WATERWISE ON THE FARM

Irrigation Efficiency
Principles to Practice

Assessing your soil & water resources

WORKBOOK

Version: WA 20 September, 2011

These materials are part of the WaterWise on the Farm education program *Introduction to Irrigation Management*.

These materials were developed by NSW Agriculture staff from the water management subprogram.

Acknowledgments: sections of these training materials use text and illustrations from *The RiverCare Irrigators Manual* developed and revised by the River Murray Water Resources Committee and Primary Industries, South Australia in 1997.

CONTENTS

This booklet contains worksheets for the activities on assessing the irrigation characteristics of your soil.

Activity 1: Hand texturing

Texture is assessed in the field by the feel of a sample of moist soil when worked between the finger and thumb.

Hand texturing is the cheapest and most convenient method of determining soil texture in the field. The ribbon test uses thumb pressure against the middle joint of the index finger to produce a ribbon about 2 mm thick.

The soil must be damp and plastic to approximate field capacity. The feel and behaviour of the soil as you moisten and knead it will assist you in identifying the soil texture.

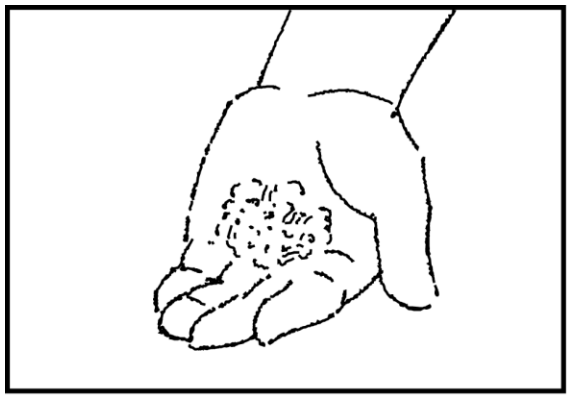
Table 1. Quick Guide to Common Soil Textures

Soil texture	Ribbon length	How the soil behaves or feels	% Clay
Sand (S)	Nil	Coherence nil to very slight, cannot be moulded; sand grains adhere to fingers	Less than 5%
Sandy loam (SL)	15-25 mm	Coherent bolus but very sandy to the touch dominant sand grains are of medium size and readily visible	10-20%
Loam (L)	About 25 mm	Loams may form a thick ribbon. Soil ball is easy to manipulate and has a smooth spongy feel with no obvious sand. Greasy to touch if organic matter present	About 25 %
Clay loam (CL)	40-50 mm	Strongly coherent, plastic bolus, smooth to manipulate	30-35%
Light clay (LC)	50-75 mm	Plastic behaviour, smooth feel easily worked, moulded and rolled into rod. Rod forms a ring without cracking	35-40 %
Light medium clay (LMC)	75-85 mm	Plastic bolus; smooth to touch, slight to moderate resistance to shearing	40-45%
Medium clay (MC)	Greater than 75 mm	Smooth plastic bolus; handles like plasticine, can be moulded into rods without cracking, resistant to shearing	45-55%
Heavy clay (HC)	Greater than 75 mm	Smooth, very plastic bolus, firm resistance to shearing Will mould into rods. Handles like stiff plasticine. Very sticky and strongly coherent. Rods form a ring without cracking	Over 50%

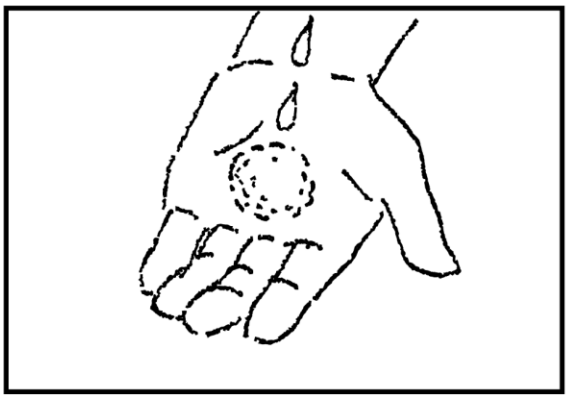
Adapted from McDonald, R.C. *et al*. (1990), The Australian Soil and Land Survey Field Handbook, 2nd edn, Inkata Press, Melbourne; and Wetherby, K. 1998, Soil Description Handbook, rev. edn, K.G. & C.V. Wetherby, Cleve, SA.

Hand texturing

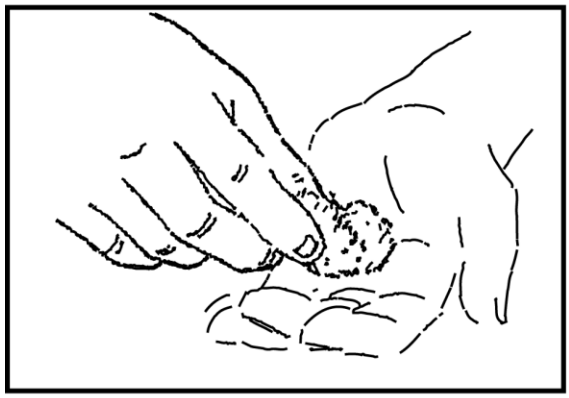
Assess the soil samples provided.



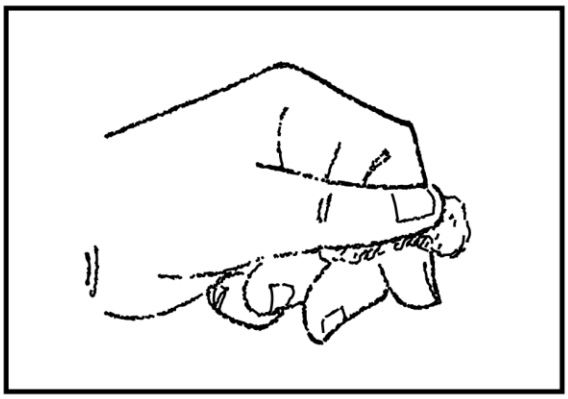
1. Take a small handful of soil.



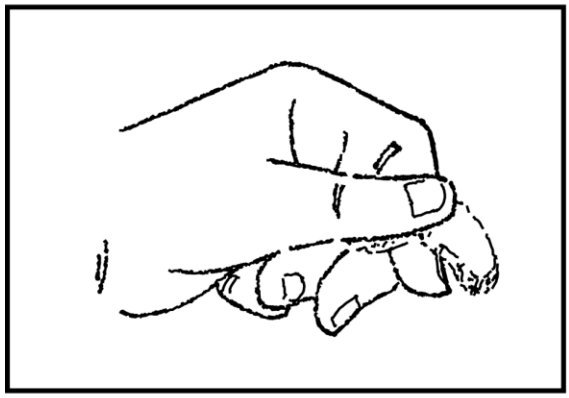
2. Add enough water to make a ball. If you can't make a ball, the soil is very sandy.



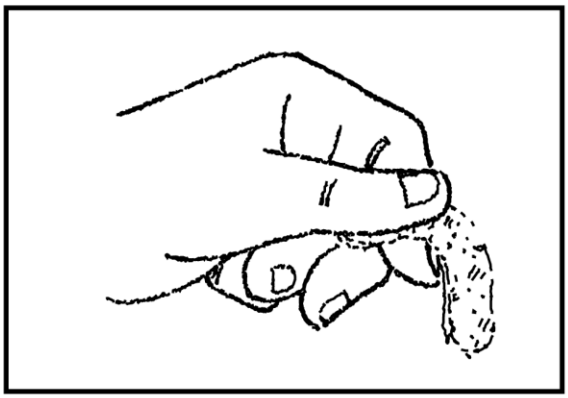
3. Feel the ball with your fingers to find out if it is gritty (sand), silky (silt) or plastic/sticky (clay).



4. Reroll the ball and with your thumb gently press it out over your forefinger to make a hanging ribbon.



5. If you can make a short ribbon your soil texture is loamy, a mixture of sand and clay.



6. The longer the ribbon the more clay is in your soil.

Sample 1

Ribbon length .....

Texture .....

Sample 2

Ribbon length.....

Texture .....

Sample 3

Ribbon length .....

Texture .....

Activity 2: Calculating RAW

In the exercises that follow, calculate the RAW by working through these 7 steps. (A worked example is supplied.)

Step 1: Identify and measure the thickness (depth) of the soil layers.

Step 2: Determine the soil texture of each layer

Step 3: Select the crop water tension group from table 2 and identify the RAW value for each soil layer

Step 4: Multiply the thickness of each soil layer by its RAW value

Step 5: Add the RAW for each soil layer to obtain the total soil profile RAW

Step 6: Identify the effective rootzone

Step 7: Determine the RAW within the crop's effective rootzone by adding the RAW for each layer (or part layer) within the rootzone RAW.

Table 2: RAW and AW values for different soil textures

Water Tension *	To - 20 kPa	To - 40 kPa	To - 60 kPa	To -100 kPa	To - 1500 kPa
	A	B	C	D	E
	Water-sensitive crops such as vegetables and some tropical fruits should be irrigated.	Most fruit crops and table grapes, most tropical fruits.	Lucerne, most pasture, crops such as maize and soybeans, and grapes**	Annual pastures and hardy crops such as cotton, sorghum and winter cereals	Available Water (AW) is the total water available in the soil. Plants stress well before this level is reached
Soil texture	Readily Available Water RAW (mm/m)				AW (mm/m)
Sand	35	35	35	40	60
Sandy loam	45	60	65	70	115
Loam	50	70	85	90	150
Clay loam	30	55	65	80	150
Light clay	25	45	55	70	150
Medium to heavy clay	25	45	55	65	140

Tension is 0 kPa at saturation point. The figures are only approximate.

**(Except when partial rootzone drying is being practised on wine grapes) should be irrigated before -60 kPa is reached.

Calculating rootzone RAW: Example 1

Lucerne is growing in 0.3 m of sandy loam over 0.5 m of light clay over 0.4 m of medium clay.

For a soil pit at this site the calculations would be:

STEP 1: Identify and measure the soil layers.

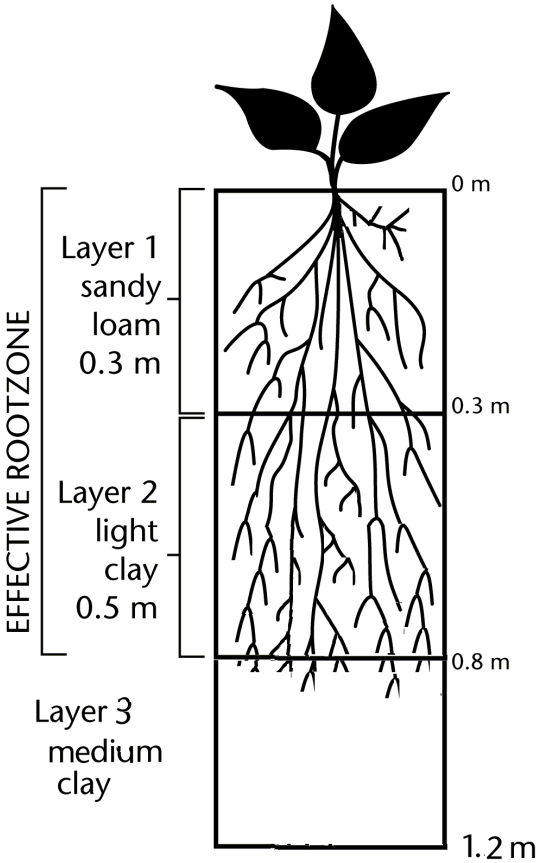
Layer 1:	0 to 0.3 m	=	0.3 m
Layer 2:	0.3 to 0.8 m	=	0.5 m
Layer 3:	0.8 to 1.2 m	=	0.4 m

STEP 2: Determine the soil texture of each layer

Layer 1: sandy loam

Layer 2: light clay

Layer 3: medium clay



STEP 3: Select the crop water tension using table 2 and identify the RAW for each soil layer.

RAW values for each layer for lucerne (column C)

Layer 1: Sandy loam	=	65 mm/m
Layer 2: Light clay	=	55 mm/m
Layer 3: Medium Clay	=	55 mm/m

STEP 4: Multiply the thickness of each soil layer by its RAW value.

Layer 1: 0.3 m x 65 mm/m	=	19.5 mm
Layer 2: 0.5 m x 55 mm/m	=	27.5 mm
Layer 3: 0.4 m x 55 mm/m	=	22 mm

STEP 5: Add up the RAW for each layer to obtain the **total RAW** stored within the soil profile

Soil Profile RAW = Layer 1 RAW + Layer 2 RAW + Layer 3 RAW

19.5 mm + 27.5 mm + 22 mm

= 69 mm

STEP 6: Identify the effective rootzone. **Effective rootzone = 0.8 m**

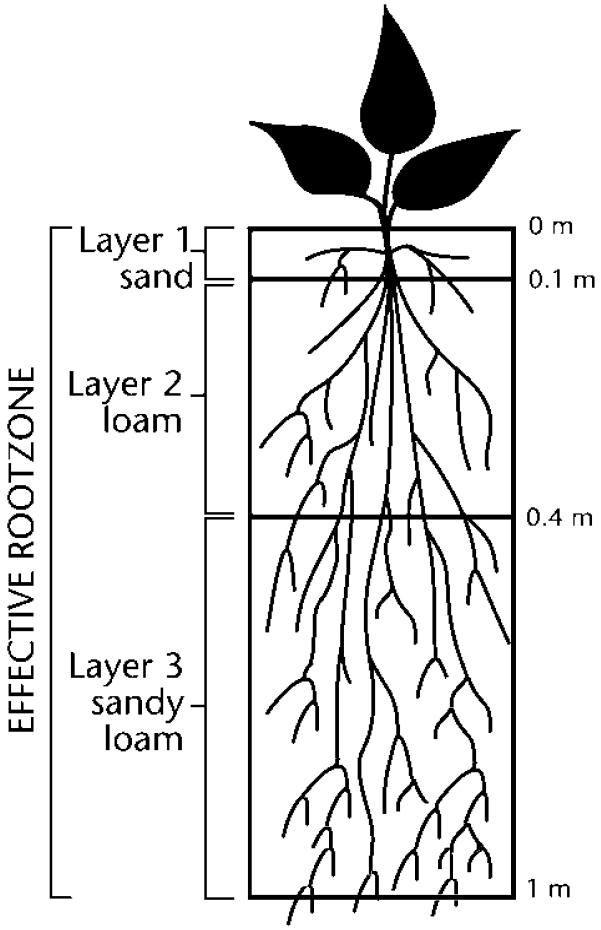
STEP 7: Add up the **Effective Rootzone RAW**

Layer 1	+	Layer 2
19.5	+	27.5

Effective Rootzone RAW = 47 mm

Calculating effective rootzone RAW: Exercise 1

A tomato crop is growing in a shallow layer of sand over layers of loam and sandy loam. The effective rootzone is estimated to be 1 metre. Calculate the RAW for this site.



Layer: ..... m

RAW of layer 1

= ..... m x .....mm/m

= ..... mm

Layer 2: ..... m

RAW of layer 2

= ..... m x ..... mm/m

= ..... mm

Layer 3: ..... m

RAW of layer 3

= ..... m x ..... mm/m

= ..... mm

Rootzone RAW for this site

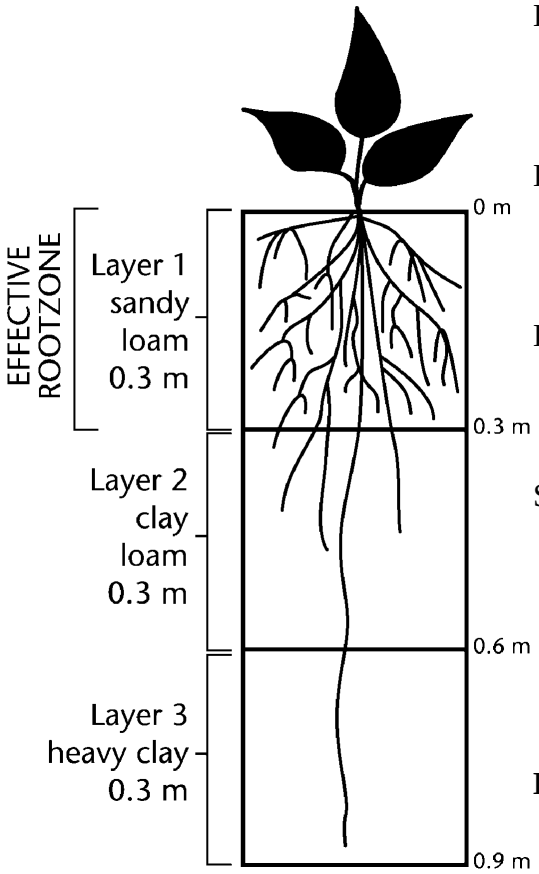
RAW 1 + RAW 2 + RAW 3

=…….mm + ..……...mm + ……mm

= ..... mm

Calculating rootzone RAW: Exercise 2

A Lettuce crop is growing in a topsoil layer of sandy loam over layers of clay loam and heavy clay. Calculate the RAW for this site.



Layer 1: RAW 1 = ... m x ……. mm/m

= ..... mm

Layer 2: RAW 2 = ... m x ..... mm/m

= ..... mm

Layer 3: RAW 3 = ... m x ..... mm/m

= ..... mm

Soil profile RAW for this site

RAW 1 + ... RAW 2 +.....RAW 3

=..... mm +…….. mm + …….mm

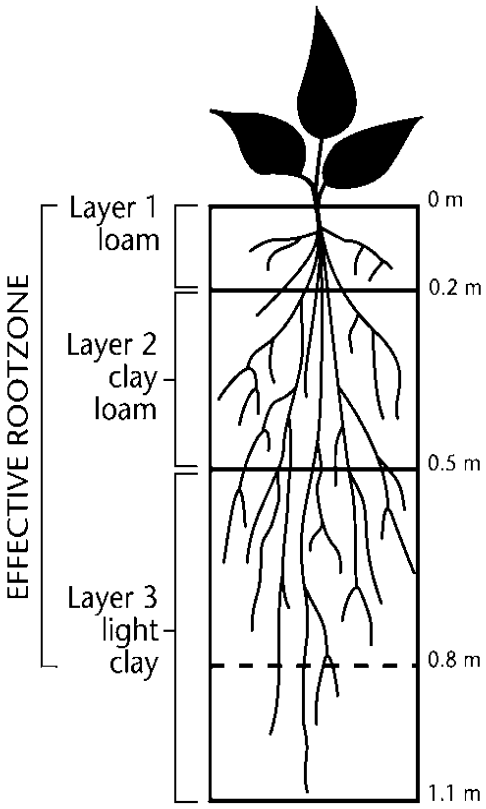
= ..... mm

Effective rootzone RAW for this site

..... mm

Calculating effective rootzone RAW: Exercise 3

A Cotton crop is growing in a topsoil layer of loam over layers of clay loam and light clay. The soil profile is 1.1 metres deep, but the effective rootzone only reaches to 0.8 metres. Calculate the RAW for this site.



Layer 1: RAW 1 = ... m x ..... mm/m

= ..... mm

Layer 2: RAW 2 = ... m x ..... mm/m

= ..... mm

Layer 3: RAW 3 = ... m x ..... mm/m

= ..... mm

Soil profile RAW for this site

= ..... RAW 1 + ... RAW 2 + ... RAW 3

= ..... mm + ... mm + ... mm

= ..... mm

NOTE

The **effective rootzone** in Layer 3 is only down to 0.8 m. Although roots may be found deeper, they are not effective for growth. Therefore we adjust the layer 3 RAW to account for the reduced effective rootzone

Layer 3 RAW x Effective rootzone depth of layer 3

= ..... x .....

= .....

Effective rootzone RAW for this site

= RAW 1 + RAW 2 + RAW 3 (part)

= ..... mm + ... mm + ... mm

= ..... mm

Activity 3: Conducting soil pit survey

What you need:

To carry out a Soil Pit survey for irrigation you need:

- Backhoe pit next to (or in) a crop
- A knife or large screwdriver
- A water bottle
- A 2-metre metal measuring tape, and
- This workbook and a pen.

What you do at each soil survey site:

For each hole, determine:

- The soil layers, by noting the difference in colour, appearance and feel
- The depth of each layer
- The depth of the crop's effective rootzone
- The texture of the soil layers
- Any other significant features such as rocks, compaction, hard pan, watertable, treasure or fossils
- RAW values

For each site, complete a soil pit survey sheet.

Soil Pit Survey Sheet: Site Number: 1 Example Sheet. (For example 1)

Property Name: *Trial Downs*				Date: *24/01/02*			Owner: *C. Material*	
Block/Paddock: *Home paddock*				Irrigation System: *Bike Shift*			Crop/enterprise: *Lucerne*	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
0.3	*0*	*0.3*	*Sandy Loam*	*65 mm/m*	*19.5 mm*	*0.3*	*19.5 mm*	
0.8	*0.3*	*0.5*	*Light Clay*	*55 mm/m*	*27.5 mm*	*0.5*	*27.5 mm*	
1.2	*0.8*	*0.4*	*Medium Clay*	*55 mm/m*	*22 mm*	*Nil*	*Nil*	*Only a few roots in this layer*
				Total Profile RAW:	*69 mm*	Rootzone RAW:	*47 mm*	
Rootzone: *0.8 m*								
Topsoil depth: *0.3 m*								
Comments on restrictive or impermeable layers *N/A*								
Depth of water table: *N/A*								

Soil Pit Survey Sheet: Site Number: ……..

Property Name:				Date:			Owner:	
Block/Paddock:				Irrigation System:			Crop/enterprise:	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
				Total Profile RAW		Rootzone RAW		
Rootzone:								
Topsoil depth:								
Comments on restrictive or impermeable layers:								
Depth of water table:								

Soil Pit Survey Sheet: Site Number: ……..

Property Name:				Date:			Owner:	
Block/Paddock:				Irrigation System:			Crop/enterprise:	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
				Total Profile RAW		Rootzone RAW		
Rootzone:								
Topsoil depth:								
Comments on restrictive or impermeable layers:								
Depth of water table:								

Soil Pit Survey Sheet: Site Number: ……..

Property Name:				Date:			Owner:	
Block/Paddock:				Irrigation System:			Crop/enterprise:	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
				Total Profile RAW		Rootzone RAW		
Rootzone:								
Topsoil depth:								
Comments on restrictive or impermeable layers:								
Depth of water table:								

Activity 4: Measuring infiltration rate

Aim:

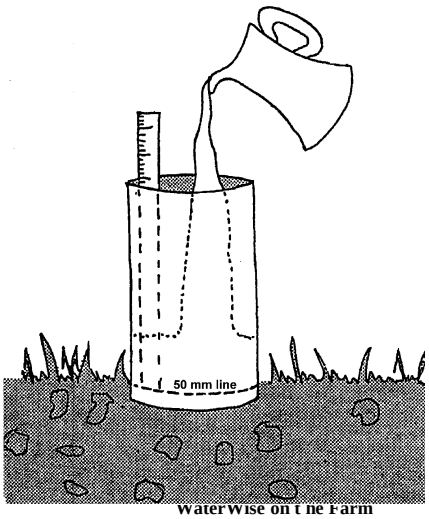
To estimate the infiltration rate of a soil by measuring how far water soaks into the soil at the monitoring site over a set period of time.

Materials required:

- A can approximately 1 litre (L) in volume (for example a 1 L Golden Circle juice can) or a piece of plastic pipe approximately 100 mm in diameter and with one end filed to a sharp edge.
- A hammer
- A piece of board a little larger than the top of the can
- A 1 L measuring jug or beaker
- A watch with a second hand or a stop watch
- At least 500 millilitres (mL) of water for each test
- A measuring rule
- A waterproof marker pen
- A cover for the sharp edge of the opened can

Procedure:

1. Remove one end of the can with a standard can opener, retaining the rolled edge.
2. Remove the other end including the rolled edge, to leave a sharp edge. This can be achieved with some types of can openers, but if these are not available, use tin snips.
3. Mark a line around the outside of the can, 50 mm from the sharp edge.
4. Find a clear flat site and place the can on the ground with the sharp edge down.
5. Place the board on top of the can and hit it with the hammer until the can is pushed down to the 50 mm line.
6. Place the rule in the can so you can measure the distance between the top of the can and the initial height of the water as soon as the water is put in (see step 7).
7. Pour water into the can until it is near the top and note the level on the rule. Start the stopwatch at the same time.
8. Record how long it takes for the water to infiltrate the soil and move down to ground level. (If there are any obvious leaks around the can, fix them and start again!)



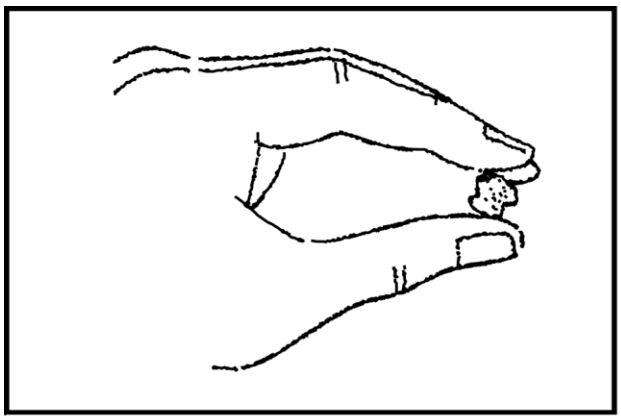
9. Calculate the infiltration rate using the following steps:
   - Record the change in water level in the can as **D** (in mm, the distance between first height and ground).
   - Note the total time in minutes that it took to fall that distance. Call this time **T**.
   - Calculate the infiltration (called **I**, in mm/h), using
     I = D ÷ T x 60
     (60 is the conversion from minutes to hours.)
10. Record your answer in the table below.
11. Remove the can and store it safely until required again.

Infiltration record sheet

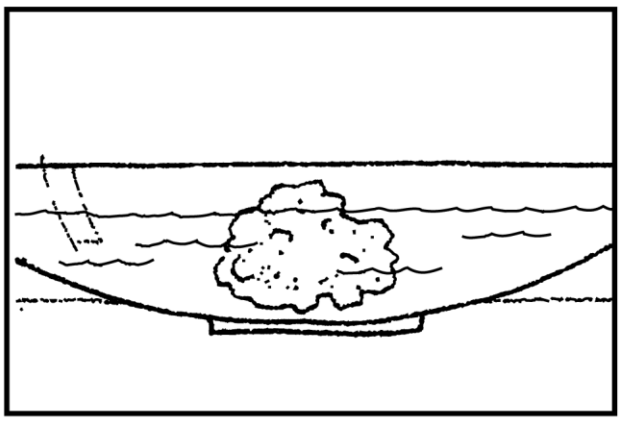
Site Number	Soil Type	Infiltration Depth D	Infiltration time T	Infiltration Rate D ÷ T x 60
1				
2				
3				
4				
5				

Note: This field test is an estimate only. Many factors will influence the results from this test and give varying results. Such factors may include soil moisture, structure, and organic matter. It is however important to understand the infiltration rate of your soils as they will play an important role in the water use efficiency of your irrigation.

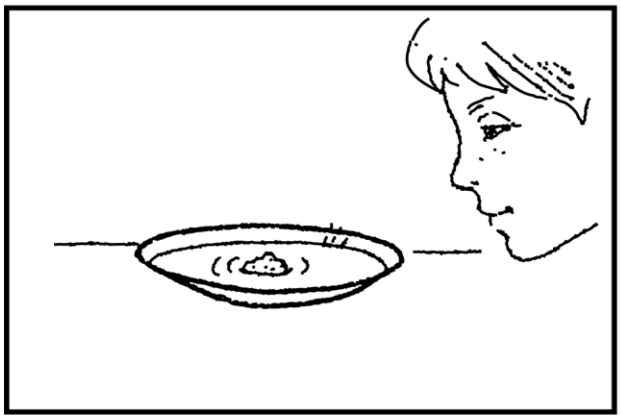
Activity 5: Slaking soils



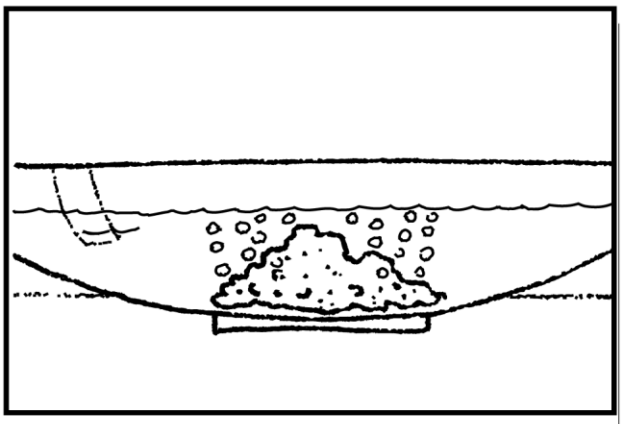
1. Take a small lump of soil, about as big as a marble.



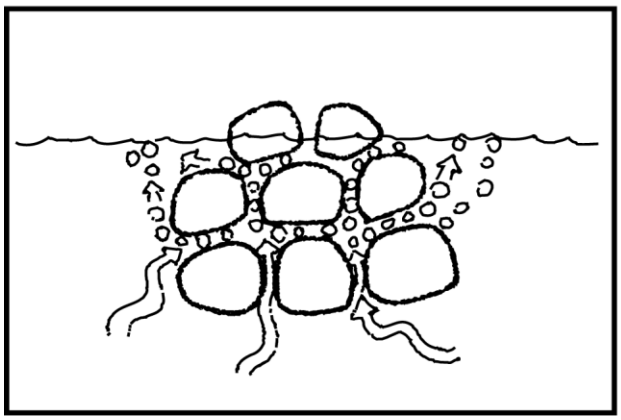
2. Place it carefully in a saucer of water.



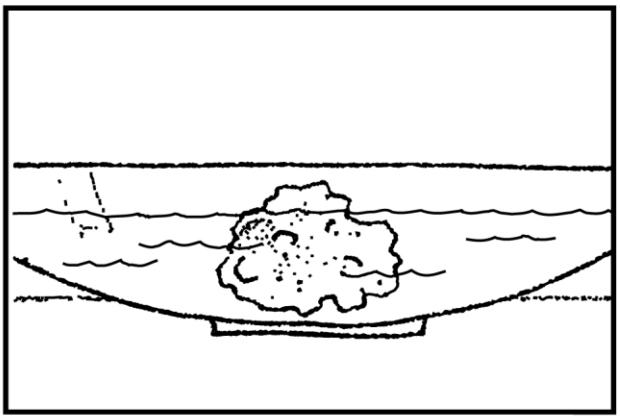
3. Watch to see whether anything happens.



4. If small bubbles appear in the water, and the lump collapses, your soil has slaked. It has no humus or organic matter to hold the soil particles together.

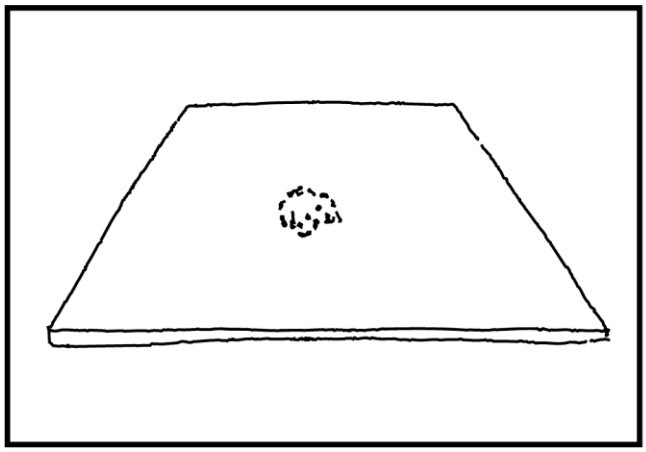


5. When soil slakes, water rushes into the air spaces in the soil, forces the air out (as bubbles) and explodes the soil lump. Slaking occurs when soil is cultivated without any organic matter going into the soil.

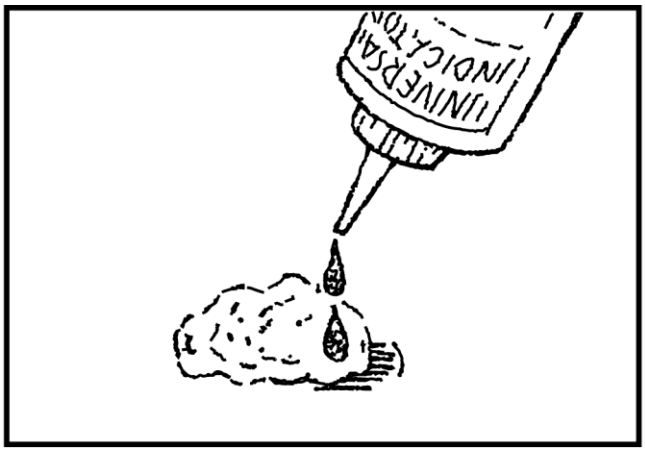


6. If nothing happens to your soil lump, it has enough organic matter in it to hold it together.
It has good structure.

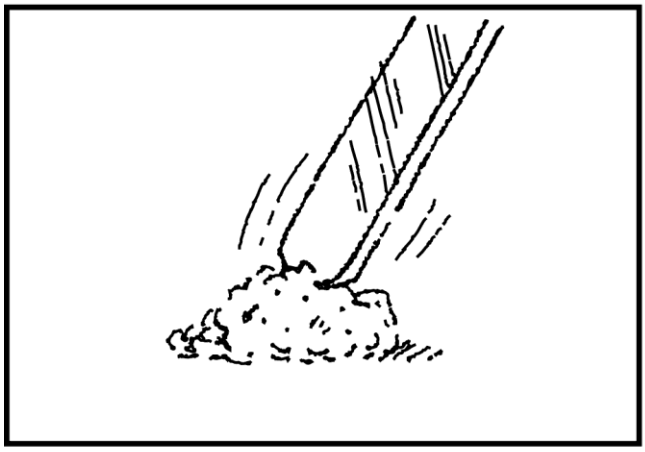
Activity 6: Soil pH



1. Put a small lump of soil on a clean surface.

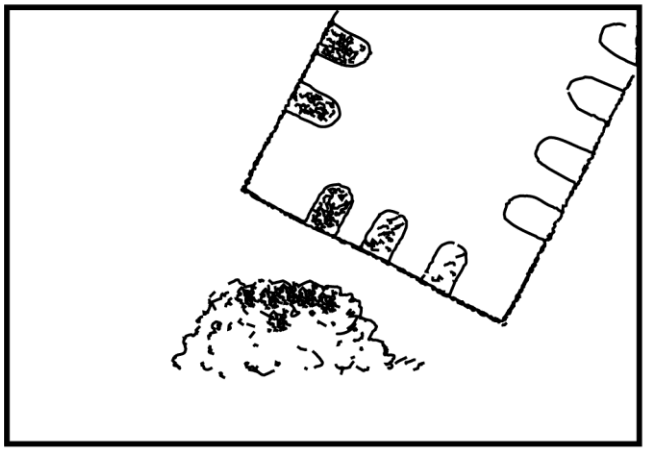


2. Add a couple of drops of universal indicator from the test kit.

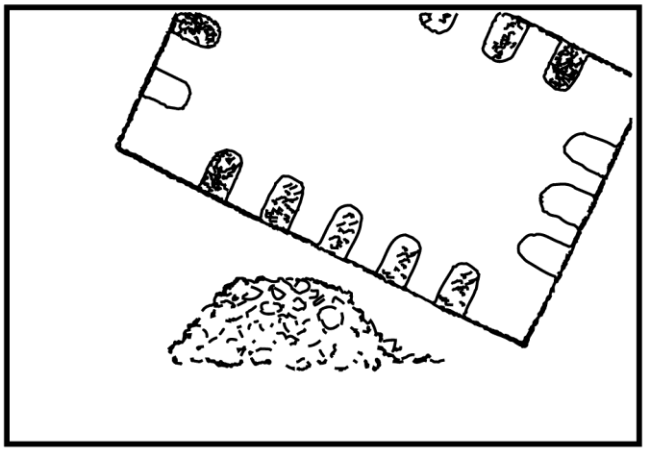


3. Mix the indicator with the soil.

4. Add some indicator powder.

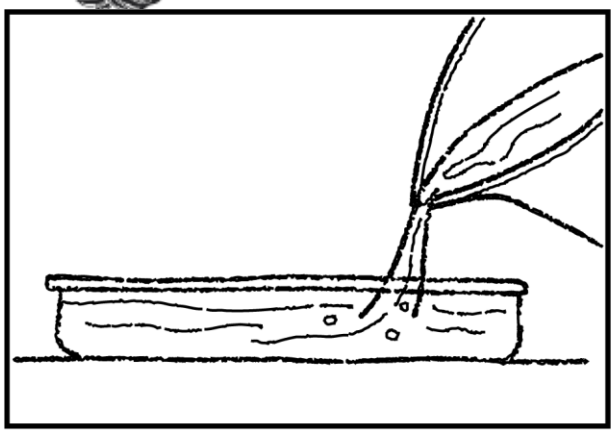


5. Check the colour of the powder against the colour card. Green is the best colour because it shows the pH is near neutral.

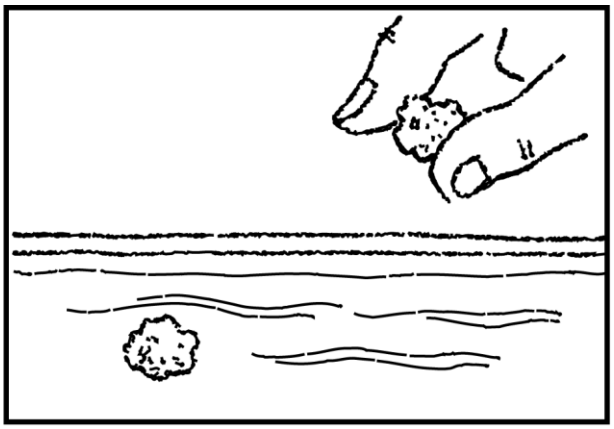


6. A yellow colour indicates your soil is acid and needs lime added to it if you want plants to grow well.

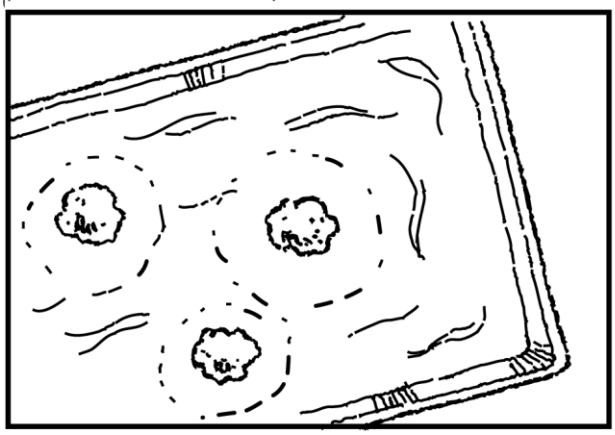
Activity 7: Sodicity and dispersion



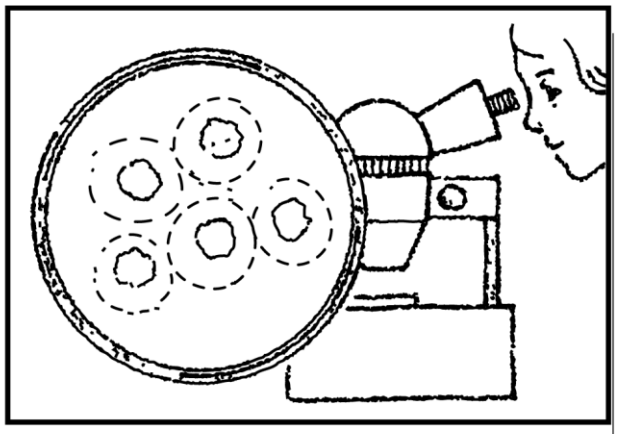
1. Pour some rainwater or distilled water into a dish placed where it will not be disturbed for several hours. (Do not use town water.)



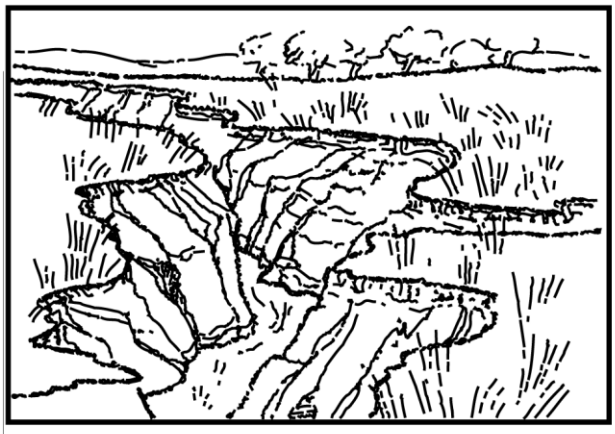
2. Drop several small lumps of dry soil into the water one at a time.



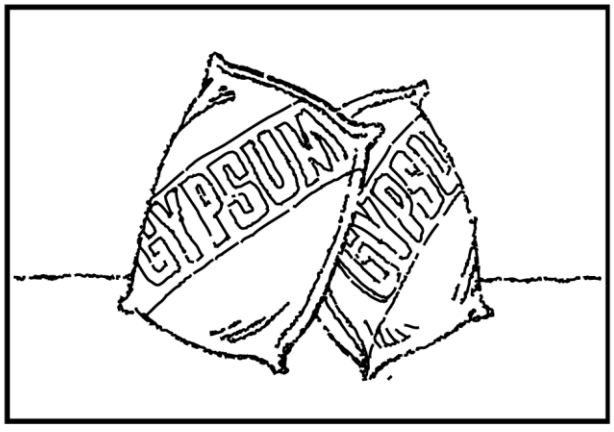
3. Check after 10 minutes whether the water around the soil has started to go cloudy. If it has, this means that the soil has started to disperse, and possibly indicates that the soil is sodic. Look again after 30 minutes, and again after 2 hours, to further check for cloudiness around the soil.



4. Sodic soil has sodium attached to the clay. When the clay is wet, the sodium attracts a water shell around each clay particle, preventing the particles from joining together. The separated (dispersed) clay particles make water look muddy or cloudy.



5. Sodic soil is a problem because it erodes easily. The individual clay particles are easily washed away by water, leaving huge gullies. The eroded particles settle into a hardsetting, crusted topsoil. It is difficult for water, air or plant roots to move through it. Slow water infiltration is a major problem in sodic soils.



4. Gypsum can help manage sodic soils in two ways. In the short term it provides a moderately saline soil solution which prevents dispersion. In the long term, the sodium in the clay is replaced with calcium from the gypsum. The calcium makes the soils less likely to separate into individual particles.

Activity 8: Soil carbonates

What you need:

- 3% hydrochloric acid (HCl) solution. This approximate strength can be prepared by adding one part of HCl (also known as 'spirits of salts', 35%) to 10 parts rainwater.
- Ceramic plate (such as a tile)
- Pen and soil survey sheet

What you do:

Warning: Always add acid to the water. Never add water to the acid

- Add one or two drops of the acid solution to a soil sample and note the strength of the effervescence.
- Record, on your soil survey sheet, the strength of effervescence according to the categories described in Table 4.

The amount of effervescence or reaction of the acid to the carbonate shows how much carbonate is in the soil. If a very strong reaction occurs, it is a carbonate layer.

Table 4: Acid reactions to fine soil carbonate

Reaction	Strength of effervescence	Approximate % Carbonate
Nil	None	Less than 0.5
Slight	Just visible	0.5 to 1.5
Moderate	Easily visible	1.5 to 4
High	Strong	4 to 8
Very high	Thick bubbles 'jump up'	More than 8

Activity 9: Soil salinity

What you need:

- A sample of soil from the rootzone of your crop or pasture. Dig a hole and take a sample from a depth of 100-300 mm. Store the sample in a plastic bag.
- If you have time (especially if sampling from near trees or in a deep-rooted pasture), take an additional sample from below 300 mm. Salinity tends to increase with depth (surface salts are flushed down by rainfall or irrigation, and brought up from below by rising groundwater and capillary action).
- A set of scales
- A screw-top jar or container
- Rainwater or distilled water
- A liquid-measuring container, and
- A salinity meter.

Testing for soil salinity - What you do:

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 stone 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. Add five parts of rainwater or distilled water to every one part of soil. Therefore, if you put 50 g of soil (weighed on scales) into the container, then you need to add 250 mL of the rainwater or distilled water.
4. Shake the container vigorously for 3 minutes to make sure the salts dissolve. In clay loam to clay soils, more shaking (for one minute every 3 minutes, repeated 3 times) brings more salts into the solution and increases the accuracy of the test.
5. Allow the solution to settle for at least 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 water or rainwater, and dry.
8. Convert your salinity meter readings to soil salinity (ECe) by finding the soil texture of the sample in table 5 and multiplying by the value of the conversion factor given.
9. 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 is an approximate value for the salinity of the soil (ECe).

Table 5: Soil salinity field test factors

Soil texture group	Approximate clay	Factor
Sands	< 10%	17
Sandy loams	10-25%	13.8
Loams	25-30%	9.5
Clay loams	30-35%	8.6
Light clays	35-45%	8.6
Medium and heavy clays	> 45%	7

Interpreting ECe

It is accepted practice that saline soils are those that have an ECe of more than 2 dS/m. If your ECe is more than 2 dS/m, seek expert advice on the suitability of your soil for the crops and pastures you want to grow, and for management options to reduce soil salinity.

Lower levels of salinity can affect the growth and yields of salt-sensitive plants such as most legumes (clovers, beans and peas), maize, and many horticultural crops. If your ECe is 1 to 2 dS/m, and you intend to grow any of these crops, you should also seek expert advice.

Activity 10: Water quality

To measure water quality you need:

- Thoroughly clean plastic or glass containers with tight clean lids and seals
- Access to, and the skills to use a ph meter
- Access to, and the skills to use an EC meter
- Access to an analytical laboratory for water analysis

Collecting a water sample

Collect a representative sample of water from your irrigation system, bore, or dam. Make sure the system is flushed through before collecting the sample.

Label the sample clearly and then send the sample to an appropriate laboratory for analysis. You need to specify what tests you require. Your irrigation adviser will guide you on this.

Interpreting the results

These notes give some general guidelines to assist in interpreting your readings and the results from laboratory tests. For further queries, seek expert advice.

Once you have analysed your water quality, make sure you follow through by taking any necessary action to improve your productivity and irrigation efficiency.

Table 6: Summary of guidelines for water quality for irrigation

	OK	Be Careful	Problem
Salinity	< 0.8 dS/m	0.8-2.3 dS/m	> 2.3 dS/m
	< 500 ppm	500-1500 ppm	> 1500 ppm
pH (normal range 6.0 to 8.5)			
• Carbonate level	< 150 mg/L (ppm)	150-350 mg/L (ppm)	> 350 mg/L (ppm)
Chloride			
• Drip irrigation	< 140 mg/L (ppm)	140-350 mg/L (ppm)	> 350 mg/L (ppm)
• Spray irrigation	< 70 mg/L ppm)	70-150 mg/L (ppm)	> 150 mg/L (ppm) (foliar absorption)
Calcium carbonate (CaCO3 SI)			
Corrosion	> - 0.5 mg/L (ppm)	-0.5 to -1.5 mg/L (ppm)	< - 1.5 mg/L (ppm)
Encrustation	< + 0.5 mg/L (ppm)	+ 0.5 to + 1.5 mg/L (ppm)	> + 1.5 mg/L (ppm)
Iron	-	0.1-1.0 mg/L (ppm)	> 1.0 mg/L (ppm)

Activity 11: On-farm basic soil survey

Select at least two sites on your property. Complete the survey sheets attached.

Indicate on a map of your property where the soil survey sites are located.

Why did you select these sites?

Where else on your property should you carry out a soil survey?

Soil Pit Survey Sheet: Site Number: ……..

Property Name:				Date:			Owner:	
Block/Paddock:				Irrigation System:			Crop/enterprise:	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
				Total Profile RAW		Rootzone RAW		
Rootzone:								
Topsoil depth:								
Comments on restrictive or impermeable layers:								
Depth of water table:								

Soil Pit Survey Sheet: Site Number: ……..

Property Name:				Date:			Owner:	
Block/Paddock:				Irrigation System:			Crop/enterprise:	
Depth (m)		Thickness (m)	Soil Texture	Texture RAW (Table 2)	Soil RAW	Rootzone Depth (m)	Rootzone RAW	Comments
Bottom	Top	A		B	A X B	C	B X C	
				Total Profile RAW		Rootzone RAW		
Rootzone:								
Topsoil depth:								
Comments on restrictive or impermeable layers:								
Depth of water table:								