NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – southern irrigators - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/south-irrig

Updated versions of this document can also be found at the above web address.

PART B. QUICK HELP GUIDE

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Chapter B1. Trouble-shooting guide

An ideal soil (Chapter A3) should supply the plants with adequate water, oxygen, nutrients and support. When the soil does not provide these requirements there is a soil problem.

Irrigation in southern NSW has developed on soils which can have severe limitations to crop growth under irrigated conditions. Common soil problems in southern NSW include:

- poor tilth
- inadequate infiltration
- poor internal drainage
- poor seedling emergence
- poor crop growth and yield

A soil problem may be due to:

- recent management — such as compaction, remoulding and smearing when tilling a soil that is too wet
- a residual management problem — such as deep subsoil compaction caused by landforming a moist clay soil
- a natural problem present at the time of European settlement — such as salt left in the soil by an inland sea covering Australia 65 million years ago

To identify a soil problem that may be effecting you, examine the soil and crop/pasture performance in your paddock. Once the problem has been identified, Tables B1–B5 will help you determine the cause of the problem and direct your to chapters of the manual with more detailed information.

Table B1. **Possible causes and signs of poor tilth**

Problem	Possible signs	Possible cause	Relevant chapters
POOR TILTH	large clods	• inadequate rolling/tillage to break down clods	C5, C8, E4
		• cultivation at incorrect moisture content	C8
		• hardsetting, crusting, sodicity	B3, C7, E2

Table B2. Possible causes and signs of inadequate infiltration

Problem	Possible signs	Possible cause	Relevant chapters
INADEQUATE INFILTRATION	low porosity	• hardsetting/crusting • sodicity	B3, C7, E1 C7, E1
	hard surface, few cracks	• hardsetting/crusting	B3, C7, E1
	dispersion	• sodicity	C7, E1
	surface poorly drained after irrigation /rainfall	• sodicity • compaction • flat land/poor layouts	B2, C7, E1 B4, C5, E3, E4 B2, B12, C7, E1

Table B3. Possible causes and signs of poor internal drainage

Problem	Possible signs	Possible cause	Relevant chapters
POOR INTERNAL DRAINAGE	waterlogging /poor aeration	• high subsoil density • sodicity	B4, C5, C6 B2, C7, E1

Table B4. Possible causes and signs of poor seedling emergence

Problem	Possible signs	Possible cause	Relevant chapters
POOR SEEDLING EMERGENCE	surface poorly drained after irrigation/ rainfall	• sodicity • compaction • unsuitable layouts /irrigation design	C7, E1 B4, C5, E4 B2, B12, E3
	dispersion	• sodicity	C7, E1
	hard surface, few cracks	• hardsetting/crusting • sodicity	C7, E2 C7, E1
	too many large clods in seedbed	• hardsetting • sodicity • compaction • tillage implement problems	C7, C8, E2 C7, E1 B4, C5, E4 C8, E4
	slime present in rice bays	• algae • excessive plant residues	B7, D2 E5

Table B5. Possible causes and signs of poor crop growth and yield

Problem	Possible signs	Possible cause	Relevant chapters
POOR CROP GROWTH AND YIELD	surface poorly drained after irrigation/rain	• sodicity • compaction • poor layouts /irrigation design	B2, C7, E1 B4, C5, D4 B9
	hard dense subsoil	• compaction and/or smearing by machinery	B4, C5, C8, E4
		• sodicity	C7, E1
	dispersion	• sodicity	C7, E1
	unusual leaf colour	• poor nutrition • waterlogging, N deficiency • pH imbalance • disease, herbicide damage	E5 B2, E5 B5
	salt tolerant weeds, rising watertables	• salinity	B6, C10

Chapter B2. Reducing waterlogging

INTRODUCTION

Waterlogging in irrigated crop and pasture production causes poor aeration and is responsible for large yield losses. These losses are often unrecognised. Accessions to the watertable are also more likely.

Many of the soil types dealt with in this manual have poor internal drainage (permeability). Therefore, particular attention must be paid to surface drainage to reduce waterlogging and to achieve optimum yields. Good surface drainage removes surplus water from an area, avoiding excessive infiltration and surface ponding. Surface drainage is controlled primarily by slope, irrigation layout, design and structures.

When irrigating non-rice crops and pastures, water should not remain ponded for more than 12 hours. Yield losses from longer durations of ponding are likely, especially for crops intolerant of waterlogging.

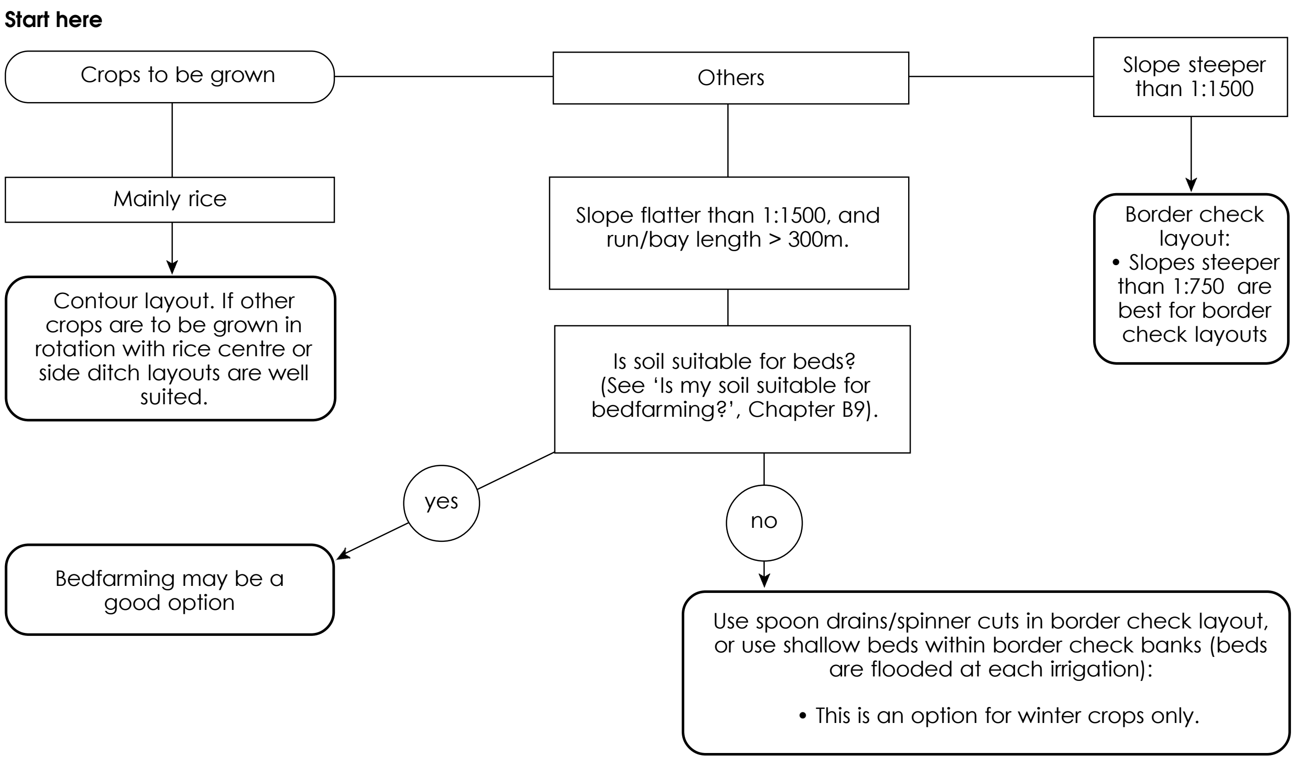
AVOIDANCE OF WATERLOGGING

Waterlogging can be reduced by:

- Development of a suitable irrigation layout
- Redevelopment of an unsuitable irrigation layout
- Use of raised beds
- Higher flow rates (water on and off quicker)
- Restriction of wheels of traffic to narrow laneways
- Irrigation scheduling

TYPE OF IRRIGATION LAYOUT

Figure B1. selection of irrigation layout



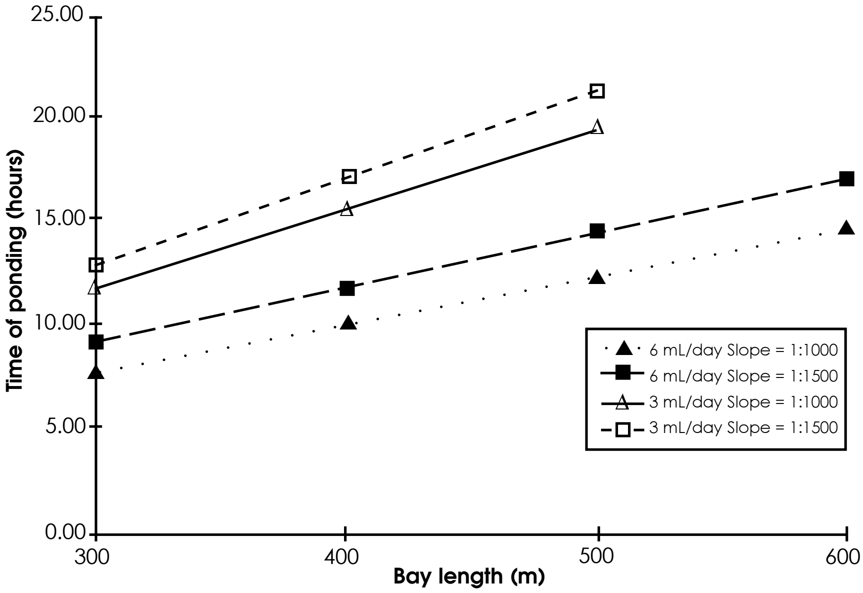
Border check irrigation layouts

The period of ponding, and therefore the degree of waterlogging, in a border check irrigation layout is controlled by:

- flow rate
- bay length
- slope

The combined effects of bay length and slope on the time of ponding is shown in Figure B2. As waterlogging increases with the time of ponding, duration of ponding should be minimised to reduce waterlogging.

Figure B2. Time of ponding vs bay length (spring irrigation, cereal crop, transitional red-brown earth)



Based on BICADM irrigation model.

Flow rate

Flow rate for a border check layout should be 1.5–2 litres per second (L/s) per metre of bay width. Table B6 gives flow rates for different bay widths based on 1.75 L/s/m of bay width.

Table B6. Flow rates for border check irrigation (based on flow rate of 1.75 L/s/m of bay width)

Bay width (m)	Flow rate required (ML/day)
20	3.0
40	6.0
60	9.1
80	12.1

Bay length

To minimise waterlogging, bay length should not exceed 400 m. Figure B2 shows that bay length has a large impact on period of ponding (waterlogging), especially at lower flow rates.

Slope of bay

Slope will affect the surface drainage of the bay and therefore is an important determinant of waterlogging. The optimum slopes for a border check irrigation layout range from 1:500–1:1500.

Slopes flatter than 1:750 may have slight hollows or depressions in which water may lie after the bay is drained, thus contributing to waterlogging. This is a consequence of variation in landforming accuracy, and is difficult to avoid. Slopes steeper than 1:750 are best suited to crops other than rice. Successful irrigation of winter crops and pastures can be obtained on slopes of 1:1000.

Suitable operation of a border check irrigation system can be obtained at slopes as low as 1:1500. Slopes flatter than about 1:1500 should be considered for bedfarming (see Chapter B9: *Is my soil suitable for raised bedfarming?*).

Contour irrigation layouts

Contour irrigation layouts are used for rice and therefore for other land uses in rotation with rice (pasture and winter crops). It is important that the layout allows fast drainage from the bay. This will reduce waterlogging in the winter crops and pastures, and increase productivity. It also reduces the occurrence of a wet rice harvest and associated soil compaction.

Flow rate

When growing non-rice crops, high flow rates in contour bays are ideal for reducing time of ponding and waterlogging. As bays become larger, greater flow rates are required to reduce waterlogging.

For example, a three-hectare bay would require a flow rate of 14 ML/day to achieve bay fill in 4–6 hours on a heavy clay soil.

Bay size

Optimum size of a contour bay ranges from 3–6 ha. This allows good water control and efficient use of machinery. The maximum size of a contour bay for winter cereal and pasture production is about three hectares. Rotation crops and pastures grown in bays larger than this require high flow rates to prevent waterlogging, and these rates may be difficult to achieve. Contour bays should be no longer than 400 m between outlet points for best drainage.

Slope

The optimum slope of a contour bay for rice production is 1:1000–1:1200, but they can be flatter. Reduced waterlogging in rotation crops must be achieved through management of flow rate and choice of bay size.

Contour interval

A contour interval of 5 cm between banks is ideal for rice, and should no more than 7.5 cm. Contour intervals of this order ensure an even depth of water over the bay.

Drainage

Toe furrows should be kept clean and continuous. Even a small ridge of soil in or beside the toe furrow will impede drainage. In bays with depressions that collect water, a shallow drain should be dug from the depression to the toe furrow, to assist drainage.

Raised beds and controlled traffic

Bedfarming is a type of furrow irrigation layout. The crop is grown on a raised bed and irrigated via furrows located either side of the bed. Ideally irrigation water moves laterally from the furrow through the bed by “subbing” (soaking up water from the furrow to the top and middle of the bed against gravity). This layout reduces waterlogging because flooding over the soil surface is avoided. Since the bed is raised above the furrow, excess water in the bed may drain back into the furrow to prevent waterlogging.

Restriction of wheel traffic to the furrows also reduces the waterlogging problems associated with compacted soil.

Suitable soil types for raised beds

See B9: *Is my soil suitable for raised bedfarming?*

Slope

Raised beds provide the best irrigation layout, for suitable soil types, where paddocks are relatively flat. Raised beds are suited to flatter grades, ranging from 1:1000–1:2500.

Bed geometry

Raised beds are normally 1.5–2.0 m wide, allowing a bed top width of 1.0–1.5 m. Optimum bed width varies with soil type. Acceptable subbing can be achieved in 1.8–2.0 m wide beds on a self mulching clay. Some red-brown earths and non self-mulching clays require bed widths of 1.0–1.5 m for adequate water entry. On all soil types, the rate of subbing will be reduced by bed-shoulder compaction if machinery wheels are too wide.

The height of beds ranges from 15–20 cm, but varies with furrow length and slope. For flatter grades and longer furrows, the height of beds must be increased to prevent waterlogging.

Furrow length

The optimum length of the furrow depends on soil type and slope. Shorter furrow lengths are preferred on lighter soils to prevent over-watering the top end of the paddock. On heavy soils, furrow lengths of up to 800 m have been used after landforming. Shorter furrow lengths are also required as slope becomes flatter. This is necessary to prevent over-watering and waterlogging of the beds.

Irrigation scheduling

Irrigation scheduling is recommended to match water application to plant needs. This aims to prevent both drought stress and waterlogging of the crop (see Chapter E7: *Irrigation scheduling*).

Chapter B3. Managing crusting and hardsetting soil

INTRODUCTION

Crusting and hardsetting is evident in soils with a high content of fine sand and/or silt (loamy soil) and low organic matter levels.
A crusting or hardsetting topsoil can be recognised as a hard surface layer, showing very little structure and few shrinkage cracks. Crusts are recognised as a hard surface layer up to 1 cm thick. Hardset layers are greater than 1 cm thick, and usually the entire topsoil sets hard.

Crusting is common on loamy soils.

Crusting and hardsetting can occur naturally on any soil but will be worse when:

- surface soil has a loam texture (high content of fine sand and/or silt)
- surface soil is low in organic matter
- soil structure has been damaged by cultivation, particularly when the soil was too dry
- soil is not protected from raindrop impact by plants or stubble
- surface soil is sodic

PREVENTING AND REPAIRING SOIL CRUSTS AND HARDSETTING LAYERS

Create surface cover

Cereal crops and pasture grasses, with their fibrous root systems, create pathways for water flow and root growth. This improves the structure of the topsoil and prevents hardsetting and crusting. Organic residues also help to overcome hardsetting and crusting by improving aggregation.

Raindrop impact and the flooding of the soil during irrigation, can damage the structure of loam topsoils. By retaining stubble or good plant cover, structural damage leading to the formation of crusts and hardset layers may be avoided.

Increase soil organic matter levels

Soil management should aim to maintain soil organic matter levels above 2%. Soil organic matter can be increased by reducing the number and severity of cultivations, maintaining plant cover, and retaining stubbles. These are all good conservation farming practices. Ploughing in ‘green manure crops’ may also be used to improve the organic matter content of the topsoil, although this practice tends to disrupt continuous vertical macropores in the topsoil.

Apply gypsum to sodic topsoils

Topsoils with an exchangeable sodium percentage greater than 6, or an dispersion score greater than 6, are sodic and prone to dispersion (see Chapter C7: *Slaking and dispersion*). Dispersion leads to crusting or hardsetting of the topsoil. Sodic topsoils would benefit from an application of gypsum prior to sowing (except rice) to reduce crusting or hardsetting, and improve water entry and seedling emergence.

Tillage

Where the subsoil is a cracking clay, crusting and hardsetting problems may be ameliorated by mouldboard ploughing. This shatters the crust or hardset layer, and brings subsoil clay to the surface to promote cracking in the topsoil. Attention must be paid to the depth of subsoil to ensure depth of ploughing is sufficient to bring swelling clay to the surface. This technique is suitable for soils with a non-sodic subsoil. If sodic clay soil is brought to the surface, problems may be exacerbated.

Deep ripping and chisel ploughing are options to break a crust or hardset layer and improve water entry. A crust breaking roller (spiked roller) is also an effective implement for breaking a crusted layer and improving seedling emergence.

Minimising tillage will also help to prevent crusting and hardsetting. Only till the soil when there is no other option and at a water content just below the plastic limit.

Chapter B4. Do I have a compaction problem?

INTRODUCTION

Compaction occurs when soil is compressed into a smaller volume so that its density is increased and air filled porosity is decreased. This results in poor internal drainage and resistance to root growth. Compaction is a consequence of machinery or animal traffic on wet/moist soil. Compaction can cause serious yield losses if not recognised and treated quickly. Compaction is often associated with remoulding of soil, which is the disruption of continuous soil pores without an increase in bulk density of the soil.

IDENTIFICATION OF SOIL COMPACTION

Methods for recognising compaction problems are:

Paddock history

Any operation of machinery or grazing of stock on wet soil is likely to cause some soil compaction. Severe damage is usually associated with wheel ruts caused during a wet harvest, and plough pans caused by tillage above the optimum moisture content (plastic limit).

Waterlogging

Waterlogging may be the result of poor internal drainage after soil has been compacted. Stunted plant growth with yellowing leaves is a symptom of waterlogging and may indicate compaction.

Irrigation interval

A forced decrease in irrigation interval may also indicate compaction. Compacted soil stores less water for plant uptake. This happens because soil porosity is reduced and because plant roots have greater difficulty extracting the water that is potentially available. Irrigation water must be added to the soil more often to satisfy plant water requirements

Soil examination

Examining the soil is a good way to diagnose compaction and allows the severity of the problem to be determined. Platey aggregates and/or restricted root growth suggest that compaction has occurred. Knowing the soil group will also indicate the likelihood of compaction. As an example, self-mulching clay soils are more prone to compaction than the non self-mulching clays, since the latter are more dense and structurally poor in the first place.

In order to assess the severity of compaction in a paddock, choose the best, average and worst yielding areas for examination. The procedure for assessing the degree of compaction is presented in Chapter C5: *Soil structure*, and gives an indication as to whether a soil is severely compacted or is well structured soil.

REPAIRING COMPACTED SOIL

Compacted soil can be repaired by the following methods:

- Growing a crop to dry the soil and promote cracking of the compacted layer
- Deep ripping the soil at an appropriate soil moisture content to shatter the compacted layer

Drying the soil

Compaction in self-mulching clays (cracking clay) can be repaired by growing a crop to dry the soil and promote cracking of the compacted layer. This method will not be successful in non self-mulching clays and red-brown earths, because there is insufficient cracking clay in them to create large cracks.

To ensure successful amelioration of compacted layers, the following points should be considered:

- Winter cereals are usually best suited to drying a soil profile.
- Cracks will form when clay soils dry out due to the swelling and shrinking of the clay.

Techniques for effective drying and opening of clay soils include:

- Sow a winter cereal crop as normal. The crop should be adequately fertilised and sown on time.
- Crop irrigation should cease so that the soil is dry to the compaction depth at harvest.

Deep ripping

Deep ripping is a short term remedy which will break the compacted layer, allowing air, water and roots to penetrate the soil to a greater depth. Depth to compaction layer should be checked (see Chapter C2: *Soil pit digging — where, how and why?*), as well as soil moisture suitable for cultivation at that depth (see Chapter C8: *Assessing soil moisture*). This will ensure that tillage is carried out at a depth adequate to break the compacted layer, and at the correct moisture content to prevent further structural damage (smearing).

Cultivation should not invert the soil, which would bring sodic subsoil to the surface. The soil should be deep ripped to about 10 cm below the compacted layer to allow for variation in depth of compacted layer across the paddock. See also Chapter C5: *Soil structure*, and Chapter E5: *Improving soil structure by crop rotation.*

AVOIDING COMPACTION

Avoiding compaction problems tends to be much less expensive than repairing compaction. Aim to achieve the following:

- where possible avoid driving on, or tilling soil, that is wetter than the plastic limit (see Chapter C8)
- if driving on wet soil is unavoidable, minimise the damage by restricting the wheels of farm machinery to narrow laneways. Consider the use of guidance systems for farm machinery
- be aware that heavy stocking rates of livestock can aggravate compaction, especially if the soil is wet

Chapter B5. Is my soil acid?

Most crops and pasture plants grow best in soils with pH 5–7. Most can tolerate soil conditions where pH is more than 7 (slightly alkaline) better than where pH is less than 5 (strongly acid). Low pH is a more widespread problem than high pH. A low pH problem can be diagnosed in the following ways:

Paddock history

A history of clover dominant pastures, rice, intensive cropping or high nitrogen applications may contribute to a reduction in soil pH. If legumes (clovers, lucerne, soybeans) show symptoms such as yellowing of leaves, poor root growth and poor nodulation, soil acidity may be a problem.

As pH decreases, toxic elements such as aluminium and manganese become more available, and nutrients such as phosphorus and molybdenum become less available. Symptoms of toxicity or deficiency of these elements are a telltale sign.

Soil type

Coarser textured (sandier) soils are more likely to be acid. Therefore sandhill soils and red-brown earths are likely to develop soil acidity faster than other soil types.

Soil test

Soil pH may be tested in either a calcium chloride solution (pH_{CaCl}) or in water (pH_{water}). The test in calcium chloride is more representative of the acidity/alkalinity a plant experiences in the soil. A pH_{CaCl} of less than 5 indicates that the soil is strongly acid, and growth of many crop species is likely to be less than optimal.

A reduction in pH also makes aluminium more available to plants. If the exchangeable aluminium percentage (Al%) is greater than 5%, then plant growth is likely to be reduced due to aluminium toxicity. Furthermore, as soil salinity increases, plant tolerance to aluminium toxicity decreases. Therefore, on severely saline soils (ECe more than 6 dS/m) aluminium toxicity may be evident where the exchangeable Al% is less than 5%.

MANAGING ACID SOILS

The following courses of action can be taken to improve plant production where pH_{CaCl} is less than 5:

- lime application to increase soil pH
- choose acid-tolerant crops

Acidity (low soil pH) develops first at the soil surface and over time moves down into the lower layers of the soil. If soil acidity is allowed to develop, and soil is not limed, the subsoil may become acid. Subsoil acidity is difficult and costly to overcome.

LIME APPLICATION

The most effective way to ameliorate acid soils is to apply lime (calcium carbonate). The actual rate will depend on pH, exchangeable aluminium present and soil texture.

When liming soil, aim to increase the pH_{CaCl} to at least 5.2. Soil texture should be determined to establish the lime application rate.

To increase soil pH by 0.5, the following lime application rates should be used: (Fenton, Helyar, and Orchard, Agfact AC.19)

- 2.5 t/ha for a clay soil
- 1.7 t/ha for a silty clay loam
- 1.3 t/ha for a sandy clay loam
- 1.0 t/ha for a sandy loam

A faster and more effective change in pH will occur if the lime is incorporated into the soil rather than broadcast.

USE OF ACID-TOLERANT CROPS

Liming would be the first priority when growing high value irrigation crops on acid soils. However, if this is not an immediate option, crops of higher acid/aluminium tolerance can be grown. Table B7 indicates the acid tolerance of several crop and pasture species.

Table B7. Acid tolerance of some crop and pasture species

Crop acid tolerance	Crop
Sensitive	Canola Soybeans Lucerne Faba beans Mungbeans Barley Strawberry, Berseem and Persian clovers Wallaby grass (*Danthonia* sp.) Wheat (some varieties[1])
Tolerant	White clover Phalaris Maize Sub-clover (Seaton Pk., Goulburn, Junee, Clare) Wheat[1]
Highly Tolerant	Triticale[1] Lupins Oats[1] Rice[2] Sub-clover (Trikkala, Riverina, Woogenellup)

[1] For a full list of varietal reactions to soil acidity see *Winter crop variety sowing guide*, published annually by NSW Agriculture.
[2] When soils are flooded, such as for rice production, they attain a pH_{CaCl} of around 6.5, even if they were more acid before the flooding.

Chapter B6. Is my soil saline?

INTRODUCTION

The development of irrigation in southern NSW has seen agricultural land use change from extensive semi-arid grazing to irrigated land. While irrigation has improved the productivity of land, it may also lead to the development of shallow watertables and subsequent soil salinisation. Soil salinity reduces the productivity of agricultural land and substantial yield losses can occur before definite signs of salinity become visible. Therefore it is important to recognise and monitor soil salinity on your farm.

Salinity refers to an accumulation of salt in the plant root zone or on the soil surface. It usually occurs as a result of groundwater rising to within two metres of the soil surface, resulting in a concentration of salt in the root zone as moisture is drawn into the surface soil by capillary action. This chapter described some of the diagnostic tools that are available to recognise and prevent soil salinity problems. Procedures for monitoring groundwater, testing water quality and soil salinity are described below.

Where the volume of irrigation water plus rain exceeds the amount of evaporation and transpiration by plants, then seepage into groundwater occurs. This process is known as groundwater recharge and may cause watertables to rise. Rises may also be caused by the lateral movement of groundwater from surrounding areas. Watertable levels can drop where groundwater is pumped for irrigation or is used by deep rooted plants.

CAUSES OF SALINITY

Water added to the soil as rainfall or irrigation can drain from the surface before soaking in, can be used by plants or evaporate from the soil. However, water in excess of plant needs or evaporation drains below the root zone to the watertable. Farming methods that result in excessive irrigation water draining through the soil have been responsible for much of the increase in watertable heights in southern NSW.

As watertables rise, the salts that naturally occur in the soil are dissolved in the groundwater. When the watertable rises to within approximately two metres of the soil surface, water can move into the plant root zone by capillary rise. Salt becomes concentrated in the root zone as water evaporates or is taken up by plants. Soil salinity increases as this process continues.

WATERTABLE MONITORING

Testwells and piezometers

Groundwater within two metres of the soil surface can rise further up the soil profile into the plant root zone through capillary action. This may lead to waterlogging and an accumulation of salt in the root zone. In sloping paddocks, the groundwater may move laterally and seep into local drains, creeks and rivers. The salt within this drainage water lowers the quality of the water and may cause problems downstream. Therefore groundwater monitoring is important.

There are two approaches to groundwater monitoring:

Testwell

Testwells are made up of a length of slotted pipe 3–4 m placed in an augered hole. They measure the free water depth to the local watertable below a paddock. Testwells to measure watertable depth can highlight potential salinity hazards in a particular area. The Salt Action Irrigation *Salinity Field Kit* manual provides instructions required to construct and install a testwell. It also presents information regarding the measurement of watertable depth and the interpretation of these measurements.

Piezometer

A piezometer is a tube where the slotted section is inserted into the aquifer. Water moves from the aquifer into the tube through the slotted section of the tube. The height to which the water rises is a measure of the pressure of the groundwater in that aquifer. If the aquifer is not confined by rock or dense soil, the level of water in the piezometer will be equivalent to the depth of the local watertable. Piezometers are used to monitor changes is groundwater pressure levels to a depth of 8–30 m.

The placement of piezometers and testwells at different depths will provide information about trends in groundwater movement when monitored over time.

Quality of the water in piezometers and testwells should be tested, to determine its salinity and sodicity hazard (see *Salinity Field Kit* manual).

The quality of information from testwells and piezometers is strongly influenced by how well the tubes are installed. For example, if soil on the sides of the excavated holes is compacted and/or smeared, water movement is likely to be very different to that occurring in undisturbed soil. Therefore it is essential that the installations be set up professionally.

QUALITY OF IRRIGATION WATER

The quality of all water used on the farm should be monitored to prevent the possibility of salts in water damaging plants and soil:

- saline water for irrigation may increase soil salinity, with the likelihood of reduced yields and death of plants
- sodic water could result in sodium accumulating in the soil, causing a decline in soil structure

The *Salinity Field Kit* provides equipment and instructions for:

- sampling both surface and groundwater
- measuring the salinity of water samples
- determining the suitability of water for irrigation of specific crops and pastures

To actively monitor and assess water quality on your farm, see Part 1: Water Sampling and Testing Water Salinity in the *Salinity Field Kit* manual.

Water salinity

Salinity guidelines for irrigation water are summarised in Table B8 (page B6.6). They apply to water from any source. The soil salinity limits for two levels of production losses for the main crops and pasture plants grown in the Riverina are shown.

Sodium hazard

Soil structural stability may decline if the irrigation water is sodic leading to surface crusting, poor water infiltration, low soil workability and muddy irrigation water. Sodium adsorption ratio (SAR) is a ratio for irrigation waters and soil extracts used to express the relative activity of sodium ions (compared to calcium and magnesium ions) in exchange reactions with soil. Exchangeable sodium percentage (ESP) of the soil increases as the SAR of water passing through it becomes greater. SAR of irrigation water should be kept below about 3 to avoid such problems

SAR is calculated as follows (in units of cation concentrations or Meq/L):

$$SAR = \frac{\text{(sodium concentration)}}{\text{square root[(calcium concentration + magnesium concentration)/2]}}$$

As the SAR increases, the need for higher water salinity also increases to maintain good soil structure that permits leaching. Irrigators whose water is low in salinity and high in sodium should seek management advice from NSW Agriculture to minimise adverse impacts on the soil.

SOIL SALINITY

Recognising salinity symptoms in the field

It may be difficult to recognise salinity problems in the paddock because plants often respond to excess salt in the same way they would respond to other problems, such as water stress. There may be no obvious plant symptoms or signs of salt on the soil surface. Plant yields may decline by up to 30% before signs of salinity become evident.

Early visible signs of salinity in the paddock include:

- poor crop growth
- increasing numbers of salt tolerant weeds such as couch and barley grass
- development of grass dominant pastures - legumes are more susceptible to high salinity than grass species
- prolonged wetness in patches
- unusually friable soil structure in low-lying areas

Severe visible symptoms of salinity include:

- bare salt encrusted soil surface
- white crystals, that are salty to taste, found on dry soil surface
- settling of suspended clay particles to give unusually clear water in puddles or drains
- dominance of salt tolerant plants

- greasy looking black patches, due to dispersion of organic matter under high pH conditions, caused by the presence of bicarbonate salts
- death of trees in surrounding areas
- total crop failure — germination is slow and plants grow poorly
- leaves appear smaller and darker in colour than normal
- marginal and tip burning of leaves, followed by yellowing and bronzing

Laboratory testing for soil salinity

To test a soil for salinity, a sample of soil is mixed with water and an electric current is passed between two electrodes placed in the solution. The greater the salt concentration, the greater the current (conductivity). If no salt is present, very little electric current passes. There are two methods of measuring soil salinity:

Electrical conductivity of the saturated paste extract (ECe)
The most accurate way of preparing the soil sample is to make a saturated paste. This involves the addition of distilled water to a soil sample until a characteristic sticky point is reached. A suction filter is then used to extract a sufficient amount of water to perform an electrical conductivity (Ec_e in dS/m) measurement. The advantage of this method is that it is related to the water-holding capacity of the soil and thus is representative of what a plant root would experience. Unfortunately, this saturation extract method is tedious and time consuming to carry out.

Electrical conductivity of the 1:5 soil:water extract ($EC_{1:5}$)
A simpler and more commonly used approach is to mix the soil with five times its weight of distilled water. Salinity is estimated by measuring electrical conductivity of this 1:5 soil:water suspension ($EC_{1:5}$ in dS/m). However, this procedure does not take into account the effects of soil texture – the readings from different soil types cannot be compared directly. Another possible problem is that in soil with significant amounts of gypsum, $EC_{1:5}$ will be over-estimated.

Monitoring Soil Salinity on your farm

Soil salinity on the farm can be measured by a field test (see Chapter C10: *Soil salinity testing in the field*). For this test 1 part of soil is added to 5 parts water, and the salinity of the resulting solution is measured using a portable (hand held) EC meter. This result is then multiplied by a conversion factor depending on the soil texture, and the actual soil salinity (EC_e) found.

Some laboratories use units other than dS/m (deciSiemens per metre) as salinity units. Two commonly used conversion factors are as follows:

1 dS/m = 1000 µmS/cm (EC units) = 640 ppm (mg/kg)

Indirect methods — Electromagnetic induction (EM) devices

Electromagnetic induction (EM) devices rapidly estimate soil conductivity in the field by measuring the ease with which a magnetically-induced current passes through the soil.

EM instruments used for measuring soil conductivity include the EM38, EM31 and EM34. They are useful for describing apparent electrical conductivity (EC_a) across paddocks. Each site requires ground truthing because of variation in some soil factors, such as water content and clay, that also affect apparent conductivity.

These instruments monitor apparent conductivity at different depths of the soil:

- the EM38 best describes conductivity within the root zone (to a depth of about 1–2 m)
- the EM31 is used for deeper subsoil studies of shallow aquifers and deeper watertables (to a depth of approximately 3.5–7 m)
- the EM34 measures conductivity to depths ranging from 7–30 m, and is used mainly for catchment scale surveys of soil salinity.

Management options where soil salinity is diagnosed

Options to consider if the soil is saline, or about to become so, include:

- Minimise leakage from channels and dams
- Avoid bare fallows
- Schedule irrigations according to actual crop requirements, and apply water in a way that minimises deep drainage losses (fast watering on and off).
- Groundwater pumping and recycling (the water can be used for irrigation if of sufficient quality).
- Planting of deep-rooted perennial plants such lucerne and trees in recharge zones
- Where sodic groundwater is added to the soil, gypsum may have to be applied to prevent the soil from dispersing when it rains.

Land management and monitoring

The soil salinity information collected on your farm can be used to make land management decisions. The *Salinity Field Kit* manual presents four land use classes based on differing levels of soil salinity. The appropriate management strategies for each class of land is presented in the manual.

For suggestions about land management techniques appropriate for the level of soil salinity on your farm, see Part 4: Land Management and Monitoring in the *Salinity Field Kit* manual.

Table B8: Tolerance of Crops and Pastures to water salinity and rootzone soil salinity (in decisiemens per metre, dS/m)

	WATER SALINITY LIMITS for flood irrigation							
Soil Type	**Well Drained Soils**		**Moderate to Slow Draining Soils**		**Very Slow Draining Soils**		**ROOT ZONE SOIL SALINITY**	
Yield Reduction	**Up to 10%**	**25%**	**Up to 10%**	**25%**	**Up to 10%**	**25%**	**Up to 10%**	**25%**
Pasture Legumes								
White Clover	1.2	3.1	0.8	2.0	–	–	1.2	3.1
Sub Clover	1.2	3.1	0.8	2.0	0.4	1.0	1.2	3.1
Strawberry Clover	2.1	4.0	1.4	2.6	0.7	1.3	2.1	4.0
Lucerne (most varieties)	2.0	5.4	1.3	3.5	–	–	2.0	5.4
Lucerne (salt tolerant varieties)	3.6	5.9	2.4	3.9	–	–	3.6	5.9
Berseem Clover	6.0	18	4.0	12	2.0	6.0	6.0	18
Pasture Grasses								
Paspalum	2.0	4.6	1.3	3.0	0.6	1.5	2.0	4.6
Phalaris	4.2	8.0	2.8	5.3	1.4	2.6	4.2	8.0
Perennial Ryegrass	5.6	8.9	3.7	5.8	1.8	2.9	5.6	8.9
Tall Wheatgrass	7.5	13.3	5.0	8.8	2.5	4.4	7.5	13.3
Puccinellia	16	22	10.6	15	5.3	7.3	16	22
Saltbush	12	20	8.0	13	4.0	6.6	12	20
Winter Crops								
Faba Beans	1.8	4.0	1.2	2.6	–	–	1.8	4.0
Oats	5.0	6.3	3.3	4.2	1.7	2.1	5.0	6.3
Wheat	6.0	9.5	4.0	6.3	2.0	3.1	6.0	9.5
Canola	6.5	11	4.3	7.3	2.1	3.6	6.5	11
Barley	8.0	13	5.3	8.6	2.6	4.3	8.0	13
Summer Crops								
Rice	–	–	–	–	1.0	1.7	3.0	5.1
Maize	1.7	3.8	1.1	2.5	0.6	1.2	1.7	3.8
Grain Sorghum	1.0	1.5	0.7	1.0	0.3	0.5	1.0	1.5
Soybeans	2.0	2.6	1.3	1.7	0.6	0.8	2.0	2.6
Sunflowers	5.5	6.5	3.6	4.3	–	–	5.5	6.5
Millet	6.0	9.0	4.0	6.0	2.0	3.0	6.0	9.0

Chapter B7. Is my soil suitable for rice growing?

INTRODUCTION

Potentially, rice growing can make considerable contributions to rising watertables and subsequent salinisation of soil. To ensure sustainable rice production in southern NSW, growers aim to use less than 15–16 ML/ha per season, depending on weather conditions during the particular season. Where rice water use is greater than 16 ML/ha, it is likely that excessive water has drained below the root zone and to the watertable. Rice growers can either grow rice only on suitable soils that have minimal water losses, or they can amend the soil to reduce its permeability.

SOIL TYPE SELECTION FOR RICE FARMING

Soil types most likely to restrict water losses in rice are those with a high proportion of dispersive clay in the soil profile. In general, the best soils for rice growing are:

- non self-mulching clays
- sodic transitional red-brown earths

More specific criteria, other than soil type, must be met for a soil to be approved for rice growing. Soil classification criteria differ slightly between the Murray and Murrumbidgee regions, but the general requirement for both areas is a specific depth of heavy and/or medium clay in the soil profile. The criteria for the Murray irrigation districts are outlined in Table B9, with those for the Murrumbidgee in Table B10.

Table B9. Rice soil suitability criteria for the Murray region.

Rice growing category	Depth of continuous medium or heavy clay in top 3.6 m of soil
suitable for rice under continuous rotation	>3.0 m
marginal for rice growing (1 crop every 4 yrs)	2–3 m (minimum is 2 m in the top 2.5 m of soil)

Source: Murray Irrigation Limited Rice Growing Policy for 1998–99

Table B10 Rice soil suitability criteria for the Murrumbidgee region.

Rice growing category	Depth of continuous medium to heavy clay in top 3.5 m of soil
suitable for rice under continuous rotation	> 2.0 m where a sodic heavy clay B horizon is present from 0.1 to 0.6 m OR > 3.0 m if there is no low permeability B horizon present

Source: Dept. of Land and Water Conservation recommendations for 1998–99

The classification ‘marginal for rice growing’ is no longer used in the Murrumbidgee region.

To assess whether your soil is suitable for rice growing soil surveys must be carried out. In Murray Irrigation Limited's area, new rice land, land previously classified as marginal and land previously unclassified by grid drilling, will all require electromagnetic surveying (EM31), as well as proof boring.

In the remaining areas, soil suitability is determined either by grid drilling or by EM surveying, with proof soil texture assessments carried out on the bore samples by accredited operators.

OTHER METHODS TO REDUCE WATER LOSSES IN RICE

Puddling

Puddling is a technique where a flooded soil is rotary hoed to increase the soil strength and density at the depth of hoeing. This reduces the number of pores capable of transmitting water and therefore deep drainage losses. Accessions to the watertable are minimised. The soil is flooded for a couple of days until it is properly wetted, and then rotary hoed while there is about 2 cm of free water on the surface. A front wheel assist tractor is almost essential, and the rotary hoe should cover the wheel tracks.

Guidelines for puddling were developed by CSIRO at Griffith, and details are given in Table B11.

Soil compaction

A method of compacting soils for rice by using a 30 t road compaction machine has been tested in the Murray Valley. Whilst this method does appear to have reduced water losses, it cannot be recommended at this stage because the effects on other crops and pastures grown in the compacted land have not been adequately assessed.

Table B11. Puddling guidelines developed by CSIRO, Griffith.

Equipment

1 Light front wheel assist tractor highly recommended
- 100 h.p. FWA is ideal
- some farmers have successfully puddled large areas with 140 h.p. tractors

2 Rotary hoe matched to tractor
- Wide enough to cover wheel tracks to avoid establishment problems in deep tracks, weed problems on soil ridges, and sideways displacement of fertiliser
- Match the PTO power of the tractor (eg 100 h.p. FWA tractor with 2.5m rotary hoe)

3 'L' shaped blades on the rotary hoe
We know this type of blade can reduce percolation. We have not tested any other shapes. Overseas studies suggest that the 'L' shaped blades are more effective than 'C' blades in reducing deep percolation

4 Remove depth wheels
They may make nuisance tracks

5 Keep back doors down
Doors should skim the water surface to create an even surface

6 Rotor speed at least 300 rpm
The faster the rotor speed;
— the better the puddling effect
— the less cloddy the seedbed
At low rotor speeds (eg 100 rpm) the the blades may become blocked

7 Forward tractor speed — not too fast
The aim is to produce a smeared layer at the bottom of the cultivated layer. The slower the ground speed, the more thorough the puddling. For a rotor speed of 300 rpm, forward speed should not exceed 3–4 km/h.

Paddock Preparation

1 Need good crossovers
To get over banks without damaging them

2 Preliminary soil cultivation as for conventional cultivation
We have found that puddling can be done without preliminary cultivation, but the problem is how to get nitrogen in

3 Drill in nitrogen as deep as possible

4 Flood bays for a couple of days before puddling
The soil below the surface should be wet enough to smear, but not to break up

5 Pasture paddocks
If nitrogen does not need to be drilled in, the paddock can be puddled without any preliminary cultivations

Puddling

1 Rotary hoe while there is shallow water present on the surface
The water keeps the rotary hoe clean and stops it from blocking. Adjust the back doors to achieve the desired seedbed. The water should be as shallow as possible — there should be only a trace of free water on the high side with clods showing through before puddling. If water is too deep, it is difficult to see where you have been

2 Minimise muddy water
- Flood one bay at a time (shallow)
- Puddle the bay, then drain the dirty water into to the next bay to be puddled
- Allow the water in the puddled bay to evaporate or soak away before topping up with fresh water (but don't let soil dry out)
- Muddy water can reduce the activity of herbicides (especially Londax) and delays establishent

3 Working depth of about 10 cm is adequate

4 Plan your cultivating pattern to avoid tight turns

5 Do not allow the soil to dry out and crack after hoeing
The smeared layer may crack and and become less effective in reducing deep percolation

6 Carry out sowing and pesticide application as usual

Chapter B8. Is my soil suitable for direct drilling?

INTRODUCTION

Successful direct drilling offers many benefits to farmers including:

- increased soil porosity and infiltration
- decreased tractor hours and fuel costs
- lower risk of compaction
- increased trafficability of the soil (which may mean more timely sowing).

Some important factors to consider when deciding whether to adopt direct drilling are:

- good soil structure/friability
- machinery to suit soil conditions
- good soil moisture at sowing

GOOD SOIL STRUCTURE/FRIABILITY

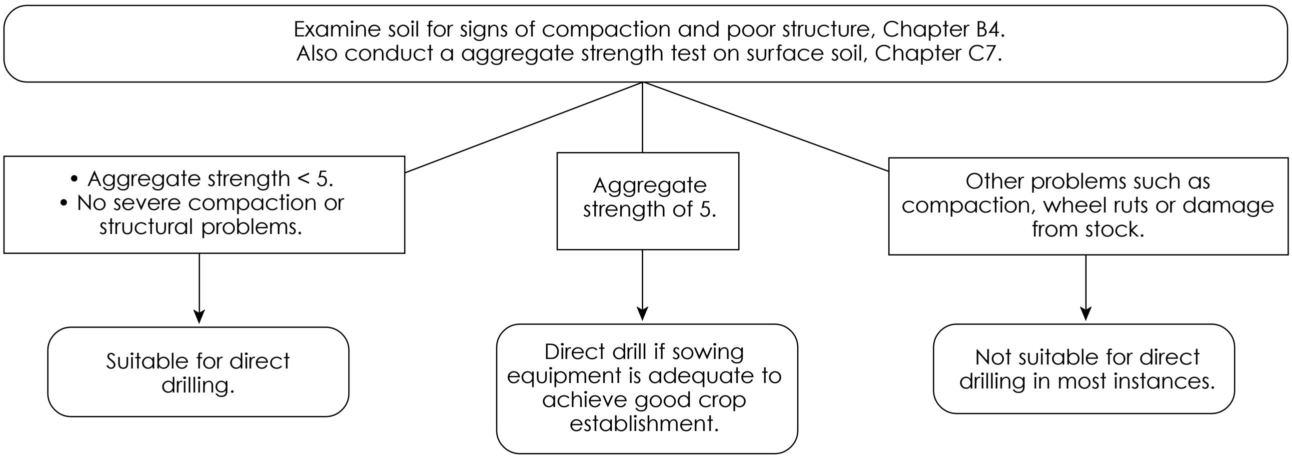
Friability refers to the ease with which soil aggregates can be broken down into smaller aggregates or fragments (by a force such as hand pressure). A friable soil will feel 'softer' since aggregate strength is lower.

Direct drilling is more likely to be successful when the soil is well structured and friable. Soils with severe structural problems, such as compaction or hardsetting, are less suitable for direct drilling because sowing equipment tends to get damaged in these situations. Seedbed conditions are also likely to be sub-optimal for seedling establishment.

On the other hand, soil structure is likely to improve in time with direct drilling and other conservation farming practices. This is due mainly to the build up of soil organic matter, as opposed to the destruction of organic matter and soil structure with conventional cultivation.

Figure B3 will help you decide whether your soil is suitable for direct drilling. Examination of the topsoil condition is necessary (see Chapters C2 and C5).

Figure B3. Suitability of soils for direct drilling



MACHINERY TO SUIT SOIL CONDITIONS

In most instances, soil will be much harder in direct drill situations compared to a conventionally cultivated soil. It is therefore, important to have machinery that can sow directly into hard soil and provide suitable conditions for plant establishment. A wider range of soil types can be successfully direct drilled if the sowing machinery has the following features:

- narrow points for good penetration into the topsoil
- tine breakout force of at least 1.1 kN (250 lbf) will be required for the majority of Riverina soils
- breakout force of 1.55 kN (350 lbf) or more will be needed in the heavier soils
- press wheels or rollers can provide better seed/soil contact for improved germination.

ADEQUATE SOIL MOISTURE AT SOWING

Adequate soil moisture at sowing is more critical for direct-drilled crops than conventionally cultivated soils because:

- a direct drilled crop cannot be sown as deep as a conventionally sown crop, as direct drilling may bring up large clods when tines penetrate deeply in relatively dry soils.
- the soil has not been previously cultivated and good soil/seed contact may be hard to achieve in direct-drilled soils. This can be partly compensated for by the use of press wheels.

However soil moisture content, to the sowing depth, should be at, or just below, the plastic limit to avoid soil structural damage or an excessively cloddy seedbed (see Chapter C8: *Assessing soil moisture*).

Chapter B9. Is my soil suitable for raised bedfarming?

SOIL REQUIREMENTS FOR BEDFARMING

A bedfarming system involves growing crops on raised beds that are irrigated via furrows. Furrows are generally spaced 1.5–2.0 m apart. Traffic is usually confined to furrows, thus confining soil compaction to specific wheel rows/traffic lanes.

The major limitation of a soil for bedfarming is its ability to take up irrigation water from the furrow and allow water entry through the entire bed (known as subbing). A soil that subs readily is well suited to bedfarming.

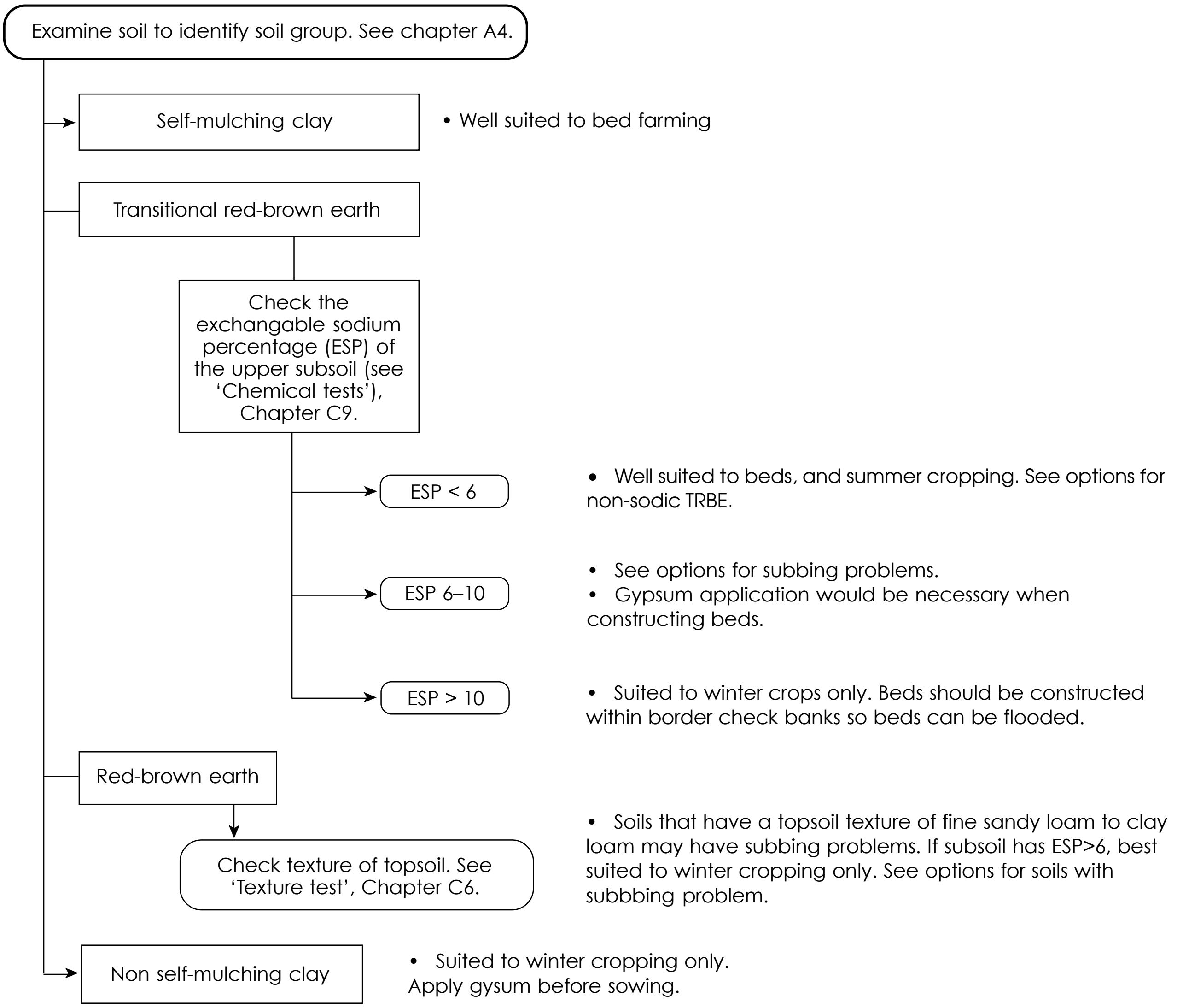
There are number of factors that determine the suitability of a soil for bedfarming. These include:

- soil group
- soil texture
- sodicity
- salinity
- watertable depth
- pH

SOIL GROUP, TEXTURE, AND SODICITY

The following flowchart (Figure B4) will help you decide whether your soil is suitable for bedfarming, based on the soil group, texture and sodicity.

Figure B4. Soil suitability for bedfarming



SOIL SALINITY AND WATERTABLE HEIGHT

Bedfarming should be avoided on saline soil and areas with shallow watertables. Growing crops on beds formed up in these soils will result in the concentration of salts in the top of the bed and affect the viability of the development for further crop production.

Soil salinity and watertable height should be determined prior to the development of raised beds. Soil samples should be collected and tested for salinity levels (refer to Chapter B6: *Is my soil saline?*). The suitability of the soil for bedfarming can then be determined. A soil salinity (ECe) of more than 2 dS/m will restrict growth of plants with a low salt tolerance.

The watertable height should also be determined before developing land for bedfarming. This information can be obtained from your local office of your water supply organisation or from the Department of Land and Water Conservation. If the watertable is at or likely to be around the 1.5 m depth, options other than bedfarming should be considered. After development of a suitable paddock for bedfarming, soil salinity and watertable depth should be monitored over time.

SOIL pH

Soil pH should also be checked before developing land for bedfarming. Most crops prefer a pH around neutral. Strongly acid soils should generally be avoided or treated. If the soil is strongly acid, lime should be incorporated before bedding up for the initial crop.

OPTIONS FOR BEDFARMING SOILS WITH SUBBING PROBLEMS

Subbing problems generally arise in the loam topsoils of the red-brown earth (RBE) and transitional red-brown earth (TRBE) soils. This occurs because the textures of these topsoils do not allow water to be readily taken up by subbing.

RBEs and sodic TRBEs (subsoil ESP > 6)

- Narrow beds:
  - Form narrow beds (1.5–1.8 m wide) within border check bays
  - flood tops of beds as well as furrows at each irrigation
  - slightly shallower beds (around 10 cm high) and relatively flat grades (flatter than 1:1200–1:1400) are required
  - flow rates should allow for fast watering.
  - grow only two rows of summer crop per bed
  - hills, with furrow spacings of 0.75–1.0m, are another good option
- Permanent trickle irrigation (saturated soil culture)
  - method is suitable for production of soybeans only
  - maintains small amounts of water in the furrows at all times after crop establishment
  - it is important to maintain water levels, as the soybean plant quickly adapts to saturated conditions and becomes stressed if the soil is allowed to dry

Non-sodic TRBEs (subsoil ESP < 6)

- when landforming removes the loam topsoil from the paddock to expose the subsoil
- the subsoil generally has better structure than the topsoil, and will store more water after an irrigation when the topsoil is removed
- this soil type is evident in paddocks where cut areas yield better than uncut or fill areas.

On all soil types, subbing problems may also develop where shoulder compaction occurs due to the use of wheels on farm machinery that are too wide.

Chapter B10. Managing paddocks with soil variation

INTRODUCTION

Irrigators are aware of variations in soil condition and crop performance in at least some of their paddocks.

This chapter provides some general guidelines about the management of soil variations to minimise differences in crop performance and yield. It also previews yield mapping technology, outlines how to sample the soil after studying a yield map, and describes how remote sensing data (eg. airborne thermal infra-red scanning) can assist.

SOURCES OF SOIL-RELATED VARIATION WITHIN IRRIGATION PADDOCKS

Variations in crop performance within a paddock may be due to any one, or a combination of factors. These include:

- insect and disease pressures
- passage of narrow, intense rain and hail storms
- changes in field slope
- presence of gilgais
- management variations (eg. contrasting periods of inundation by flood irrigation water between one end of a field and another),
- machinery malfunction (eg. uneven fertiliser or herbicide application)
- contrasting physical and chemical properties of soil.

Soil factors responsible for crop variations include:

- degree of compaction by farm machinery (due, for example, to heavy rain on a paddock part-way through a harvesting or land forming operation),
- soil stability in water, which is related to sodicity, electrical conductivity, pH, organic matter and clay mineral type
- soil texture, which influences infiltration rate, water-holding capacity and ability to shrink and swell
- depth of topsoil
- salinity
- pH
- nutrient reserves

PRODUCTION OF WITHIN-FIELD YIELD MAPS

The introduction of yield monitors on harvesters has allowed irrigators to easily identify poor yielding areas within paddocks. Soil sampling in the low and high yielding sections of a field will allow soil factors causing yield differences to be identified. Precise soil management programs to overcome crop yield variation can then be designed. Geographic Information Systems (GIS) enable yields and soil conditions to be mapped within the paddock. This will allow the irrigator to apply the appropriate inputs at various locations.

Where yield monitors are unavailable, crop yield variations can be mapped by hand-harvesting small sub-sections of paddocks. Another approach is to map the average yield of large sub-sections of paddocks by noting the weight or the number of truck loads of grain.

Aerial photographs and airborne video scans of crops and bare soil can help to show the location of problem areas. Even just a walk through a crop or pasture will provide a good indication of the best and worst performing sections of a field.

Because the effect of soil properties on crop growth usually is strongly influenced by temperature and rainfall, yield monitoring needs to be repeated over several contrasting growing seasons.

INTERPRETING YIELD MAPS

Much can be learnt, even from the most basic of yield maps, by assessing soil condition at the best, worst and average points within a paddock. If the paddock contains obviously different soil units – eg. a mosaic of red and grey soil – the best, average and worst yielding areas within each of these two soil groups should have their soil tested.

The soil description sheet for an existing irrigation development should be filled out for each of these locations soon after harvest. The results should then be compared with the critical values presented throughout Section C.

If a strong relationship is evident between the measured soil properties and grain/pasture yields, these soil properties should then be mapped. The soil factor maps produced form the basis of subsequent soil management programs. For example, a soil stability map will indicate where gypsum should be applied to the soil and at what rates.

Yield maps are also useful for ensuring that access tubes for soil moisture monitoring are located in representative positions within a field.

USE OF REMOTE SENSING DATA

Remote sensing data may help to greatly improve the accuracy of these soil factor maps. Where there is a strong relationship between key soil factors and patterns seen in aerial photographs or videos, accurate maps can be produced of that soil factor. For example salinity can be quite obvious on an aerial photo.

Chapter B11. Soil survey for irrigation development or redevelopment

INTRODUCTION

When soil properties within a paddock are variable, it is usually impossible to deliver irrigation water uniformly to all sections. As a consequence, some parts of paddocks will receive more or less water than is optimal, with lower yields than is possible, and variations in product quality.

When planning a new irrigation development, each paddock should have soil conditions and slope as uniform as possible. Consequently, the soil should be mapped before any irrigation design work is carried out. In fields already developed for irrigation, soil variability may be so great that the paddock has to be redeveloped for irrigation to minimise the variation within a paddock. Again, soil survey should occur prior to redesign. This is particularly important if a field is intended for rice growing.

In practice, it is unlikely to ever be economically feasible to completely remove across-field soil variability. However, if good quality soil survey information is available, the variations within each paddock can be minimised in a cost-effective fashion.

SOIL SURVEY PRIOR TO NEW IRRIGATION DEVELOPMENT

Money spent on soil survey prior to development usually is repaid several times over because of the potential management problems that it highlights. Soil survey information provides a benchmark that can be used to monitor changes in soil condition and fertility, in the chosen crop system, after irrigation development.

An electromagnetic survey (EM31 or EM38) can be used initially to identify variations in factors related to the electrical conductivity of the soil. The location of backhoe pits, in a grid pattern, can be based on the outcome of an EM survey. The grid spacing will depend on the level of variation shown in the survey. More pits should be dug in an area of high variation in EM readings than in areas of low variation. EM data assists with site selection for backhoe pits or soil auger samples by identifying areas of high and low soil conductivity, and helps to locate soil property boundaries between the sites.

Landholders can assess their soils themselves for development purposes by noting the following features in the topsoil (0–5 cm), subsurface (5–30 cm) and subsoil (30–100 cm):

- soil texture
- available water
- suitability of soil moisture for landforming
- aggregate stability in water
- natural regeneration potential
- salinity
- pH

These soil factors should be measured at several sites and mapped. Geographic Information Systems (GISs) are available to map soil properties on home computers – they allow the different layers of soil information for a field to be stored in an orderly fashion. This allows the variation in each soil property and combinations of properties to be observed. The maps also allow soil with similar, difficult-to-modify, properties (e.g. water holding capacity, shrink/swell potential) to be included within the same management units.

After design of the irrigation layout:

- landform each of the new irrigation paddocks (when dry if possible); try to avoid deep cuts into sodic subsoil
- create check banks, contour banks or raised beds, depending on chosen irrigation layout
- refer to the next chapter for suggestions about how to treat the soil after landforming

SOIL SURVEY PRIOR TO REDEVELOPMENT OF IRRIGATION PADDOCKS

Irrigated paddocks are redeveloped for a number of reasons. These include:

- subsided areas with poor surface drainage
- impractical paddock size or shape
- impractical mosaic of contrasting soil types
- improved irrigating and drainage
- incorporating drainage and reuse systems
- different land uses (eg. crop type)

Redevelopment provides an opportunity to properly assess, and if possible correct, soil problems that have been reducing farm profitability. It also allows soil with similar, difficult-to-modify, properties (e.g. water holding capacity) to be included within the same management units.

The procedures described above for development of new irrigation paddocks should be followed when redeveloping. The best grid spacing to use is uncertain. A spacing of 75 m is recommended, as a first approximation, for land that obviously contains soil variation (e.g. a mosaic of red and grey soil). For land with less obvious variation, a spacing of 150 m is suggested. Soil variation mapped by an EM survey can be used as a guide for the location and grid spacing of backhoe pits and auger sampling sites.

You can assess your soil for new irrigation development or redevelopment by noting the following features in the topsoil (0–5 cm), subsurface (5–30 cm) and subsoil (30–100 cm):

- soil texture
- available water
- suitability of soil moisture for landforming
- aggregate stability in water
- natural regeneration potential
- salinity
- pH

These soil factors can be mapped using a GIS as previously mentioned.

After design of the irrigation layout follow the same guidelines as for development of a new irrigation layout.

Chapter B12. Managing recently landformed areas

INTRODUCTION

Landforming is necessary to improve irrigation application efficiency and surface drainage. However landforming can have the following detrimental effects on soil condition:

- exposure of unfavourable subsoil
- structural damage

These problems should be dealt with before growing a crop after landforming.

SOIL MANAGEMENT PROBLEMS THAT MAY OCCUR DURING AND AFTER LANDFORMING

Exposure of unstable subsoil

Subsoil exposure is usually unavoidable because of the need to provide an even slope in irrigated fields. The subsoil may be low in nutrients and organic matter. Worse still, it may be sodic, and therefore dispersive, have a high pH and perhaps be saline. The subsoil generally has a higher density than the topsoil, which offers higher resistance to root growth and may cause slower infiltration and internal drainage.

Structural Damage

Compaction

To avoid compaction of clay soil during landforming, the soil profile should be dried as much as possible prior to landforming. This can be achieved by growing a well fertilised crop such as wheat. The chance of the soil being drier than the plastic limit at landforming is maximised, and the risk of soil compaction is minimised.

However, due to the tight schedules of landforming contractors, it is difficult to reshape fields at exactly the correct soil water content. If the soil is wetter than the plastic limit there is a risk of compaction occurring. Compaction provides unfavourable conditions for plant growth. This occurs through a reduction in porosity and available water content, and an increase in soil density which reduces drainage and enhances waterlogging.

Pulverisation

On loam soil, landforming under dry conditions may create excessive amounts of dust. When re-wetted, this pulverised soil tends to set hard and become very dense.

However, if there is heavy rain before landforming and the contractors cannot be delayed, deep compaction may occur. The extent of compaction must be identified after landforming, and methods to repair the compaction considered. (see Chapter B4: *Do I have a compaction problem?*).

TECHNIQUES FOR OBTAINING MAXIMUM PRODUCTION FROM LANDFORMED AREAS

Topsoiling cut areas

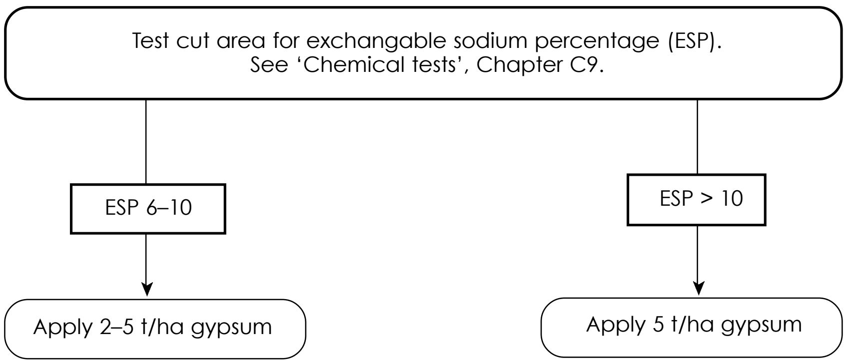
Where subsoil has unfavourable characteristics, it is desirable to stockpile topsoil during landforming. The subsoil is then landformed and the topsoil replaced. Research has shown that topsoiling is the quickest, and most effective way of returning cut areas to maximum production, and is therefore highly recommended. A subsoil exposed in a heavily cut area should receive at least 10 cm of topsoil for best results.

It should be noted that some non-sodic transitional red-brown earths have a subsoil that has superior physical characteristics relative to its topsoil. In these soils topsoiling should not be carried out. The topsoil is best removed from the paddock and used for other purposes.

Gypsum application to cut areas

If topsoiling is not possible, exposed sodic subsoil will have to be reclaimed by applying gypsum. To determine the appropriate gypsum application rate, sodicity (ESP) needs to be measured by a laboratory test. Where ESP >6 the soil is sodic and will respond to gypsum application. Figure B5 indicates the gypsum application rate to prevent dispersion in sodic soils.

Figure B5. Gypsum application rates for cut areas



Note that gypsum should not be applied within 18 months before sowing a rice crop.

N, P and Zn application to cut areas

Where subsoil has been exposed the levels of some nutrients are likely to be low. Application of deficient nutrients, will improve yields of crops and pastures grown on landformed paddocks.

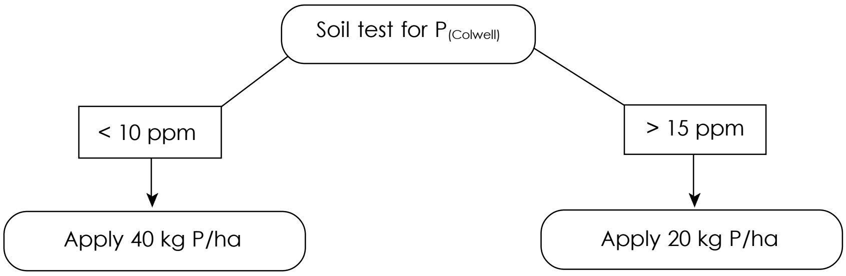
Nitrogen

Yield responses in winter cereals sown in cut areas are likely when nitrogen is applied at 100 kg N/ha. Between 20–50 kg N/ha should be drilled prior to sowing. The remaining N can be applied at about eight weeks after sowing if establishment is good.

Phosphorus

Soil P levels are determined at commercial testing laboratories using the Colwell test. Figure B6 shows the recommended rate of P application in cut areas.

Figure B6. Phosphorus application rates for cut areas



Zinc

Zinc should be applied to all cut areas (where topsoiling has not been carried out). Application rate is dependent on soil pH in some soil types. Figure B7 will enable you to determine the appropriate Zn application rate for your soil.

Figure B7. Zinc application rates for cut areas