sites.

Management actions suitable to deliver on this strategy

- Engineering actions to complement soil and vegetation actions
- Intercept surface water above saline areas and direct it to streams
- Use of banks and drop structures
- E3, SR1, SR2, SR3, SR4.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Are these discharge areas important for catchment scale salinity management?
- Is seasonal waterlogging of saline areas an important driver of salinity processes?
- Can saline land rehabilitation be done on the saline land when water is redirected?
- Can engineering structures be safely constructed?
- Is surface water runoff and stream flow from this landscape important as a dilution flow or as a water source in catchment water and salinity management?

Strategy 10	Maintain or maximise runoff to streams

Assumptions for this strategy to be appropriate

- Landscape is important for water supply and dilution flows
- Possible to direct water to streams without degrading riparian zone.

Constraints for this strategy to be appropriate

- High level of understanding of catchment water processes and the required dynamics
- Benefits are mostly down catchment – obtaining landholder assistance for works which provide low on farm benefits
- Salinity may be a low priority issue within these landscapes.

Management actions suitable to deliver on this strategy

- Maintaining current runoff characteristics by managing land use change
- Engineering actions to complement soil and vegetation actions
- Intercepting surface water above saline areas and directing to streams
- Use of banks and drop structures
- E3, E5.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Is surface water runoff and stream flow from this landscape important as a dilution flow or as a water source in catchment water and salinity management?
- Can runoff characteristics be safeguarded through intervention?
- Are these discharge areas important for catchment scale salinity management?
- Can engineering structures be safely constructed?

Strategy 11	Manage and avoid acid sulfate hazards

Assumptions for this strategy to be appropriate

- Some parts of some landscapes contain areas of potential acid sulfate soils and/or current acid sulfate soils
- That preventative actions can be taken to minimise the impact of acid sulfate processes
- There are differences between coastal and inland processes
- That inland acid sulfate soils are often accompanied by dryland salinity sites.

Constraints for this strategy to be appropriate

- High level of understanding of acid sulfate processes is needed
- Salinity may be a medium to low priority issue within these landscapes.

Management actions suitable to deliver on this strategy

- Maintaining current characteristics by managing land use change
- Vegetation and/or soil actions to rehabilitate or maintain
- Identifying acid sulfate prone areas and avoiding unsuitable urban, agricultural and infrastructure development
- S1, AS2, E2, E7, E8.

Mainly 'yes' answers to the following questions would indicate that this is an appropriate strategy.

- Is there known acid sulfate hazard or potential hazard?
- Are current acid sulfate processes impacting on land or water resources?
- Can negative impacts be minimised though intervention?

5. Detailed management actions

This section presents detailed information on each of the 54 currently defined management actions for rural areas.

Each description incorporates information about the following:

- Management action group
- Aim of the management action
- Opportunities – where the greatest impact on salinity processes may be achieved
- Constraints – relevant to the action and the location of the action
- Logistics – what you target and what you should understand about the landscape
- Design – what the action may look like and design considerations
- Example – how the action may be implemented.

The list below in not exhaustive and new management actions or land management techniques can be added over time after assessment of their efficacy in delivering on strategies.

Management action group – Vegetation for ecosystem service		**Code**
Management action	**Establish and manage blocks of trees to reduce recharge**	**VE1**

Trees planted in large blocks (greater than 2 ha) to use available water and reduce recharge.

Opportunities – biggest impact on salinity

- Discrete high recharge areas where trees can effectively use water and grow to reduce recharge
- Groundwater flow systems where processes are local and response times are short.

Constraints – smallest impact on salinity

- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape.

Logistics

- Target suitable areas – usually those with low levels of agricultural production
- A moderate understanding of landscape processes is required in order to target appropriate areas – landscape assessment is needed.

Design

- Plant blocks of trees at suitable locations.

Example

- Area is identified as suitable through EMI (Electro-Magnetic Induction) survey, soil testing and landscape position
- Rocky ridges are planted with a mixture of eucalypts and native understorey species
- The planting area is 500 m long and 80 m wide and several hundred metres from the nearest salt land outbreak.

Management action group – Vegetation for ecosystem service		**Code**
Management action	**Establish and manage trees to intercept lateral groundwater flow**	**VE2**

Trees planted at specific points in the landscape to intercept shallow laterally flowing groundwater.

Opportunities – biggest impact on salinity

- Where groundwater flow is shallow
- Where solid rock is close to the surface – some granite, basalt, rhyolite
- Soils with texture contrast between the A and B horizons, or with other physical barriers to water movement through the profile
- Where groundwater processes are well understood.

Constraints – smallest impact on salinity

- Groundwater flow systems where shallow lateral groundwater flow is only a small contributor to the salinity process
- Where tree planting design is driven by factors other than interception planting.

Logistics

- Needs to be targeted at specific areas in the landscape.

Design

- 8-15 rows of trees wide at suitable locations.

Example

- Area is identified as suitable through EMI survey and soil testing
- Area just above the break of slope (top of colluvial material) is planted with a mixture of eucalypts and understorey species
- The planting area is 300 m long 40 m wide and several hundred metres from the nearest salt land outbreak.

Management action group – Vegetation for ecosystem service		Code
Management action	**Maintain and improve existing native woody vegetation to reduce discharge**	**VE3**

Protect and enhance native vegetation, especially woody vegetation, to use available water and reduce groundwater recharge.

Opportunities – biggest impact on salinity

- Discrete high recharge areas supporting remnant native vegetation
- Groundwater flow systems where processes are local and response times are short.

Constraints – smallest impact on salinity

- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape
- Areas with little existing native vegetation
- Landscapes where the existing native vegetation does not occur on significant recharge areas.

Logistics

- Target suitable areas with low levels of agricultural production and the potential to significantly improve the extent and quality of protected and managed native vegetation
- Identify and target areas where extensive native vegetation is currently ‘managing salinity’ and where any change to this vegetation could result in a major impact on the salinity situation
- A moderate understanding of landscape processes is required in order to target appropriate areas – landscape assessment is needed.

Design

- Fence remnant vegetation and manage trees and understorey species to promote regeneration
- Plant additional trees or shrubs at suitable locations.

Example

- A vegetation/salinity assessment is conducted for a group of farmers
- Area is identified as suitable through EMI survey and soil testing
- Remnant areas of native vegetation of high conservation value are identified and protected

Areas of high value remnant native vegetation which correspond with high recharge areas and current or potential discharge areas are targeted for improved management.

Management action group – Vegetation for ecosystem service		Code
Management action	**Maintain and improve riparian native vegetation to reduce discharge to streams**	**VE4**

Protect and enhance native vegetation, particularly woody vegetation, to use available water and reduce discharge to streams.

Opportunities – biggest impact on salinity

- Where there is a strong connection between shallow groundwater and base flow in streams
- Areas with incised drainage patterns
- Where vegetation can effectively use groundwater to moderate salinity entering streams through base flow
- Groundwater flow systems where processes are local and response times are short
- Where a high proportion of groundwater flow is shallow
- Where solid rock is close to the surface – some granite, basalt, rhyolite
- Soils with texture contrast between the A and B horizons, or with other physical barriers to water movement through the profile
- Where groundwater processes are well understood.

Constraints – smallest impact on salinity

- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape
- Groundwater flow systems where shallow lateral groundwater flow is only a small contributor to the salinity process
- Where riparian tree planting design is driven by factors other than interception
- Where riparian areas do not overlap with discharge areas.

Logistics

- Protect, manage and establish a range of suitable native species in riparian zones
- A moderate understanding of landscape processes is required to target appropriate areas – landscape assessment is needed.

Design

- Fence the riparian zone 30-100 m wide
- Plant both trees and shrubs
- Provide stock watering points.

Example

- A vegetation/salinity assessment is conducted for a group of farmers
- Area is identified as suitable through EMI survey, stream water testing and soil testing
- An incised creek is fenced to a minimum riparian width of 50 m
- Casuarinas, river red gum, yellow box trees and other recommended understorey plants are established
- Alternative watering points are provided so that stock do not need access to the riparian zone.

Management action group – Vegetation for ecosystem service		Code
Management action	**Establish and manage trees that are integrated into farming logistics to reduce recharge**	**VE5**

Trees planted in strips and small blocks (less than 2 ha) to use available water and reduce recharge.

Opportunities – biggest impact on salinity

- Discrete high recharge areas where trees can effectively use water to reduce recharge
- Areas with a low proportion of perennial woody and non-woody vegetation
- Groundwater flow systems where processes are local and response times are short.

Constraints – smallest impact on salinity

- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape
- Where salinity processes are complex and poorly understood and it is difficult to effectively target small scale tree planting.

Logistics

- A moderate understanding of landscape processes is required to target appropriate areas – landscape assessment is needed.
- Design
- Plant 3-8 rows of trees along new and existing fence lines.

Example

- Target planting of strips of trees to divide land classes
- Target planting to provide multipurpose benefits
- Farm plan drawn up to create a program of small scale works
- Tree planting complements and adds value to other important land use changes – especially grazing management and soil management.

Management action group – Vegetation for ecosystem service		**Code**
Management action	**Revegetate non-agricultural land with native species to manage recharge**	**VE6**

Trees planted or regrowth managed in large blocks (greater than 2 ha) to use available water and reduce recharge. This action is appropriate when areas previously developed for agriculture are now considered more suited to providing salinity recharge or discharge management as an ecosystem service.

Opportunities – biggest impact on salinity

- Discrete high recharge areas where trees can effectively use water to reduce recharge
- Discrete high recharge areas where trees can effectively use water to reduce discharge
- Groundwater flow systems where processes are local and response times are short
- Discharge areas where trees or native vegetation can effectively use water and grow to reduce on-site and off-site impacts.

Constraints – smallest impact on salinity

- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape.

Logistics

- Target suitable areas – usually areas with low levels of agricultural production
- A moderate understanding of landscape processes is required to target appropriate areas – landscape assessment needed.

Design

- Plant trees or manage regrowth at suitable locations
- Ongoing management and protection of trees.

Example

- Area is identified as being suitable by EMI survey and soil testing
- An accessible area along a slope is planted with a mixture of eucalypts and understorey species
- The planting area is 500 m long by 80 m wide and several hundred metres from the nearest salt land outbreak
- Inaccessible areas are managed to promote regrowth of woodland species through the use of fire, clay seed bombs and grazing
- The inaccessible management area is 2500 m long by 150 m wide and several hundred metres from the nearest salt land outbreak.

Management action group – Vegetation for ecosystem service		Code
Management action	**Use targeted planting of trees to buffer salt stored in geological layers**	**VE7**

Trees planted in specific areas of the landscape to buffer salt stored in specific stratigraphic layers and structures within the underlying rocks.

Opportunities – biggest impact on salinity

- Where significant salt stores are located in specific geological layers
- Where there is a detailed understanding of groundwater processes
- Where there is a good understanding of geological and geomorphological processes
- Where salt stores can be influenced by changes in vegetation management.

Constraints – smallest impact on salinity

- Where limited understanding of landscape processes hinders successfully implementation of this management action
- Where tree planting design is driven by factors other than targeting salt stores
- Each situation is unique so it is difficult to identify suitable areas.

Logistics

- Needs to be targeted at specific areas in the landscape.

Design

- Geological formation containing salt store identified for targeting
- Map exposed rock outcrop and land surface contours at paddock scale
- Establish and maintain woodland vegetation to buffer salt store.

Example

- Area is identified as suitable by ground-truthing geological mapping and stratigraphy at a paddock scale
- EMI survey and soil testing
- A mixture of eucalypts and understorey species is planted along the specific geological outcrop within the target area
- The planting area is 1000 m long by 400 m wide and several hundred metres from the nearest salt land outbreak.

Management action group – Vegetation for production		Code
Management action	**Improve grazing management of existing perennial pastures to manage recharge**	**VP1**

Grazing management can have a large impact on the water use characteristics of plants in the landscape. Management should include tactical grazing practices which promote year-round plant growth and plant water use, and should promote species variety.

Opportunities – biggest impact on salinity

- Areas with an average annual rainfall of 450-700 mm
- Pastures containing a mix of annual and perennial species
- Pastures with a high proportion of native species.

Constraints – smallest impact on salinity

- High winter rainfall areas
- In shallow soils in cool and colder climates where evaporation rates are lower and plants have little ability to store and use water during winter.

Logistics

- Must combine infrastructure including fencing and water points with management skills to promote and enhance perennial pastures.

Design

- Paddocks split into areas suitable for active grazing management
- Take into consideration landscape, landform units and land capability when designing paddock layout.

Example

- Landholder expresses interest in developing more productive and healthy pastures
- Five large paddocks are split into 20 smaller areas based on water availability and landforms
- Landholder is supported to increase knowledge and skills in grazing management
- Stock are rotated through paddocks
- Grazing and rest/recovery periods implemented to promote life cycle of *Danthonia* and *Bothriochloa* grass species
- With ongoing support and training the landholder becomes confident with grazing systems.

Management action group – Vegetation for production		Code
Management action	**Establish and manage perennial pasture to manage recharge**	**VP2**

Establish perennial pasture to replace grazing and farming systems based on annual plants. Management should include grazing practices which promote year-round growth and water use.

Opportunities – biggest impact on salinity

- Areas with an average annual rainfall of 500-700 mm
- When periods of pasture growth overlap with periods of recharge and deep drainage.

Constraints – smallest impact on salinity

- High winter rainfall areas
- Cool and cold climates and shallow soils where plants have little ability to store and use water during winter
- When perennial pasture has been present for less than 10 years
- Methods to establish pasture may cause other negative impacts – bare ground, erosion, loss of biodiversity
- When management of pastures results in low leaf area index.

Logistics

- Combine species establishment with infrastructure including fencing and water points and management skills to promote and enhance perennial pastures
- Support and maintain pasture management which enhances perenniality and maximises water use.

Design

- Paddocks split into areas suitable for active grazing management
- Species established that provide prolonged growth in most seasons.

Example

- Landholder expresses interest in developing more productive and healthy pastures
- Five large paddocks are split into 20 smaller areas based on water availability and landform
- Landholder is supported to increase knowledge and skills in grazing management
- Stock are rotated through paddocks
- Landholder identifies areas which are most suitable for sowing pastures
- Landholder sprays establishment area with herbicide to remove competition
- Perennial based pasture mix established with minimum tillage practices
- Grazing and rest/recovery periods implemented to promote life cycle of pastures
- Landholder becomes confident with grazing systems with ongoing support and training.

Management action group – Vegetation for production		**Code**
Management action	**Establish and manage pastures to intercept shallow lateral groundwater flow**	**VP3**

Pastures (usually lucerne) are planted at specific points in the landscape to intercept shallow lateral flow of groundwater.

Opportunities – biggest impact on salinity

- Where a high proportion of groundwater flow is shallow
- Where solid rock is close to the surface – some granite, basalt, rhyolite
- Soils with texture contrast between the A and B horizons, or with physical barriers to water movement through the profile.

Constraints – smallest impact on salinity

- Groundwater flow systems where shallow lateral groundwater flow is only a small contributor to the salinity process
- Where soil conditions (e.g. acidic subsoils) are not suitable for deep rooted perennial pastures
- Climates where pasture is inactive at times of the year when moisture is present
- Areas with an annual rainfall in excess of 800 mm
- Areas with a large surplus of winter rainfall.

Logistics

- Needs to be targeted at specific areas in the landscape
- A detailed understanding of landscape processes is required to target appropriate areas.

Design

- Strips of pasture 100-300 m wide at suitable locations.

Example

- Area is identified as being suitable by EMI survey and soil testing
- Area just above alluvial slopes (base of colluvial material) is planted with a lucerne-base perennial mix including winter and summer active species
- The pasture planting area is 1500 m long by 400 m wide and is next to a waterlogged and salt affected area.

Management action group – Vegetation for production		Code
Management action	**Maximise agricultural production from pastures by input of additional ameliorants to manage recharge**	**VP4**

Maximise growth of annual and perennial pasture crops to use moisture which is available in the soil profile. This action is based on maximising water use in pasture systems by the addition of inputs so as to reduce potential recharge and salinity problems in the short term.

Opportunities – biggest impact on salinity

- Soils with heavy texture
- Soils without sub-surface constraints on plant growth
- Areas without a seasonal climatic constraint on plant water use
- Areas with an average annual rainfall less than 750 mm
- Where pasture land contributes a high proportion of recharge
- When the problems being ameliorated are the most limiting factor to plant water use and recharge control.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Areas with cold winters
- Areas with winter rainfall and crops of winter annuals
- Areas with a winter rainfall surplus
- Where cropping contributes a small proportion of recharge.

Logistics

- Monitor and understand soil moisture
- Understand and remediate chemical and physical constraints to plant growth.

Design

- Target heavy textured soils with pastures based on perennial plants
- Soil and plant tissue testing is used to identify limiting factors.

Example

- A pasture of phalaris and clover is targeted for additional production
- Sub-surface acidity and lack of available calcium is identified as the main constraint on plant growth
- Inputs are used to correct sub-surface acidity and pasture establishment programs are amended to include more acid tolerant species.

Management action group – Vegetation for production		**Code**
Management action	**Improve grazing management to improve or maintain native pastures to manage recharge**	**VP5**

Management should include grazing practices which promote species diversity and year-round growth and water use. Pasture management could also include the introduction of extra species by sowing and as seeds in mulch.

Opportunities – biggest impact on salinity

- Areas with an average annual rainfall of 300-700 mm
- Where the existing pasture base contains a mix of annual and perennial species
- Pastures with a high proportion of native species.

Constraints – smallest impact on salinity

- Areas with a high winter rainfall
- Cool and cold climates and shallow soils, where plants have little ability to store and use water during winter.

Logistics

- Combine infrastructure, including fencing and water points, with management skills to promote and enhance perennial pastures.

Design

- Split paddocks into areas suitable for active grazing management
- Take into consideration landscape, landform units and land capability when designing paddock layout.

Example

- Landholder expresses interest in developing more productive and healthy pastures
- Five large paddocks are split into 20 smaller areas based on water availability and landforms
- Landholder is supported to increase knowledge and skills in grazing management
- Stock are rotated through paddocks
- Grazing and rest/recovery periods implemented to promote life cycle of *Danthonia* and *Bothriochloa* grass species.
- Landholder becomes confident managing grazing system with ongoing support and training
- Landholder spreads *Microlaena* grass seed to enhance pasture.

Management action group – Vegetation for production		**Code**
Management action	**Establish and manage blocks of perennial forage shrubs to manage recharge**	**VP6**

This action involves establishing perennial forage shrubs to replace grazing and farming systems based on annual plants. Management should include grazing practices which promote year-round growth and water use. Shrubs are usually grown in dryland situations.

Opportunities – biggest impact on salinity

- Areas with an average annual rainfall of 300-700mm

Constraints – smallest impact on salinity

- High winter rainfall areas
- Cool and cold climates
- Shallow soils or other constraints to soil water storage and use by shrubs.

Logistics

- Combine species establishment with infrastructure, including fencing and water points, and management skills to promote and enhance perennial shrubs.

Design

- Paddocks split into areas suitable for active grazing management
- Species established which provide a long growth period in most seasons.

Example

- Five large paddocks are split into 20 smaller areas based on water availability and landform
- *Tagasaste* (tree Lucerne) is established as seedlings
- Stock are rotated through paddocks
- In eastern NSW, common species used include *tagasaste*, *Leucaena*, *Hardenbergia* species, saltbush species and some *Acacia* species
- Grazing and rest/recovery periods implemented to promote life cycle shrubs and also groundcover grass species (*Danthonia* and *Bothriochloa spp.)*
- With support and training the landholder becomes confident managing grazing systems.

Management action group – Vegetation for production		Code
Management action	**Establish commercial forestry to manage recharge**	**VP7**

Trees planted in large blocks (greater than 5 ha) usually as a monoculture to use available moisture and reduce recharge.

Opportunities – biggest impact on salinity

- Discrete high recharge areas where trees can effectively use water and grow so as to reduce recharge
- Groundwater flow systems where processes are local and response times are short
- Areas with low runoff and low average annual rainfall (less than 600 mm)
- Areas with an average annual rainfall over 900 mm
- Areas which contribute a large salt load to streams
- Large areas of salt land
- Where grazing management of a perennial pasture is less suitable and forestry is the most appropriate land use.

Constraints – smallest impact on salinity

- Negative impact – large scale forestry can change the water balance by using a high proportion of surface water runoff while also reducing recharge. This can adversely affect the salinity of local streams, the amount of water available for dilution flows, and water supply in a catchment.
- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs when plants are not actively growing
- Where recharge occurs diffusely across the landscape.

Logistics

- Target suitable areas – usually salt land with low levels of agricultural production and high salt load in streams
- A moderate understanding of landscape processes is required to target appropriate areas – landscape assessment needed.

Design

- Block planting of monocultures of trees at suitable locations.

Example

- Area is identified as suitable by assessment of local salinity processes and surface stream water flow
- Rocky ridge and high slopes planted with a mixture of eucalypts and pines
- Planting is 4000 m long by 1500 m wide and several hundred metres from the nearest salt land outbreak.

Management action group – Vegetation for production		Code
Management action	**Establish and manage farm scale forestry integrated into farming logistics to reduce recharge**	**VP8**

Trees planted in strips and small scale forestry blocks (2-20 ha) to use available water and reduce recharge.

Opportunities – biggest impact on salinity

- Discrete high recharge areas where trees can effectively use water to reduce recharge
- Areas with a low proportion of perennial woody and non-woody vegetation
- Groundwater flow systems where processes are local and response times are short.

Constraints – smallest impact on salinity

- Where the recharge occurs diffusely across the landscape
- It is difficult to effectively target small scale tree planting where salinity processes are complex and poorly understood
- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long.

Logistics

- Target suitable areas (see examples below)
- A moderate understanding of landscape processes is required to target appropriate areas – landscape assessment is needed.

Design

- Plant trees in rows and strips along ridges and new and existing fence lines. Tree belts are 10-40 rows wide (40-300 m).

Example

- Group of farmers undertake to plant 500 ha of trees in a cluster of 10 farms within 100 km of an existing processing mill
- Target planting of blocks of trees on high recharge areas
- Target planting of strips of trees to divide land classes
- Target planting to provide multipurpose benefits
- Farm plans drawn up to create a program of small scale works.

Management action group – Vegetation for production		**Code**
Management action	**Establish and manage perennial horticulture to manage recharge**	**VP9**

Establishing perennial horticulture to replace grazing and farming systems based on annual plants. Management should include minimal irrigation and be based on dryland production systems. Well managed irrigation practices should be used only as a backup. In eastern NSW, perennial horticulture often includes fruit trees, olives, nut trees, grape vines, lavender or jojoba.

Opportunities – biggest impact on salinity

- Areas with an average annual rainfall of 300-800 mm
- Where the growth cycle of the crop overlaps with annual recharge events
- Where new horticulture can replace farming systems based on annual plants.

Constraints – smallest impact on salinity

- A detailed understanding of landscape processes is required to successfully target this management action to benefit salinity
- Areas with high winter rainfall
- Cool and cold climates
- Shallow soils or other constraints to soil water storage and use by plants
- In areas with existing perennial native vegetation
- Poorly managed irrigation can increase recharge and negatively impact on salinity
- Deciduous crops have a high potential to increase recharge during winter.

Logistics

- Combine species establishment with infrastructure and best practice irrigation management
- A detailed understanding of landscape processes is required to successfully target this management action to benefit salinity.

Design

- Identify where replacing annual farming systems will have a significant impact on recharge
- Split paddocks into areas suitable for active grazing management as part of perennial horticulture systems
- Establish species which have a long growth period in most seasons.

Example

- Site assessment undertaken with EMI and soil testing
- Four ha of dryland olive trees established at top of a colluvial slope
- Olive paddocks split into areas suitable for active grazing management
- Grazing and rest/recovery periods implemented to promote life cycle of olive trees and also groundcover grass species (*Danthonia* and *Bothriochloa spp.)*
- With support and training the landholder becomes confident with perennial horticulture and grazing systems.

Management action group – Farming systems		Code
Management action	**Implement pasture cropping with annual cereals in perennial pastures to manage recharge**	**FS1**

This practice involves maintaining a perennial pasture while growing annual crops. Pasture cropping can have several outcomes within a grazing and farming system. Soil cover is maintained and areas maintain year-round water use. In favourable years a viable grain yield is obtained. In less than favourable years the annual crop sown becomes grazing yield.

Opportunities – biggest impact on salinity

- Areas with a high proportion of perennial pastures – particularly summer active
- Where mixed farming is practiced on areas where annual recharge is the main component of salinity processes.

Constraints – smallest impact on salinity

- Pastures with a low perennial species component
- Cool and cold climates and shallow soils, where plants have little ability to store and use water during winter.

Logistics

- Annual crops are sown into existing perennial pasture
- Usually winter cereals are sown into pasture dominated by summer growing native grasses
- Access is required to suitable sowing equipment.

Design

- Identify where mixed farming is practiced in areas where yearly recharge is an important for salinity processes
- Winter cereals are usually planted in autumn.

Example

- Gradational soils are targeted on a farm with salinity problems affected by recharge occurring in winter months
- Oats and barley are sown into pastures with a perennial base
- In favourable years a grain yield is obtained
- In less than favourable years the annual oats and barley are added to grazing yield.

Management action group – Farming systems		**Code**
Management action	**Maximise agricultural production by using ameliorants in annual cropping systems to manage recharge**	**FS2**

This action is based on the idea that maximising water use in annual cropping systems in the short term will reduce potential recharge and lessen salinity problems. This action also includes using ameliorants which address soil chemical or biological constraints.

Opportunities – biggest impact on salinity

- Soils with heavy texture
- Soils without sub-surface constraints on plant growth
- Areas without seasonal climatic constraints on plant water use
- Areas with an average annual rainfall of less than 500 mm
- Where cropping land contributes a high proportion of recharge.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with surplus rainfall in winter
- Where cropping land contributes a small proportion of recharge
- Where episodic recharge is not a contributor to salinity processes.

Logistics

- Monitor, understand and respond to changes in soil moisture
- Understand and address chemical and physical constraints to plant growth.

Design

- Target heavy textured soils which are cropped.

Example

- A cropping program based on winter cereals is underway
- Sub-surface acidity is highlighted as being the major constraint to plant growth
- Inputs are used to correct sub-surface acidity and cropping programs are amended to include more acid tolerant species.

Management action group – Farming systems		Code
Management action	**Implement rotational cropping with a perennial pasture component to manage recharge**	**FS3**

Annual crops are grown in rotation with sown perennial pastures. Moisture not used by the annual crop is used in the perennial pasture phase.

This action aims to dry the soil profile during the pasture phase. The cropping phase has the potential to fill up the soil profile with water and cause deep drainage.

It aims to add diversity to land use over time by farming a number of different crops.

Opportunities – biggest impact on salinity

- Heavy textured soils which allow water to stay in the root zone
- Areas with an average annual rainfall of less than 550 mm
- Soil and climate conditions which allow the pasture phase to dry out the soil profile.

Constraints – smallest impact on salinity

- Free draining soils
- High rainfall areas
- Cool and cold climates
- Areas with predominantly winter rainfall, or evenly distributed rainfall over 600 mm per year.

Logistics

- Cropping rotations are planned to manage soil nutrition and plant disease
- Soil moisture and climate guide decisions to reduce risk of deep drainage.

Design

- Cropping rotation is planned. Water balance and climate guide the decision to use a perennial pasture phase of phalaris
- Target soils with heavy texture which have a history of annual cropping programs linked to local recharge and salinity processes.

Example

- Cropping rotation is planned. Water balance and climate guide decisions to use a pasture phase in either year 3, 4 or 5.

Management action group – Farming systems		Code
Management action	**Implement opportunity cropping with annual crops and green manures to manage recharge**	**FS4**

Annual crops use moisture available in the soil profile. Usually a summer crop is grown within a winter cropping program.

This option is based on the idea that it is better to have plants using soil moisture than have the moisture potentially becoming recharge and adding to salinity problems.

Opportunities – biggest impact on salinity

- Soils with heavy texture
- In wet seasons.

Constraints – smallest impact on salinity

- Free-draining gradational soils
- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape.

Logistics

- Monitor, understand and respond to soil moisture conditions
- Use of controlled traffic equipment is ideal.

Design

- Target heavy textured soils in low areas.

Example

- A cropping program based on winter cereals is underway
- Excess moisture is found to be available after the growing season
- A summer legume crop is sown with the aim of providing organic matter to the soil and using the available moisture before it becomes recharge
- If additional adequate rain falls during the growing season the crop will provide a harvestable yield. If not, the crop is not harvested and becomes a mulch/green manure input to increase soil health.

Management action group – Farming systems		Code
Management action	**Deep rip soil to improve soil structure and manage recharge**	**FS5**

This action is based on the idea that improving soil structure by deep ripping will create conditions which maximise water use in annual cropping systems and pastures. It aims to increase plant water use and soil water storage to reduce potential recharge and salinity problems.

Opportunities – biggest impact on salinity

- Soils with structural constraints on plant growth
- Soils with structural constraints to water storage in the root zone
- Areas without seasonal climatic constraints on plant water use
- Areas with average annual rainfall less than 600 mm
- Where soils with structural constraints on plant growth contribute a high proportion of recharge.

Constraints – smallest impact on salinity

- Potentially negative impact – may increase recharge if other limitations to plant growth are not reduced
- Potentially negative impact – may cause tunnelling in soils with sodic A_2 or B_1 horizons
- Soils with bleached A_2 horizon
- Soils with A_1 horizons less than 20 cm deep
- Free draining gradational soils
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with surplus winter rainfall
- Where the ripped area contributes only a small proportion of recharge
- Onsite and offsite damage can occur if high intensity rainfall coincides with the ripping program
- Risk of damage to existing woody vegetation
- Risk of erosion unless contour ripping used.

Logistics

- Deep ripping with Yeomans style implements conducted during pasture/cropping rotation
- Monitor, understand and respond to soil moisture changes
- Understand and address climatic, chemical and physical constraints on plant growth.

Design

- Target heavy textured soils where previous land use practices have induced structure problems
- Monitor and understand soil moisture use and water movement
- Understand and address chemical and biological constraints on plant growth.

Example

- A cropping program based on winter cereals is underway
- Hardpan at a depth of 20 cm is identified as the main constraint on plant growth
- Deep ripping undertaken as part of cropping pasture rotation.

Management action group – Farming systems		Code
Management action	**Implement zero-till farming systems to increase soil water storage, soil water use and to reduce recharge**	**FS6**

This refers to one-pass disc seeding with less than 5 per cent topsoil disturbance.

This action addresses soil physical, biological and chemical constraints. It improves soil condition to maximise water use in production systems. It also improves soil water storage in the root zone and the potential for this water to be used by plants.

Opportunities – biggest impact on salinity

- Soils with heavy texture
- Areas without a seasonal climatic constraint on plant water use
- Areas with an average annual rainfall of less than 550 mm
- Where cropping land contributes a high proportion of recharge
- Areas with a long history of tillage – particularly inversion tillage
- Areas which have been managed as no-till systems (one-pass seeding using a narrow knife point or disc with 5-20 per cent soil disturbance) as a stepping stone towards a zero-till system
- Areas with significant groundcover
- Areas with good soil biological health and organic matter in the A horizon.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Where episodic recharge is a major component of salinity processes
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with a surplus of winter rainfall
- Where cropping land contributes to a small proportion of recharge
- Negative impact – recharge can increase if the soil and cropping program are not managed to control recharge
- Negative impact – recharge can increase if soil structural constraints are ameliorated before other limitations to plant growth and water use become effective
- Negative impact – if change to zero-till system results in cropping land expanding, the extent and intensity of landscape recharge may increase
- Soils with a high gravel content
- If soil disturbance during tillage is <u>not</u> the main limiting factor for plant growth
- A high level of grazing management is required to maintain groundcover.

Logistics

- Use disc seeding machine
- Reduced number of cultivations compared with multiple tillage systems
- Cultivations for weed control replaced with use of herbicide
- High level of groundcover maintained during cropping program.

Design

- Monitor, understand and respond to changing soil conditions
- Understand and address biological, chemical and physical constraints to plant growth.

Example

- Cropping land converted to zero-till through technical support and incentives
- Ongoing support to aid in monitoring of soil condition
- Ongoing support to aid implementation of zero-till system
- Cropping program decisions are informed by an understanding of soil moisture conditions.

Management action group – Farming systems		**Code**
Management action	**Implement controlled traffic farming systems to increase soil water storage, soil water use and to reduce recharge**	**FS7**

Field machinery is confined to using the same wheel tracks. This action keeps soil compaction to the wheel tracks and allows maximum soil health improvement between the tracks. It aims to improve soil condition and maximise growth of plants so as to use moisture in the soil profile. It also improves soil water storage in the root zone and increases the potential for plants to use this water.

Opportunities – biggest impact on salinity

- Where soil compaction from machinery is the biggest limiting factor to soil health and plant water use
- Where cropping land contributes a high proportion of recharge
- Soils with heavy texture
- Areas without seasonal climatic constraints on plant water use
- Areas with an average annual rainfall of less than 550 mm
- Areas with a long history of tillage – particularly inversion tillage
- Areas which have been managed as zero-till systems
- Areas with significant groundcover
- Areas with good soil biological health and organic matter in the A horizon.

Constraints – smallest impact on salinity

- If soil compaction due to machinery is not the main limiting factor for plant growth
- Free draining gradational soils
- Where episodic recharge is a major component of salinity processes
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with a surplus of winter rainfall
- Where cropping land contributes a small proportion of recharge
- Negative impact – recharge can increase if the soil and cropping program are not managed to control recharge
- Negative impact – recharge can increase if soil structural constraints are ameliorated before other limitations to plant growth and water use become effective
- Negative impact – if change to zero-till system results in cropping land expanding, the extent and intensity of landscape recharge may increase
- Soils with high gravel content.

Logistics

- Use disc seeding machine
- Tracks are designed and located with Geographical Positioning Systems (GPS) equipment
- GPS equipment is linked to auto-steer technology
- Reduction in number of cultivations compared with multiple tillage systems
- Cultivations for weed control replaced with herbicide
- High level of groundcover maintained during cropping program.

Design

- Monitor, understand and respond to changing soil conditions
- Need to understand and address biological, chemical and physical constraints on plant growth.

Example

- Cropping land converted to zero-till through technical support and incentives
- Ongoing support to aid in monitoring of soil condition
- Ongoing support to aid implementation of zero-till system
- Cropping program decision informed by understanding of soil moisture condition.

Management action group – Farming systems		**Code**
Management action	**Implement no-till farming systems to increase soil water storage, soil water use and to reduce recharge**	**FS8**

This refers to one-pass seeding using a narrow knife point or disc with 5-20 per cent soil disturbance.

This action addresses soil physical, biological and chemical constraints. It improves the soil condition allowing for maximum water use and crop growth in production systems. It also improves soil water storage in the root zone and the potential for plants to use this.

Opportunities – biggest impact on salinity

- Soils with heavy texture
- Areas without seasonal climatic constraints on plant water use
- Areas with an average annual rainfall of less than 550 mm
- Where cropping land contributes a high proportion of recharge
- Areas with a long history of tillage – particularly inversion tillage
- Areas which have been managed as reduced-till systems as a stepping stone to no-till systems
- Areas with significant groundcover
- Areas with good soil biological health and organic matter in the A horizon.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Areas where episodic recharge is a major component of salinity processes
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with a surplus of winter rainfall
- Where cropping land contributes a small proportion of recharge
- Negative impact – recharge can increase if the soil and cropping program are not managed to control recharge
- Negative impact – recharge can increase if soil structural constraints are ameliorated before other limitations to plant growth and water use become effective
- Negative impact – if change to no-till system results in cropping land expanding, the extent and intensity of landscape recharge may increase
- Soils with high gravel content
- If soil disturbance during tillage is <u>not</u> the main limiting factor for plant growth
- Need high level of grazing management to maintain groundcover.

Logistics

- Use of no-till equipment and farming systems.

Design

- Monitor, understand and respond to soil moisture changes
- Understand and address biological, chemical and physical constraints on plant growth.

Example

- Cropping land converted to no-till through technical support and incentive program
- Ongoing support to aid in monitoring of soil condition
- Cropping program decision informed by understanding of soil moisture condition.

Management action group – Farming systems		**Code**
Management action	**Implement reduced-till farming systems to increase soil water storage, soil water use and to reduce recharge**	**FS9**

This refers to one tillage pass before seeding with a full cultivation during seeding.

This action is better for soil than using multiple tillage but is still considered to have negative impacts on soil health. It does not address soil physical, biological and chemical constraints as well as no-till or zero-till systems.

Opportunities – biggest impact on salinity

- Where cropping land contributes a high proportion of recharge
- Soils with heavy texture
- Areas without seasonal climatic constraints on plant water use
- Areas with an average annual rainfall of less than 550 mm
- Areas with a long history of tillage – particularly inversion tillage
- Areas with significant groundcover
- Areas with good soil biological health and organic matter in the A horizon
- Where reduced till systems are seen as a stepping stone toward no-till systems.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Where episodic recharge is major component of salinity processes
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with surplus rainfall in winter
- Where cropping land contributes a small proportion of recharge
- Negative impact – recharge can increase if the soil and cropping program are not managed to control recharge
- Negative impact – recharge can increase if soil structural constraints are ameliorated before other limitations to plant growth and water use become effective
- Negative impact – if change to reduced-till system results in cropping land expanding, the extent and intensity of landscape recharge may increase
- Soils with high gravel content
- If soil disturbance during tillage is <u>not</u> the main limiting factor for plant growth
- Soils with self-mulching surfaces.

Logistics

- Reduction in number of cultivations from multiple-till systems
- Cultivations for weed control replaced by use of herbicide.

Design

- Monitor, understand and respond to changing soil conditions
- Understand and address biological, chemical and physical constraints to plant growth.

Example

- Cropping land converted to reduced-till through technical support
- Ongoing support to aid in monitoring of soil condition
- Ongoing support to aid progress towards no-till and zero til systems
- Cropping program decisions are informed by an understanding of soil moisture conditions.

Management action group – Farming systems		Code
Management action	**Implement direct-drill farming systems to increase soil water storage, soil water use and to reduce recharge**	**FS10**

This refers to one tillage pass seeding with full topsoil disturbance.

This action is better for soil than multiple tillage but is still considered to have negative impacts on soil health. It does not address soil physical, biological and chemical constraints as well as do no-till or zero-till systems.

Opportunities – biggest impact on salinity

- Where the cropping land contributes a high proportion of recharge
- Soils with heavy texture
- Areas without a seasonal climatic constraints on plant water use
- Areas with an average annual rainfall of less than 550 mm
- Areas with a long history of tillage – particularly inversion tillage
- Areas with good soil biological health and organic matter in the A horizon
- Where direct drill systems are seen as a stepping stone toward no-till systems.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Where episodic recharge is a major component of salinity processes
- Areas with cool winters
- Areas with winter rainfall and crops of winter annuals
- Areas with a surplus of winter rainfall
- Where cropping land contributes a small proportion of recharge
- Negative impact – recharge can increase if the soil and cropping program are not managed to control recharge
- Negative impact – recharge can increase if soil structural constraints are ameliorated before other limitations to plant growth and water use become effective
- Negative impact – if change to direct drill system results in cropping land expanding, the extent and intensity of landscape recharge may increase
- Soils with high gravel content
- If soil disturbance during tillage is <u>not</u> the main limiting factor to plant growth
- A high level of grazing management is required to maintain groundcover
- Soils with self mulching surfaces.

Logistics

- Reduction in number of cultivations compared with multiple tillage systems
- Cultivations for weed control replaced with herbicide.

Design

- Monitor, understand and respond to changing soil conditions
- Understand and address biological, chemical and physical constraints to plant growth.

Example

- Cropping land converted to direct-drill through technical support
- Ongoing support to aid in monitoring of soil condition
- Ongoing support to aid progress towards no-till system
- Cropping program decisions are informed by understanding of soil moisture conditions.

Management action group – Farming systems		**Code**
Management action	**Use green manures and manure crops to increase soil water storage, soil water use and to reduce recharge**	**FS11**

Annual plants are established to improve soil health and green manure crops are grown. These use moisture available in the soil profile and reduce recharge. This land management option is based on the idea that it is better to have plants using soil moisture and maintaining soil heath than leaving a soil bare and exposing it to erosion.

Opportunities – biggest impact on salinity

- Wet seasons
- Soils with heavy texture
- Where green manure crop will improve limiting soil conditions.

Constraints – smallest impact on salinity

- Free draining gradational soils
- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Where recharge occurs diffusely across the landscape
- Where pasture has a high perennial component
- Where green manure crops will have a limited impact on soil conditions.

Logistics

- Target areas where soil structure problems are the main limiting factor
- Monitor, understand and respond to soil moisture conditions
- Need access to soil, so controlled traffic equipment is ideal.

Design

- Target heavy textured soils in low areas.

Example 1

- Soil identified with structure problems
- Excess moisture is found to be available after the growing season
- A summer legume crop is sown to provide organic matter to the soil and to use available moisture before it becomes recharge
- If additional adequate rain falls during the growing season the crop will provide a harvestable yield. If not, the crop is not harvested and becomes a mulch/green manure input to increase soil health.

Example 2

- Soil identified with structure problems
- A winter cereal crop is sown to provide organic matter to use available moisture before it becomes recharge. Crop is slashed while green and left to break down on the soil.

Management action group – Soil ameliorants		**Code**
Management action	**Ameliorate soil sodicity by adding gypsum to increase plant water use and reduce recharge**	**SA1**

This action ameliorates surface soil sodicity by adding gypsum. Soil sodicity impacts on soil health and limits plant water use. Calcium in the gypsum displaces sodium on clay particles and stabilises them, reducing dispersion. Gypsum can have benefits as part of discharge site rehabilitation. Its soil health benefits increase plant water use and reduce recharge.

Opportunities – biggest impact on salinity

- Where soil sodicity is the main limiting factor for soil health and plant water use
- Soils with sodic surface soil – Exchangeable Sodium Percentage (ESP) above 6
- Soils with a pH greater than 7
- Soils with a texture of clay loam or heavier
- Where zero-till farming systems are used
- The greatest positive impact will occur where soil testing recommends a blend of gypsum and lime.

Constraints – smallest impact on salinity

- Where soil sodicity is a minor limiting factor for soil health and plant water use
- Gypsum is usually a short term ameliorant
- This is a complementary management action – it relies on appropriate management of tillage and grazing
- High level landscape and soil understanding is required for a positive outcome
- Low impacts on acid surface soil profiles.

Logistics

- Equipment and resources required to spread gypsum
- Monitor, understand and respond to soil conditions
- Understand and address chemical and physical constraints to plant growth.

Design

- Understand chemical and physical characteristics of the soil
- Determine appropriate rates of gypsum application and continue to apply over the long term. Target appropriate soil areas.

Example

- A discharge rehabilitation program is underway based on the establishment of salt tolerant pastures
- Surface sodicity is identified as a major constraint on plant growth
- Soil is tested to understand soil conditions
- Based on soil testing recommendations, granular gypsum is applied with a spreader
- Ongoing management of pasture is supported.

Management action group – Soil ameliorants		Code
Management action	**Ameliorate soil sodicity by adding lime to increase plant water use, reduce recharge and manage discharge sites**	**SA2**

This action ameliorates surface soil sodicity by adding lime. The calcium in the lime displaces sodium on clay particles and stabilises them, which reduces dispersion. Lime application can have major benefits as part of discharge site rehabilitation. It has soil health benefits which increase plant water use and reduce recharge.

Opportunities – biggest impact on salinity

- Where soil sodicity is the main limiting factor for soil health and plant water use
- Lime application can have major benefits in the rehabilitation of discharge sites
- Soils with sodic surface horizons – ESP greater than 6
- Soils with a pH less than 7
- Soils with a clay loam texture or heavier
- Where zero-till farming systems are used
- The greatest positive impact will occur where soil testing recommends a blend of gypsum and lime.

Constraints – smallest impact on salinity

- Short term ameliorant
- Relies on complementary management of tillage and grazing
- A detailed understanding of landscape and soil processes is required for a successful outcome
- Not suitable for alkaline surface soils.

Logistics

- Equipment and resources needed to spread lime
- Monitor, understand and respond to soil conditions
- Understand and address chemical and physical constraints to plant growth.

Design

- Understand chemical and physical characteristics of the soil
- Determine appropriate rates of lime and/or gypsum application and continue to apply over the long term. Target appropriate soil areas.

Example

- A discharge rehabilitation program is underway based on the establishment of salt tolerant pastures
- Surface sodicity is identified as a major constraint on plant growth
- Soil is tested to understand conditions
- Based on soil testing recommendations, granular gypsum is applied with a spreader
- Ongoing management of pasture is supported.

Management action group – Soil ameliorants		**Code**
Management action	**Ameliorate soil acidity by adding lime to increase plant water use, reduce recharge and manage discharge sites**	**SA3**

This action ameliorates surface soil acidity by the addition of lime. The calcium in the lime neutralises the excess hydrogen ions in the soil. Lime application can have major benefits as part of discharge site rehabilitation. It can have soil health benefits which increase plant water use and reduce recharge.

Opportunities – biggest impact on salinity

- Soils with a pH less than 6 (measured in calcium chloride)
- Soils with a pH greater than 4.5 (in calcium chloride)
- Surface soil texture is light clay or coarser.

Constraints – smallest impact on salinity

- Soil with a pH of less than 4.5
- Relies on complementary management of tillage and grazing
- A detailed understanding of landscape and soil processes is required for a successful outcome
- When land use includes removal of silage.

Logistics

- Equipment and resources to spread lime
- Need to monitor, understand and respond to soil conditions
- Understand and address chemical and physical constraints to plant growth.

Design

- Understand chemical and physical characteristics of the soil
- Determine appropriate rates of lime application and continue to apply over the long term. Target appropriate soil areas.

Example

- A pasture program is underway based on exotic perennial pastures and cereals
- Surface acidity is identified as the major constraint on plant growth
- Soil tested to understand conditions
- Based on soil testing recommendation, agricultural lime applied with a spreader
- Ongoing program designed to take advantage of increase in soil health.

Management action group – Soil ameliorants		Code
Management action	**Improve soil health by applying biological agents to the soil to increase plant water use, reduce recharge and manage discharge sites**	**SA4**

This action improves the biological health of surface soil by adding soil biology products. These contain soil fauna, which can improve soil ecology and soil biological health. Soil biology can have major benefits as part of discharge site rehabilitation as it can increase plant water use and thereby reduce recharge.

Opportunities – biggest impact on salinity

- Where poor soil biological health is the biggest limiting factor for plant water use
- Soils where there is a cover of mulch, living or dead
- When fauna that is applied adds to soil biology in a positive way.

Constraints – smallest impact on salinity

- Soil with a ph less than 4.5
- Relies on complementary management of tillage and grazing
- A detailed understanding of soil biology is required for a successful outcome
- In dry periods.

Logistics

- Equipment and resources needed to mix and spread compost tea
- Monitor, understand and respond to soil conditions
- Understand and address chemical and physical constraints to plant growth.

Design

- Understand biological, chemical and physical characteristics of the soil
- Determine appropriate rates of biological agent application and continue to apply over the long term. Target appropriate soil areas.

Example

- A pasture program is underway based on exotic perennial pastures and cereals
- Lack of soil fungi is identified as the major constraint on plant growth
- Soil is tested to understand soil conditions
- Compost tea high in fungi is applied with a spray unit
- Ongoing program is designed to take advantage of an increase in soil health.

Management action group – Soil ameliorants		Code
Management action	**Improve soil health by applying compost to increase plant water use, reduce recharge and manage discharge sites**	**SA5**

This action improves the biological health of surface soil by adding compost. Compost contains soil fauna which can improve soil ecology. The improvement in soil biological health increases plant water use and can reduce recharge. Compost also provides a physical mulch effect and can add to the physical condition of the soil surface. It can have major benefits as part of discharge site rehabilitation.

Opportunities – biggest impact on salinity

- Where poor soil biological health is the main limiting factor for plant water use
- Soils where there is a mulch cover – living or dead
- When fauna which is applied adds to the biology of soil in a positive way.

Constraints – smallest impact on salinity

- Relies on complementary management of tillage and grazing
- A detailed understanding of soil biology is required for a successful outcome
- In dry periods.

Logistics

- Equipment and resources needed to spread compost
- Monitor, understand and respond to soil conditions
- Understand and address chemical and physical constraints to plant growth.

Design

- Understand biological, chemical and physical characteristics of the soil
- Determine appropriate rates of compost and/or composted product application and continue to apply over the long term. Target appropriate soil areas.

Example

- A pasture program is underway based on exotic perennial pastures
- Poor soil biological health is identified as the major constraint on plant growth
- Soil tested to understand soil conditions
- Compost is applied with a spreader
- Ongoing program is designed to take advantage of an increase in soil health.

Management action group – Engineering		Code
Management action	**Use of groundwater to supplement or replace surface water for farm stock**	**E1**

Use of groundwater supplied by bores and infrastructure for farm water purposes can have both on-farm and wider catchment benefits.

- Remove hydraulic pressure on groundwater systems caused by farm dams
- Change the water balance and the ratio of surface water to groundwater use
- Make farm dams more effective sediment traps and ecological watering points rather than freshwater runoff and potentially causing salt land.

Opportunities – biggest impact on salinity

- An average annual rainfall of more than 500 mm
- Salinity management using vegetation is concurrently being undertaken
- Surface water is important for dilution flow and as a component of catchment supply
- Stock water is currently sourced from runoff but changes in pasture management and tree cover are reducing runoff.

Constraints – smallest impact on salinity

- Groundwater is deeper than 30 m
- Water use for stock and farm supply has an insignificant effect on salinity processes.

Logistics

- Carefully assess groundwater quality, volumes, yields and availability
- Combine species establishment with infrastructure, including fencing and water points, and management skills to promote and enhance perennial pastures
- Reduce the capture and reliance on surface water.

Design

- Target shallow groundwater
- Low flow pumps from wells to header tanks and piped reticulation systems
- Lower the top water level height of existing dams using trickle pipes
- Fence existing dams to exclude stock and large native and feral animals.

Example

- Where saline areas occur low in a valley
- It contains six dryland farms which rely on surface dams for their water supplies
- Groundwater is available at a depth of 15 m and has an electrical conductivity (EC) of 1800 µS/cm
- A farm water supply and reticulation scheme is installed in the valley with water pumped from shallow bores low in the catchment to header tanks
- Water is supplied to farms on condition that dams have lower storage and provide more surface water to the stream network
- Salt tolerant pastures and trees are established on the salt land.

Management action group – Engineering		**Code**
Management action	**Divert surface water to increase recharge in low lying areas and minimise runoff**	**E2**

This action involves the placement of in-stream structures to direct stream flow and surface runoff onto low lying areas.

The aim is to maximise the recharge of shallow groundwater and dilute shallow saline groundwater.

Opportunities – biggest impact on salinity

- Where salinity discharge management is concurrently undertaken
- The ‘flooded area’ has perennial pasture
- Groundwater is shallow but piezometric pressure is low
- Shallow groundwater has low to moderate salinity (less than 2000 µS/cm)
- Recharge events are more continuous than episodic
- Water can be diverted from a stream system without degrading the riparian zone or causing erosion.

Constraints – smallest impact on salinity

- Where the size and expansion of salt affected area is not understood
- Upward pressure on groundwater
- Shallow groundwater is salty
- Catchment scale recharge is not moderated by vegetation
- Land use in lower parts of the landscape is based on annual plants
- Grazing management does not promote or support perennial plants
- Climate and soil factors limit the ability of vegetation to use available moisture
- Farms are working on salinity management in isolation from the local catchment
- Increased recharge in an alluvial valley results in increased discharge of saline water to streams in another part of the valley through transfer of hydraulic head
- Soils with shallow A_1 horizons
- Soils with dispersive subsoils
- Soils with saline subsoils.

Logistics

- Construct weirs which spill water and raise the height of the channel.

Management action group – Engineering		Code
Management action	**Construct agricultural earthworks to maximise freshwater runoff and reduce recharge in low areas**	**E3**

Construct banks and drop structures to direct surface water runoff away from low lying salt affected areas and into streams.

This action aims to reduce recharge by:

- limiting the amount of water 'lying' on low areas
- aiding rehabilitation of low lying salt affected areas by reducing waterlogging and erosion and thereby increasing plant water use.

It also aims to maximise fresh surface water runoff.

Opportunities – biggest impact on salinity

- Where salinity discharge management is concurrently undertaken
- Recharge on low lying areas is a significant component of salinity processes
- A high proportion of the landscape is poorly drained alluvial valley
- Banks can be safely constructed with 0.05 per cent gradients or higher
- Water can be directed into a stream system without degrading the riparian zone or causing erosion.

Constraints – smallest impact on salinity

- Sodic subsoils lead to failure of earthworks due to susceptibility to tunnel erosion
- Geological structure leads to failure of earthworks
- Where the size and expansion of the salt affected area is not understood
- Flat lying sediments and sodic soils and groundwater containing sulphides.

Logistics

- Site assessment is needed – EMI or soil sampling
- Construct banks above and well away from salt affected areas
- Construct drop structures to safely dispose of surface water into streams.

Design

- Target landscapes which have large valley infill components affected by high water tables and salinity.

Example

- Saline areas assessed by EMI survey and soil sampling
- Stage 1 – prepare and construct drop structures and disposal areas
- Stage 2 – construct banks
- Stage 3 – establish salt tolerant pasture or forestry area.

Management action group – Engineering		Code
Management action	**Implement groundwater pumping and disposal**	**E4**

Extract groundwater to increase the depth to the watertable and mitigate salinity processes. Water is disposed of by evaporation and concentration, or as surface water runoff.

Opportunities – biggest impact on salinity

- Salinity management is concurrently being undertaken with a range of management actions
- Aquifer from which water is to be removed has a hydraulic connection with the aquifer containing the water that is causing the salinity outbreak
- Disposal issues: water quality and volume can be adequately managed
- Assets of high value are being impacted by salinity processes
- The high cost of engineering works is appropriate.

Constraints – smallest impact on salinity

- Low value assets are being impacted by salinity processes
- Disposal issues: water quality and volume cannot be adequately managed
- Financial resources are inadequate.

Logistics

- Careful assessment of groundwater quality, volumes, yields and availability
- Combine species establishment with infrastructure, including fencing and water points, and management skills to promote and enhance perennial pastures
- Reduce capture and reliance on surface water.

Design

- Target groundwater with a strong connection to salinity processes
- Use bores and pumps
- Construct evaporation or storage basins.

Example

- Saline areas exist in the low part of a valley and impact on a major road
- Groundwater is available at a depth of 15 m with an electrical conductivity (EC) of 2800 µS/cm (brackish)
- Water pumped from shallow bores low in the catchment to a large storage constructed so as not to leak
- Special licence is obtained to pump 2800 µS/cm water into the river during flows above 2000 ML/day.

Management action group – Engineering		Code
Management action	**Manage stream flow to create dilution flows in regulated rivers**	**E5**

This action can be used to ameliorate short term high salinity concentrations in rivers. Fresh water can be reserved, dedicated and released from storages to manage periods where river water quality exceeds thresholds for environmental and extractive uses.

Opportunities – biggest impact on salinity

- Storages exist above streams with high concentration inputs to the main channel
- Infrastructure exists to monitor and respond to water quality changes in tributaries
- Water quality in the main channel frequently exceeds thresholds.

Constraints – smallest impact on salinity

- Unregulated rivers and streams
- Water quality in tributaries is not monitored
- Storage water is too saline.

Logistics

- Releases from large storages are timed to dilute the river.

Design

- Tributaries monitored
- Dilution flows used in autumn and winter.

Example

- Tributary river gauging shows that 1800 µS/cm water is entering the main channel of a major river
- To dilute this event and maintain drinking water quality, additional 500 µS/cm water is released from a dam high in the catchment for five days.

Management action group – Engineering		**Code**
Management action	**Manage flow cycles of rivers to periodically produce dry supply channels and streams**	**E6**

This action involves replicating the pre-European flow pattern in rivers and channels. This allows the alluvial areas adjacent to the river to drain periodically. This can be used to manage the potential high groundwater and salinity processes adjacent to the channels.

Opportunities – biggest impact on salinity

- Streams ‘losing’ water to the groundwater and leaky infrastructure
- Where salinity management with vegetation is concurrently undertaken
- Irrigation occurs close to rivers and supply channels.

Constraints – smallest impact on salinity

- If there is no connection between high water table areas and supply channels or streams
- Continually available surface water and ‘seepage’ water is an important asset to stakeholders.

Logistics

- Amend river and irrigation operations to create low levels
- Reduce reliance on surface water and seepage water.

Design

- Target shallow groundwater
- Low flow pumps from wells to header tanks and piped reticulation systems
- Lower the top water level height of existing dams using trickle pipes
- Fence existing dams to exclude stock and large native and feral animals.

Example

- Saline areas and high water tables occur adjacent to a creek which is used to supply water to 30 farms
- During winter the creek is allowed to empty and drain excess groundwater
- A piped water delivery scheme is implemented to supply stock water to the farms.

Management action group – Engineering		**Code**
Management action	**Install leaky weirs to slow streams and increase freshwater recharge**	**E7**

Construct in-stream structures to produce low energy water with a hydraulic head.

This aims to maximise recharge of shallow groundwater and dilute shallow saline groundwater.

Opportunities – biggest impact on salinity

- Where salinity discharge management is concurrently undertaken
- The ‘flooded area’ has perennial pasture
- Groundwater is shallow but upward water pressure is low
- Shallow groundwater has low to moderate salinity (less than 2000 µS/cm)
- Recharge events are more continuous than episodic
- When water can be diverted from the stream system without degrading the riparian zone or causing erosion.

Constraints – smallest impact on salinity

- Where size and expansion of salt affected area is not understood
- Upward pressure on groundwater
- Shallow groundwater is salty
- Catchment scale recharge is not moderated by vegetation
- Land use in lower parts of the landscape is based on annual plants
- Grazing management does not promote or support perennial plants
- Climate and soil factors limit the ability of vegetation to use available moisture
- Farms are working on salinity management in isolation from local catchment
- Increased recharge in an alluvial valley results in increased discharge of saline water to streams in another part of the valley by raising the hydraulic head
- Soils with shallow A_1 horizons
- Soils with dispersive subsoils
- Soils with saline subsoils.

Logistics

- Construct leaky weirs in flow lines or channels.

Design

- This management action may have significant negative on-site and/or off-site impacts on salinity
- This action may be appropriate for treatment of riparian/erosion issues but is inappropriate for salinity management.

Management action group – Engineering		Code
Management action	**Construct diversion banks to connect streams with back plains and cut-offs to increase freshwater recharge**	**E8**

This action involves building earth structures to redirect surface water into streams. This aims to minimise the negative impact of surface water flow on erosion and salinity.

Opportunities – biggest impact on salinity

- Seasonal waterlogging from run-on water is the major driver of salinity processes
- Where salinity discharge management is concurrently undertaken
- Groundwater is shallow but upward water pressure is low
- Shallow groundwater has low to moderate salinity (less than 2000 µS/cm)
- Recharge events are more continuous than episodic
- Water can be diverted into the stream system without degrading the riparian zone or increasing erosion, recharge or discharge.

Constraints – smallest impact on salinity

- Size and expansion of salt affected area is not understood
- Upward pressure on the groundwater in the proposed construction areas
- Shallow groundwater is salty
- Land use in lower parts of the landscape is based on annual plants
- Grazing management does not promote or support perennial plants
- Climate and soil factors limit the ability of vegetations to use available moisture
- Farms are working on salinity management in isolation from local catchment
- Soils with shallow A_1 horizons
- Soils with dispersive subsoils and oils with saline subsoils.

Logistics

- Construct graded banks using accepted design principles
- Safe water disposal areas are required.

Design

- Consider how graded bank systems will fit into farm management
- Consider ongoing management of the site and plan for gates, fire control, feral animal control, grazing management and vehicle access.

Example

- A saline site suffers from seasonal waterlogging
- EMI survey conducted to identify the area of current and future discharge
- Soils tested for sodic, saline or dispersive subsoils
- Graded banks are constructed to direct surface water around the saline area
- Saline site managed with salt tolerant species and controlled grazing.

Management action group – Irrigation systems		Code
Management action	**Manage on-farm irrigation to achieve best practice**	**IS1**

This action involves applying irrigation best management practices to minimise impact on salinity. Irrigation best management practices should address all of the following issues:

- Salt accumulation in the root zone of the crop
- Minimising deep drainage below the root zone
- Maintaining plant productivity
- Minimising off-site and downstream impacts
- Salt loading of soils.

Actions to manage irrigation salinity issues will include:

- Matching soil types and water delivery systems to crops and rotations for maximum water use efficiency and minimal deep drainage
- Designing and providing infrastructure to maximise water use efficiency
- Managing long term salt loading of soils with irrigation water through leaching
- Capture and reuse of drainage water.

Opportunities – biggest impact on salinity

- Current irrigation practices are not best management
- Irrigation salinity processes are important in the catchment context
- Current irrigation overlies high water tables
- Current irrigation overlies soil with high stores of salt.

Constraints – smallest impact on salinity

- Irrigated areas do not impact on catchment scale salinity processes.

Logistics

- Assess current farm practices and infrastructure
- Design and apply irrigation infrastructure and methods to minimise salinity impacts.

Design

- Target high water users or irrigators whose on-farm practices are significantly worse than best management practice.

Example

- Farm identified as important for salinity management
- EMI survey and soil sampling assesses suitability for irrigation
- Infrastructure efficiency assessed through water audit and monitoring
- Skills of the irrigation manager are developed
- Irrigation management plan developed and implemented
- Ongoing monitoring, review and support provided.

Management action group – Irrigation systems		Code
Management action	**Manage irrigation supply systems to achieve best practice**	**IS2**

This action involves minimising groundwater accessions from irrigation supply systems. It can be used to manage potentially high groundwater and salinity processes adjacent to irrigation channels and water storages.

Opportunities – biggest impact on salinity

- Leakage from irrigation supply systems adds to local salinity processes
- Salinity management with on-farm best management practices is concurrently undertaken
- Irrigation is close to rivers.

Constraints – smallest impact on salinity

- Where there is no connection between high water table areas and supply channels or streams
- Where leaking storages and supply systems do not impact on catchment salinity processes.

Logistics

- Manage supply channels to reduce leakage by re-scheduling, lining or piping
- Design and locate supply systems and storages to minimise recharge
- Change from supply channels to pipelines.

Design

- Carefully site storages to avoid leakage to local groundwater
- Consider supply systems from perspective of both leakage and supply rate
- Water audits are very useful to identify potential gains in efficiency.

Example

- Water audit indicates water leakage from the farm irrigation supply system built on a sandy levee and kept full for long periods
- Supply system replaced with a pipeline and on-farm storage which is built in a suitable location to avoid adding to groundwater
- Technical support and training provided to allow for effective use of the new infrastructure.

Management action group – Irrigation systems		**Code**
Management action	**Establish effective effluent disposal systems specific to site conditions**	**IS3**

This action involves implementing effluent disposal practices to minimise impact on salinity.

Effective effluent disposal systems should address all of the following issues:

- Effluent and through flow reaching flow lines
- Destabilising and sealing of soil due to high sodium input
- Nil off-site and downstream impacts
- Salt loading of soils.

Actions to manage effluent salinity issues will include:

- Matching the effluent disposal system to soil types and climate conditions
- Designing and implementing structures that are suited to the site conditions
- Managing long term destabilising of soils due to loading of soils with sodium (bulking agent in many clothing detergents)
- Ongoing management of system and use of ameliorants such as gypsum (Department of Local Government et al. 1998)
- Regular system maintenance.

Opportunities – biggest impact on salinity

- Current effluent disposal systems are unsuitable to local conditions
- Effluent reaches flow lines
- Site overlies sodic soils
- Site overlies high water tables
- Winter dominate rainfall.

Constraints – smallest impact on salinity

- Where high water table areas and effluent disposal systems are not connected
- Where impact on catchment salinity processes is likely to be negligible.

Logistics

- Current inadequate system already in place
- Design and implement effluent disposal systems which minimise salinity impacts.

Design

- Target inefficient systems ill-suited to a particular area.
- Educate users to best management techniques and appropriate detergent and water use
- Maintenance – poorly maintained systems can release nutrients, salts and pathogens into water courses and impact water quality. Under Section 68 of the *Local Government Act 1993*, councils are responsible for regulating on-site sewage management systems.

Management action group – Salt land rehabilitation		**Code**
Management action	**Fence and isolate salt land and discharge areas to promote revegetation**	**SR1**

Salt discharge areas are fenced as separate land management units and stock access is controlled.

This action aims to allow the saline area to revegetate by controlling stock pressure or farming pressure, and recognises that many salinity sites deteriorate under constant grazing or if they are cultivated and farmed.

Opportunities – biggest impact on salinity

- Small sites (less than 2 ha) where access and ongoing management is difficult
- Where low level intervention is preferred due to the severity of the site or logistical or financial issues
- Where ecological succession is underway on salt discharge sites involving salt tolerant and waterlogging tolerant plants.

Constraints – smallest impact on salinity

- Logistics and fencing should be carefully planned as the salinity site might expand
- Plant succession might be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, loss of topsoil or exposed subsoil
- Erosion might continue and the site may become more difficult for plants to colonise.

Logistics

- Fence site.

Design

- Consider ongoing management of the site and plan for gates, fire control, feral animal control, grazing management and vehicle access.

Example

- A small saline and bare site in the corner of a paddock
- EMI survey used to design a fence line which contains an area twice as large as the current bare area
- Ongoing site management is facilitated by installation of two access gates and a water point.

Management action group – Salt land rehabilitation		**Code**
Management action	**Establish and manage salt land pasture systems to improve productivity**	**SR2**

Under this action saline discharge areas are managed as grazing systems. Plants which can tolerate and thrive in saline and waterlogged conditions are established and managed using a range of techniques.

Salt land is fenced as separate land management units and stock access is controlled.

This action recognises that many salinity sites deteriorate under constant grazing or if they are cultivated and farmed. But it also recognises that many salinity sites can be very agriculturally productive grazing areas.

Information and advice is available on the techniques used in salt land pasture establishment and management. For example, the publication *Productive use of saline land and water* is available from: www.environment.nsw.gov.au/salinity/solutions and relevant information is also available from: www.saltlandgenie.org.au.

Opportunities – biggest impact on salinity

- Site access and ongoing management are easy
- Where high level intervention is justified considering the severity of the site and logistical or financial issues
- Where ecological succession is underway on salt discharge sites being colonised by salt tolerant and waterlogging tolerant plants
- Grazing management including crash grazing or time control grazing techniques are part of whole farm management
- Animal enterprises have a high priority within the total farm enterprise.

Constraints – smallest impact on salinity

- Specialist skills are needed to design, implement and manage salt land pasture systems
- Small sites
- Sites along incised flow lines
- Site may grow in size so logistics and fencing must be carefully planned
- Success of pasture plants may be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, loss of topsoil and exposed subsoil
- Erosion might continue and the site may become more difficult for plants to colonise
- Where managers have little interest or skills in grazing management
- Where long term set stocking or continuous grazing techniques are used
- Sites not suitable for cultivation as they carry runoff water
- Close to waterways or property boundaries where weeds and unwanted spread of salt tolerant plants are issues
- Legislation protecting native grassland and woodlands from the introduction of new species.

Logistics

- Fence site
- Plant new salt tolerant species.

Design

- Consider how salt tolerant pasture systems will fit into wider farm management
- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management and vehicle access
- Pasture establishment program should add incremental value to the site over a number of years rather than trying to create a pasture in one season
- Take advantage of seasonal conditions to add value to the site – for example, sow when conditions allow access
- Consider using a range of techniques for establishing and altering pastures – grazing pressure, spreading seed, animal impact on seed bearing mulch, feeding seed to animals, management/grazing of current pastures, use of chemical herbicides, use of soil additives (fertilisers, composts, compost teas), use of soil ameliorants (gypsum, lime, dolomite).

Example

- Saline symptoms covering 2 ha in the middle of a 30 ha paddock
- EMI survey used to design the fence line so that it includes an area twice that of the current bare area
- Thirty ha paddock fenced into three grazing units – Paddock 1: most saline; Paddock 2: wet mild salinity; Paddock 3: dry no symptoms
- Access gates and water points are included in the design to facilitate ongoing management
- Paddock 1: a salt tolerant pasture mix is sown using a no-till implement during a dry autumn when the site could be accessed by machinery and equipment
- New pasture carefully managed to allow establishment
- Mulch used to help regenerate continually bare areas
- Paddock 2: permanent perennial exotic pasture is sown based on mix of Lucerne, grasses and clovers
- Paddock 3 is cropped with winter cereals in rotation with a pasture phase.

Management action group – Salt land rehabilitation		**Code**
Management action	**Establish forestry systems on salt land to improve productivity**	**SR3**

This action aims to lower the water table in saline areas by the establishment of salt tolerant trees species. Saline areas are fenced as separate land management units and stock access is controlled. Salt tolerant trees are established for productive forests.

A large volume of information and advice is available on techniques used in salt land forest establishment and management. For example, the publication *Productive use of saline land and water* is available from: www.environment.nsw.gov.au/resources/salinity/Book4DrylandSalinity.pdf

Opportunities – biggest impact on salinity

- Access and ongoing management are suitable for forestry equipment
- Where high level intervention is justified considering the severity of the site and logistical or financial issues
- Animal enterprises have a low priority in the total farm enterprise
- Forestry enterprises and silviculture have a high priority in the total farm enterprise
- Close to markets for timber products.

Constraints – smallest impact on salinity

- Specialist skills are needed to design and implement forestry systems on saline land
- Markets for timber products from salt land are not established
- Site may grow in size so logistics and fencing must be carefully planned
- Success of trees may be limited by constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, soil chemistry, micro-climate, loss of topsoil and exposed subsoil
- Erosion might continue and the site may become more difficult for plants to colonise
- Trees may concentrate salt in the root zone and die.

Logistics

- Fence site
- Design layout using forestry techniques
- Contractors plant trees
- Control weeds with herbicide
- Fertilise trees.

Design

- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management, and vehicle and equipment access
- Select the most suitable tree species available
- Layout should maximise biodiversity benefit to enhance habitat which will add to farm amenity as wind breaks, land division etc.

Example

- Site located along a wide flow line within a cropping landscape
- EMI survey used to locate the fence line so that it includes an area twice that of the current bare area
- Multiple access gates and a water point are included in the design to facilitate ongoing management
- Flyways designed within the forests for biodiversity outcomes
- Tracks constructed for heavy equipment
- Understorey species planted to maximise biodiversity
- Trees thinned at Year 4
- Trees harvested at Year 15.

Management action group – Salt land rehabilitation		Code
Management action	**Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation**	**SR4**

This action aims to ameliorate land degradation on a saline discharge site. It is aimed more at land rehabilitation and amenity than forestry or agricultural production.

Opportunities – biggest impact on salinity

- Where site conditions, access and ongoing management make production difficult
- Public land impacted by salinity
- Sites impacting on public resources and infrastructure
- Grazing management and animal enterprises have a low priority in the total farm enterprise
- Highly erodible sodic and saline soils.

Constraints – smallest impact on salinity

- Site may grow in size so logistics must be carefully planned
- Degradation of the site may continue after implementation and limit effectiveness of the rehabilitation program
- Suitability or success of rehabilitation measures may be limited by site constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, soil chemistry, micro-climate, loss of topsoil, exposed subsoil, soil structure and soil biological health
- Specialist skills are needed to design and implement salt land rehabilitation.

Logistics

- Suitable on sites where a high intervention level is required
- Site constraints including severity of the site and site access
- Potential cost to rehabilitate the site needs to be considered.

Design

- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management, and vehicle and equipment access
- Select the most suitable available plant species
- Layout should maximise biodiversity benefit to enhance habitat which will add to farm amenity as wind breaks, land division etc. Consider the impact of all soil constraints, but particularly sodicity and salinity.

Examples

- Assessment : EMI survey, soil testing, surface water and groundwater testing, historical analysis
- Earthworks: drop structures, controlled waterways, flumes
- Soil chemical ameliorants: gypsum, lime, dolomite, fertiliser
- Soil biological ameliorants: composts, soil fauna
- Soil surface mulches: hay, hydro-seeding, brush matting, any safe organic matter.

Management action group – Salt land rehabilitation		Code
Management action	**Establish and manage salt land grazing systems based on forage shrubs to improve productivity**	**SR5**

Saline discharge areas are managed with grazing systems based on edible forage shrubs. Shrubs which can tolerate and thrive in saline and waterlogged conditions are established and managed with a range of techniques which include direct seeding, transplanted seedlings and speedlings.

Salt land is fenced as separate land management units and stock access is controlled. Preparation techniques range from intensive ripping and mounding to low impact seeding.

This action recognises that many sites deteriorate under constant grazing or if cultivated and farmed but that some sites can be very agriculturally productive if used for specialised grazing.

A large volume of information and advice is available on the techniques used in the management of salt land with forage shrubs. For example, the publication *Productive use of saline land and water* is available from: www.environment.nsw.gov.au/resources/salinity/Book4DrylandSalinity.pdf.

Opportunities – biggest impact on salinity

- Where access and ongoing management is easy
- Where high level intervention is justified considering the severity of the site and logistical or financial issues
- Where the addition of a shrub layer will amplify ecological succession and lead to colonisation by more salt tolerant and waterlogging tolerant plants
- Grazing management includes crash grazing or time control grazing techniques as part of whole farm management
- Farms where animal enterprises have a high priority in the total farm enterprise.

Constraints – smallest impact on salinity

- Specialist skills are needed to advise and implement salt land grazing systems based on forage shrubs
- Sites which are frost pockets
- High available aluminium in the subsoil
- Small sites
- Sites along incised flow lines
- Site may grow in size so logistics and fencing must be carefully planned
- Success of shrubs may be limited by soil constraints such as winter waterlogging, acidity, high levels of available aluminium
- Erosion may continue and become more difficult for plants to colonise
- Managers have little interest or skills in grazing management
- Long term set-stocking or continuous grazing techniques are used
- Legislation protecting native grassland and woodlands from the introduction of new plant species.

Logistics

- Fence site
- Plant new salt tolerant shrub species.

Design

- Consider how salt tolerant shrub grazing systems will fit into wider farm management
- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management, vehicle access
- Pasture establishment program should add incremental value to the site over a number of years rather than trying to create a pasture in one season
- Take advantage of seasonal conditions to add value to the site – for example, sow when conditions allow access
- Consider using a range of techniques for establishing and altering the site – grazing pressure, spreading seed, animal impact on seed bearing mulch, feeding seed to animals, management/grazing of current pastures, chemical herbicides, soil additives (fertilisers, composts, compost teas), soil ameliorants (gypsum, lime, dolomite).

Example

- Saline symptoms covering 2 ha in the middle of a 30 ha paddock
- EMI survey used to design the fence line so that it includes an area twice that of the current bare area
- Thirty ha paddock fenced into three grazing units – Paddock 1: bare and most saline; Paddock 2: mild salinity; Paddock 3: showing no salinity symptoms
- Access gates and water points are included in the design to facilitate ongoing management
- Old man saltbush (*Atriplex nummularia*) established by hand as Speedlings in shallow ripped lines in Paddock 1
- New shrubs carefully managed to allow for establishment
- Grazing management used to encourage and support colonisation by grasses as saltbush establishes
- Paddock 2 becomes permanent perennial exotic pasture based on mix of lucerne, grasses and clovers
- Paddock 3 is cropped with winter cereals in rotation with a pasture phase.

Management action group – Salt land rehabilitation		Code
Management action	**Pond water on dry scalds to promote revegetation**	**SR6**

This action is successful in managing land degradation which is evident as dry scalds in western NSW. There are benefits to grazing production but the major outcome is to rehabilitate the site.

Opportunities – biggest impact on salinity

- Sodic and saline sites without significant upward pressure from groundwater.

Constraints – smallest impact on salinity

- Specialist skills are needed to advise and implement the use of water ponding to rehabilitate dry scalds
- High rainfall sites
- Slopes above 1 per cent
- Site may grow in size so logistics must be carefully planned
- Suitability or success of rehabilitation measures may be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, soil chemistry, micro-climate, loss of topsoil, exposed subsoil, soil structure and soil health.

Logistics

- Survey area
- Build low level structures to pond water on scalds
- Revegetate with suitable species.

Design

- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management and vehicle and equipment access
- Select the most suitable available plant species.

Examples

- Landholder identifies scalded area
- Surveyed
- Low level earthen structures built by grader to pond rain water on scalds
- Site revegetated with a range of grass species seeds
- Landholder manages grazing of site with solar powered electric fencing.

Management action group – Salt land rehabilitation		Code
Management action	**Reduce animal impact on scalds by providing mineral supplements to stock**	**SR7**

This action aims to allow the saline area to revegetate by reducing stock pressure. Animals frequently congregate on saline areas to scratch the soil surface and lick the salt which is concentrated near the surface. It aims to reduce this pressure by providing alternative mineral supplements which will reduce animal need for salt minerals present on saline areas.

It is seen to be moderately successful, particularly when combined with changes in grazing management and/or rehabilitation of saline areas.

Opportunities – biggest impact on salinity

- Small sites (less than 2 ha) where access and ongoing management is difficult
- Where a low level intervention is the preferred management action due to the severity of the site, logistical or financial issues
- Where ecological succession is underway and salt tolerant and waterlogging tolerant plants are already colonising a salt discharge site
- Where there is shade for stock during hot times
- In paddocks with a good water supply during summer.

Constraints – smallest impact on salinity

- Where animal impact is not the most limiting factor for plant growth on a saline site
- Where animals paw the ground to expose evaporating moisture (‘sheep air conditioning’) during hotter times
- Succession of plants may be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, loss of topsoil and exposed subsoil
- Grazing animal management is not a high priority in the farm enterprise
- Erosion may continue and it may become more difficult for plants to colonise the scald.

Logistics

- Provide mineral supplement licks.

Design

- Consider ongoing grazing management of the site and surrounding areas.

Example

- Small saline sites within large paddocks in steep terrain
- Sheep are observed to congregate and lick saline areas, particularly in late winter
- Veterinary advice is obtained on possible mineral deficiencies in late winter
- Licks are provided but distant from the saline areas
- Scald areas are mulched with old hay.

Management action group – Salt land rehabilitation		Code
Management action	**Mulch sites to reduce evaporation and promote pasture growth**	**SR8**

Evaporation of surface water and groundwater concentrates salt in the surface layers of soil at many salt discharge sites.

Applying mulch can have two benefits on salt discharge sites:

- Reduce the rate of evaporation and concentration of salt, which reduces salt concentration in the surface soil
- Influence microclimate to allow for increased colonisation of bare areas by grasses.

Sources of mulch sources include crop straw, pasture hay, recycled organics, spoilt or old hay, aged animal manures, biosolids, green waste – recycled plant material, jute mesh, animal products – docking tails, wool waste, limbs/branches from woody vegetation and shrubs, bedding material from intensive animal/poultry housing, brush matting using existing leptospermum, kunzea, melaleuca, compost and woodchips.

Mulch can be applied by many methods, from hand spreading to hydro-seeding equipment.

Opportunities – biggest impact on salinity

- Where evaporation processes and microclimate are the limiting factors for salt land rehabilitation
- Where salt land is fenced as separate land management units
- Stock access is controlled
- Small sites
- Where access and ongoing management is easy
- Where high level intervention is justified considering the severity of the site and logistical or financial issues
- Where ecological succession is underway on salt discharge sites being colonised by salt tolerant and waterlogging tolerant plants
- Grazing management includes crash grazing or time control grazing techniques as part of the whole farm management
- Animal enterprises have a high priority within the total farm enterprise
- Where agriculture is of low importance.

Constraints – smallest impact on salinity

- Specialist skills are needed to design, implement and manage salt land pasture systems
- Success of pasture plants may be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, loss of topsoil and exposed subsoil
- Erosion might continue and the site may become more difficult for plants to colonise
- Managers have little interest or skills in grazing management
- Long term set-stocking or continuous grazing techniques are used.

Logistics

- Fence site
- Mulch site
- Restrict stock access to short grazing periods with long intervening recovery times.

Design

- Consider how salt discharge systems will fit into wider farm management
- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management and vehicle access.

Example

- Site with saline symptoms in three small patches of 100 m^2 each in the middle of a 20 ha paddock
- EMI survey used to design fence line location to isolate all bare areas as one ‘saline paddock’
- Mulch applied by hand spreading.

Management action group – Salt land rehabilitation		Code
Management action	Mulch sites using tactical animal impact	SR9

This action is closely related to SR8, adding planned use of animals. Evaporation of surface and groundwater concentrates salt in the surface layers of the soil at many salt discharge sites.

Applying mulch can have two benefits on salt discharge sites:

- Reduce the rate of evaporation and concentration of salt which reduce salt concentration in the surface soil
- Influence microclimate to allow for increased colonisation of bare areas by grasses.

Mulch can be spread, bedded down and incorporated into the surface soil by the planned tactical use of livestock. This may alter the soil surface to allow better infiltration of rainfall and improved pasture regeneration.

Mulch can come from a range of sources but if animals are used to maximise spread then the more palatable it is the better. Crop straw and pasture hay are frequently used. Other techniques involve short term concentration of animals on existing mulches which are not palatable.

Applying mulch can be done in many ways including:

- Placing large round bales in the middle of scald areas and introducing high numbers of cattle or sheep for a short period
- Adding supplements encourages animals to spread the mulch – for example, molasses on bales of hay
- Tactical sheep or cattle movements to encourage seed drop from other pastures through manuring.

Opportunities – biggest impact on salinity

- Where evaporation process and microclimate are the limiting factors for salt land rehabilitation
- Where salt land is fenced as separate land management units
- Stock access is controlled
- Small sites
- Where access and ongoing management is easy
- Where a low level intervention is suitable considering the severity of the site, and logistical or financial issues
- Where ecological succession is underway on salt discharge sites being colonised by salt tolerant and waterlogging tolerant plants
- Grazing management including crash grazing or time control grazing techniques are part of whole farm management
- Animal enterprises have a high priority within the total farm enterprise.

Constraints – smallest impact on salinity

- Specialist skills are needed to design, implement and manage salt land pasture systems
- Success of pasture plants may be limited by soil constraints such as soil salinity, waterlogging, sodicity, acidity, alkalinity, loss of topsoil and exposed subsoil

- Erosion might continue and the site may become more difficult for plants to colonise
- Where managers have little interest or skills in grazing management
- Where long term set stocking or continuous grazing techniques are used.

Logistics

- Fence site
- Place mulch materials on bare areas
- Restrict stock access to short grazing periods with long intervening recovery times.

Design

- Consider how salt discharge systems will fit into wider farm management
- Consider ongoing management and plan for gates, fire control, feral animal control, grazing management, vehicle access.

Example

- Site with saline symptoms in three small patches of 100 m^2 in the middle of a 20 ha paddock
- EMI survey used to design fence line location to isolate all bare areas as one ‘saline paddock’
- Two ha site is isolated with electric fencing
- Large round bales of pasture hay are placed on saline areas
- Salt tolerant pasture seed mixes are hand spread on scalds
- Molasses is poured into the hay
- Twenty steers are put in the ‘salt paddock’ for three days and then removed
- Site is not grazed for 90 days.

Management action group – Acid sulfate		Code
Management action	**Improve or maintain the hydrological regime to keep acid sulfate soil saturated**	**AS1**

This action aims to limit any potential for acid sulfate development by maintaining potential acid sulfate soil (ASS) material in a saturated anaerobic state. It recognises that many potential ASS sites do not generate acid leachate until they are drained. Discharge areas in potential ASS are not to be drained and in some cases should be re-hydrated. Site disturbance should be limited and stock controlled.

There is a degree of overlap, but not total concurrence, between the management of coastal ASS (Tulau 2007) and inland ASS (Fitzpatrick & Shand 2008; EP&HC 2011).

Acid sulfate soil identification and management is complex and generally outside the scope of this document. For information on ASS remediation go to:

www.environment.nsw.gov.au/publications/20070321acidsulfatesoils.htm

www.clw.csiro.au/acidsulfatesoils/ass-book.html

www.environment.gov.au/system/files/resources/bcef08f2-0c60-4931-9b5e-1522ca55da74/files/guidance-management-acid-sulfate-soils.pdf

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Opportunities – biggest impact on salinity

- Where potential ASS has been identified but oxidisation has not yet occurred.

Constraints – smallest impact on salinity

- Identifying potential acid sulfate soils
- Difficulty improving or maintaining the hydrological regime due to prolonged drought or upstream water extraction
- A wetter hydrological regime may run counter to other aims – for example, agricultural production, salinity control
- Specialist advice and site assessment may be required.

Logistics

- Assess site
- Fencing may be required
- Earthworks may be required to return to a wetter hydrological regime
- Water releases may be required.

Design

- Consider ongoing management of site and plan for hydrology, gates, fencing, grazing management, earthworks and vehicle access.

Management action group – Acid sulfate		**Code**
Management action	**Isolate and improve acid sulfate soil sites**	**AS2**

This action aims to limit any potential for acid discharge and to remediate as far as is practicable any acid sulfate soil (ASS) material. Sites that contain ASS material are fenced and managed in accordance with the relevant remediation guidelines. There is a degree of overlap, but not total concurrence, between the management of coastal ASS (Tulau 2007) and inland ASS (Fitzpatrick, R & Shand, P 2008; EP&HC 2011).

Acid sulfate soil identification and management is complex and generally outside the scope of this document. For information on ASS remediation go to:

www.environment.nsw.gov.au/publications/20070321acidsulfatesoils.htm

www.clw.csiro.au/acidsulfatesoils/ass-book.html

www.environment.gov.au/system/files/resources/bcef08f2-0c60-4931-9b5e-1522ca55da74/files/guidance-management-acid-sulfate-soils.pdf

Opportunities – biggest impact on salinity

- Where acid is being actively generated from ASS sediment.

Constraints – smallest impact on salinity

- General difficulty in treating acid sulfate soils
- Difficulty in maintaining or improving hydrological regime due to prolonged drought or upstream water extraction
- Maintenance of wetter hydrological regime may run counter to other aims such as production or salinity remediation
- Specialist advice and site assessment may be required.

Logistics

- Assess site.
- Fencing may be required
- Earthworks may be required to return to a wetter hydrological regime
- Water releases may be required
- Liming may be required
- Retention of acid waters may be required
- Ongoing monitoring may be required.

Design

- Consider ongoing management and plan for hydrology, gates, fencing, grazing management, earthworks and vehicle access.

6. High hazard land use

Sixteen high hazard management actions are presented in this chapter. These have the potential to make salinity problems worse and may override positive salinity management actions. If a land use action is identified as high hazard it is to be actively discouraged.

A summary of high hazard land use actions (Table 5) is followed by detailed description for each management action. Included for each of the Discouraged Land Use (DLU) are:

- Brief descriptions and background
- Biggest negative impacts on salinity – where this action be most severe
- Smallest negative impacts on salinity – where this action will be least severe
- Potential mitigating actions – how the hazard might be minimised.

High hazard management actions are assessed for their impact and their priority for salinity management within the landscape. A high hazard management action which may result in immediate and severe salinity impacts in one landscape may be less damaging in another. The dynamics of an action may vary. Sometimes the action is very suitable for delivering on a strategy, but may be unsuitable for a different strategy.

The list below in not exhaustive and new management actions or land management techniques can be added after their efficacy has been assessed.

Table 6: Summary of high hazard land use actions

Code	Management action
DLU1	Long fallows in farming systems
DLU2	Poor management of grazing pastures
DLU3	Annual cropping with annual plants
DLU4	Clearing and poor management of native vegetation
DLU5	Farm dams in flow lines
DLU6	Reducing runoff from fresh surface water catchments
DLU7	Locating infrastructure on discharge areas
DLU8	Poor soil management – tillage causing poor structure
DLU9	Poor soil management – chemical and biological
DLU10	Poor soil management – loss of surface soil layers
DLU11	Deep ripping of soils to maximise water infiltration to subsoil
DLU12	Flat contour banks
DLU13	Irrigation using inefficient on-farm water delivery practices
DLU14	Poor targeting of land suitable for irrigation

Code	Management action
DLU15	Loading of soils with salt through irrigation and flow management
DLU16	Construction of drains to lower water tables

High hazard land use management action	**Long fallows in farming systems**	**Code** **DLU1**

Long fallows are used to store water in the soil profile but increase the risk of deep drainage. They are commonly used in cropping programs with annual crops.

Biggest negative impact on salinity

- Free draining gradational soils
- Average annual rainfall over 450 mm
- Where the temporal rainfall pattern does not match the growth pattern of a crop – e.g. winter dominant rainfall in summer cropping program
- Cropping areas overlap with important recharge areas
- Recharge occurs diffusely across the landscape.

Smallest negative impact on salinity

- Soils with heavy texture
- Where soil moisture is monitored and cropping program responds to excess moisture with opportunity cropping or change in perennial phase.

Potential mitigating actions

- Measure and respond to soil moisture and potential deep drainage
- Only long fallow on heavy textured soil types in low rainfall areas.

High hazard land use management action	Poor management of grazing pastures	Code DLU2

Pastures which are poorly managed do not convert available moisture into plant material. This can increase deep drainage, recharge and salinity. Poor pasture management limits the ability of plants to use available moisture by being:

- Dominated by annual plants with small annual growth windows
- Continually grazed producing small leaf area
- Dominated by plants which are not active when moisture is available.

Biggest negative impact on salinity

- Free draining gradational soils
- Average annual rainfall over 550 mm but below 850 mm
- Where the temporal rainfall pattern does not match the growth pattern of pastures – e.g. winter dominant rainfall but spring/summer dominant annual pastures
- Poorly managed pastures overlap with important recharge areas
- Recharge occurs diffusely across the landscape
- Wet climatic cycles
- Cool winters and winter dominant or evenly distributed rainfall.

Smallest negative impact on salinity

- Heavy textured soils which allow water to stay in the root zone
- Average annual rainfall below 550 mm or above 850 mm
- Areas with warm winters
- Soil and climate conditions allow a dry soil profile to be created by a pasture phase
- Areas where summer annual pastures are grown in summer dominant rainfall
- Dry climate cycles.

Potential mitigating actions

- Measure and respond to soil moisture and potential deep drainage
- Manage grazing to allow for maximum evapotranspiration by increasing leaf area index
- Manage grazing management to encourage perennial plants
- Management actions: VP1, VP2, VP3, VP4, VP5, VP6.

High hazard land use management action	**Annual cropping with annual plants**	**Code** **DLU3**

Annual crops have a high potential to create deep drainage as their use of available soil moisture is limited by the amount and timing of rainfall. Cropping has the potential to fill the soil profile with water and thereby cause deep drainage.

Biggest negative impact on salinity

- Free draining gradational soils
- Areas with average annual rainfall over 650 mm
- Where the temporal rainfall pattern does not match the growth pattern of a crop – e.g. winter dominant rainfall in summer cropping program
- Cropping overlaps with important recharge areas
- Recharge occurs diffusely across the landscape
- When winter cereals are grown in cool climates with winter dominant rainfall
- In wet climatic cycles.

Smallest negative impact on salinity

- Heavy textured soils which allow water to stay in the root zone
- Average annual rainfall below 550 mm
- Soil and climate conditions allow a dry soil profile to be created by a pasture phase
- When summer annual crops are grown in summer dominant rainfall
- In dry climate cycles.

Potential mitigating actions

- Measure and respond to soil moisture and potential deep drainage
- Phase farming with a perennial component
- Short 2 year farming phase
- Management actions: FS1, FS2, FS3, FS4, FS6.

High hazard land use management action	Clearing and poor management of native vegetation	Code DLU4

Native vegetation moderates recharge. Clearing and poor management of existing native vegetation can reduce water use by vegetation and increase rates of recharge.

Biggest negative impact on salinity

- Where existing native vegetation is located on discrete high recharge areas
- Groundwater flow systems where processes are local and response times are short
- Free draining soils
- Average annual rainfall between 550 and 850 mm.

Smallest negative impact on salinity

- Where native vegetation on high recharge areas cannot effectively use water to grow and reduce recharge
- Average annual rainfall over 850 mm
- In dry climate cycles
- Intermediate or regional groundwater flow systems where groundwater flows over distances of greater than 5 km across sub-catchment boundaries, and where response times are long
- Recharge occurs diffusely across the landscape
- Areas with low levels of native vegetation
- Areas of native vegetation do not overlap with important recharge areas.

Potential mitigating actions

- Replace cleared vegetation with land use that does not have deep drainage.

High hazard land use management action	**Farm dams in flow lines**	**Code** **DLU5**

Farm dams can increase hydraulic head and add to land salinisation processes.

Biggest negative impact on salinity
- Free draining gradational soils
- Dams are located above high salt stores
- Dams are located above high water tables
- Dams are located along flow lines above groundwater flow paths
- Areas with high rates of evaporation.

Smallest negative impact on salinity
- Dams are not located above high salt stores
- Dams are not located above high water tables
- Dams are not located along flow lines above groundwater flow paths
- Soils with heavy texture.

Potential mitigating actions
- Top water level in dam is lowered with pipes
- Dams become sediment traps with pipes to moderate storm water flow.

High hazard land use management action	Reducing runoff from fresh surface water catchments	Code DLU6

Changing land use over larger areas can alter the surface water hydrology of catchments. This can influence the salinity of local streams and water quality and quantity in the wider catchment.

Biggest negative impact on salinity

- Areas with low levels of stream salinity
- Where high volumes of water are delivered to the local streams and the wider catchment
- High rainfall areas with an annual rainfall of over 800 mm.

Smallest negative impact on salinity

- Streams contribute high salinity to the wider catchment
- Low rainfall areas with an annual rainfall of less than 650 mm
- Areas with low surface runoff.

Potential mitigating actions

- Careful targeting of land use changes which impact on runoff
- Careful targeting of areas which supply runoff to rivers and streams
- Catchment scale management of water quality and quantity issues.

High hazard land use management action	Locating infrastructure on discharge areas	Code DLU7

Poorly placed infrastructure can lead to two negative outcomes:

- Amplification of salinity processes
- Damage to infrastructure.

Biggest negative impact on salinity

- Infrastructure changes the hydrology of groundwater and surface water – e.g. roads or railway lines across drainage lines
- Infrastructure is below ground level – e.g. pipelines
- Infrastructure adds to groundwater recharge – e.g. recreational water bodies or high irrigation sporting facilities
- Construction techniques for infrastructure do not include design for saline conditions
- Areas with high levels of land salinity.

Smallest negative impact on salinity

- Areas with low levels of land salinity
- Free draining or gradational soils with deep groundwater.

Potential mitigating actions

- Careful planning when locating infrastructure
- Careful planning of construction techniques.

High hazard land use management action	Poor soil management – tillage causing poor structure.	Code DLU8

Poorly managed tillage has the potential to negatively impact on soil structure. This limits the ability of soils to store water and can lead to increased deep drainage and increased erosion.

Annual crops have a high potential to create deep drainage as their ability to use available moisture is limited by the structure of the soil.

Biggest negative impact on salinity

- Free draining gradational soils
- Crop growth has the potential to limit deep drainage
- Tillage/cropping occurs above important recharge areas
- On sodic soils.

Smallest negative impact on salinity

- Where tillage does not occur above important recharge areas or salt stores
- In dry climatic cycles.

Potential mitigating actions

- Measure and respond to soil structure conditions, moisture and potential deep drainage
- No-till farming systems
- Management actions: FS1, FS5, FS6.

High hazard land use management action	**Poor soil management – chemical and biological**	**Code** **DLU9**

Poorly managed soil chemistry and soil biology can make plants less able to use soil water and the capacity of soils to store it. This can lead to increased deep drainage.

The ability of annual crops and pastures to use available soil moisture and avoid deep drainage is limited by the structure of the soil.

Biggest negative impact on salinity

- Significant imbalances in soil chemistry
- Significant limitations on soil biology
- Soils with chemical and biological limitations occur above important recharge areas.

Smallest negative impact on salinity

- Soil limitations affecting tillage do not occur above important recharge areas or important salt stores
- Chemical and biological limitations on soils are not the main limitations to plant growth – this may be poor grazing management or low rainfall/irrigation.

Potential mitigating actions

- Measure and respond to soil conditions, moisture and potential deep drainage
- No-till farming systems
- Management actions: FS1, FS3, FS5, FS7, VP4.

High hazard land use management action	**Poor soil management – loss of surface soil layers**	**Code DLU10**

Loss of topsoil through wind, sheet, rill or gully erosion can have negative effects on salinity processes and impacts. Loss of topsoils can limit the ability of plants to use water and also the capacity of soils to store soil water and buffer recharge events.

Loss of topsoil can also expose saline subsoils and other subsurface constraints such as sodicity, acidity, alkalinity or mineral toxicity. These can all limit plant growth and lead to both increased rate of recharge or increased rates of discharge and salt concentration.

This loss can limit the success of rehabilitation or salinity prevention actions.

Biggest negative impact on salinity

- Thin surface soils occur over subsoils with significant constraints to plant growth – sodicity, acidity, alkalinity or mineral toxicity
- Thin light textured and sandy surface soils occur over saline and/or sodic subsoils
- Topsoils overlie sodic and poorly structured subsoils on low slopes and in flow lines.

Smallest negative impact on salinity

- Subsoil limitations do not occur above important recharge areas, discharge areas or important salt stores.

Potential mitigating actions

- Reduce erosion through grazing management, farming systems, and tillage management
- Reduce erosion through rehabilitation
- Measure and respond to sub-soil conditions
- Management actions: VE6, VP1, SR1, SR2, SR3, SR4, SR5, SR6, FS5, FS6, FS7, E3.

High hazard land use management action	**Deep ripping of soils to maximise water infiltration to subsoil**	**Code DLU11**

Deep ripping of soils is commonly used to overcome soil structural constraints. This can result in excess water being directed to subsoils where it becomes deep drainage or shallow water flow, and lead to worsening of the salinisation processes of land and water. A comprehensive understanding of both soil conditions and landscape scale salinity processes is needed to successfully use this technique.

Biggest negative impact on salinity

- Soil structural barriers are not the main limitation to plant water use
- Soil ripping occurs on important recharge areas
- Soil ripping occurs on important discharge areas
- Soil ripping occurs above important salt stores
- Ripping occurs where farm management does not allow efficient use of available soil water due to poor farming systems or grazing practices
- In discharge areas
- Where sodic subsoils can cause tunnel erosion.

Smallest negative impact on salinity

- In free draining gradational soils where the main limitation to plant growth is shallow structural barriers
- Where the land manager has high levels of skill in landscape grazing management
- Where ripping and subsoil limitations do not coincide with important recharge areas, discharge areas or salt stores.

Potential mitigating actions

- Management changes from plant growing systems dominated by annuals to those dominated by perennials
- Measure and respond to sub-soil conditions
- Management actions: VE1, VP1, VP2, FS1, SR3, SR4, SR5, SR6, FS2, FS3, E3.

High hazard land use management action	**Flat contour banks**	**Code DLU12**

Building banks which do not direct surface water flow, but are built along the contour, can have negative salinity outcomes.

Flat banks direct water to subsoils. Unless this water is used by plants it can become additional deep drainage and recharge. This can result in excess water being directed to subsoils, which becomes deep drainage or shallow lateral flow. This can lead to an increase in salinisation processes of land and water.

To successfully use this technique a comprehensive understanding of both soil conditions and landscape scale salinity processes is required. It frequently has negative salinity outcomes.

Biggest negative impact on salinity

- Soil moisture is not the main limitation to plant water use
- Banks are constructed on important recharge areas
- Banks are constructed on important discharge areas
- Banks are constructed on important salt stores
- Banks are not managed to allow efficient use of available soil water due to poor farming systems or grazing practices
- Where sodic subsoils can cause tunnel erosion.

Smallest negative impact on salinity

- Free draining gradational soils where the main limitation to plant growth is soil moisture
- Where the land manager has high levels of skill in landscape grazing management.

Potential mitigating actions

- Management changes from plant growing systems dominated by annuals to those dominated by perennials
- Measure and respond to sub-soil conditions
- Management actions: VE1, VP1, VP2, FS1, SR3, SR4, SR5, SR6, FS2, FS3, E3.

High hazard land use management action	Irrigation using inefficient on-farm water delivery practices	Code DLU13

Irrigated agriculture and urban irrigation management have a high potential to create excessive rates of deep drainage. The ability of irrigated plants to use available moisture and avoid deep drainage is limited by the amount and the timing of irrigation. Over-irrigation fills up the soil profile with water and causes deep drainage.

This hazard is closely linked to DLU 14 – Poor targeting of land suitable for irrigation. Certain irrigation techniques will be more or less sustainable, depending on the land that is being used for irrigation.

Biggest negative impact on salinity

- Flood irrigation
- Irrigation of free-draining gradational soils
- Where irrigated areas have high water tables
- Annual rainfall below 800 mm
- Where the temporal rainfall pattern does not match the growth pattern of the irrigated crop – e.g. winter dominant rainfall but summer irrigation cropping program
- Irrigation occurs above important recharge areas
- Irrigation occurs above important discharge areas
- Irrigation occurs above important salt stores
- Irrigation does not have surface or subsurface drainage
- Where drainage of saline water from irrigated land can impact on important assets such as wetlands or streams.

Smallest negative impact on salinity

- Heavy textured soils which allow water to stay in the root zone
- Average annual rainfall over 800 mm
- When management of irrigated crops and pastures allows a dry soil profile which limits deep drainage
- When a high degree of monitoring and irrigation skills are used.

Potential mitigating actions

- Measure and respond to soil moisture and potential deep drainage
- Apply best management practices for irrigation
- Phase farming used with a perennial component
- Management actions: IS1, IS2, FS3, FS4, E4, E5, E6.

High hazard land use management action	Poor targeting of land suitable for irrigation	Code DLU14

Irrigated agriculture and urban irrigation management have a high potential to create excessive rates of deep drainage and loading of soils with salt. The ability of irrigated plants to use available moisture and avoid deep drainage is limited by the soil and landscape conditions, as well as the amount and the timing of irrigation. Poor targeting of land suitable for irrigation can lead to high water tables, irrigation-induced salinity or long term loading of soils with salt.

This hazard is closely linked to DLU 13 – Irrigation using inefficient on-farm water delivery practices.

Certain irrigation techniques will be more or less sustainable, depending on the land that is being irrigated.

Biggest negative impact on salinity

- Inefficient on-farm water delivery systems
- Available water is unsuitable for irrigation due to chemistry (salinity, pH or Sodium Adsorption Ratio [SAR])
- Irrigation of free-draining gradational soils
- Irrigation of soils not on currently active alluvial plains or draining to the current stream
- Where irrigated areas have high water tables
- Annual rainfall below 800 mm
- Where the temporal rainfall pattern does not match the growth pattern of the irrigated crop – e.g. winter dominant rainfall in summer irrigation cropping program
- Irrigation occurs above important recharge areas
- Irrigation occurs above important discharge areas
- Irrigation occurs above important salt stores
- Irrigation areas do not have surface or subsurface drainage
- Drainage of saline water from irrigated land can impact on important assets such as wetlands or streams.

Smallest negative impact on salinity

- Average annual rainfall over 800 mm
- Management of irrigated crops and pastures allows for management of salt loading and leaching
- Irrigation water is suitable. Irrigation is occasional and not continuous or annual
- High levels of skills in farm layout management are applied
- High degree of monitoring and irrigation skills are applied.

Potential mitigating actions

- Assess and consider land and water resources when selecting land for irrigation
- Measure and respond to soil moisture and potential deep drainage
- Measure and respond to loading of salt into soils by irrigation
- Management actions: IS1, IS2, FS3, FS4, E4, E5, E6.

High hazard land use management action	**Loading of soils with salt through irrigation and flow management**	**Code DLU15**

Irrigated agriculture, urban management and flow regimes into wetlands have a high potential to create loading of soils with salt.

The ability of a soil profile to cope with salt loading is governed by the water quality and quantity being applied, and the background soil conditions.

Loading of soils with salt can lead to a decline in soil fertility and leaching of salt into off-site environments.

Biggest negative impact on salinity

- Irrigation water is above 800 µS/cm
- Irrigation water has high SAR
- Leaching fractions are not used as part of irrigation programs
- Soils that have moderate or high background salt levels
- Soils that have a physical barrier to drainage and leaching of salt
- Irrigation of soils which are not on currently active alluvial plains and which do not drain to the current stream
- Where water with high salt levels is directed to wetlands and plains through flow management.

Smallest negative impact on salinity

- Average annual rainfall over 800 mm
- Management of irrigated crops and pastures allows for management of salt loading and leaching
- Water used for irrigation is of suitable quality
- High levels of skill in farm layout management are applied
- When high degree of monitoring and irrigation skills are applied
- Irrigation is occasional and not continuous or annual
- Water directed to wetlands and flood plains over time contains both fresh and high salinity water events.

Potential mitigating actions

- Assess and consider land and water resources when selecting land suitable for irrigation
- Measure and respond to soil moisture and potential deep drainage
- Measure and respond to loading of salt into soils through irrigation
- Measure and respond to loading of salt into wetlands and floodplains through flow management
- Management actions: IS1, IS2, FS3, FS4, E4, E5, E6.

High hazard land use management action	**Construction of drains to lower water tables**	**Code DLU16**

Constructing drains to lower levels of groundwater can mitigate salinity processes. Water is disposed of by evaporation and concentration, or as surface water runoff. Disposal of drainage water into streams has a high potential to create loading of soils with salt.

The ability of a soil landscape to cope with salt loading is governed by the quality and quantity of water applied and the background soil conditions.

Loading of soils with salt can lead to changes in soil fertility and leaching of salt into off-site environments.

The chemistry of drainage water, including acidity, alkalinity and sodicity, can worsen salinity issues.

Biggest negative impact on salinity

- Drainage water has an electrical conductivity (EC) above 800 μS/cm
- Drainage water has a high SAR which will impact on local site conditions
- Drainage water has a high acidity which will impact on local site conditions
- Soils with moderate or high levels of background salt
- Water with high salt levels is directed to wetlands and plains through flow management
- Low value assets are being impacted by salinity processes (cost and level of engineering may greater than any benefits achieved)
- Disposal issues cannot be addressed because of water quality or volume
- Financial resources are inadequate.

Smallest negative impact on salinity

- Average annual rainfall over 800mm
- Management of irrigated and dryland crops and pastures allows for management of salt loading and leaching
- Drainage water is of low salinity
- High levels of skills in farm layout management are applied
- Intensive monitoring is implemented
- Salinity management is being undertaken concurrently with other management actions
- Where there is a connection between the water being removed and the water that is causing salinity
- Disposal issues relating to water quality and volume can be addressed
- Assets of high value are being impacted by salinity processes
- The high cost of engineering intervention is appropriate.

Potential mitigating actions

- Assess and consider land and water resources before selecting land suitable for construction of drains
- Measure and respond to loading of salt into wetlands and floodplains through flow management
- Management issues: IS1, IS2, FS3, FS4, E4, E5, E6.

7. Management outcomes

In addition to the salinity outcomes these management actions provide (e.g. salt load and salinity concentration in streams), there is a number of associated outcomes that may be beneficial or detrimental to other natural resource management applications.

Management actions may have both positive and negative outcomes. Section 7.1 lists positive outcomes in terms of soil, vegetation, air and water quality, and engineering. Section 7.2 outlines negative outcomes that may result from implementing high hazard land management actions.

7.1 Positive management outcomes

There are twenty management actions to address salinity that may have positive outcomes for other aspects of land management. These outcomes include:

Soil outcomes

- SO1: Increased soil fertility by amelioration of the most limiting factor
- SO2: Improved soil structure
- SO3: Increased soil biological health
- SO4: Increased water storage in the root zone
- SO5: Increased soil carbon storage.

Vegetation outcomes

- V1: Healthy plants – increased efficiency of conversion of available water to plant material
- V2: Perennial plants – longer growth windows of plants
- V3: Responsive plants – plants able use water when it becomes available
- V4: Plant diversity – a range of plants with a range of growth cycles and water use characteristics
- V5: Plants as carbon sequesters – increased woody mass tying up addition carbon.

Groundwater engineering outcomes

- GWE1: Lowered water tables by extraction.

Surface water engineering outcomes

- SWE1: Diluted water tables
- SWE2: Redirection of surface water
- SWE3: Redirection of surface water to reduce recharge
- SWE4: Dilution of surface water through flow management
- SWE5: Reduced hydraulic head on groundwater.

Air quality outcomes

- AQ1: Reduce dust in atmosphere.

Biodiversity outcomes

- BO1: Landscape connectivity
- BO2: Increased biodiversity
- BO3: Habitat protection and improvement.

Water quality outcomes

- WQ1: Decreased turbidity.

Potential outcomes resulting from each management action group are provided in Table 7.

Table 7: Summary of management actions and outcomes

Code	Management action	Outcomes
	Management action group VE: Vegetation for ecosystem service	
VE1	Establish and manage blocks of trees to reduce recharge	V1, V2,V3, V4, V5, SO5, BO1, BO2, BO3
VE2	Establish and manage trees to intercept lateral groundwater flow	V2,V3,V4, V5, SO5, BO1, WQ1
VE3	Maintain and improve existing native woody vegetation to reduce discharge	V1, V2,V3, V4, V5, SO2, SO3, SO4, SO5, BO1, BO2, BO3
VE4	Maintain and improve riparian native vegetation to reduce discharge to streams	V1, V2, V3, V4, V5, SO4, SO5, BO1, BO2, BO3, WQ1
VE5	Establish and manage trees that are integrated into farming logistics to reduce recharge	V1, V2,V3,V4, V5, SO4, SO5
VE6	Revegetate non-agricultural land with native species to manage recharge	V1, V2, V3, V4, BO1, BO2, BO3, WQ1
VE7	Use targeted planting of trees to buffer salt stored in geological layers	V2,V3,V4, V5
	Management action group VP: Vegetation for production	
VP1	Improve grazing management of existing perennial pastures to manage recharge.	V1, V2,V3, V4 SO2, SO3, SO4
VP2	Establish and manage perennial pastures to manage recharge	V1, V2,V3, V4 SO2, SO3, SO4
VP3	Establish and manage perennial pastures to intercept shallow lateral groundwater flow	V2,V3, V4, WQ1
VP4	Maximise agricultural production from pastures by input of additional ameliorants to manage recharge	SO1, V1

Code	Management action	Outcomes
VP5	Improve grazing management to improve or maintain native pastures to manage recharge	V1, V2,V3, V4 SO2, SO3, SO4
VP6	Establish and manage blocks of perennial forage shrubs to manage recharge	V1, V2,V3, V4 SO2, SO3, SO4
VP7	Establish commercial forestry to manage recharge	V2, V3, V5
VP8	Establish and manage farm scale forestry integrated into farming logistics to reduce recharge	V2, V3, V5
VP9	Establish and manage perennial horticulture to manage recharge	V1, V2,V3, V4 SO2, SO3, SO4
	Management action group FS: Farming systems	
FS1	Implement pasture cropping with annual cereals in perennial pastures to manage recharge	V1, V2,V3, V4 SO2, SO3, SO4
FS2	Maximise agricultural production by using ameliorants in annual cropping systems to manage recharge	SO1, V1
FS3	Implement rotational cropping with a perennial pasture component to manage recharge	S04, V2, V4
FS4	Implement opportunity cropping with annual crops and green manures to manage recharge	V1, V3, V4 SO4
FS5	Deep rip soil to improve soil structure and manage recharge	SO2, SO4
FS6	Implement zero-till farming systems to increase soil water storage, soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4
FS7	Implement controlled traffic farming systems to increase soil water storage , soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4
FS8	Implement no-till farming systems to increase soil water storage, soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4
FS9	Implement reduced-till farming systems to increase soil water storage, soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4

Code	Management action	Outcomes
FS10	Implement direct-drill farming systems to increase soil water storage, soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4
FS11	Use green manures and manure crops to increase soil water storage, soil water use and to reduce recharge	V1, V3 SO1, SO2, SO3, SO4, SO5
	Management action group SA: Soil ameliorants	
SA1	Ameliorate soil sodicity by adding gypsum to increase plant water use and reduce recharge	SO1, SO2, SO3, SO4, WQ1
SA2	Ameliorate soil sodicity by adding lime to increase plant water use, reduce recharge and manage discharge sites	SO1, SO2, SO3, SO4, WQ1
SA3	Ameliorate soil acidity by adding lime to increase plant water use, reduce recharge and manage discharge sites	SO1, SO2, SO3, SO4
SA4	Improve soil health by applying biological agents to the soil to increase plant water use, reduce recharge and manage discharge sites	SO1, SO2, SO3, SO4, WQ1
SA5	Improve soil health by applying compost to increase plant water use, reduce recharge and manage discharge sites	SO1, SO2, SO3, SO4, SO5, WQ1
	Management action group E: Engineering	
E1	Use groundwater to supplement or replace surface water for farm stock	GWE1, SWE3
E2	Divert surface water to increase recharge in low lying areas and minimise runoff	SWE2
E3	Construct agricultural earthworks to maximise freshwater runoff and reduce recharge in low areas	SWE2,SWE3
E4	Implement groundwater pumping and disposal	GWE1
E5	Manage stream flow to create dilution flows in regulated rivers	SWE4, WQ1
E6	Manage flow cycles of rivers to periodically produce dry supply channels and streams	SWE5
E7	Install leaky weirs to slow streams and increase freshwater recharge	WQ1
E8	Construct diversion banks to connect streams with back plains to increase freshwater recharge	SO5

Code	Management action	Outcomes
Management action group IS: Irrigation systems		
IS1	Manage on-farm irrigation to achieve best practice	SWE3, SWE4, SWE5
IS2	Manage irrigation supply systems to achieve best practice	SWE2, SWE5
IS3	Establish effective effluent disposal systems specific to site conditions	SO2, SO3
Management action group SR: Salt land rehabilitation		
SR1	Fence and isolate salt land and discharge areas to promote revegetation	V1, V2,V3
SR2	Establish and manage salt land pasture systems to improve productivity	V1, V2,V3, V4 SO2, SO3, SO4
SR3	Establish forestry systems on salt land to improve productivity	V1, V2,V3, V4, V5 SO2, SO3, SO4, SO5
SR4	Undertake rehabilitation to ameliorate land salinity processes and reduce land degradation	V1, V2,V3, V4 SO1, SO2, SO3, SO4, WQ1
SR5	Establish and manage salt land grazing systems based on forage shrubs to improve productivity	V1, V2,V3, V4 SO2, SO3, SO4
SR6	Pond water on dry scalds to promote revegetation	V1, V2,V3, V4 SO1, SO2, SO3, SO4
SR7	Reduce animal impact on scalds by providing mineral supplements to stock	SO1
SR8	Mulch sites to reduce evaporation and promote pasture growth	SO1, SO2, SO3
SR9	Mulch sites using tactical animal impact	SO1, SO2, SO3
Management action group AS: Acid sulfate		
AS1	Improve or maintain the hydrological regime to keep acid sulfate soil saturated	SO1, SO2, SO3, SO4
AS2	Isolate and improve acid sulfate soil sites	SO2, SO3

7.2 Negative outcomes from high hazard land management actions

High hazard management actions have a range of impacts that can cause a negative outcome in the landscape. Some high hazard actions will cause a negative outcome at a very specific location in the landscape. High hazard management actions range in their significance across landscapes and also across management areas.

Typically, salinity processes will be amplified and salt mobilisation increased due to:

- Lowered evapotranspiration (plant water use)
- Rising and high water tables
- Changed water balance and surface water management.

These negative outcomes of high hazard management actions can be grouped and further detailed as:

- NO1: Lower plant water use leading to more recharge
- NO2: Increased hydraulic head
- NO3: Lower surface water runoff resulting in less dilution flows
- NO4: Conditions limit capacity for soil water storage
- NO5: Conditions limit capacity for plant water use
- NO6: Damage to infrastructure
- NO7: Adding salt to soil profile.

The negative outcomes associated with the various high hazard management actions are listed in Table 8 below.

Table 8: Summary of actively discouraged management actions and the associated negative outcomes

Code	Management action	Negative outcome
DLU1	Long fallows in cropping systems	NO1
DLU2	Poor grazing management	NO1
DLU3	Annual cropping	NO1
DLU4	Clearing of native vegetation	NO1
DLU5	Farm dams in flow lines	NO2
DLU6	Drying up fresh surface water catchments	NO3
DLU7	Locating infrastructure on discharge areas	NO2, NO6, NO7
DLU8	Poor soil management – tillage causing poor structure	NO4, NO5
DLU9	Poor soil management – chemistry and biological	NO4, NO5
DLU10	Poor soil management – loss of surface soil layers	NO4, NO5
DLU11	Deep ripping of soils to maximise water infiltration to subsoil	NO4, NO5
DLU12	Flat contour banks	NO4, NO5

Code	Management action	Negative outcome
DLU13	Irrigation using poor practices	NO2, NO7
DLU14	Poor targeting of locations suitable for irrigation	NO2, NO5, NO7
DLU15	Loading of soils with salt through irrigation and flow management	NO7

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Appendix A: Background to general landscape salinity management

A1. Themes of land use design for general salinity management

The following themes provide general concepts for the design of strategies and actions used to manage salinity. Land use systems and practices should deliver on these themes to manage current salinity issues and avoid future problems.

A1.1. Soil themes

Soil theme 1: soil biological health – land use systems which maintain and improve soil organic matter and biological life.

Soil theme 2: soil chemistry – land use systems which address soil chemical imbalances.

Soil theme 3: soil structure – land use systems which maintain and improve soil structure caused by past management practices and cropping cycles.

Soil theme 4: carbon sequestration – land use systems which sequester carbon into soils

Soils themes are aimed at addressing three components of soil health – chemistry, structure and soil biology.

Successful soil actions must deliver on these components and must also result in increased water use by plants to be successful as salinity management tools. This is achieved by:

- Creating conditions which promote and maximise the growth and water use of plants
- Creating conditions to promote and maximise the plant-available water holding capacity of soils in the landscape.

A1.2. Vegetation themes

Vegetation theme 1: perennial landscape – land use systems based on perennial plants.

Vegetation theme 2: diverse landscape – land use systems based on a range of plants in the landscape. Diverse landscapes have a range of water use characteristics across seasonal and climatic cycles.

Vegetation theme 3: resilient landscapes – land use systems based on plants which can cope with the limiting extremes of the climate and landscape factors including salinity.

Vegetation theme 4: robust landscapes – land use systems which can take advantage of favourable conditions in moisture and temperature to rapidly expand biomass production and leaf area index.

Vegetation theme 5: sequester carbon into vegetation – land use systems which can sequester carbon into vegetation.

Vegetation themes are aimed at promoting perennial diverse landscapes which maximise evapotranspiration and impact on recharge (rainfall or river flow that reaches groundwater, which can lead to rising water tables that mobilise salt stored in soil) and discharge.

Successful vegetation actions result in landscapes which:

- Mimic the water and vegetation characteristics of pre-European landscapes
- Have balanced water use and recharge.

A1.3. Engineering themes

Engineering theme 1: internal systems – water and salt remains within the system.

Engineering theme 2: complement vegetation systems – the watertable is lowered by engineering methods to allow a complementary vegetation system to be emplaced to manage excess discharge.

Engineering themes are aimed at influencing the water balance and hydrogeological balance. Engineering interventions partition and allocate water by physical means. Successful engineering actions result in lowering of water tables.

Appendix B: Land use design for saline land management

It is important to understand the characteristics of land affected by salinity because these may determine how successful management will be.

There are two types of saline sites:

Rehabilitation sites:

- Sites that have degraded to a point where it is not viable to try and return the area to productive agricultural
- These commonly occur along flow lines, so the biodiversity benefit which can be built into revegetation has a high potential
- On the tablelands and slopes of NSW these sites commonly occur along eroded flow lines and gullies.

Potentially productive agricultural sites:

- These sites can be productive areas if appropriate salt-tolerant species are managed effectively
- These sites are suitable for a range of pasture, shrub and tree species
- On the tablelands and slopes of NSW these sites are suitable for grazing systems based on salt tolerant pastures.

B1. Issues for consideration in site management

Waterlogging:

- Sites can be waterlogged seasonally or more permanently waterlogged due to climatic influences
- Waterlogging can impact on access, infrastructure, grazing management timing, and types of plants which are suitable for establishment.

Soil chemistry:

- **Salt levels** in soils vary temporally and spatially. This means sites will exhibit a range of salt levels across a site and over a period of time
- **Sodicity** is common on saline discharge sites, particularly where initial scalding and erosion exposes sodic sub-soils
- **Variation**. A range of anions and cations can be present in varying ratios at any site. Consequently, sites with similar soil chemistry signatures will respond to management in similar ways. However, a wide variation in soil chemistry can translate into a variable likelihood of success of any remediation practices
- **Soil pH** is one characteristic which can vary between saline sites – some are alkaline and some acid. This can impact on the success of plants and also the suitability of soil ameliorants such as gypsum and lime.

Saline areas and erosion:

- Many saline areas occur in flow lines and depressions
- Saline discharge areas frequently have runoff water and erode
- Salt land and eroded land frequently occur together. So planning to intervene and manage a saline area must consider the impact on and the affect of erosion processes.

Expansion of sites:

- Saline areas are slowly expanding in many areas. This means that site management must allow for the site to get larger

- The expanded area of salinity is now impacting the fences of many sites which addressed initial symptoms
- Techniques for assessing possible spread of salinity include EMI 31 and 38 surveys and soil sampling.

B2. Considerations for design of successful saline discharge site management

The range of conditions on saline discharge areas can be quite challenging for a salinity remediation practitioner. There are some common considerations in examples of successful management.

Rehabilitation versus production

- Recognise the difference between rehabilitation and agricultural production
- Plan the site and manage for the outcome which is suitable at the site. If you try and do both at once you may end up doing neither.

Recognise the land is different – fence the discharge site

- Saline discharge areas are sensitive areas to manage
- It is important to recognise how different they are and set up infrastructure which allows them to be managed. This means considering fencing and stock water supply in many cases
- Many sites have benefited greatly from adding a fence and nothing else.

Manage for what you want

- Manage to encourage and support diverse perennial vegetation systems
- Management actions used in grazing management of saline areas are an important tool
- There are many examples of very positive outcomes on saline sites where change in in grazing management has been the only action.

Promote perennial diverse water use – across the site and across the year

- This requires plants which are able to grow in saline and waterlogged conditions and management of those plants to allow them to grow and thrive
- Plants in the mix should have growth periods across the year and in different types of seasons.

Some discharge site management examples and techniques are listed below:

- Fence saline areas into manageable grazing/stocking sizes and remove discharge areas from the management program of larger ‘dryer’ paddocks
- Add gypsum and lime to address soil chemical issues
- Plant salt tolerant and waterlogging tolerant trees and shrubs
- Use mulches to reduce evaporation and the surface concentration of salt and to promote organic matter in topsoil. Mulch can be spread by placing hay bales in position and allowing a large number of stock to have access for a short time, or it can be spread by a variety of physical methods
- Targeted earthworks can be used to remediate erosion issues and to prevent water from lying on the site. Collection, redirection and dispersal of water in saline and sodic landscapes require careful planning and implementation. There are many examples of earthworks being unsuccessful in saline discharge management.