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 C. DIAGNOSIS OF SOIL

# Chapter C1.
# How to use this section

## KEY CHECKS FOR PRODUCTIVE IRRIGATED SOILS

The following table gives a general outline of desirable soil conditions. These will vary for many situations. However the key checks can act as a ‘standard’, against which you can judge the condition of your soil.

**Table C1. Key checks for productive irrigated soils**

| Key check | Ideal |
|---|---|
| Soil surface | Free from severe crusting and surface compaction. |
| Soil profile | Well-structured (good structure).<br>Free from compaction layers (including plough pans). |
| Slaking score | Loamy topsoils should score < 3.<br>Slaking not such a problem for swelling clay topsoils of Murray and Murrumbidgee valleys. |
| Dispersion index | Use minimum cultivation for dispersion index > 4.<br>Periodic gypsum use for dispersion index > 8. |
| Soil pH($CaCl_2$) | Surface pH($CaCl_2$) between 5.0 and 8.0. |
| Organic matter | Organic matter levels > 2%, or organic carbon >1.16% (Leco method) or >0.87% (Walkley and Black method) |
| Soil salinity | Soil salinity < 2 dS/m where possible. Soils of salinity > 2 dS/m may require specific management. |
| Soil phosphorus | Soil P(Colwell) at 15–20 ppm for rice growing.<br>For non rice-crops, maintain soil P (Colwell) at:<br>• 25 ppm for sands • 35 ppm for clays |

To use the management table on the following pages you should classify your soil (at least the cultivation layer or top 15 cm) into one of the following three categories:

(i) sands and loams
(ii) dispersive clays and clay loams
(iii) non-dispersive clays and clay loams.

**Figure C0. Soil characteristics guide**

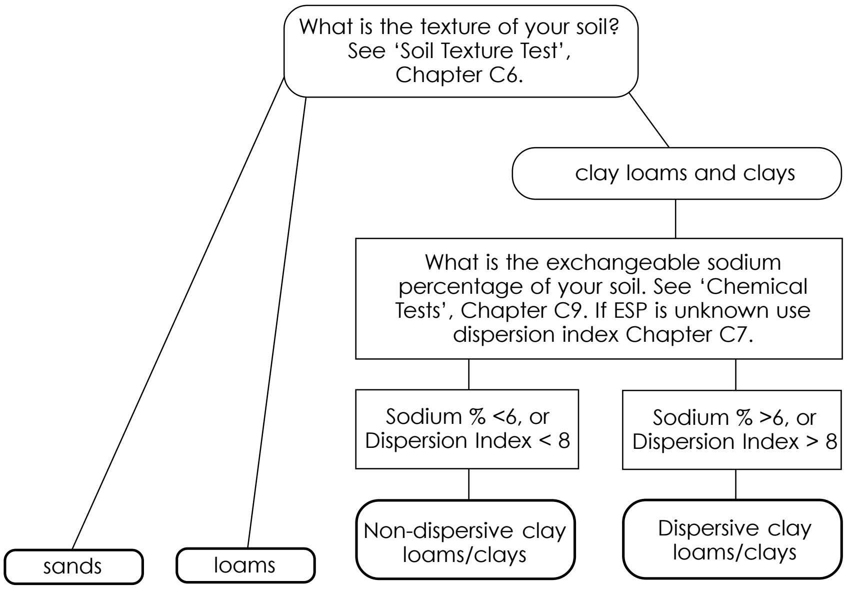


**Table C2. Management and key checks**

| Key check: | Management to improve condition/status: |
|---|---|
| **Soil surface problems** | ***If crusted:*** *need to increase soil organic matter, and protect the soil surface with a mulch, and use gypsum when soil is dispersive*<br>Non-rice; – retain stubble on soil surface<br>– use minimum tillage/direct drill<br>– any cultivation should be non-inversion<br>– use gypsum where dispersion index is greater than 8<br><br>***If hardest or compacted:*** *need to break up the hard layer without damaging soil structure and burying the soil surface.*<br>Not such a problem for rice.<br>Non-rice:<br>– minimise cultivation<br>– use non-inversion cultivation to break up the hardset layer. Deep banding fertiliser at sowing may achieve the same result.<br>– try gypsum test strip where dispersion index is greater than 8<br>– permanent beds reduce compaction<br>– keep stock off wet paddocks if possible<br>Rice:<br>– non-inversion cultivation offers benefits for reducing muddy water and other structural problems in rice.<br>Large amounts of plant residue at the soil surface may slow seedling growth, therefore residue incorporation may benefit establishment in this situation. |
| **Poor soil structure** | Non-rice:<br>*(i) loam soils: need to increase soil organic matter*<br>– reduce cultivation, and cultivate only at correct moisture content<br>– break up any plough pans or compaction layers with non-inversion cultivation<br>– use less aggressive cultivation methods<br>– rotate to a pasture phase<br>– stubble retention may be of benefit<br>– if the soil is suitable for rice, then a rice crop may increase the friability of the soil, allowing easier/better crop establishment<br>*(ii) dispersive clays and clay loams: gypsum use is likely to be beneficial*<br>– gypsum or gypsum used with non-inversion cultivation will benefit these soils<br>– reduced tillage will assist in stabilising the surface of these soils<br>*(iii) non-dispersive clays and clay loams: compaction is the main structural problem*<br>– cultivate to break up any compacted layers or plough pans, or use a crop to dry and crack soil<br>– permanent beds are likely to reduce compaction problems (especially if harvesting equipment runs in furrows) |
| **Slaking score greater than 2** | Non-rice:<br>*(i) loam/clay loam soils: slaking loam soils are likely to form crusts or set hard when dry*<br>– management as for crusted surface soils (previous page)<br>*(ii) clay soils: slaking does not present a major problem for clays as they crack upon drying*<br><br>Non-rice: *gypsum application is likely to be the major form of management on dispersive soils*<br>*(i) Dispersion index greater than 4*<br>– minimise cultivation<br>*(ii) Dispersion index greater than 8*<br>– minimise cultivation<br>– gypsum use should be considered<br>– gypsum and deep cultivation may improve plant growth where subsoils are dispersive<br>Rice: *gypsum should only be used on paddocks that have a history of muddy water or where muddy water is expected*<br>*(i) Dispersion index of greater than 12*<br>– check exchangeable sodium percentage (see "Chemical tests", Chapter C9) of soil; if greater than 10, gypsum use is advisable.<br>– use minimum tillage (eg ridge rollers) and rice on rice rotations where possible |

| | |
|---|---|
| **Soil pH** | Non-rice: – lime should be applied to soils with pH(CaCl) < 5<br>Rice: – not a problem for aerial sown rice |
| **Organic matter** | *If organic matter is below 2%*<br>– switch to direct drilling (using narrow points), or at least minimise tillage<br>– retain stubble on soil surface<br>– rotate to a pasture phase |
| **Soil phosphorus** | If soil phosphorus is below ideal level, contact your local agronomist or fertiliser representative for advice on required application rates. |

# Chapter C2. Soil pit digging: where, how and when?

## INTRODUCTION

This chapter explains where, how and when to dig an observation pit to examine the soil profile. It should be read before using the brief description sheets, outlined at the beginning of Chapters C3, C4 and C5.

There are several alternative methods for digging soil inspection holes including:

- spade
- coring tube
- auger
- backhoe

## WHERE TO DIG AN INSPECTION HOLE/PIT

You are examining the soil profile to make conclusions about soil suitability for crop production. Yield differences, aerial photos or soil colour can be used to help you decide where to dig a pit. It is useful to look at a site with no apparent problems to appreciate the problems in poor areas. The digging of inspection pits in nearby areas that have never been farmed also provides a useful comparison.

Do not dig holes/pits in areas of the paddock that are not representative. For instance, choose an area away from the ends of the paddock where machines turn, and at least 15 metres in from the edge of the paddock across the direction of water flow. If beds are in place find a traffic row and dig a hole/pit to assess the effect of traffic on soil structure.

For new irrigation developments or redevelopments, an EM survey will identify variation in soil conductivity. This may aid in the location of holes/pits for soil assessment. If an EM survey is unavailable then pits should be dug on a grid pattern with a spacing of approximately 150 metres. After landforming a paddock, inspections at approximately three of the pre-development inspection sites should be adequate.

## LOCATION OF PITS/HOLES USING GPS EQUIPMENT

Recently developed Global Positioning System (GPS) instruments can be used to locate your position in a paddock. This allows you to record your sampling site location (for example, where you have dug a pit) and easily return to it for a follow up soil examination. Accuracy of GPS units vary with cost; errors of ± 100 m for a hand-held unit with no correctional capabilities (costing a few hundred dollars) down to errors of ± 10–20 mm for a less-portable unit costing several thousand dollars.

The use of positioning systems, in conjunction with yield maps, will allow you to locate and examine the soil at sites of say, high yield, average yield and low yield. Basic yield maps can be made by hand harvesting at key sites.

The availability and use of yield sensors and positioning systems is likely to increase. The use of positioning systems, and the subsequent mapping of yield and other soil factors provide the basis for increasing the efficiency of farming operations. They will allow soil in a paddock to be treated according to its needs, rather than as a single homogeneous block. This approach is referred to as precision agriculture or site-specific farming.

## METHODS FOR DIGGING PITS/HOLES

### Spade

Advantages of the spade method are:

- simplicity and low cost.
- accessibility and portability.
- speed — more, but smaller, replicates than with a backhoe.
- feel — the feel of the soil as you are digging can provide detailed information about the structure.
- may make it easier to see natural crack lines.
- a good technique to use when the soil is very moist.

Another advantage is that the spade can be carried with you at all times and will be available whenever you wish to examine soil structure. Some users have found that it is easier to sample the subsoil if the spade blade is cut to a width of approximately 15 cm at the cutting edge.

Start by pushing the spade in at approximately 25 cm intervals – parallel to the direction of traffic, if this is known. Note how deep you can push the spade to get an idea of where hard or compacted zones may lie. In very dry soil you may need your foot for leverage, whereas in wet soil you will probably get better a better ideas by just pushing the spade in by hand.

If you find hard zones at depth, examine the soil in more detail. Use the spade to scrape away loose soil (moisture will affect how easily the loose soil can be removed) and note the depth, and condition of the loose soil. Look at the top of the hard layer that you have uncovered – you can use your hand to lightly scrape away very loose soil. Take particular notice of the amount of cracking (if the soil is dry) and the number of biopores (old root channels, tunnels created by ants and earthworms).

With the top of the firm layer now exposed (note that this firmness is not necessarily compaction) dig out a spadeful of soil. Keep the soil on the blade of the spade and note the orientation and the depth from which it came. Look for platey or massive structures, within the spadeful of soil, that are associated with vehicle compaction. Where the soil is hardset, pore spaces are poorly connected and often have a honeycomb-like appearance. When examining soil structure to depth it will be easier if you dig a small hole first, then take a slice of soil from the side of the hole for examination.

A spade is particularly useful to quickly assess the impact, either good or bad, of a tillage operation.

You can use a spade in conjunction with a backhoe pit. Dig down parallel to the edge of the pit until the soil feels firm. Throw the spadeful of loose soil into the pit. Repeat the process along the top edge of the pit. If a hard layer exists it can be more obvious when using this technique than by just looking at the vertical face of the pit.

Information collected using the spade method can be drawn onto the description sheets for interpretation and later reference.

Disadvantages of the spade method:

- difficulty assessing the subsoil
- the cross sectional view of the soil will not be as good as with a backhoe pit
- moisture can greatly alter the feel of the soil when digging; dry soil is hard even when in good structural condition.

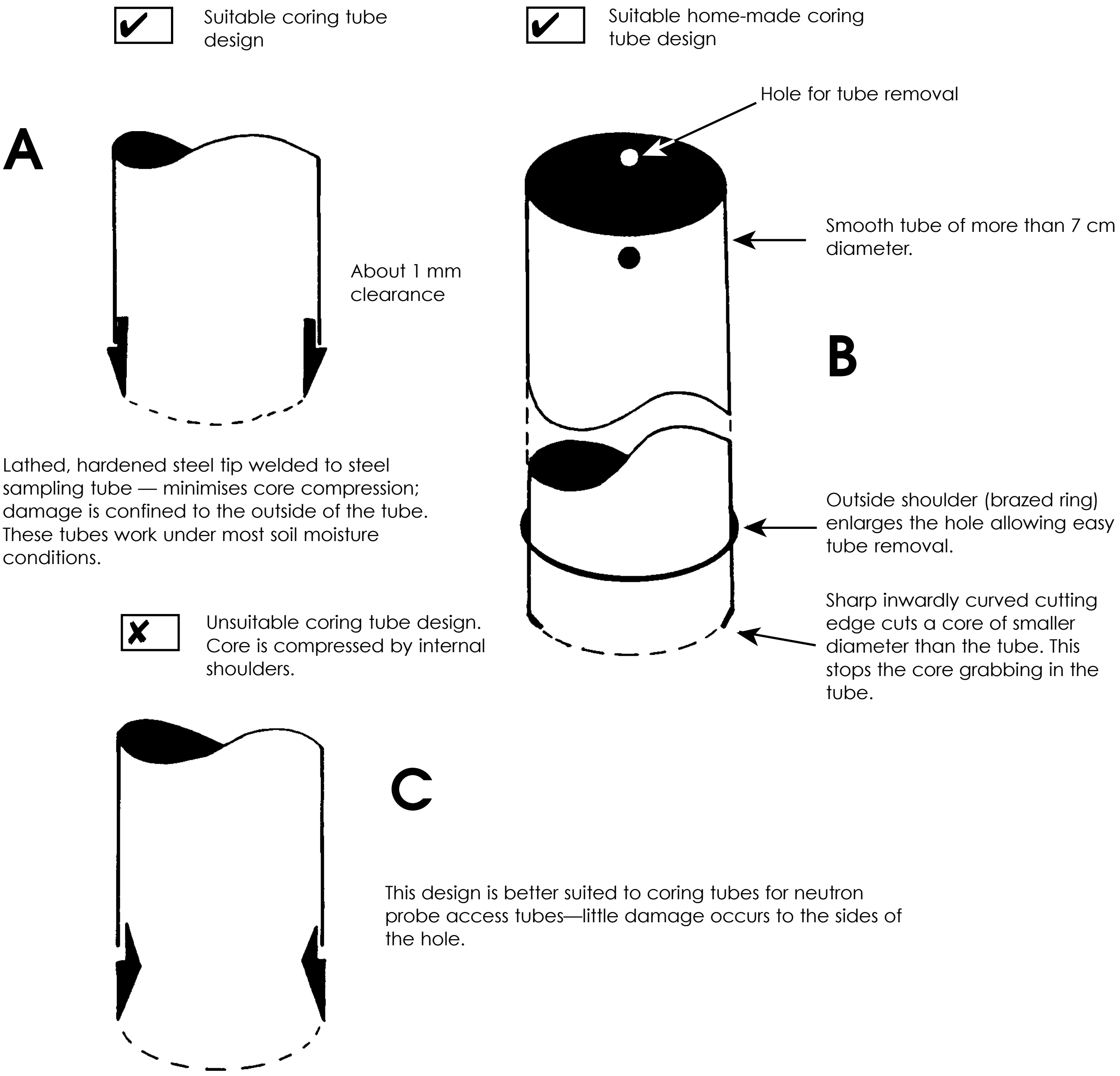
### Coring tube

Coring tubes can be useful if it is not possible to dig a pit. Generally the force required to insert a coring tube by hand is high. A tractor with a hydraulic ram is easier and is an effective alternative.

Soil cores are particularly useful when sampling a paddock prior to irrigation development or redevelopment, where the emphasis is on soil chemical properties rather than severity of soil compaction.

Figure C1 shows three designs for coring tubes made from steel tube of 1.6 mm wall thickness. Exhaust pipe (50 mm diameter) may be used; larger tubes (75 or 100 mm diameter) give better cores. The shape of the cutting tip should force excess soil outside the tube (Designs A and B) leaving the core relatively undisturbed. Design C is unsuitable for examining soil structure: it is better suited to creating a relatively undisturbed hole (eg. for neutron probe access tubes) at the expense of remoulding the core.

**Figure C1. Cross sectional view of three coring tube designs**



Lathed, hardened steel tip welded to steel sampling tube — minimises core compression; damage is confined to the outside of the tube. These tubes work under most soil moisture conditions.

Sharp inwardly curved cutting edge cuts a core of smaller diameter than the tube. This stops the core grabbing in the tube.

This design is better suited to coring tubes for neutron probe access tubes—little damage occurs to the sides of the hole.

Lightly smear the inside and outside of the tube with a non-contaminating lubricant (eg. mould release oil) to prevent the soil from sticking.

Often the success of soil coring will depend upon moisture conditions. Good samples are difficult to obtain from loose, wet profiles (the core may stick to the soil tube), or extremely dry profiles (the core tends to crack and fall apart as it is removed). Severely deformed cores should be rejected. A convenient way to store cores for later reference is in split PVC pipe.

Expose the soil structure within the core by picking off the smeared outer layer (a knife is a convenient tool). Often the soil structure will become more obvious as the soil dries and the cracking pattern becomes conspicuous.

Advantages of soil cores:

- Cores can be kept as a record of soil types and problems.
- Deep samples can be taken more conveniently than with the spade method.
- Less disruptive than backhoe pits.

Disadvantages of soil cores:

- Slow.
- Machinery and operator required.
- Core can stick in tube.
- Small sample.
- Outside of core smeared.
- No guarantee that structure is completely undisturbed: moist soil may compress.

## Soil auger

Soil augers greatly modify the structure of a soil sample. However, they can be used successfully to sample for soil moisture or for chemical analysis. They may also be useful for quick paddock examination of soil texture and colour prior to digging backhoe pits.

A post hole digger may also be used to obtain disturbed samples from depth. However there may be some mixing of soil from different depths, and is only suitable for coarse examination.

Advantages of soil auger:

- Simple and fast.

Disadvantages of soil augers:

- Not suitable for removing soil for structural assessment.

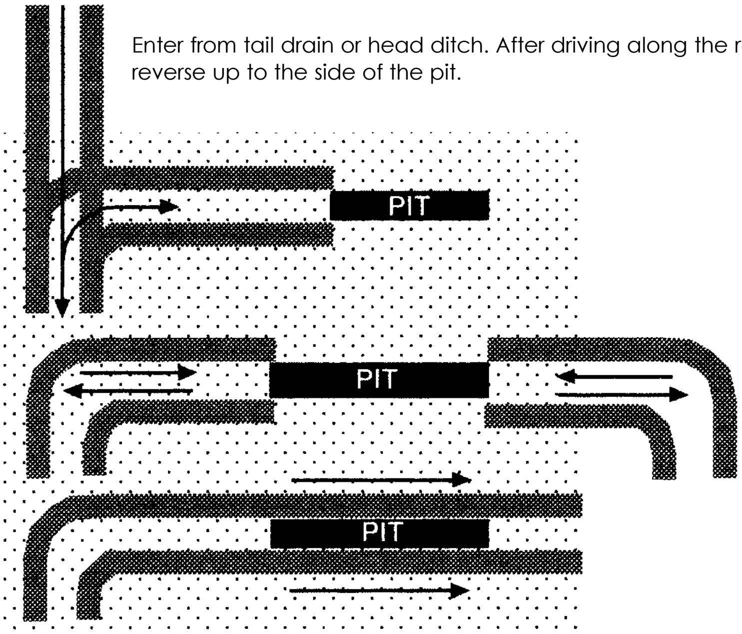
## Backhoe pits

### How to dig a backhoe pit

A backhoe pit provides a good overview of the entire root zone of a crop. It allows easy sampling of both the topsoil and the subsoil.

It is important that what you see in the pit has not been changed by driving the back-hoe over the area where the pit will be. Before driving into the paddock, decide exactly where you want the pit. Reverse the back-hoe up to the spot so that you can dig in undisturbed ground (see Figure C2). Avoid digging pits exactly on top of the sites of previous backhoe pit investigations.

**Figure C2. Moving a backhoe to and from a pit**



Enter from tail drain or head ditch. After driving along the rows, reverse up to the side of the pit.

Reverse the backhoe up to the site, dig the pit and drive away forwards. ☑

When digging a long pit, reverse in from both ends. ☑

Avoid driving the backhow along the sides of the pit. This can alter the pit profile. ☒

Keep the sides of the pit vertical. Vertical sides make a better profile (depth is easier to measure) and minimise the amount of sideways heave as the backhoe bucket moves in and out of the hole (heave disturbs the soil profile).

Because plant roots often extend well below 1m, you will need to dig the pit 1.2–1.5 m deep. A little extra depth allows you to examine the whole profile in comfort, and to allow room for the soil you will be removing from the walls. The recommended dimensions for an inspection pit are shown in Figure C3. A width of 1 m is shown, although sometimes it may be more convenient to make the pit 0.5 m wide. For particularly important pits which need to be photographed, a secondary pit can be dug at right-angles to the main pit to provide extra width.

If digging a pit that is longer than recommended, back in from each end to prevent compaction from backhoe wheels (Figure C2).

Important warnings when digging a backhoe pit

- Check on the location of underground cables and pipes before digging a backhoe pit. Striking such objects during excavation endangers the backhoe operator, and the cost of repair may be great
- Keep the backhoe boom well clear of overhead power lines.
- In NSW, the maximum allowable depth for backhoe pits without benching (see Figure C4) or special support is 1.5 m. WorkCover has stipulated that it is illegal for people to get into pits that are any deeper because of the danger of wall collapse. The danger of collapse is reduced if the excavated soil is dumped well clear of the pit (see Figure C3).
- Clean excavating equipment carefully to prevent the spread of soil-borne diseases and weeds. For disease suppression, equipment should be washed to get rid of large lumps of soil then rinsed with a 1% bleach solution. Sampling equipment, footwear and vehicles also require this treatment, preferably on a concrete pad, before leaving a farm.

**Figure C3. The recommended dimensions for a soil pit**

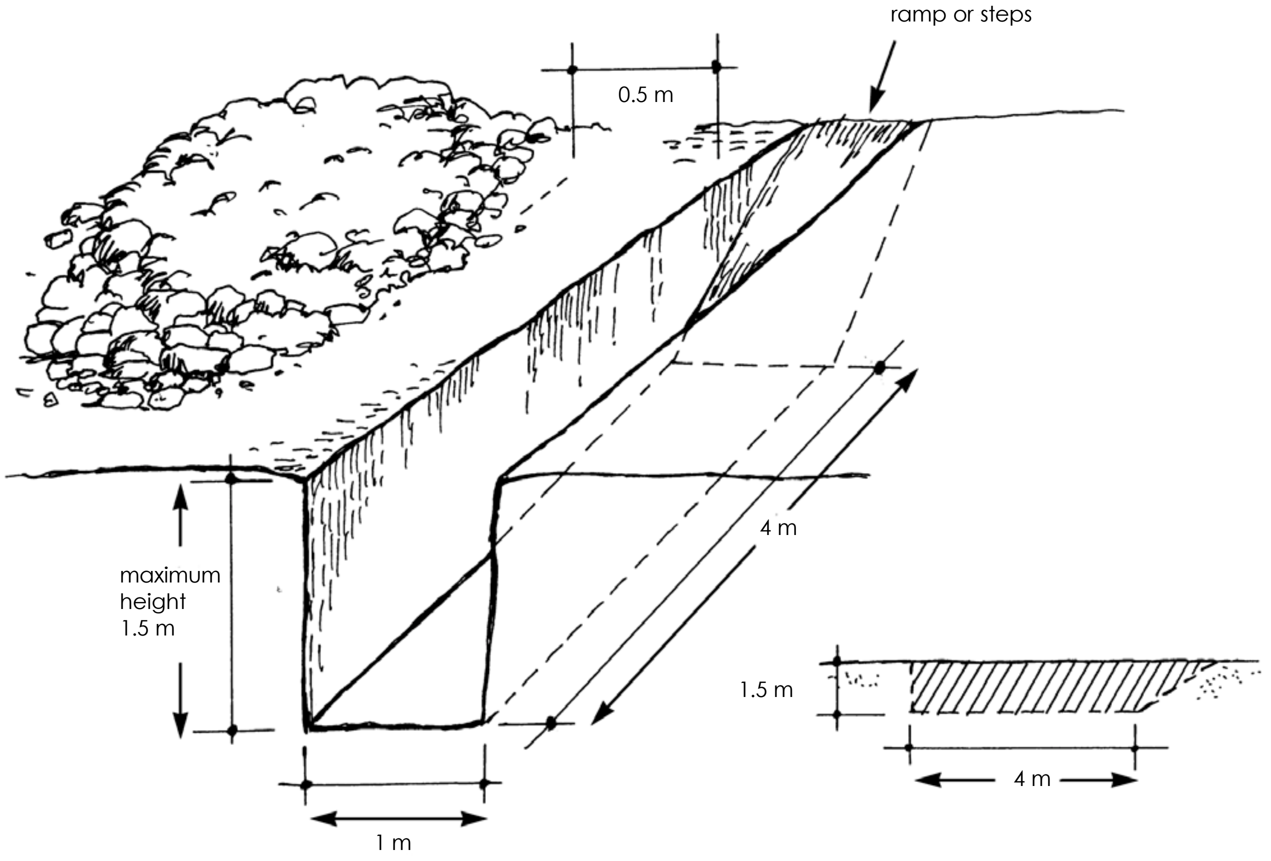
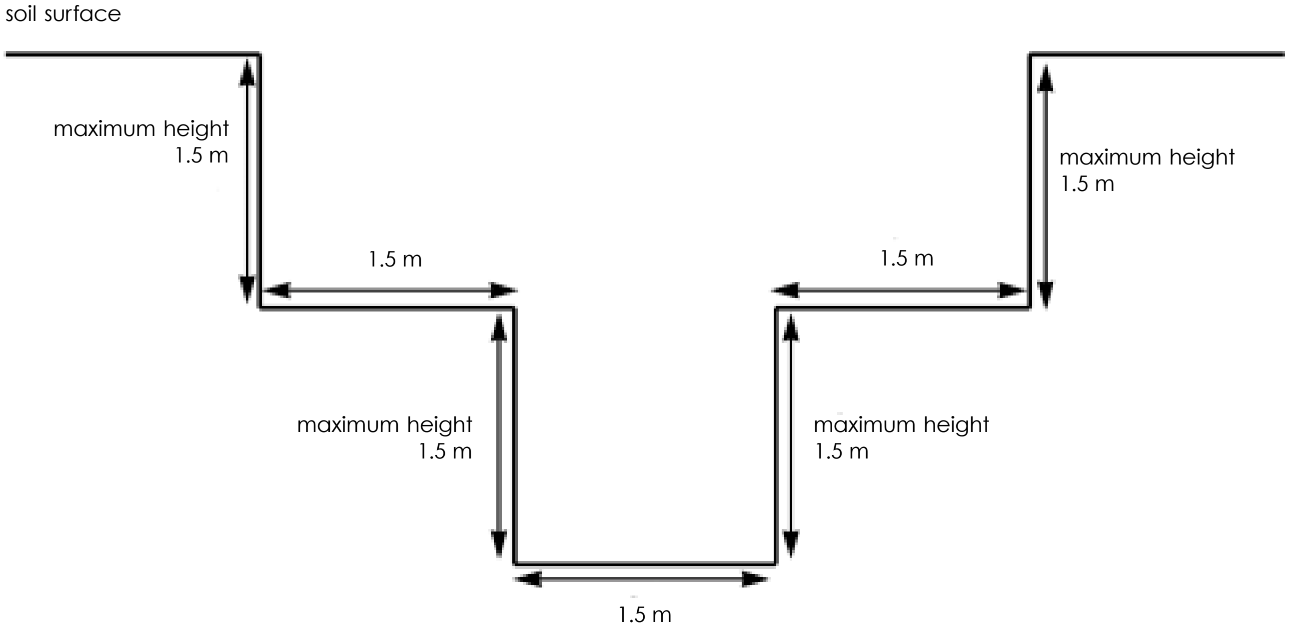


**Figure C4. Benching for pit inspections deeper than 1.5 m**



- If livestock are in the paddock, and if pits are to be left unattended, consider the erection of a temporary fence around each pit to avoid injury to livestock.

If possible, pile the excavated soil on the uphill side of the pit. Then, if it rains heavily, the pile will stop some run-off getting into the pit. Cover the pit face with a plastic sheet if rain is imminent.

Fill in the pit soon after inspecting it to allow the soil to settle before planting the next crop. Subsided pits may be a hazard to light, fast-moving traffic (eg. spray rigs), so mark them with clearly visible and flexible plastic pegs.

**Preparing a backhoe pit for examination**

Clear away any soil spilt on the soil surface above the face you wish to examine. This is important as it allows you to locate the original surface as a reference for the depth of features.

Pick back an area on the face of the pit to remove soil compacted/ smeared by the backhoe bucket. This will reveal the natural structure and colour. Use a tool such as a chisel, screw driver, or pocket knife.

Work across the pit face and then from top to bottom, prising out the damaged exterior of the pit face. This systematic trimming will enable you to remove most of the marks left by your knife. If the profile is to be photographed, ensure that the lighting is as even as possible – shadows over part of the soil will obscure important details in the photographs.

## WHEN TO DIG INSPECTION PITS

The following times are suitable for inspecting the soil using one of the above mentioned methods:

### Existing irrigation developments

- *Immediately after harvest*, when soil structure can be related to the events such as land preparation or harvest and to the last crop's performance. Examples of during-season problems are stunted plants and unusually short irrigation cycles due to poor water infiltration. You can plan your tillage and fertiliser operations for the coming season, and there is time for the soil to settle after the pit is filled in.
- *Immediately after a pasture phase***,** to check whether the soil structure has been improved under pasture. To provide a benchmark for comparison with any changes under cropping.
- *After a test run of tillage equipment***,** to see if the operation was effective, and not creating more problems than it was supposed to solve. Problems include excessive cloddiness, too much dust and/or smearing at the base of the tines. Equipment may require adjusting, or it may be best to cease tillage until soil conditions improve.
- *After changes in management practice***,** to determine whether a soil problem is being overcome by a new approach to crop management. The irrigator can see, for example, the results of changing to minimum tillage.

Comparisons between farmed and adjacent unfarmed (pristine) areas may be carried out at any time, but the comparison is most meaningful when all of the sites are examined at the same water content. The most suitable soil water content is for soil examination is at, or just below, the plastic limit.

### New irrigation developments

- *When developing new country*, to avoid soil with inherent problems. If soil the needs amelioration, this can be costed into the project. Soil evaluation allows you to select the most appropriate irrigation system and fertiliser program. Problems in the first cropping sequence can thus be predicted and avoided.
- *After country has been developed*, as pits enable you to determine if structural damage occurred during landforming. Bad structural problems can result from landforming that took place when the soil was too wet. Exposed areas of subsoil may have fertility problems.

## WHY DIG AN INSPECTION PIT?

An inspection pit will permit a more thorough and more accurate assessment of the characteristics of a soil profile. Whilst it is time consuming, digging a soil pit in representative soil types is worthwhile in order to gain a clear picture of a soil's features and its limitations beyond the normal rootzone, something which is not always possible from auger samples or a shovel hole.

# Chapter C3.
# How to assess a soil profile

## INTRODUCTION

This chapter focuses on the collection of information regarding the paddock where the assessment is to be made, and a description of the soil at the representative site (or sites). The chapters which follow describe how to assess certain other key soil characteristics, such as the soil surface, and soil structure and texture.

## INFORMATION FROM THE PADDOCK AND FARM

Before you examine the soil profile, spend a little time describing the paddock. Such background information will help you to place in context the features that you find on and beneath the soil surface.

Figure C5 shows an example of how you would fill in details for section 1 of the sheet.

**Figure C5. Farm and paddock information sheet**

**1. Farm and paddock information**

| | |
|---|---|
| farmer:<br>property:<br>paddock:<br>date:<br>inspected by: | paddock history: previous crops, yield, fertilser, tillage, disease?<br>reason for inspection: |

sketch a map of site, extra notes etc.

### Farmer, property, paddock

Record the location of the inspection. If this is your own property, the name of the farmer may seem unnecessary, but an agronomist using the sheet may visit many farms and will need a record of the location.

### Reason for inspection

Clarify why you are examining a soil. The reason for inspection may be a particular problem, and that in turn suggests which features to examine first. After examining those features, you can reassess your first impression.

## Paddock history

**Sometimes the first sign of a soil structure problem is poor crop growth. Seedling emergence may be sparse, and they may be slower to emerge and develop; plants may be shorter than plants in other paddocks or there may be variations in plant height within one paddock. A crop may appear to run out of soil moisture because its roots cannot penetrate a hard layer to reach moisture lower down, or moisture from irrigation does not penetrate far into the soil.**

Accurate and detailed records are a great help in determining the cause of poor crop growth. Note some of the following key information from your farm diary, if possible, for the last five years.

crops grown;
their yields;
plant diseases;
any periods of water stress (too wet or too dry)
lime or gypsum applications; and
fertiliser applications.

**Take into account the effect that the previous crop may have had on soil fertility. For example, a previous crop may have depleted the soil nitrogen. Did you apply enough fertiliser? Was any waterlogging evident (ponding of water)? Was the ground compacted during harvest? Was the crop ever water stressed? Were irrigations scheduled correctly?**

The above may all be reasons that crops have not performed as well as expected. However, there may be other reasons, such as weather conditions, lack of soil water, poor nutrition, waterlogging etc.

## Sketch map

Make a sketch map of the site as a record: you may want to go back to the same site to investigate further.

## INITIAL OBSERVATIONS

The initial observations are to gain a basic understanding of the soil you are dealing with. From these observations the soil can be also grouped into one of five soil groups used in this SOILpak. Since many of these features, such as colour, texture and horizon depth, are unlikely to change quickly this observation need only be carried out once at the same site.

### Method

(1) Pick a site. This may be representative of the paddock or an area of particular interest.

(2) Dig a hole. The deeper the better, but at least 50 cm. The hole should be large enough to get a clear view of one face.

(3) Using a knife or screwdriver, flick out small amounts of soil from the soil face to remove smearing caused by the shovel.

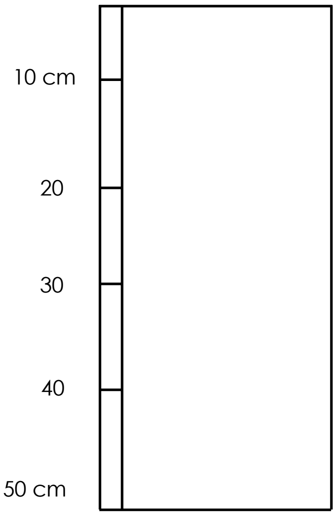
**Figure C6. Initial observations**

**2. Initial observations**

(i) record depth at which layers/horizons seem to change
(ii) record some features of any observable horizons in table

| observable horizon | colour | texture | dispersion (0 - 16) | moisture |
|---|---|---|---|---|
| | | | | |

Indicate where horizon boundries occur (if any), and any additional info.on profile diagram



**Soil Group** (see introduction chapters for description of soil groups)

Sandhill soil ☐
Red-brown earth ☐
Transitional red-brown earth ☐
Non self-mulching clay ☐
Self-mulching clay ☐

(4) Using colour and texture, try to determine different layers in your soil. Record these layers (horizons) on your observation sheet. The soil texturing test is described in Chapter C6.

(5) Measure the depth at which boundaries between horizons occur, and record on the observation sheet, along with the colour and texture of each horizon.

(6) Make an assessment of moisture for each of the observed horizons and record details.

(7) Take soil samples from each layer to conduct dispersion tests. Slaking and dispersion tests are required when assessing surface structure (see following chapters and soil description sheets). The dispersion test for soil from each horizon can be conducted when assessing surface soil dispersion.

(8) Using information obtained from initial observations and soil introductory chapters, place the soil that you examined into one of the five soil groups listed on the soil description sheet.

**Remember: depth and texture of topsoil (if there is any topsoil) are important in determining soil group.**

*Intact soil colour*

Assess the colour of intact aggregates, as distinct from the smallest aggregates. Colour may be useful for distinguishing between soil horizons. Red colours can indicate a freely drained soil (unless sodic). Yellow, grey, greenish or bluish colours may indicate poor drainage. Plant residues buried in wet soil may induce a bluish colour in the surrounding soil; decomposition of the organic matter uses up oxygen and creates an anaerobic zone for a short time. Mottling (blotches of colour different from the main soil colour) indicate that the soil may have been periodically waterlogged in the past, but not necessarily now.

*How to assess intact soil colour:* Break a moist aggregate and judge the colour. Use broad categories.

*Texture*

Soil texture is an estimate of the amount of clay, silt, and sand in a soil. Soil texture is assessed by the behaviour of a small handful of soil when moistened and kneaded into a ball, and then pressed out between thumb and forefinger. How the ball behaves depends mainly upon the proportions of gravel, coarse sand, fine sand, silt and clay in it.

*When to assess surface soil texture:* Texture is a basic property of a soil. It changes extremely slowly (over thousands of years). However, operations such as deep tillage may bring up subsoil, and earthworks may expose subsoil, thus changing surface soil texture.

It is important to repeat the assessment at various depths. Texture, together with soil colour, is an indicator of soil group and soil type. They are important in determining soil management.

*Soil moisture*

Soil moisture can be rated as:

dry
moderately moist
moist
wet

Tillage at the wrong soil moisture content can degrade soil structure. You can also assess moisture for sowing. If contemplating deep tillage, a knowledge of subsoil moisture will help you decide on the likely effect (see Chapter C8).

*Bleaching*

Look for a layer that is paler than the upper part of the topsoil. It need not be white, just a paler colour. It may be a continuous layer, or occur as scattered patches across a field.

Some soils have a bleached layer in the lower part of the topsoil. This is paler than the upper topsoil, but is still part of it.

Bleaching is caused by waterlogging, usually because a subsoil with low permeability prevents the topsoil draining. It alerts you to past waterlogging, and a subsoil which may be restricting drainage from the topsoil, as well as restricting root growth.

*Cementing*

Look for a hard layer. Try to distinguish a cemented layer from a plough pan (compacted layer). A cemented layer does not slake when a dry piece is placed in water (see slaking and dispersion test in Chapter C7), and it does not soften when it is wet. The opposite is true of a plough pan.

Sometimes soils have a layer of naturally hard material which is cemented chemically, and may contain of lime, iron or silica. Such a layer impedes drainage and root growth.

Deep tillage is the best way to break a cemented layer.

*Lime or gypsum*

Lime can occur as particles too small to see, or can occur as white nodules up to 5 cm wide. If the nodules fizz when a dilute acid (such as dilute hydrochloric acid or vinegar) is dropped on it, lime is present.

Gypsum occurs as crystals: they can be white, tinged pink or colourless. The crystals are usually needle shaped, but are occasionally shaped like whole finger nails.

Both lime and gypsum are sources of calcium.

Lime is calcium carbonate. It may occur in neutral to alkaline soils. It is a good sign if found close to the surface, since it helps to promote structural stability.

Gypsum is calcium sulphate. Gypsum occurs deep in the soil profile, usually below 70 cm.

## NOTE ON COMPACTION

Compaction does not affect most Riverina soils in the way it affects soils further to the north. The main reason is that Riverina soils are mostly dense and poorly structured in the first place.

A simple test can be carried out in a moist soil to indicate if a compacted layer exists. It is similar to the soil probe method used to assess infiltration. A probe can be made from a 1m length of thick steel rod, widened and sharpened at the tip, and with a short length of pipe welded to the top to form a handle. The probe is pushed into the soil, and the resistance noted to assess possible soil compaction.

# Chapter C4. Soil surface

## WHAT DOES ‘SOIL SURFACE’ MEAN?

The soil surface is the soil and its surface cover that you see without digging. Surface cover (vegetation and plant residues) can be considered to be part of the soil surface, because surface cover influences soil surface properties. You may need to separate the components of the soil surface by removing the cover to see the actual top of the soil.

The upper 5 cm of soil is taken to be the ‘surface’ in this manual.

> ***Significance of surface structure***
>
> **The structure of surface soil influences water infiltration rates and water storage at each irrigation, as well as seedling emergence, and ease of tillage.**
>
> **Some soils can appear very well structured, but still have infiltration problems. This is why it is important to do the slaking and dispersion tests, and to note whether the soil shrinks and swells. A soil that disperses is likely to form a surface crust and may also set hard on drying. A soil that slakes badly may do the same. A soil that shrinks and swells is able to repair its structure.**

## HOW TO ASSESS THE STRUCTURE OF THE SOIL SURFACE

To examine the soil surface, you may need a screwdriver or blunt knife to prise pieces out. Dig until you come to soil that has a different structure from the surface. Note the depth of the surface soil if it is less than 5 cm. The surface soil may be a 1 cm thick crust above better structured soil, or it may be a recently cultivated layer above uncultivated soil.

**Figure C7. Soil surface**

**3. Soil surface**

**Structural features of the soil surface** (for each feature, enter notes or simply tick)

hard-set ..........................................................................................................

crusted ..........................................................................................................

poached (damage from stock) ..........................................................................................................

cracked ..........................................................................................................

self-mulched ..........................................................................................................

cloddy ..........................................................................................................

| | | |
|---|---|---|
| cover % (crop, stubble, weeds): | slaking (0 –4): | dispersion (0–16): |

The soil surface may take one of the following forms:

- The tilled layer in a recently cultivated soil that has not had rain to settle it. Such a surface layer may consist of fine aggregates or coarse clods. However, if rain on a cultivated soil creates a crust, then the crust is the soil surface because its structure is different from the soil below. The soil below is then referred to as subsurface soil;
- The loose material above a firm (not recently tilled) topsoil. Such a layer may consist of loose, fine aggregates on a self-mulching soil, or a layer of separate grains of sand;
- Compacted, crusted or hard-set soil, before you come to better-structured soil. If the thickness is up to 1 cm, it is a crust. If the thickness is much greater, possibly the full depth of the topsoil, it may be a hard-setting soil.

Describing the condition of the soil surface

(1) Note on the soil description sheet any of the surface features described in the boxes below.

(2) Make an assessment of amount of surface cover on the soil surface and record in the box on the soil description sheet.

(3) Take samples of the soil surface for slaking and dispersion tests. See slaking and dispersion test in Chapter C7. Record the results on the soil description sheet.

Enter depths on the sheet for zones in the soil profile that you identify as being different from those around it.

***Hardset***

**Self-mulching clays do not hardset. A hard surface layer may be due to compaction (stock or machinery) or dispersion.**

**Loams may hardset when organic matter content is low. A long history of cropping, with little or no pasture may be the cause. Retain stubble or sow pasture to protect the soil surface from raindrop impact, and to improve organic matter content.**

**Tillage to break the hardset layer may be required to establish plants, but till when the soil is close to the plastic limit to avoid dust formation, compaction or smearing. Minimum tillage or no-till is of most benefit after the soil has been restored to good structure.**

***Crusted***

**Self-mulching clays: a fragile crust may occur, but is usually not significant enough to cause plant growth and infiltration problems.**

**Non self-mulching clays: a crust is likely due to the dispersive nature of these soils.**

**Red-brown earths and transitional red-brown earths: these may crust due to low organic matter content, particularly in a fine sandy loam or a silty loam. If this is a cropping paddock, refer to paddock history to see how long since pasture. Have there been seedling emergence problems? Surface cover may reduce the tendency to crust. Increase surface roughness to form hollows that will retain water and assist infiltration. Harrows will break a thin crust and may assist seedling emergence.**

*Cloddy*

Self-mulching clays: A cloddy tilled layer will mellow (improve in structure with wetting and drying, or frost). Further tillage before mellowing is unlikely to improve soil structure. After the soil structure has mellowed, till only the depth of dry soil.

Red-brown earths and transitional red-brown earths: A cloddy layer may require further tillage (only when a seed bed is required) when the soil is close to the plastic limit (see Chapter C8). A cloddy surface soil may be favourable for water infiltration.

*Dispersive*

Determine slaking and dispersion score of surface soil. Record this in separate boxes (see also slaking and dispersion test in Chapter C7). It may help to determine whether gypsum will improve a crusted or hard-set soil.

*Cracked*

A description of intensity of cracking may be useful. It may influence your decision on the appropriate action for other features.

*Pugged*

Cracking clays recover from pugging as they dry and crack. Pugging damage on a cropping paddock can be alleviated by tillage when the soil is dry. Pugging damage to a self-mulching clay is probably best left to repair itself.

Loamy topsoils (red-brown earths, transitional red-brown earths) under heavy grazing pug when wet and pulverise when dry. Till a pugged cropping paddock when the soil is at the plastic limit. A pugged loam pasture will improve in time. Reduce grazing pressure and allow root growth and earthworms to open up the soil.

*Friable*

A friable surface is well structured. Provided that there are no root-restricting layers in the soil profile, this soil is very suitable for direct drilling.

*Significance of surface cover*

Surface cover reduces the impact of raindrops, thereby protecting surface structure. Cover also slows down water running over the surface, increasing the intake of water to the soil at each irrigation or rainfall event. Large amounts of surface cover at sowing time can pose a problem to some sowing implements.

# Chapter C5. Soil structure

## STRUCTURAL FORM AND RATING OF THE SOIL PROFILE

***Significance of soil structural form***

**The form of soil structure is a description of the arrangement of soil particles into larger units, and of the pore spaces between the units. It affects the movement of water through the soil, the movement of air into and out of the soil, and the ease of penetration by roots. Soil structural form is distinct from other aspects of soil structure, such as structural stability and structural resiliency. In common usage, 'soil structural form' is often referred to simply as 'soil structure'.**

**Of a number of paddocks with similar soil texture, those paddocks with good soil structure are more versatile than those with poor soil structure. A greater range of options is available when soil structure is good.**

**Poor soil structure indicates the need for different management strategies; perhaps a change in irrigation frequency, minimising tillage or reduced stocking rates on wet soil.**

Section 4 of the soil description sheet has columns for recording your assessments of several soil structural features. These assessments are used to give an overall structure assessment for individual zones/ horizons in the soil profile.

**Figure C8. Soil profile: structural form**

**4. Soil profile: structural form and rating**

| depth (cm) (%) | aggregate size (cm) | ease of fracture | new roots | aggregate shape | fracture faces | peds within aggregates | porosity (0–2) | colour of smallest aggregates | structure score (0–2] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

**presence of hard pan?**

The observable features that will influence the relative structure assessment will differ with soil texture (eg. sand, loam, clay etc.) and structural stability (eg. dispersive, non-dispersive). Important tips for assessing soils with three key characteristics are explained below.

### Non dispersive clay soils or horizons

The features, from left to right on the soil description sheet, are in priority order for clay textured soils. They start with aggregate size, the feature that has the most influence upon the suitability for plant growth. After assessing and recording structural features for each horizon, an assessment can be given using Tables C3 and C4. Remember that in these soils compaction can often be detected by large, platey aggregates.

### Dispersive clay soils or horizons

It is important to remember that dispersive clay soils are generally poorly structured and therefore a dispersion test may help in assessing the structural condition of a soil. There may be little point in attempting to make a structure assessment of a soil that has a dispersion index of > 6 or an exchangeable sodium percentage of > 6%. In these instances the soil's structure will invariably be poor.

### Loamy textured soils or horizons

For loam soils the most important feature influencing its suitability for plant growth is ease of fracture (or friability). This test should be conducted when the soil is dry. When moist most loam soils will appear to be friable, and is therefore less useful when soil is moist.

When conducting a friability assessment on loam soils, it is important to note how the soil breaks down. If the soil breaks down into sharp angled lumps and /or becomes very powdery, the soil is in poor condition. A well structured soil breaks down easily into small aggregates and particles when dry. This is evident in well structured soils that have a 'soft' feel to walk upon. Other indicators of good friability are;

- a shovel or similar implement can be easily pushed into the soil when dry
- a groove can be easily scraped on the soil with your boot when dry
- the soil breaks up into small aggregates and fragments when cultivated.

A poorly structured soil will form large clods when cultivated.

Porosity is also an important indicator of physical condition in loam soils. A loam that is friable when dry will obviously have good porosity. A less friable soil that is massive when dry may have many visible macropores (pores visible with naked eye). Macropores are desirable for plant growth, especially when the soil is very weakly structured or massive.

A loam soil in good physical condition will often have 'weakly developed' structure, and therefore aggregate shape and size are hard to assess. Because of the low clay content, fracture faces in loamy soils are likely to be dull, even where the soil is well structured. Therefore the features that should be observed (in priority order) are;

1. Ease of fracture (friability)
2. Porosity
3. New roots — tap rooted plants such as canola are good for detecting hard layers in the soil.

Use Tables C3 and C4 to decide upon a structure assessment for each zone or horizon. The assessment in its simplest form will place the soil into one of three categories — poor, moderate or good soil structure.

## HOW AND WHEN TO ASSESS SOIL STRUCTURE

You may use the hole that you have already dug for the initial observations.

It is possible to record differences due to a single cultivation, as well as long-term changes. Use your assessment as a systematic way to check past decisions and plan future management. For example, before deciding to deep till, examine the soil to see if there is a real need for that operation. If there is a hardpan, measure its depth so that you can set the depth of the cultivation tines to break the pan. Check again after a short run with the machine to see if it is doing the job.

### Depth

Enter depths on the sheet for zones in the soil profile that you identify as being distinctive. These zones may be the same as those described in the initial soil observations. However, these horizons may need to be subdivided if structure varies greatly within each horizon.

### Aggregate size

***Significance of aggregate size***

**Small aggregates indicate a good tilth, whereas large aggregates indicate cloddiness.**

**When examining wet soil, it can be difficult to determine the natural fracture plane between aggregates, and hence their size. Very dry soil can have high strength because of interlocking aggregates. Use enough force to expose natural faces; hitting a dry lump with an implement may be the best technique.**

Aggregate size is relevant mainly to clay soils. Break a lump of soil into smaller and smaller pieces, using moderate hand pressure. Take note of the size of the lump just before you begin tearing through the fabric of the soil, leaving a fine grainy surface. This is the point at which you are no longer breaking the soil along natural fracture planes — you are tearing the aggregate apart.

Note the most common size or note size differences where you have aggregates of widely varying size. For example, in a cloddy tilled layer, some clods may be larger than 4 cm with the remainder of the soil made up of clods smaller than 1 cm or dust.

## Ease of fracture

***Significance of ease of fracture***

**Well-structured soil parts along natural faces (the aggregates 'part' from one another). Poorly-structured soil breaks where you apply the force rather than along natural faces.**

When examining dry soil, distinguishing between 'parting' and 'breaking' requires some experience. Think of dry, poorly-structured soil as 'snapping' apart. If a well-structured soil crumbles into small aggregates when it is dry, it is friable.

When examining wet soil, parting of aggregates from one another is easier to detect. Don't squash the soil, but tease it apart. If it fractures easily, it is well-structured. If it will not part but stretches like dough or plasticine, or tears apart, the soil is poorly-structured.

## New roots

***Significance of new roots***

**Roots where present, are the best indicators of soil structure. New roots are indicators of current structure. Roots grow where they can — along the easiest path. A prolific growth of new roots throughout the soil indicates good soil structure. Where roots follow cracks and grow around aggregates rather than penetrating them, the structure is poor. Good soil structure allows roots to grow straight. Roots may bend or branch above a compacted layer. Unrestricted roots are round in cross-section, whereas roots in a compacted soil may show flattening or bulging.**

Follow some plant roots as you dig through the soil. Note any abrupt change of direction. This is also a good way to detect a hardpan. If the soil is too hard for plant roots to grow vertically, they may turn and grow horizontally. Check that roots growing vertically are not deformed. If there is evidence of healthy root growth well below the plough layer, there is no need to dig further.

Note that roots sometimes bend or branch for reasons other than a restricting soil layer, such as herbicide damage, soil diseases and unfavourable soil pH. Do not confuse branching due to compacted soil with proliferation of lateral roots in a well-structured soil.

## Aggregate shape

*How to assess aggregate shape:* Look at undisturbed lumps of soil from the side of the hole that you dug, or from the middle of a new spadeful. Using the description of aggregate shape and size in Figure C9, observe and record the aggregate shape and size for each horizon.

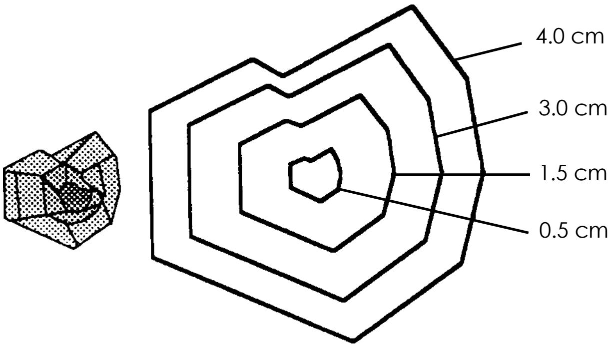
The shape of aggregates depends upon the forces acting on the soil. Tillage and traffic change the shape from what is considered natural.

### Massive

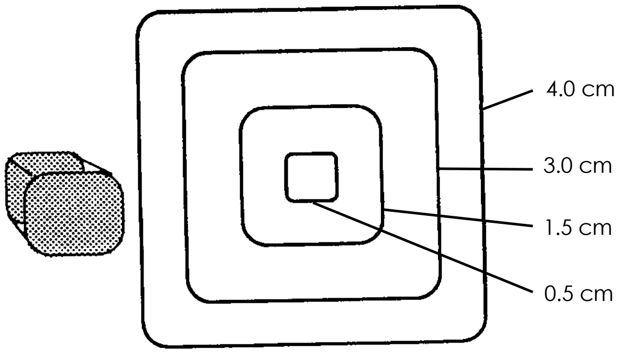
Massive aggregates are dense and have few pores. They appear dull and 'featureless'. Massiveness is a sign of poor structure.

Figure C9. Common aggregate (clod) shapes and sizes

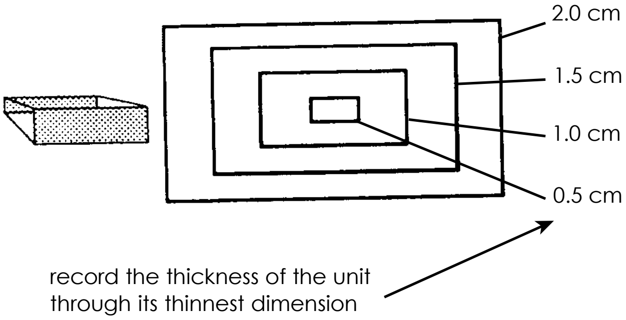
**Many-faced**



**Cube-shaped, rounded corners**

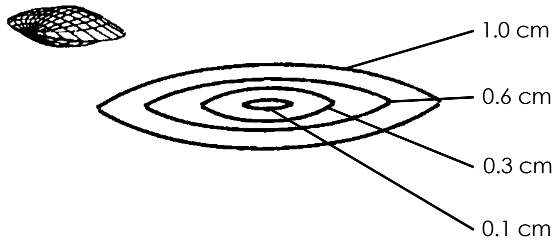


**Platy (2–3 times longer and/or wider than deep)**

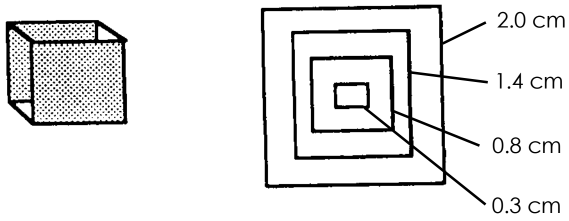


record the thickness of the unit through its thinnest dimension

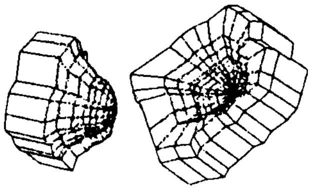
**Lens-shaped (2-sided, thicker in the middle)**



**Cube-shaped, square corners**



**Shell-shaped (cup and ball), generally larger than 1 cm**



### Many-faced aggregates

Many-faced aggregates are a sign of good structure. They may be loosely joined as a thin, fragile crust (not usually strong enough to inhibit seedling emergence) or bound into a very porous, crumbly aggregates.

### Cube with square corners

These aggregates occur naturally in non self-mulching clays, but may also be the products of a massive block fractured by drying. Knowledge of similar soils in the area helps. Look under trees or pastures to see if the soil naturally has aggregates with square corners.

### Platey aggregates

Platey aggregates show as obvious horizontal layering in the soil profile, or may show in the way a lump of soil parts. Prise a lump from the soil and remember its orientation. Break it into smaller pieces by forcing it in different directions. If it parts more easily along horizontal fractures than in other directions, and produces flat plates, it is platey. Platiness is a sign of poor soil structure. A thick platey layer is worse than a thin one. Platiness is common under wheel tracks and does not usually extend deeper than 30 cm below the surface.

### Cube with rounded corners

These aggregates occur naturally, together with many-faced aggregates, below the surface. They may fit together in larger aggregates.

### Lens-shaped aggregates

Lens-shaped aggregates occur naturally in clay subsoils and are a sign of good structure. They may be hard to find because often we see only part of a large lens-shaped aggregate (half a lens appears as wedge-shaped). Lens or wedge-shaped aggregates usually part into smaller aggregates. They occur at all angles in the soil although larger aggregates typically have a face at 45° to the horizontal.

### Shell-shaped aggregates

Shell-shaped aggregates (Figure C9) are another sign of degradation in clays. You may find clods that separate along a cup-and-ball shaped fracture, suggesting that one clod has been pressed into another. This is a sign of poor soil structure. Shell-shaped aggregates are tightly curved and have dull faces, quite distinct from lens or wedge shaped.

## Fracture faces

In clays, the fracture faces may be shiny, indicating a natural fracture plane between aggregates, or dull, indicating that the soil has been remoulded. In loams, rough faces with many pores indicate good structure. Shiny faces do not occur naturally in loam soils.

Examine the faces of a lump of soil removed from the side of a hole. Break the lump apart to reveal faces between aggregates. A good way to learn to recognise the different kinds of fracture face is to compare soils that have been treated differently: for example, compare soil from a pasture with soil from a wheel track; or soil from a plough pan with soil from below the pan.

Be careful not confuse natural shiny faces with shiny smeared layers made during cultivation.

### Peds

***Significance of proportion of small aggregates***

**This refines the observation of aggregate size by showing the internal structure of larger aggregates. It confirms other observations such as ease of fracture, aggregate shape and fracture faces.**

**Moisture content has a large influence on the soil's behaviour in this test. However, it is possible to distinguish soils that are puggy when wet, or brittle when dry from those that are friable.**

Peds are small aggregates within larger aggregates. To assess the proportion of smallest aggregates, start by rolling an aggregate gently between thumb and forefinger to break it down. Record the proportion of the broken down aggregate that are shiny-faced in clays, or are more than single-grained in loams.

### Porosity

***Significance of porosity***

**Pores large enough to see are the means by which water, nutrients and air are able to move into and through the soil. Root growth is sparse within non-porous clods, and therefore the extraction of nutrients and moisture is limited.**

**In dry soils it is more difficult to feel porosity because even well-structured soils are hard when dry. It is best to assess the soil when it is moderately moist.**

**In dry loam soils macropores can often be seen as small vertical channels (around 0.5 mm diameter), when the soil is hardset.**

Pores are the spaces between and within soil aggregates. Porosity refers to the amount of pores in the soil. Macropores are relatively large, and most can be seen with the naked eye. They include the spaces between aggregates caused by cultivation, shrinking and cracking, and channels made by plant roots, earthworms and insects.

Examine the soil and feel how it breaks. Attempt to break a lump into smaller and smaller pieces. The feel of the soil (crumbly for good structure; doughy, flinty or powdery for poor structure) also tells you if the soil is porous. Rate porosity by the potential pathways for root penetration.

### Colour of smallest aggregates

The colour of the smallest aggregates as an indicator of soil structure is of low importance. Well-structured soils generally have strong colours because of high organic matter content and/or high iron content. Thus dark grey or reddish-brown colours indicate good structure. Pale colours such as light grey or slightly brown indicate less well structured soil. Bluish colours indicate a tendency to waterlogging.

## STRUCTURE ASSESSMENT

A system for assessing soil structure is presented in Tables C3 and C4. The system provides for only three structure groups — **poor, moderate and good**. However, in practice you can assess a soil into in-between groups (eg. poor to moderate) depending on what you find. Note that sodic layers (ESP >6, or Dispersion Index > 8, see Chapter C7) are likely to have poor structure.

Most Riverina soils would be in the ‘firm soils’ category in Table C3.

Few Riverina soils could be categorised as loose soils, unless recently cultivated or ameliorated with gypsum. Exceptions would be self-mulching soils and loose sands.

The final column in section 4 of the soil description sheet is for you to record your overall assessment of soil structure from the various observations. Give single values for individual zones/horizons within the soil.

**Loose soil can be moved by scraping with the hand, or with a trowel or spade (but not by digging). It may be a loose seedbed, a loose tilled layer (even if cloddy) or a self-mulched layer. Very loose soil may be found at depth in association with salinity, which promotes fine aggregation.**

**Firm soil is soil below the depth of tillage, or below a natural loose self-mulched layer. It has aggregates that fit together along faces, and which require at least gentle hand force to lever them apart. Firm soil is not necessarily compacted. Firmness is a natural state of the soil at depth, but surface soil may be firm if compacted, crusted or hard-set.**

**When assessing soils dominated by silt and fine sand (soils that do not develop shiny faces) ignore all references to shiny faces. This is common in red-brown earth, transitional red-brown earth, and sandhill soils.**

Use Tables C3 and C4 (see next two pages) to choose a structure assessment. The table shows three assessment levels for both firm soil and loose soils:

poor structure
moderate structure
good structure

With experience you can further subdivide your assessment to give a more accurate description of a soil’s structural state: eg, moderately good structure.

### Structure after rotation crops and tillage

When rotation crops and tillage are used to loosen compacted soils, it is usually assumed that they are successful in achieving better soil structure. However, this is not always the case, and the only way to find out is to have a good look. Farmers who carry out an inspection are often surprised to find out that compaction and soil structure have not improved, and may even be worse.

It is suggested that you make a thorough inspection of your soil after a major tillage operation and/or rotation. Use any of the methods described earlier in this chapter. Results can be compared to those made prior to the operation or rotation, and judgements made as to their success or failure. Appropriate adjustments to your equipment and future soil management may need to be made.

**Table C3 A system for classifying soil structure — firm soil**

| **Features** | **Assessment** | | |
|---|---|---|---|
| **Firm soil, moist** | **Poor structure** | **Moderate structure** | **Good structure** |
| Aggregate size: width of natural sub-units produced by moderate hand pressure | Mostly more than 50 mm wide | 5–50 mm wide | Mostly less than 50 mm wide |
| Ease of fracture | Difficult for a spade or knife to penetrate soil made up of large, tightly fitting blocks; breaks like heavy dough or plasticine | Moderate hand pressure needed to part blocks | Parts readily into porous sub-units |
| New roots | Very few new roots | Medium number of new roots | Prolific growth of new roots throughout the sample |
| Aggregate shape | Massive, platey or shell-shaped corners | Mixed shapes | Many-faced, cube with round corners, lens or wedge |
| Fracture faces | Soil breaks along the lines of force applied in any direction, into units with sharp corners; internal faces have no protruding sub-aggregates | Some natural separation planes with shiny faces, but most fracturing is along the line of force, to produce angular corners and smooth, dull internal faces | Natural fracture planes dominate; most of the faces are smooth and shiny, although, often there are protruding many-faced, round-cornered aggregates |
| Peds within aggregates: proportion of smaller aggregates within aggregates, revealed by rolling the sub-units between thumb and forefinger | Less than 10% of breakdown products are shiny-faced aggregates (clays) or larger than single grains (loams) | 50% of breakdown are shiny-faced aggregates (clays) or larger than single grains (loams) | More than 90% of breakdown products are shiny-faced aggregates (clays) or are larger than single grains (loams) |
| Porosity: internal porosity of smallest aggregates | Poor porosity (0) | Moderate porosity (1) | Good porosity (2) |
| Colour of smallest aggregates | Bluish | Light grey or slightly brown | Dark grey to strong deep red |
| Extra notes for dry soil | Requires a very strong blow with an implement to break the blocks, revealing smooth, dull faces with sharp corners; flinty | Hard hand pressure required to break the blocks | Falls apart with light hand pressure to produce small, natural aggregates |

**Table C4 A system for classifying soil structure — loose soil**

| **Features** | | **Assessment** | |
|---|---|---|---|
| **Firm soil, moist** | **Poor structure** | **Moderate structure** | **Good structure** |
| Aggregate size | Diameter of the dominant fraction usually more than 20 mm | Diameter of the dominant fraction usually between 5 mm and 20 mm | Diameter of the dominant fraction usually less than 5 mm |
| Ease of fracture into constituent natural sub-units, if present | At least half the soil is large, dense and massive clods; dull and smooth fracture faces or loose sand grains/powder | At least half of the clods are larger compound aggregates which can be parted by moderate hand pressure into their constituent natural aggregates | Comprised wholly of natural aggregates that may be separate or compound (very easily parted by hand into their constituent natural aggregates). When broken the aggregates separate along many-angled, often shiny faces. If shiny faces not evident, the soil has many obvious pores and is friable |
| Aggregate shape | Cube-shaped with square, sharp edges, or shell-shaped | Mixed shapes | Many-faced, or cube-shaped with rounded edges |
| Porosity: internal porosity of smallest aggregates | Poor porosity<br>(0) | Moderate porosity<br>(1) | Good porosity<br>(2) |
| Extra notes for dry soil | A large proportion of large, hard, flinty clods with sharp edges | As above, but compound aggregates are firmer; some are flinty | Falls apart with light hand pressure to produce small natural aggregates |

Reference: SOILpak structure assessment as modified by David McKenzie and Sue Greenhalgh.
In: Final Report to Cotton Research and Development Corporation.

## CONCLUSIONS

Using information gathered in the four sections of the soil description sheet, state what soil group you have examined and any structural problems that may be restricting plant growth, and your conclusions.

The five sub sections of the SOILpak soil description sheet have been placed together overleaf. You can photocopy the two pages of this sheet to use for your own field assessments.

## Figure C10 Conclusions from soil examination (example)

### 1. Farm and paddock information

farmer: ***Trevor Fosdyke***

property: ***" Ponderosa"***

paddock: ***big***

date: ***12/4/97***

inspected by: ***Trev***

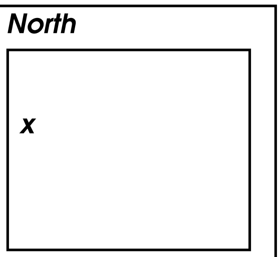
paddock history: previous crops, yield, fertilser, tillage, disease?

***1995 – rice, yield 12t/ha aerial sown, 200 kg/ha urea***
***1996 – rice yield 10 t/ha areial sown , 200kg/ha urea***
***– fallowed (offset disc and scarifier) in October 96***

reason for inspection: ***Suspect compaction (plough pan) may be a problem. need to know if gypsum will be of any benefit to wheat crop***

sketch a map of site, extra notes etc.

***Along the west fence about 30 metres south of the box tree***

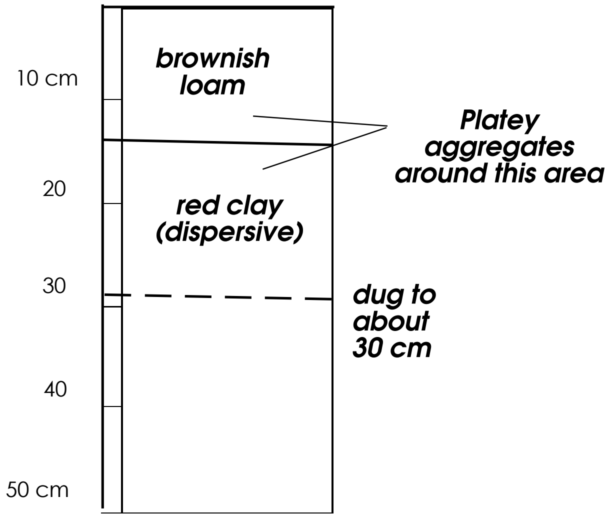


### 2. Initial observations

(i) record depth at which layers/horizons seem to change
(ii) record some features of any observable horizons in table

| observable horizon | colour | texture | dispersion (0 - 16) | moisture |
|---|---|---|---|---|
| ***0–15 cm*** | ***red-brown*** | ***loam*** | ***0*** | ***dry*** |
| ***16 - ?*** | ***moist*** | ***heavy clay*** | ***12*** | ***moist*** |

Indicate where horizon boundries occur (if any), and any additional info.on profile diagram



**Soil Group** (see introduction chapters for description of soil groups)

Sandhill soil ☐

Red-brown earth ☒

Transitional red-brown earth ☐

Non self-mulching clay ☐

Self-mulching clay ☐

### 3. Surface soil

**structural features of the soil surface** (for each feature, enter notes or simply tick)

hard-set

crusted ***crust formed after rain in October***

poached (damage from stock)

cracked

self-mulched

cloddy

cover % (crop, stubble, weeds): ***10 %***

slaking (0 –4): ***3***

dispersion (0–16): ***0***

### 4. Soil profile: structural form and rating

| depth (cm) (%) | aggregate size (cm) | ease of fracture | new roots | aggregate shape | fracture faces | peds within aggregates | porosity (0–2) | colour of smallest aggregates | structure score (0–2] |
|---|---|---|---|---|---|---|---|---|---|
| ***0–15*** | ***0–0.7*** | ***hard*** | ***yes*** | ***massive*** | ***dull*** | ***0*** | ***1*** | ***brown*** | ***0*** |
| ***16–30*** | ***1–6*** | ***hard*** | ***yes*** | ***platey*** | ***dull*** | ***0*** | ***0*** | ***brown*** | ***0*** |
| ***30+*** | ***1–6*** | ***hard*** | ***few*** | ***blocky*** | ***shiny*** | ***25*** | ***1*** | ***red*** | ***0.5*** |

**presence of hard pan?**

hard pan evident between 10 and 16 cm (platey aggregates)

### 5. Conclusions

What are the main structural features of this soil (if any) that may be restricting maximum plant growth?

***Hardsetting topsoil, heavy poorly structured sodic subsoil.***

## SOIL ASSESSMENT FORM

### 1. Farm and paddock information

farmer:

property:

paddock:

date:

inspected by:

paddock history: previous crops, yield, fertilser, tillage, disease?

reason for inspection:

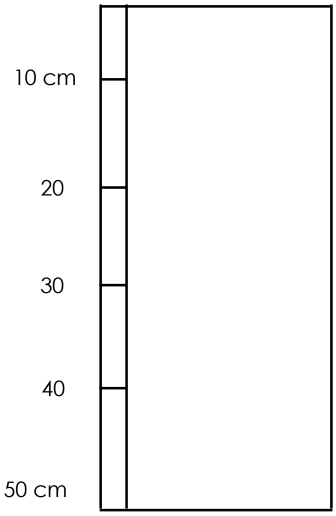
sketch a map of site, extra notes etc.

### 2. Initial observations

(i) record depth at which layers/horizons seem to change
(ii) record some features of any observable horizons in table

| observable horizon | colour | texture | dispersion (0 - 16) | moisture |
|---|---|---|---|---|
| | | | | |

Indicate where horizon boundries occur (if any), and any additional info.on profile diagram



**Soil Group** (see introduction chapters for description of soil groups)

- Sandhill soil ☐
- Red-brown earth ☐
- Transitional red-brown earth ☐
- Non self-mulching clay ☐
- Self-mulching clay ☐

## 3. Soil surface

**structural features of the soil surface** (for each feature, enter notes or simply tick)

hard-set ..........................................................................................................................................................................

crusted ............................................................................................................................................................................

poached (damage from stock) ..........................................................................................................................................

cracked ...........................................................................................................................................................................

self-mulched .....................................................................................................................................................................

cloddy ..............................................................................................................................................................................

|  |  |  |
|---|---|---|
| cover % (crop, stubble, weeds): | slaking (0 –4): | dispersion (0–16): |

## 4. Soil profile: structural form and rating

| depth (cm) (%) | aggregate size (cm) | ease of fracture | new roots | aggregate shape | fracture faces | peds within aggregates | porosity (0–2) | colour of smallest aggregates | structure score (0–2] |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |

**presence of hard pan?**

## 5. Conclusions

What are the main structural features of this soil (if any) that may be restricting maximum plant growth?

# Chapter C6. Soil texture

## WHAT IS SOIL TEXTURE?

Soil texture is an estimate of the proportions of sand, silt and clay in the soil.

Texture of the soil surface will strongly influence the structure of the surface layers. This will affect seedling emergence, water infiltration and percolation, trafficability and ease of tillage. Texture also affects soil water holding capacity in both the topsoil and subsoil, and the behaviour of some herbicides. Clays hold more nutrients than loams and sands, but they are likely to have poorer aeration and permeability.

Texture varies from place to place. Many paddocks are not uniform and it is wise to check texture in several places within a paddock. Texture variation may help to explain difference in plant growth between parts of a paddock or between different paddocks. Compare a sample of soil from one sampling place with soil from another place, to help you gauge relative differences in texture. Gauging relative differences in texture is easier if two soil samples are assessed at the same time — one in each hand.

## HOW TO ASSESS TEXTURE

To determine soil texture, take a sample of soil sufficient to fit comfortably into the palm of the hand. If it contains gravel, try to remove the larger pieces. Moisten the soil with a little water, and knead it until the ball of soil no longer sticks to your fingers. This is when its water content is approximately ‘field capacity.’ Add more soil or water to attain this condition. Usually the ball of soil will be ready for you to assess its texture after one or two minutes of kneading or working. Do not knead the ball too long as it may dry out.

Texture is classed into **16 texture grades**, as shown in Table C5 on the following page. Some of the terms in the table are explained below:

*Coherence:* the ball holds together.

*Sandy:* feels gritty, and coarser sand grains can be seen. Very fine sand grains make a grating sound as the soil is rubbed between fingers and thumb.

*Spongy:* typical of loams; high organic matter also creates a spongy feel.

*Silky:* the smooth soapy or slippery feel of silt.

*Plastic:* the ball can be deformed and holds its new shape strongly, typical of clays.

*Resistance to shearing:* how firm the soil feels as you form a ribbon. Place the ball between your thumb and forefinger and squeeze, sliding your thumb across the soil. Try to make a thin continuous ribbon about 2 mm thick. A light clay is easy to ribbon and shear, a medium clay is firm and stiff, and a heavy clay is very stiff (it usually takes two hands to form a ribbon).

**Table C5 Guide to determining soil texture**

| Field texture group | Coherence | Feel | Other Features | Ribbon length (cm) | Texture grade | Clay % |
|---|---|---|---|---|---|---|
| Sands | nil | sandy | single sand grains stick to fingers | nil | **sand (S)** | < 5 |
| | slight | sandy | discolours fingers with an organic stain | 5 | **loamy sand (LS)** | 5 |
| | slight | sticky | sand grains stick to fingers and with a clay stain | 5–15 | **clayey sand (CS)** | 5–10 |
| Sandy Loams | just coherent | sandy | medium sand readily felt | 15–25 | **sandy loam (SL)** | 10–25 |
| | just coherent | sandy | fine sand can be felt | 15–25 | **fine sandy loam (FSL)** | 10–25 |
| Loams | coherent | spongy, greasy | no obvious sandiness or silkiness | 25 | **loam (L)** | 25 |
| | coherent | smooth | silky, very smooth when manipulated | 25 | **silty loam (SiL)** | 25 |
| Clay Loams | strong | sandy | medium sand in a fine matrix | 25–40 | **sandy clay loam (SCL)** | 20–30 |
| | coherent | smooth, sandy | fine sand can be felt and heard | 40–50 | **fine sandy clay loam (FSCL)** | 20–30 |
| | strong | smooth | no obvious sand grains | 40–50 | **clay loam (CL)** | 30–35 |
| | coherent | smooth | silky | 40–50 | **silty clay loam(SiCL)** | 30–35 |
| Light Clays | coherent | plastic | fine to medium sand | 50–75 | **sandy clay (SC)** | 30–40 |
| | coherent | plastic | smooth and silky | 50–75 | **silty clay (SiC)** | 30–40 |
| | coherent | plastic | smooth with slight resistance to shearing | 50–75 | **light clay (LC)** | 35–45 |
| Medium and Heavy Clays | coherent | plastic | smooth, handles like plasticine; moderate resistance to shearing | 75+ | **medium clay (MC)** | 45–55 |
| | coherent | plastic | smooth, handles like plasticine; firm resistance to shearing | 75+ | **heavy clay (HC)** | >50 |

**Caution:** Do not rely solely on the length of the ribbon to assess texture — the other characteristics need to be taken into account as well.

## SOIL TEXTURE AND SOIL WATER

The ability of a soil to hold water is related to soil texture. There are three categories of stored soil water:

- *readily available water* — held between field capacity and refill point, which is the point at which plants begin to have problems extracting soil water;
- *plant available water* — held between field capacity and permanent wilting point;
- *unavailable water* — stored in very small pores that cannot be extracted by plants.

The higher the clay content of the soil, the greater the proportion of soil water which is held as unavailable water.

Texture assessment can provide a crude estimate of soil water holding capacity. Loams hold more plant available water than clays, while both loams and clays hold more plant available water than sandy soils. Loams and clay loams hold around 165 mm of plant available per metre depth of soil, while clays hold around 140 mm/m. Sandy soils usually hold less than 120 mm/m of plant available water, but coarse sands hold as little as 50 mm/m.

As soil texture affects both the water holding capacity and internal drainage of a soil, it has a major influence on irrigation scheduling (see Chapter E7: *Irrigation scheduling*).

## OTHER DECISIONS WHICH DEPEND ON SOIL TEXTURE

- Texture measurements are used to decide the suitability of a soil for tillage at the prevailing water content.
- They allow $EC_{1:5}$ data to be converted to $EC_e$ for soil salinity investigations.
- Indicate soil suitability for rice growing.
- Indicate the likelihood of a surface soil to hardset or crust.

To provide a check on the accuracy of field estimates of soil texture, some of the samples should be sent to an accredited Soil Physical Testing Laboratory for a more precise particle size analysis (PSA).

# Chapter C7.
# Slaking and dispersion

## INTRODUCTION

Soil stability in water is important for irrigated soil because soil structure can potentially be damaged with each irrigation.

If clods collapse when a soil becomes wet, one of two main processes are occurring:

- *slaking* — where large structural units disintegrate to form micro-aggregates
- *dispersion* — which is the complete disintegration of clods into clay, silt and sand particles.

Slaking and dispersion are soil characteristics that will have a large influence on the behaviour and management of a soil. They are particularly prevalent and important characteristics of the soils of the Riverina Plain.

## SLAKING

Slaking is the breakdown of a lump of soil into smaller fragments on wetting, caused by the swelling of the clay and the bursting out of entrapped air. Most clods collapse (slake) to form smaller clods when wet quickly, especially when the soil surface is low in organic matter. Slaking occurs in all soil groups of the Riverina Plain.

***Significance of slaking***

**Most cultivated soils in Australia are prone to slaking. The results can be either good or bad, depending on the size of the fragments produced.**

**Slaking is involved in the process of self-mulching, which occurs in many cracking clays. Self-mulching produces a loose surface layer of granular aggregates. Sometimes a thin, fragile crust caps the layer, but the crust is not strong enough to affect seedling emergence.**

**Crusting or hardsetting soils slake into very small fragments which run together and then set hard on drying. This condition is evident in many red-brown and transitional red-brown earths. The slaking test allows you to identify such problem soils.**

Organic matter reduces slaking by binding mineral particles and by slowing the rate of wetting. Most Australian soils are low in organic matter, and tillage can deplete organic matter levels further. The addition of organic matter during a pasture phase, or by conservation farming practices such as stubble retention, direct drilling and minimum tillage, would be beneficial in slaking soils.

## SLAKING TEST

A simple test and a scoring system for slaking is described below, which allows comparisons between soils.

### Method:

1. Take soil samples (usually only surface soil is tested for slaking) and allow to air dry for 1–5 days, depending on how wet the soil is when sampled.
2. Take at least three small (3–5 mm) crumbs of dry soil and place them in a dish or saucer of rainwater or distilled water. The water must be deep enough to completely cover the clods. Do not disturb the dish and keep it out of the wind.
3. After five minutes, assess the slaking score (0–4).

> ***Tip:* You may find it easier to use soil aggregates of 10–20 mm to assess slaking. However dispersion tests require using aggregates of 3–5 mm, and slaking and dispersion on wetting can be assessed using the one test with the same aggregates.**

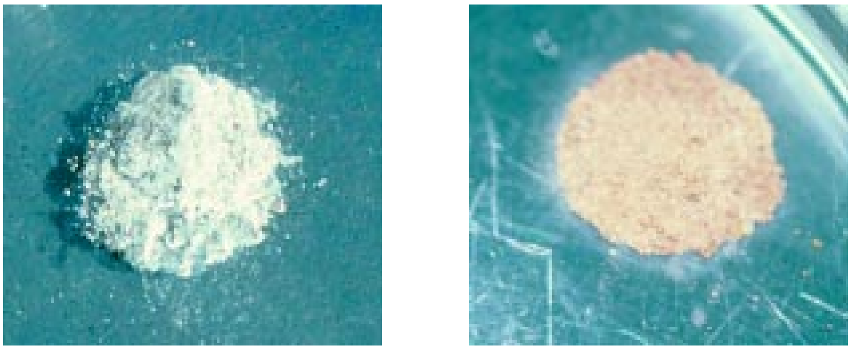
### Slaking score:

- Score 0 if the lump remains intact.
- Score 1 if the lump collapses around the edges but remains mainly intact.
- Score 2 if the lump collapses into angular pieces.
- Score 3 if the lump collapses into small (less than 2 mm) rounded pieces, forming a cone.
- Score 4 if the lump collapses into single grains (you can see sand grains).

**Figure C11. Scoring slaking**

*Slaking score 1* *Slaking score 2*

*Slaking score 3* *Slaking score 4*



## INTERPRETATION OF SLAKING SCORES AND MANAGEMENT OPTIONS

*Slaking score 0–1:* This soil is stable to wetting. This is typical of a soil under several years of pasture. No action is needed.

*Slaking score 2:* The crumbs form a loose, granular surface layer, with perhaps a thin, fragile crust. This is typical of self-mulching clays. If the soil does not disperse no action is necessary.

*Slaking score 3:* This score suggests that the surface may form a crust. It is a problem in non-swelling topsoils (sands, loams and some clay loams), but it occurs in most soils encountered in this manual, especially when cultivated. Reduced cultivation and stubble retention can overcome this problem.

*Slaking score 4:* This soil is very likely to crust and hardset (sands and loams). Reduced cultivation, stubble retention, and more frequent irrigations may be necessary on these soils.

## DISPERSION

Dispersion is the disintegration of soil clods, upon wetting, into individual clay, silt and sand grains. Dispersion is usually caused by too much sodium attached to the clay surfaces. Where sodicity occurs in the subsoil, excessive swelling and constriction of macropores is likely to be a problem for non rice crops and pastures.

***Significance of dispersion***

**A soil that disperses on wetting has a very unstable structure. It can form a surface crust or hard clods on drying. Pores below the surface can become blocked by dispersed soil particles. Dispersive soil is likely to swell strongly when wet, further restricting water and air movement. Dispersion of soil slows down the intake of water to the root zone following rainfall or irrigation. This condition will result in poor water storage, at each irrigation.**

**Dispersion after remoulding means that the soil is likely to disperse after cultivation, under wet conditions, or after raindrop impact.**

Separation of sand, silt and clay in the field after heavy rain (see Figure C12) is a reliable indicator of soil dispersion.

**Figure C12. Dispersion causes separation of light coloured sand on the soil surface following heavy rain**

## DISPERSION TEST

A test and a scoring system for dispersion is described below, which allows comparisons between soils. The test is in two parts:

i) Dispersion on wetting, where the degree of dispersion is scored after both 10 minutes and two hours

ii) Dispersion after remoulding the piece of soil

### Method:

**Dispersion on wetting:**

1. Place air-dry clods (3–5 mm diameter) in a dish and cover them with rainwater or distilled water.
2. Assess the degree of dispersion after 10 minutes and 2 hours.
3. The degree of dispersion is assessed on a scale of 0 to 4 using the following criteria and referring to Figure C13:
   - a score of 0 indicates no dispersion
   - a score of 1 is slight dispersion, recognised by a slight milkiness of water adjacent to the clod
   - a score of 2 is moderate dispersion with obvious milkiness
   - a score of 3 is strong dispersion with considerable milkiness and about half the original volume dispersed outwards
   - a score of 4 is complete dispersion leaving only sand grains in a cloud of clay
4. Leave the clods in water, and repeat the assessment after 2 hours.
5. Add the 10 minute and 2 hour scores together, giving a range of values between 0 and 8. Refer to Table C6 for the severity of dispersion.

For those clods that scored 0 the amount of dispersion after remoulding is then determined.

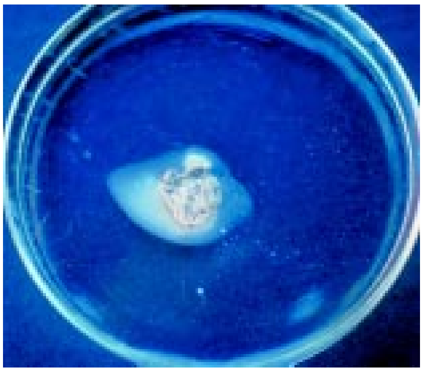
**Dispersion on remoulding:**

1. Soil is mixed with distilled water to a plastic consistency and remoulded on a plate, using a knife, for one minute. The idea of remoulding is to duplicate the state of soil after cultivation.

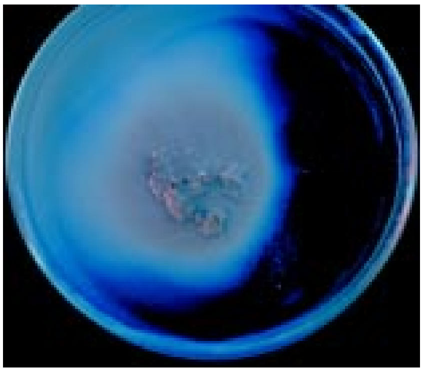
Figure C13. Scoring dispersion

**Dispersion score 0**: Nil dispersion

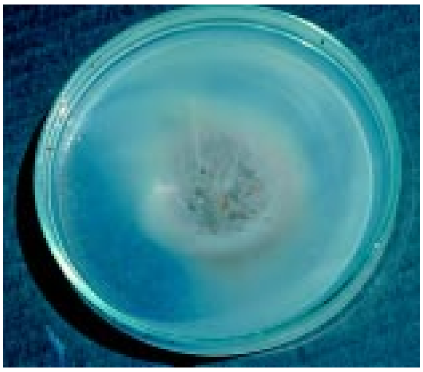
**Dispersion score 1**: Slight dispersion recognised by slight milkiness of water adjacent to aggregate



**Dispersion score 2**: Moderate dispersion with obvious milkiness



**Dispersion score 3**: Strong dispersion with considerable milkiness and about half of the original volume of the aggregate dispersed outwards



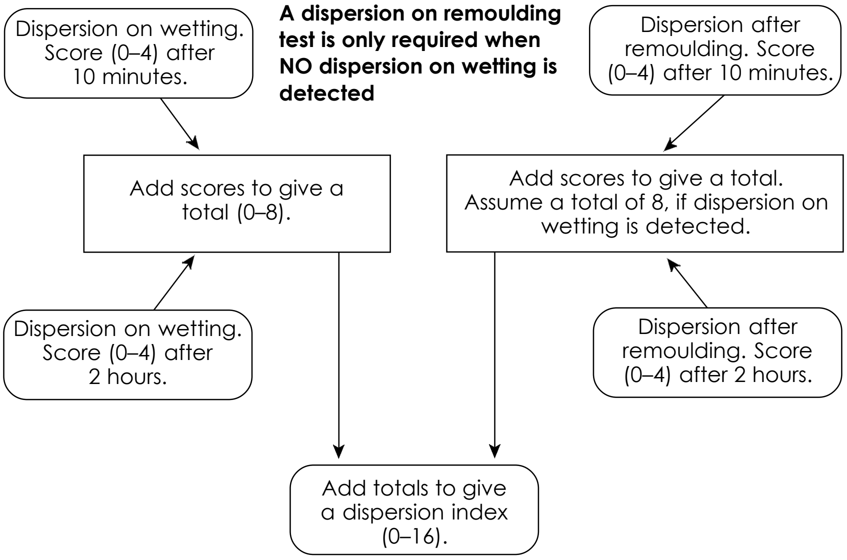
**Dispersion score 4**: Complete dispersion leaving only sand grains in a cloud of clay

2. Small balls are formed and placed in a dish containing rain or distilled water. Remoulded samples must not be allowed to dry before they are immersed in water.
3. The degree of dispersion of the remoulded soil is assessed as before.
4. The dispersion scores at 10 minute and 2 hours are then added together.

For those air-dried clods that dispersed upon wetting, 8 is added to the sum of the 10 minute and 2 hour scores, thus giving a range of values between 9 to 16. It is assumed that the air-dry clods which disperse would show rapid and complete dispersion and score 8 when remoulded. A score of 0 indicates no dispersion and 16 indicates severe dispersion. The following flowchart (Figure C14) shows the methodology.

Because this procedure cannot be done in less than 2 hours, and requires the use of air-dry clods, it is best to do it at home or in a laboratory.

**Figure C14. Dispersion index scoring method**



## INTERPRETATION OF THE DISPERSION TEST RESULTS AND MANAGEMENT OPTIONS

Management options for the full range of dispersion test data are presented in Table C6.

## FOLLOW-UP LABORATORY TESTS AT KEY SITES TO REFINE THE DISPERSION TEST RECOMMENDATIONS

To confirm the above conclusions about soil dispersion, the following laboratory tests are recommended. These tests measure the level of sodium attached to clay particles and the proportions of exchangeable cations. These measurements indicate the potential for soil dispersion.

**Table C6. Response to the soil structural stability diagnosis**

| Score ‘critical limits’* | Severity of dispersion | Management options to consider |
|---|---|---|
| 7–16 | serious dispersion | Apply gypsum (&/or lime), add organic matter, adopt conservation farming practices and management for rice muddy water. |
| 2–6 | moderate dispersion, if the soil is remoulded | Avoid working the soil when it is moist. (also applies to the above category) |
| 0–1 | negligible dispersion | Protection of soil from dilution by excess water (this reduces soil EC), and from the force of raindrop impact and overland flow. (also applies to the above two categories) |

*ASWAT (aggregate stability in water) test.
Refer to Agfact AC.10: *‘Improving soil structure with gypsum and lime’,* for details about management options such as gypsum and lime application.

## Exchangeable sodium percentage (ESP)

An excess of sodium ions attached to the clay particles leads to increased swelling of the clay and increases the likelihood of dispersion. Evidence of a dispersion problem include crusting of surface soils, and decreased permeability to water and air in the subsoil.

Take soil samples (approximately 0.8 kg) from key sites of interest identified by the dispersion test. Have them analysed for exchangeable sodium percentage (ESP) at a NATA-certified laboratory using the ‘Tucker method’, the only reliable procedure available for exchangeable cation analysis in soil containing free lime (calcium carbonate) and gypsum (calcium sulphate).

A soil with an ESP greater than six is referred to as sodic. However, ESP values as low as two can cause soil structural problems if the concentration of salt in soil solution is very low.

You can ask your laboratory to test your irrigation water for dissolved cations to determine the sodium adsorption ratio (SAR) of the water. This gives an indication of the potential for increasing the soil’s sodicity when irrigating with water from that particular source. If you are in an area with irrigation water which contains high amounts of sodium and magnesium in relation to calcium, do regular tests of soil ESP to help determine if it is increasing.

## Exchangeable calcium: magnesium (Ca:Mg) ratio

Exchangeable magnesium aggravates the adverse effects of sodium. It is measured at the same time as exchangeable sodium (see above), calcium and potassium (Tucker method). A calcium/magnesium ratio of less than 2:1 (and particularly less than 1:1) indicates a tendency towards clay dispersion and poor soil structure.

**In clay soils the higher the Ca:Mg ratio, and the lower the Na %, the more likely that soil is to be self-mulching.**

**Self-mulching clays usually have a Ca:Mg ratio of 2-4, and Na % of <3%.**

**Non self-mulching clays generally have Ca:Mg ratios of around one, with Na % usually >5%.**

**Therefore Ca:Mg ratios along with exchangeable sodium percentage (Na %) are important indicators of soil structure stability and land use potential of clay soils.**

### Electrical conductivity and Electrochemical Stability Index (ESI)

Electrical conductivity (EC) of a soil is a measure of its salinity. As EC increases, soil dispersion decreases for a given sodicity value. Conversely, very low EC values mean that a soil may become dispersive where ESP of the soil is only two. Methods for measuring salinity are described in Chapters B6 and C10.

Therefore, instead of looking just at ESP values, the electrochemical stability index (ESI) needs to be calculated. The ESI is calculated as $EC_{1:5}$ divided by ESP (($EC_{1:5}$ /ESP). A tentative critical ESI value is 0.05. An economically viable response to gypsum and/or lime can be expected where ESI values are at or below this level.

### pH

As soil pH increases the charge of some clay particles becomes more positive, so the soil will become more dispersive. Procedures for measuring pH are described in Chapter C9: *Other chemical tests*, and for salinity in Chapter C10: *Testing soil salinity in the field.*

### Lime (calcium carbonate; $CaCO_3$) content

As the lime ($CaCO_3$) content of a soil increases, the likelihood of a soil being dispersive decreases, even when ESP values are high. When $CaCO_3$ concentration is above 0.3% (particularly if it is finely divided rather than in the form of nodules), soil stability in water is likely to be acceptable.

## CRITICAL LIMITS FOR SOIL DISPERSION

The critical limits of several soil factors at which soil dispersion occurs are given in Table C7.

**Table C7. Critical limits for soil dispersion based on laboratory tests**

| Soil property as determined using laboratory tests | Critical limit above which soil dispersion is likely to occur* |
|---|---|
| Exchangeable sodium percentage (ESP) | > 6 %[#] |
| Electrochemical stability index (ESI) | < 0.05 |
| Calcium:magnesium ratio (Ca:Mg) | < 2 |
| Lime concentration | < 0.03 % |

* For non-rice crops and pastures, it is desirable that these limits are such that the soil does not disperse. However for rice crops, dispersion in the subsoil is favoured so that water losses are minimised. Therefore the value of these limits can be such that dispersion occurs.

[#] Note that the critical limit for ESP may range between > 2% and > 15% depending upon soil salinity.

# Chapter C8.
# Assessing soil moisture

## INTRODUCTION

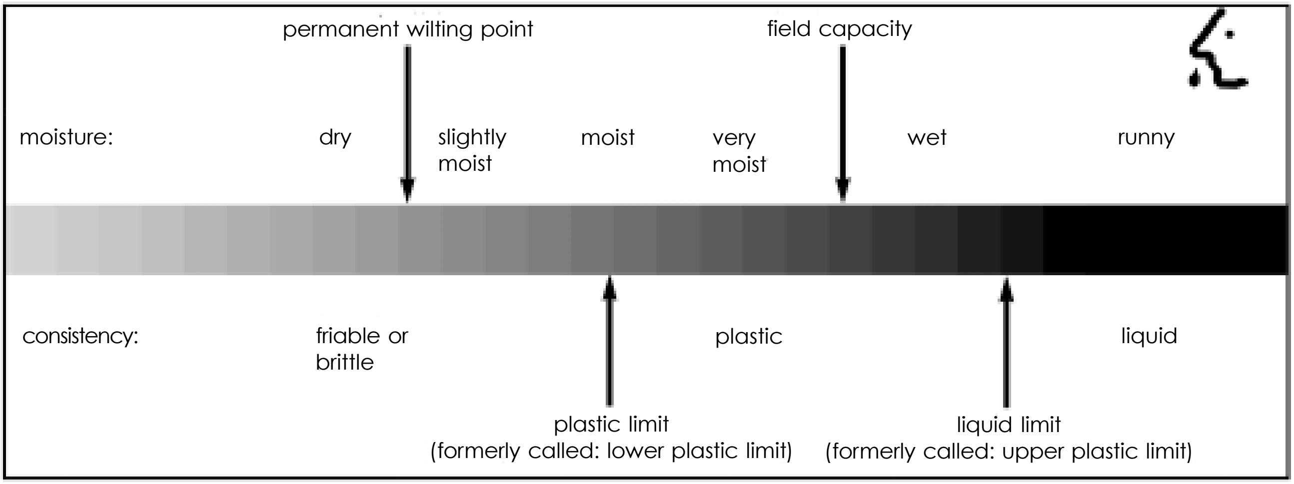
This chapter explains the importance of determining the soil moisture status before tillage and before irrigating. It also presents techniques for estimating soil moisture.

### Characteristics of soil at different moisture contents

As the moisture content of a soil changes, the soil's consistency goes through a series of different states (Figure C15).

- *Dry soil* is crumbly if loose or brittle if compacted. Soil fractures easily and loosens at low moisture content.
- The *plastic limit* is the water content above which a soil becomes plastic (can be remoulded).
- The *liquid limit* is the moisture content above which the soil starts to flow like a liquid. Liquid soil is called slurry.

**Figure C15. Soil moisture and consistency**



## SOIL MOISTURE BEFORE TILLAGE

Soil water greatly affects soil strength and determines the way a soil responds to external forces. Such external forces include disturbance by tillage, and loads on the soil surface (wheels can compact a wet subsoil, even though the surface is dry).

Dry tillage benefits self-mulching clays, but may cause major damage to soil structure in some soils with a loamy topsoil, such as red-brown earths and transitional red-brown earths. This is evident when cultivated loamy soils are pulverised to become dusty and powder-like.

Tillage of clay soils when too wet can damage their structure by smearing and compaction. A moisture content drier than the plastic limit is best for tilling clay soils.

The range of moisture contents suitable for cultivating non-dispersive clays is small, but for dispersive (sodic) clays the range is even more restricted. Compaction and smearing can occur in most clays if cultivated too wet. If cultivated too dry, tine/disc penetration will be poor or large clods will be produced. Gypsum application may help to 'widen' the range of water contents at which tillage can be conducted successfully.

When tilling to depth, it is important that the soil be at or near the correct moisture content. Therefore soil water content should be estimated throughout and below the depth of tillage.

***Plastic limit*** **is the point above which the water content of a soil is sufficient to enable it to be remoulded (soil is plastic), and below which it cannot be remoulded (soil is brittle).**

***Permanent wilting point*** **is the soil water content at which plants wilt, and do not recover when evaporative stress lessens (at night) or when the soil becomes moist again.**

**Plastic limit is slightly wetter than permanent wilting point. When plant symptoms show a soil to be at permanent wilting point, it is likely that the root zone is slightly drier than the plastic limit. Clay soils should be tilled at this water content. Loamy soils should be tilled at or just above the plastic limit.**

When considering a tillage operation, the following method can be used to determine soil moisture status of the soil.

## METHOD TO ASSESS SOIL MOISTURE FOR TILLAGE

A simple and very effective way to determine suitability for tillage is to mould some soil in your hand. This method allows you to estimate the closeness of the soil water content to the plastic limit. See if the soil will form a ball, try to form a ribbon, then try to roll it into a thin rod.

This method is reliable and there are several 'exit points' where it is obvious that there is no need to continue. For example, if a soil easily forms a ribbon, then it is much wetter than the plastic limit and would smear if tilled. Therefore there is no point in doing the rod test. Figure C16 gives the full method.

### Is the soil dry?

Take a handful of soil — it could be one lump or some loose soil. Try to squeeze it into a ball with your hand. If the soil forms a ball then you should see whether it forms a ribbon or a rod. This will allow you to determine whether the soil is at the plastic limit.

A dry soil will not form a ball when squeezed in the hand, but will break into smaller fragments or powder. A very compact lump or dry clod of heavy clay will not break. Rods cannot be formed. The soil is drier than the plastic limit. As there is no plant available water, it is at or below wilting point.

You can safely till a clay soil at this water content: it will shatter, not smear. A silty or sandy soil is too dry to till: it will pulverise.

### Does the soil ribbon?

If the soil forms a ball then it is moist. Place the ball between your thumb and forefinger and squeeze, sliding your thumb across the soil. If a ribbon forms, the soil is much wetter than the plastic limit.

Silts, sands and loams can be tilled when the soil ribbons. Tillage will smear a clay soil at this water content.

## Does the soil form a rod?

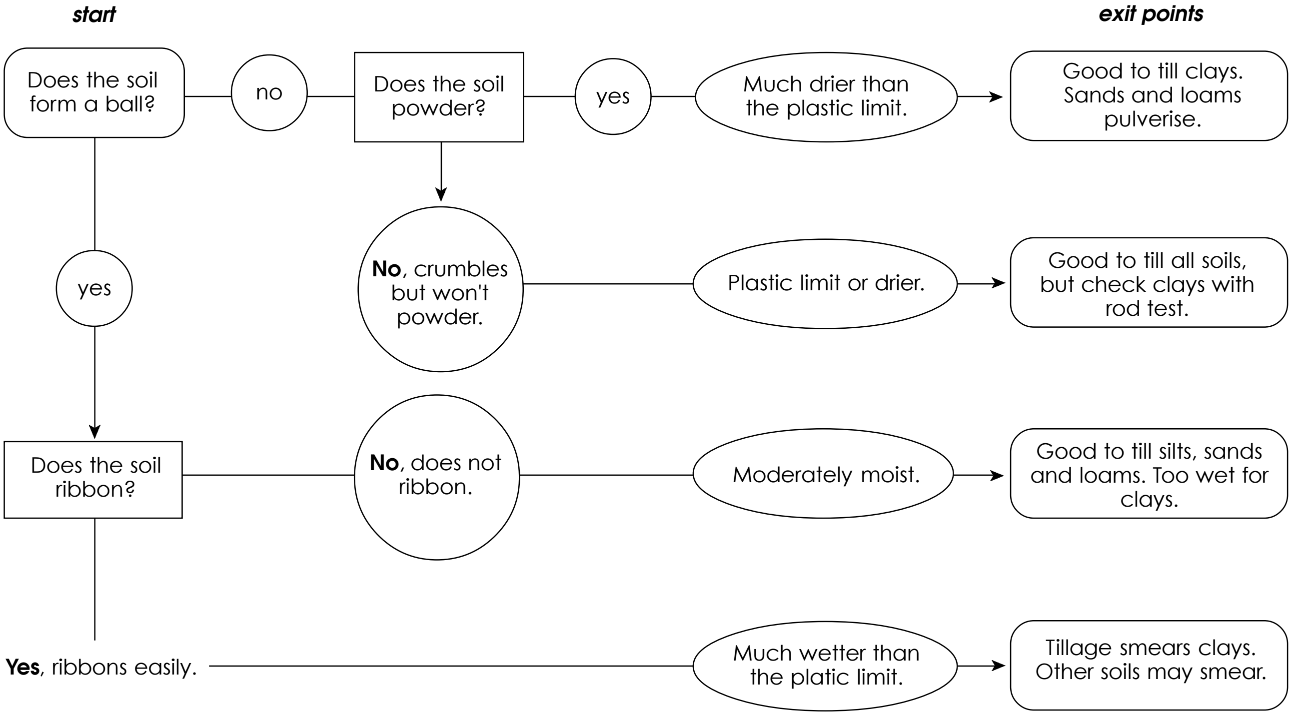
This test applies to clay soils only as not all soils form a rod. A soil requires a high clay content to make it plastic enough for remoulding into a rod.

To form a rod, roll the soil on a flat surface to form a rod of 3 mm thickness. If it is just possible to form a rod, the soil is at the plastic limit. If you can form a rod easily, the soil is wetter than the plastic limit. Clay soils will smear in both these situations.

If a clay soil crumbles in the process of forming a rod, it is drier than the plastic limit, and may be just dry enough to permit tillage.

Figure C16 will guide you with the assessment of soil water content, and will help you decide whether the soil water content is suitable for tillage.

**Figure C16. Guide to assessing soil water content by hand**



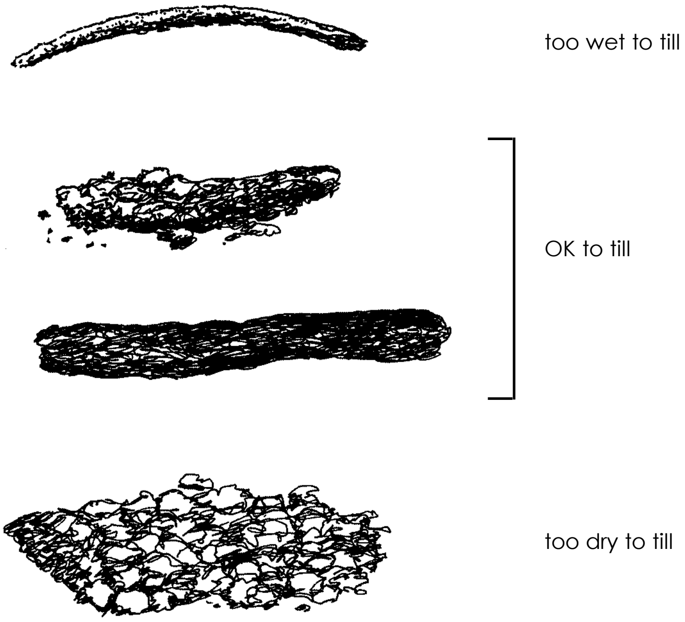
Moisture test by hand:

**Advantages:**
If you check relevant depths of soil, this test shows suitability for tillage, and suitability for sowing.

**Cautions:**
Do this test quickly to avoid soil drying in your hands.

Figure C17 indicates the soil behaviour during the rod test at different soil water contents. This is a useful guide for deciding whether the moisture content of a clay soil is suitable for tillage.

**Figure C17. Closeness to the plastic limit — using the rod test for clay soils**



### Advantages of assessing soil water content by hand:

Determination of soil water content at relevant depths of soil shows suitability for tillage and sowing.

### Disadvantages of assessing soil water content by hand:

The test must be done fairly quickly because the heat of your hands will dry the soil. If the soil dries in your hands it will no longer be at field water content.

## SOIL MOISTURE BEFORE IRRIGATING

Irrigators frequently assess when the next irrigation should take place by the appearance of the crop or pasture. However, if moisture stress (wilting) is showing, plants are already struggling to obtain water, and yield potential has been lost. A better method is to assess the moisture status of the soil, rather than wait until symptoms of water stress in the plants are noticed.

The method is the same as that described above for tillage. If the soil water status is dry or at plastic limit, plants have little or no access to moisture, and irrigating is already overdue. If the soil is moderately moist, water is still readily available for plants, but it may soon run out. It is at this soil moisture status that plans to irrigate should be made.

The assessment should be carried out at various depths throughout the rooting zone, the depth of which will vary with different crops/ plants and with soil characteristics.

***Effective rooting depth*** **is the lowest depth at which the plant/crop will extract a significant amount of water. Below this depth there may still be roots, however the contribution of these roots to crop growth is comparatively small.**

A description of the feel of the soil at several key points of soil water content is presented in Table C8.

**Table C8. Guide to assessing soil water content for irrigation**

| Soil Water Status | Sands, Silts and Sandy Loams | Loams | Clay Loams and Clays |
|---|---|---|---|
| **DRY** | Flows through fingers or fragments break to powder. | Does not form a ball when squeezed in hand. Fragments break to powder. | Does not form a ball. Fragments break to smaller fragments or peds. |
| **PLASTIC LIMIT** | Does not form a ball or rod. Fragments do not powder. | Does not form a ball or rod. Fragments do not powder. | Forms a ball. Does not ribbon. **Just** makes a 3 mm rod. |
| **MODERATELY MOIST** | Appears dry. Ball does not hold together. | Forms a crumbly ball on squeezing in hand. | Forms a ball. Does not ribbon. Forms a rod to 3 mm. |
| **MOIST** | Forms a weak ball but breaks easily. | Forms a ball. Does not ribbon. | Forms a ball. Ribbons easily |
| **WET** | Ball leaves wet outline on hand when squeezed. | Ball leaves wet outline on hand when squeezed. Sticky. | Ball leaves wet outline on hand when squeezed. Sticky. |

Assessing soil water content will help you decide if pre-watering is needed in late summer, if and when to irrigate winter crops in spring, and the timing of irrigations for annual pastures. However, more sophisticated ways to time irrigations for summer crops and perennial pastures are described in Chapter E7: *Irrigation scheduling.*

# Chapter C9.
# Other chemical tests

## INTRODUCTION

This chapter contains brief descriptions of several soil tests available through commercial laboratories, or which can be conducted in the field. Tests for the following soil chemical properties are described:

- pH
- nutrients
- organic matter

## pH

Soil pH is a measure of how acidic or alkaline a soil is. Soil pH is measured using one of three methods:

### Measuring soil pH

1. *Raupach's field method*. An immediate approximate measure of soil pH can be obtained easily in the field by using a testing kit based on the Raupach method. A small sample of soil is placed on a white tile, and indicator solution is added until a smooth paste is obtained. The colour produced is highlighted by lightly dusting the paste with a white powder (barium sulphate). The colour is compared to a reference chart that shows pH to within half a unit. However, ensure that the indicator solution is not beyond its expiry date — old indicator is likely to give misleading pH results.

   Field pH test kits using the Raupach method can be obtained from rural suppliers or from Inoculo Laboratories at Scoresby, Vic. Note that these kits over-estimate pH by 0.5–0.8 compared to the standard method described in 3. below.

2. *pH in water*. Measuring pH in water gives similar values of pH to that found using Raupach's field method. pH in water is generally measured using a 1:5 soil:water extract. The pH is measured with a combined glass electrode and calomel electrode in the solution. Other soil:water ratios may be used but they give different values of pH.

3. *pH in 0.01M $CaCl_2$*. This is a more accurate procedure, carried out in soil testing laboratories. The pH of a 1:5 soil:0.01 M calcium chloride extract is measured at 25°C. A calcium chloride solution is used rather than water as it is more representative of the acidity/ alkalinity a plant experiences in the soil. The calcium chloride method gives pH values about 0.5–0.8 less than the above two methods for most soil types.

Therefore, when you report pH values, it is important to state whether pH was measured in calcium chloride ($CaCl_2$) or water, or with the field test kit. Results from the calcium chloride method are independent of the soil:solution ratio.

Soil acidity varies with rainfall and temperature. Therefore it is important to record sampling dates and to sample under similar conditions if you are comparing over different years.

Lime is used to increase soil pH. Fertilisers such as ammonium sulphate, and organic matter conservation, tend to acidify a soil (lower pH).

### Interpreting pH results

The pH ($CaCl_2$) of most soils varies down the profile and between sites. Strongly acid soils have a pH less than 5 while the pH of strongly alkaline soils is greater than 8. Values of pH between 5 and 8 are very common.

**Strongly acid soils (pH<5):**

A very low pH is detrimental to plant growth because the acidity allows some elements to become more available, and others less available. These elements include aluminium and manganese which become present in toxic levels at low pH. Phosphate has reduced availability at low pH.

**Strongly alkaline soils (pH>8):**

A pH greater than 8.5 usually indicates high exchangeable sodium levels, and the presence of carbonates. These are alkaline sodic soils which are dispersive and have poor soil structure.

Nutrient imbalances also occur at high pH, with phosphate, iron, zinc and manganese all being poorly available.

**Desirable soil pH**

The desirable pH ($CaCl_2$) range for plant production is 5 to 7.

## NUTRIENT TESTING

Crops and pastures will grow poorly, regardless of soil structural condition, if not provided with a well-balanced and adequate supply of nutrients.

The best way to monitor nutrients is via plant tissue analysis. Soil tests tend to be more difficult to interpret. Nevertheless, testing soil for its N, P, K and S content can be a useful indication of plant nutrient deficiency.

For more information about nutrient testing and management, refer to sowing guides for your specific crop or pasture.

## SOIL ORGANIC MATTER

Changes in organic matter levels over time may be used to indicate the effects of a management system on soil condition. A high level of organic matter generally indicates better soil structure.

### Measuring organic matter

Soil test laboratories measure the organic carbon content of a soil using the Walkley-Black test. However, this procedure cannot distinguish between biologically useful carbon and carbon that is inert (for example, charcoal). Some soil may contain substantial amounts of charcoal, especially where land clearing and tree burning or stubble burning has been practiced.

To convert organic carbon content, as determined by the Walkley–Black test, to organic matter content, multiply the organic carbon by a factor of 2.3.

### Interpreting organic matter values

Most soils in Australia, even in their natural state, are low in organic matter compared with soils in other parts of the world. In southern NSW, a virgin grey or brown cracking clay could have an organic matter content anywhere between 1.4% and 4.0% in the surface 10 cm. Typically, the red-brown earths and have organic matter levels around 1.75% in the topsoil.

In general terms, total soil organic matter contents of:

- <1% is very low
- 1-2% is low
- 2-4% is satisfactory
- > 4% is high

At present the Walkley Black is not particularly useful for diagnosing soil condition, because organic matter levels cannot be directly related to the degree of slaking. The Walkley–Black test results are of limited value as they can only be used to compare and rank soil types and paddocks, and to monitor organic matter levels under different crops and pastures. In several years time it is likely that greatly improved procedures will be available to measure the various forms of soil organic carbon, and to provide practical interpretation of the results.

# Chapter C10.
# Testing soil salinity in the field

## INTRODUCTION

Soil salinity can be measured using a simple field test. This will give an indication of the salts in the soil of your farm. The test is reasonably accurate in indicating if salts may cause yield losses or soil problems, but sending soil samples away for laboratory testing is strongly recommended to be certain (see local NSW Agriculture offices for the addresses of soil laboratories).

## SOIL SALINITY FIELD TEST

To perform the test you will need a sample of soil from the root zone of your crop or pasture. Dig a hole with a shovel and take a sample (in a plastic bag). This sample should be taken from a depth of **10–30cm.**

If you have time (especially if sampling from near trees or in a deep-rooted pasture), take a sample from below 30cm. This is because salinity tends to increase with depth (as surface salts are flushed down by rainfall or irrigation, and brought up from below by rising groundwater).

Note that soil salinity will be highest before a rain break or before irrigating, so you may want to test your soils then.

### Field test procedure

For the field test you will need a set of scales, a screw-top jar or container, rainwater or distilled water, a liquid measuring container, and a salinity meter, as well as a sample of the soil to be tested.

**Method:**

1. Take a soil sample and leave it to dry as long as possible (leave the sample bag open to let moisture escape).
2. Crush the air dried sample so there are no large aggregates (clods of soil). You may need to crush these aggregates with a rolling pin or hammer. Soil particles should be no larger than 2 mm. Remove as much foreign matter, plant material and stones from the sample as you can.
3. The test involves adding one part soil for every five parts water. So if you put 50g of soil (weighed on scales) into the container, then you need to add 250ml of the rainwater or distilled water.
4. Shake the container vigorously for three minutes to make sure the salts dissolve. In clay loam to clay soils, more shaking (for one minute every three minutes repeated three times) will bring more salts into the solution and increase the accuracy of the test.
5. Allow the solution to settle for at lest one minute before testing.
6. Place the salinity meter in the solution (but not in the soil at the bottom of the jar) and read the display once it has stabilised.
7. Wash the meter electrodes and sample jar with distilled or rainwater, and dry.

8. Convert your salinity meter readings to soil salinity ($EC_e$) by multiplying the value by the Conversion Factor in Table C9 based on the texture of the soil sample.

**Table C9. Salinity field test conversion factors by soil texture**

| Soil Texture Group | Texture Grade | Approximate Clay Content | Factor |
|---|---|---|---|
| Sands | S, LS, CS | <10% | **17** |
| Sandy Loams | SL, FSL | 10–25% | **13.8** |
| Loams | L,SiL | 25–30% | **9.5** |
| Clay Loams | SCL, FSCL, CL, SiCL | 30–35% | **8.6** |
| Light Clays | SC, SiC, LC | 35–45% | **8.6** |
| Medium and Heavy Clays | MC, HC | >45% | **7** |

For example, if your soil is a clay loam with a meter reading of 0.5 dS/m, multiply 0.5 by 8.6. The resulting value of 4.3 dS/m, an approximate value for the salinity of the soil ($EC_e$).

Table B8 (in Chapter B6: *Is my soil saline?*) shows the root zone soil salinity tolerance for a range of local crops and pastures. If you think that salinity may be affecting your crops, pastures or soils, then a sample (say 500g, in a sealed plastic bag) taken from some representative sites in the field, should be sent to a soil laboratory for more accurate testing.

## LAND MANAGEMENT AND MONITORING

> ***Interpreting ECe***
>
> **Conventionally, saline soils are defined as those having an ECe value greater than 2 dS/m. However, much lower levels of salinity than this can affect the growth and yield of sensitive plants such as maize, most legumes (beans, peas, clovers and to some degree lucerne) and some grasses**
>
> **Saline soils are often friable because the high salt concentration allows the clay particles to flocculate (form clusters) even when the soil has high exchangeable sodium**

You can use information collected on soil salinity to assist in making land management decisions. To make these decisions clearer, you should class your land according to it's soil salinity and relative risk of further soil salinisation occurring.

The range of soil salinity levels of the land use classes reflect the impact that soil salinity has on plant growth. At a soil salinity of 2 dS/m salts in the soil have minimal impact on the yield of most agricultural crops. When a soil salinity level of 6 dS/m is reached, the yield of most agricultural crops has declined to the extent that they are not profitable to grow. Compare your soil salinity reading to the land use class values shown in Table C10, and determine which land use class your soil belongs to.

**Table C10 Land use classes in irrigation areas according to soil salinity**

| | Land Use Class | Root Zone Soil Salinity | | Land Management |
|---|---|---|---|---|
| | | **Ds/m** | **Level** | |
| Lands suited to agricultural production | A | 0–2 | Low | Soil salinity has little or no effect on agricultural production. |
| | B | 2–6 | Moderate | Most agricultural crops can still be grown productively, though some yield loss may occur due to salt in the soil. |
| Lands requiring protection measures | C | 6–15 | High | For soils with no potential for leaching: fence off and establish a perennial groundcover. Leaching crops can be used if there is potential for salt leaching. |
| | D | more than 15 | Extreme | Manage land to establish perennial vegetation cover. Fence area off from stock until pasture is established. |

Class A and B lands: Best suited to agricultural production. Concentrate your resources such as irrigation water, fertiliser and seed on this land to ensure maximum economic return. On class B soils, grow crops that are more salt tolerant (e.g. wheat and barley not soybeans; or balansa not white clover).

Class C and D soils: Should be protected to stop further degradation. Try to establish a perennial pasture that protects the soil and uses water all year round (and allow revegetation by native salt-tolerant species). Fence off the area from stock until a pasture is established; after then it should be able to handle limited grazing (so you can get some return from this land). Trees can be planted around the edge of the area, and drains cut through the site to drain away excess water. Consult your local salinity officer.

For more advice on managing land by land use classes see your local salinity officer or read the Irrigation Salinity Note: *Managing Land by Salinity Classes.*