WaterWise on the Farm

Introduction to Irrigation Management

Evaluating your pressurised system

System 5

Fixed under-canopy micro

System 6

Fixed overhead, solid set

Bike shift

160501

Contents

Aim

To assess your irrigation system you need to determine the rate that water is being applied, and how uniformly that water is being distributed. To check these you need to know the MAR, the DU, and the pressures and flows within your system.

These worksheets outline the equipment and procedures needed for you to evaluate fixed overhead, solid set and bike shift and fixed under-canopy micro irrigation systems.

Systems overview

Fixed overhead

Fixed overhead systems are used for permanent horticultural plantings, like orchards, and, in certain circumstances, effluent irrigation of pastures.

Fixed overhead systems are 'permanent' irrigation systems. Like most pressure irrigation systems, they rely on a pump to deliver water to the irrigation area via a permanent, buried mainline. The mainline is usually a plastic material like PVC.

The irrigation area is divided into a number of blocks. A submain (one for each block) runs off the mainline and serves that block. Submains are permanent (buried) and are usually a plastic material like PVC or polythene. From the submain, water reaches the crop though a permanent (generally buried) grid of laterals fitted with sprinklers on riser pipes. Laterals are usually a plastic material like PVC or polythene.

In orchards the sprinklers are on riser pipes which extend above the tree canopy. Riser pipes are usually of small diameter (15 – 25 mm) PVC, polythene or galvanised wrought iron pipes. In effluent systems the 1–1.5 m high risers are normally galvanised wrought iron pipe braced to prevent damage from grazing stock.

Fixed overhead sprinklers are generally 'knocker' type and provide from 5 to 20 mm/h and operate between 200 and 350 kPa. They are normally spaced on a rectangular or square grid up to about 20 x 20 metres, though triangular spacings are sometimes used.

Pros of fixed overhead

- Low (or no) labour requirement.
- Suited to automation.
- Frost control possible.
- Low maintenance.

Cons of fixed overhead

- High capital cost per hectare.
- Wetting patterns liable to distortion in windy conditions.
- Difficult to maintain sprinklers on tall risers.
- Bracing required for tall risers and effluent areas.

Solid set

This irrigation system is suited to seedlings and vegetable crops or crops that need to be rotated from field to field each year. The system can remain in place for the life of the crop and be removed prior to harvest or it can be used in the seedling stage, prior to transplant, and then moved to the next irrigation block.

Like most pressure irrigation systems, the solid set system relies on a pump to deliver water to the irrigation areas via a permanent, buried mainline. The mainline is usually a plastic material like PVC.

The irrigation area is divided into a number of blocks. A submain (one for each block) runs off the mainline and serves that block. Submains are either permanent (buried) or portable (surface laid). Buried submains are usually a plastic material like PVC or polythene and surface submains are either a metal material like aluminium or a plastic material like polythene. From the submain, water reaches the crop though a surface grid of laterals fitted with sprinklers. Laterals are usually aluminium but polythene laterals are sometimes used.

Solid set sprinklers are generally of the 'knocker' type and provide from 5 to 20 mm/h and operate between 200 and 450 kPa.

Pros of solid set

- Low labour requirement.
- Low (or no) crop damage due to pipe movement.
- No laneways required.

Cons of solid set

- High capital cost per hectare.
- Wetting patterns liable to distortion in windy conditions.

Bike shift

As the name implies, bike shift irrigation is the shifting of irrigation positions with the aid of a bike.

It is mainly used to irrigate pastures and is most commonly found on dairy enterprises. It can be adapted to irrigate some horticultural crops like vegetables, orchards and ornamental plants, but this is only possible where laneways are provided to allow bike movement of irrigation positions.

Like most pressure irrigation systems, bike shift relies on a pump to deliver water to the irrigation areas via a permanent, buried mainline. The mainline is usually a plastic material like PVC. The bike shift irrigation area is divided into a number of blocks. A turf valve connected to the mainline by a buried polythene lateral serves each block.

Flexible, low density polythene piping runs from each turf valve to a sprinkler mounted on a skid frame. The frame design allows it to be easily picked up and towed with a bike and is stable enough not to be overturned by stock. Generally, the number of irrigation positions per turf valve is either 12 or 9 and each one of these positions is served, in turn, by the same sprinkler.

Bike shift sprinklers generally provide from 3 to 6 mm/hour and operate between 250 and 300 kPa.

Pros of bike shift

- medium pressure sprinklers means lower pumping cost and lower class mainlines.
- all paddocks are watered simultaneously.
- suited to odd shaped paddocks.
- can be used in hilly areas provided sprinklers fitted with pressure regulators.

Cons of bike shift

- It is only suited to pasture irrigation unless provision is made for laneways in horticultural crops.
- A 4 wheeled bike is generally required, particularly for areas greater than 10 ha.
- Labour and time required to shift hoses.
- Need for good surface to move the skid frame.
- Slower watering time.

Fixed under-canopy micro-irrigation systems

These systems are suited to under-tree irrigation and also have specific application in some intensive horticulture enterprises like ornamental and vegetable growing.

Like most pressure irrigation systems, micro-irrigation systems rely on a pump to deliver water to the irrigation areas via a permanent, buried mainline. The mainline is usually a plastic material like PVC.

The irrigation area is divided into a number of blocks. A submain (one for each block) runs off the mainline and serves that block. Submains are usually permanent (buried) and are typically of a plastic material like PVC or polythene. From the submain, water reaches the crop though a surface (not often buried) grid of laterals fitted with micro emitters. Laterals are normally of polythene pipe.

Fixed under-canopy micro systems have two types of emitters. One is a fixed spray head (known as a micro jet but sometimes called a micro spray) and the other is a small rotating sprinkler (usually called a mini sprinkler). Both types require water filtration to avoid emitter blockages due to their small discharge openings.

Microjets can provide between 20 and 200 litres per hour at operating pressures between 100 and 250 kPa. Their diameter of coverage ranges from about 1 to 7 metres.

Mini sprinklers can provide up to 600 litres per hour at operating pressures between 150 and 350 kPa. Their diameter of coverage ranges from about 2 to 12 metres.

Pros of micro

- Good control of rootzone moisture.
- Suited to automation.
- Low labour costs.
- Low pumping costs.
- Fertigation (and chlorination) possible though the system.
- Crop access possible during (or shortly after) irrigation cycles.

Cons of micro

- High capital cost.
- Frequent watering may be required (not always a con).
- Blockages of emitters.
- Defined maintenance regime (with visual assessment of operating system) required.
- Emitters easily damaged in farming operations like fruit picking

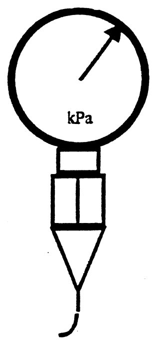
Equipment needed

To measure pressure:

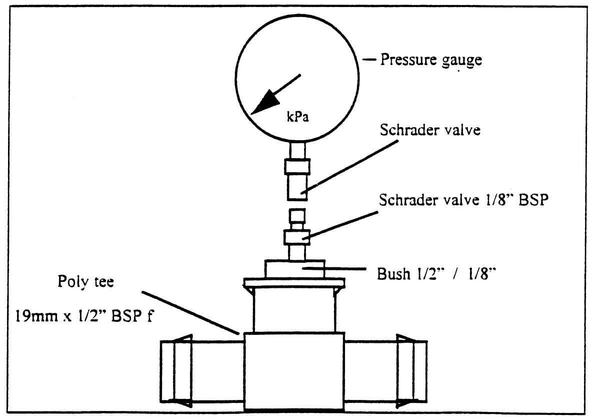
- an accurate pressure gauge with an appropriate scale so it works mid-range at your normal pressures (say 0 to 400 kPa for low pressure systems, or 0 to1000kPa for high pressure systems)

- a pitot tube attachment (pronounced pit-oh) if you have overhead or large low-level sprinklers, or a theaded 15 mm PVC tee and fittings such as reducing bushes for small low-level sprinklers, or a Schader valve attachment.

Figure 1, a & b



on a "Pitot" tube



Schrader valve

To measure flow:

- plastic tubing that can be placed over the sprinkler nozzles and long enough to go from the sprinkler to a bucket
- a large bucket or small drum of known volume
- a watch capable of measuring seconds

To measure sprinkler coverage:

- catch cans (depending on your grid size, anywhere from 36 to 200 may be needed)
- a 30-metre measuring tape
- weights to place in containers to stop them blowing away
- a shovel for smoothing areas to set containers
- a measuring cylinder or jug with graduations in millilitres
- a calculator, a pen and blank evaluation sheets
- for overhead systems – ladder or a platform to allow access to the sprinklers

Evaluation method

To assess the performance of your system, you need to measure the pressure and flow at various points in the system and, to measure evenness of application, collect the output of the sprinklers using catch cans. Work though the following procedure.

Step 1 On your field record sheet, note the brand, type, model, colour nozzle sizes and normal operating pressures of the sprinklers to be used as well as the spacings of the sprinklers and catch cans. Make a sketch plan of the site and catch can layout.

Step 2 Place the catch cans in a grid pattern and use a tape to make sure they are the correct distance apart. Use whichever is the appropriate layout for your system (as shown in the figures on the following pages). Make sure the catch cans are upright and stable, and if necessary weight them down with stones or gravel. Make sure that grass and other foliage does not interfere with water entering the catch cans. Make a sketch plan of the site and catch can layout.

Step 3 Turn on the water to fill and pressurise the lines. When the system has been fully pressurised, measure and record the pressure and flow at the sprinklers to be tested. (If any sprinklers have double jets, a measurement should be made at each jet and the results added together.) **Make sure you stop the sprinklers rotating and direct water away from the catch cans.**

Step 4 **Start the test.** Release the sprinkler arms and run the test, recording the start time. Ideally the test time should be 1 hour.

Step 5 While the test is in progress, check the pressures and flows at a number of other positions on other laterals.

Step 6 Whilst the test is in progress record the wind direction and strength as this can have a large effect on the results

Step 7 At the end of the test period stop the sprinklers and collect the water in the catch cans. Do this by accurately measuring the volume of water collected in each can. Use a graduated jug or measuring cylinder.

Step 8 Record these volumes in the space provided on the evaluation sheet.

Step 9 Convert the volumes collected (mL) to irrigation depth (mm) using Table 1 then calculate the MAR and DU for your system.

If/when time permits:

Step 10 Repeat the test for several sites and under different conditions, for example windy and calm.

Step 11 Calculate the average pressure, and average flow for the sprinklers tested.

Catch can layout

Choose four sprinklers along two laterals for the test (as shown below), or four adjoining sprinklers.

The idea is to measure the output from 4 sprinklers in the one test – assuming they can be spaced as you normally operate. The test collects from a one-quarter section of each of the four sprinklers.

Figure 2. Typical catch can layout

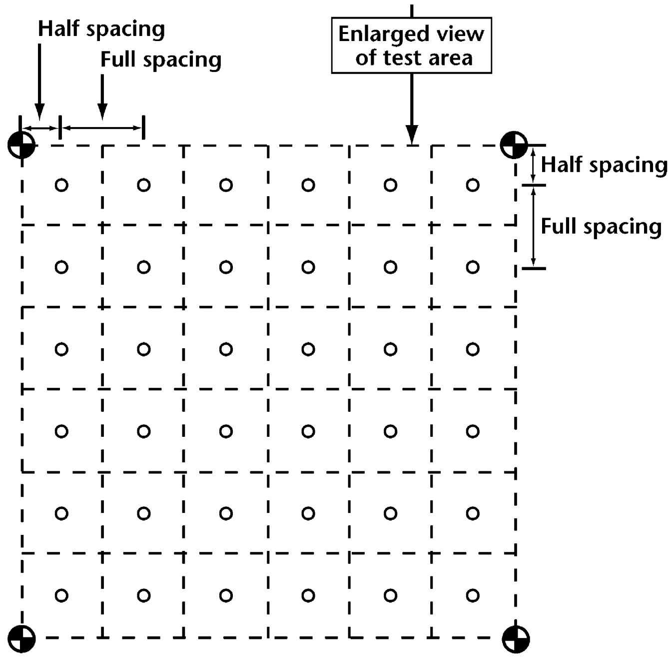
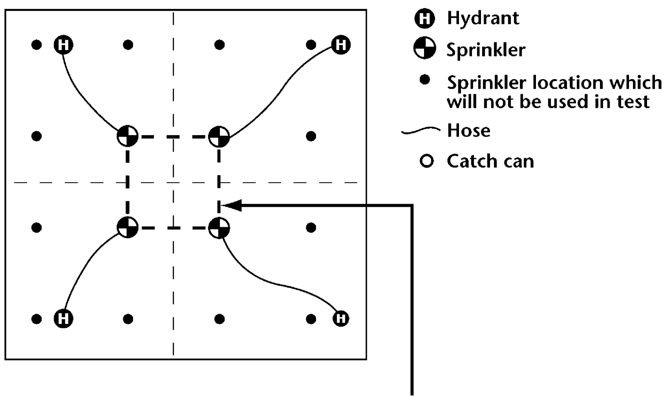


Figure 3. Enlarged layout for a bike shift system

Cans go in centre square.

Figure 3



Set out the catch cans as shown. The corner cans should be spaced half-a-can spacings from the sprinkler.

Space the cans 4 metres apart for 20-metre sprinkler spacing (36 containers, 5 spaces of 4 metres). For undercanopy micro systems the cans will be much closer, perhaps 1 metre apart, making a grid of 6 m x 6 m.

(For an 18-metre sprinkler spacing you could use 6 spaces of 3 metres ending up with a 7 x 7 grid of 49 cans. Other spacings and more or less cans can be used for different arrangements. There is nothing 'magic' about the number of cans!)

Worked example

Here is a partially completed evaluation sheet for a system:

Field record sheet

Name: John Bike-Shift	Crop: Pasture
Location: Hereabouts	Effective root depth: 15 cm
Soil texture Loam	RAW for crop: 22 mm
Spacing of sprinklers 18 metres	
Sprinkler make	Sprinkler model
Nozzle size 5	
Frequency of irrigation ____ days	

Pressure and flow record sheet

Sprinkler position on laterals

	Lateral 1				Lateral 2			
USE EITHER THESE HEADINGS >>>	**1st Sprinkler**	**1st mid-position**	**2nd mid-position**	**Last sprinkler**	**1st Sprinkler**	**1st mid-position**	**2nd mid-position**	**Last sprinkler**
OR THESE HEADINGS >>>	**Near**	**High**	**Low**	**Far**	**Near**	**High**	**Low**	**Far**
Pressure (kPa)	300	275	285	270				
Container volume (L) { A }	38	37.5	25	38				
Catch time (s) { B }	62.5	66	42	67				
Calculated flow rate (L/min) (A ÷ B) x 60	36.4	34.1	35.7	34.5				

NB Volumes are in litres and catch times in seconds. If you use other units don't forget to convert them!

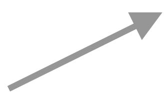
Catch can record sheet and conversion sheet

							TOTAL of row
vol in mL	1. 54	2. 39	3. 24	4. 26	5. 35	6. 51	
depth in mm	5.4	3.9	2.4	2.6	3.5	5.1	22.9
vol in mL	7. 36	8. 29	9. 21	10. 18	11. 27	12. 34	
depth in mm	3.6	2.9	2.1	1.8	2.7	3.4	16.5
vol in mL	13. 22	14. 21	15. 16	16. 21	17. 19	18. 24	
depth in mm	2.2	2.1	1.6	2.1	1.9	2.4	12.3
vol in mL	19. 28	20. 24	21. 19	22. 16	23. 23	24. 27	
depth in mm	2.8	2.4	1.9	1.6	2.3	2.7	13.7
vol in mL	25. 36	26. 23	27. 18	28. 18	29. 26	30. 35	
depth in mm	3.6	2.3	1.8	1.8	2.6	3.5	15.6
vol in mL	31. 51	32. 34	33. 25	34. 23	35. 37	36. 49	
depth in mm	5.1	3.4	2.5	2.3	3.7	4.9	21.9

Total of all container depths: 102.9mm

Start time 11.40 **Finish Time** 12.40 **Test duration** 1 hour

Wind direction (draw an arrow relative to the catch can layout)



Converting mL to mm of irrigation

For catch-cans of 110 to 115 mm diameter across the top, just divide the collected amount by 10 to get mm of irrigation.

For instance if you collected 674 mL this is equivalent to a depth of 67.4 mm.

If the size of the catch cans is different, or you wish to be more accurate, use the table alongside.

Divide the amount caught by the figure in the right hand column. For instance, if the diameter is 110 mm and you catch 674 mL this is 674 ÷ 9.5 = 71 mm

Table 1. Converting mL to mm

Diameter of catch can (mm)	Figure to divide the collected amount by
75	4.4
80	5.0
90	6.4
100	7.9
102	8.2
104	8.5
106	8.8
108	9.2
110	9.5
112	9.9
113	10.0
114	10.2
115	10.4
120	11.3
125	12.25
145	16.5
165	21.3
200	31.4
220	38.0

If you use 4-litre square plastic ‘ice cream’ containers,
1 litre collected in one of these is equivalent to 25 mm of irrigation.
On a calculator **“water collected in mL” ÷ 40 = mm**

Calculating MAR

Step 1 Convert the volumes listed on the catch can record sheet to depth of irrigation using the data in table 1.

Step 2 Add up all the depths of irrigation in millimetres and divide this total by the number of catch cans.

Step 3 If the test duration was NOT exactly one hour you now need to convert the average obtained to a per hour equivalent. (Do this by dividing the average by the test duration (minutes) and then multiplying by 60 (see the example) to obtain **MAR** per hour.)

Example: Calculating MAR

	Example	**Your data**
Total of all catch can depths Call the total **{ A }**	**= 102.9 mm**	
Average depth = Call the average **{ B }**	[A] ÷ number of cans = [A] ÷ 36 = 102.9 ÷ 36 **= 2.9 mm**	
Convert to a 'per hour' figure	[B] ÷ minutes of test x 60 = 2.9 ÷ 60 x 60	
The MAR is	= 2.9 mm/h	

Calculating DU

Step 1 Find the 25% (¼) of catch cans with the lowest amounts in them. Circle these on your record sheet.

Step 2 Add these LQ depths and divide by the number of containers ¼ of the total number of catch cans). This gives you the LQ average in mm.

Step 3 If the test duration was NOT exactly one hour you now need to convert the average obtained in 'Step 2' to a per hour equivalent**.** (Do this by dividing the average by the test duration (minutes) and then multiplying by 60 (see the example)

Step 4 Divide the **LQ** average (per hour rate) by the **MAR** to obtain the **DU**.

Step 5 Multiply the result by 100 to make it into a percentage.

Example: Calculating DU

	Example	**Your data**
Total catch cans used is : ¼ of the catch cans **[LQ]** is: (If this is not a whole number round down to a whole number.)	36 9	
Totals depths of the LQ cans Call this **{ C }**	1.8 + 2.1 + 1.6 + 2.1 + 1.9 + 1.9 + 1.6 + 1.8 + 1.8 =16.6 mm	
Average depths in LQ cans Call this **{ D }**	= [C] ÷ by [LQ] = 16.6 ÷ 9 = 1.84 mm	
Convert to 'per hour' figure **LQ average per hour**	[D] ÷ minutes of test x 60 = 1.84 ÷ 60 x 60 = 1.84 mm/h	
DU% = [D/h] ÷ MAR Multiply by 100	= 1.84 ÷ 2.9 = 0.63 = 63 %	

How long to irrigate

Take the RAW for the soil and divide this by the MAR. The result indicates how long it will take to apply the RAW amount, if the system is 100% efficient

Example: how long to irrigate

	Example	Your data
RAW for this crop	**say 21 mm**	
MAR calculated earlier	**2.9**	
If the system was 100% efficient the time to apply the RAW would be	**= RAW ÷ MAR** **= 21 ÷ 2.9** **= 7.2 hours**	

Because the system is NOT 100% efficient, the irrigation time obtained is sometimes increased to compensate for the inefficiency. **This is a management decision** and you must carefully consider the points below.

The consequences of increasing the irrigation time are:

- Increased water use(+ nearly 60% in example – see below)
- increased pumping costs
- excessive run-off and losses to deep drainage may occur
- allocation/supply may mean smaller areas can be irrigated
- yield may decrease due to many waterlogged roots
- yield may increase as all areas get sufficient water

To demonstrate the additional time needed to compensate for an inefficient system, work through the following example.

Example: how long to irrigate to compensate for system inefficiency

	Example	Your data
Time calculated for 100% efficiency	**= 7.2 hours**	
Adjusted irrigation time to compensate for the DU	**= 7.2 ÷ 0.63** **= 11.4 hours**	

Maintain your irrigation system and MAXIMISE distribution uniformity (DU).

Measuring pressure and flow

Step 1 Select which sprinklers are to be checked. Check the near, far, high and low positions as a minimum.

Step 2 Measuring the pressure and flow at each position. Make sure the system is operating at the normal pressure in the normal shift arrangement!

Large under-tree sprinklers or overhead sprinklers

- Pressure: Position the pitot tube and gauge with the point of the tube about 3 mm (1/8') from the nozzle in the stream of the water.

- Flow: Place a length of flexible plastic tubing over the nozzle and direct the discharge into a container for a minimum of 15 seconds. If two nozzles are fitted, they need to be tested separately and their flows (L/min) need to be added together to give the total flow rate of the sprinkler.
  For undercanopy systems, hold the impact arm back and direct the stream into the container. Avoid losses from splashing!
  Use a measuring cylinder to record the volume (mL).

For each sprinkler tested note down the brand/model, nozzle size, colour, nominal flow rate and spacings on your evaluation sheet.

Hint: straight-drilled nozzle sizes can be checked using the shank end of unworn drill bits. The one with the snuggest fit is the current size of the nozzle. Check against the manufacturer's charts for the correct size.

Low-level sprinklers

- Pressure: Pinch off the lead tubing and unscrew the sprinkler from the stand or stake. Screw the T-piece holding the pressure gauge onto the stand or stake and replace the sprinkler on top of the fitting. Release the lead tube and allow the sprinkler to operate normally. Record the sprinkler pressure reading on your evaluation sheet.

- Flow: Direct the stream into a bucket for one minute. Avoid losses from splashing. Use a graduated measuring cylinder to record the volume in (mL). Record the volume on your evaluation sheet.

For each outlet tested note down the brand/model, nozzle size, colour, nominal flow rate and spacings on your evaluation sheet.

Hint: straight-drilled nozzle sizes can be checked using the shank end of unworn drill bits. The one with the snuggest fit is the current size of the nozzle. Check against the manufacturer's charts for the correct size.

Step 3 Make sure all results are recorded.

If a large variation occurs between readings, you should conduct more checks to ensure your readings are true. If they are, you then need to identify why there is such a large variation in the system.

What do the pressure and flow readings tell us?

You have collected a series of figures on your record sheet. Using these figures you can calculate the variations for the system.

Too great a variation indicates that the system is not operating most effectively. Pressure variation is written as ± % indicating it is 'above' or 'below' the desired figure.

Calculating the pressure variation

		Example	Your data
Add the maximum and minimum pressures.	=	**max + min**	
	=	**300 + 270**	
	=	**570**	
Divide the result by two.	=	**570 ÷ 2**	
This gives the midpoint pressure	=	**285 kPa**	
To calculate the pressure variation			
Take the midpoint from the maximum.	=	**max – midpoint**	
	=	**300 – 285 kPa**	
		15 kPa	
Divide the difference by the midpoint.		**15 ÷ 285**	
	=	**0.0526**	
Multiply by 100 to get a percentage.		**0.0526 x 100**	
	=	**5.26 % close enough to 5%**	
Pressure variation is:	=	**± 5%**	

In the above example the pressure variation is ± 5.% A variation of more than ± 10% is unacceptable and indicates either a poor system design or that the valve unit has a problem.

(Note that pressure variation comparisons are only valid if all outlets/sprinklers are the same. If pressure compensators are used in your system you will need to account for these.)

Calculating flow variation

		Example	Your data
Add the maximum and minimum flow	=	**Max + min**	
	=	**36.4+ 34.1**	
	=	**70.5**	
Divide the result by two to give the midpoint.	=	**70.5 ÷ 2**	
Midpoint flow is	=	**35.25 L/min**	
Take the midpoint from the maximum		**Max – midpoint**	
	=	**36.4– 35.25**	
		= 1.15	
Divide the difference by the midpoint		**1.15 ÷ 35.25**	
	=	**0.033**	
Multiply by 100 to get a percentage.	=	**0.033 x 100**	
Flow variation is written as a ± %.	=	**± 3.3 %**	

If the variation is more than ± 5% it is unacceptable.

Check these figures out against the yellow sprinklers in the appendices supplied with the pressure workshop notes.

How close was this set?

Blank evaluation sheets

Field record sheet

Name:	Crop:
Location:	Effective root depth: cm
Soil texture	RAW for crop: mm
Spacing of sprinklers metres	
Sprinkler make	Sprinkler model
Nozzle size	
Frequency of irrigation days	

Pressure and flow record sheet

Sprinkler position on laterals

	Fill in details of laterals and emitters positions below							
Pressure (kPa)								
Container volume (L)								
Catch time (s)								
Calculated flow rate (L/min) ***L/s x 60 = Flow***								

NB Volumes are in litres and catch times in seconds. If you use other units, don't forget to convert them!

Converting mL to mm of irrigation

Table 1. Converting mL to mm

Diameter of catch can (mm)	Figure to divide the collected amount by
75	4.4
80	5.0
90	6.4
100	7.9
102	8.2
104	8.5
106	8.8
108	9.2
110	9.5
112	9.9
113	10.0
114	10.2
115	10.4
120	11.3
125	12.25
145	16.5
165	21.3
200	31.4
220	38.0

For catch-cans of 110 to 115 mm diameter across the top, just divide the collected amount by 10 to get mm of irrigation.

For instance if you collected 674 mL this is equivalent to a depth of 67.4mm.

If the size of the catch cans is different, or you wish to be more accurate, use the table alongside.

Divide the amount caught by the figure in the right hand column. For instance if the diameter is 110 mm and you catch 674 mL this is 674 ÷ 9.5 = 71 mm

If you wish to use 4-litre square plastic ice cream containers,
1 Litre in one of these is equivalent to 25 mm of irrigation.
On a calculator **“water collected in mL” ÷ 40 = mm**

Catch can record and conversion sheet

(for a 36-can test)

							TOTAL of row
vol in mL	1.	2.	3.	4.	5.	6.	
depth in mm							
vol in mL	7.	8.	9.	10.	11.	12.	
depth in mm							
vol in mL	13.	14.	15.	16.	17.	18.	
depth in mm							
vol in mL	19.	20.	21.	22.	23.	24.	
depth in mm							
vol in mL	25.	26.	27.	28.	29.	30.	
depth in mm							
vol in mL							
depth in mm							
				Total of all container depths:[A]			

Start time : **Finish time:** **Test duration:**

Wind direction
(draw an arrow relative to the catch can layout)

Calculating MAR

In a well-designed system, the MAR figure for the whole irrigation should be less than or equal to the infiltration rate of the soil.

	Example	**Your data**
Total of all catch can depths Call the total **{ A }**	**= 102.9 mm**	
Average depth = Call the average **{ B }**	**[A] ÷ number of cans** **= [A] ÷ 36** **= 102.9 ÷ 36** **= 2.9 mm**	
Convert to a 'per hour' figure **The MAR is**	[B] ÷ minutes of test x 60 **= 2.9 ÷ 60 x 60** **= 2.9 mm/h**	

Calculating the DU%

	Example	**Your data**
Total catch cans used is : ¼ of the catch cans **[LQ]** is: (If this is not a whole number round down to a whole number.)	**36** 9	
Totals depths of the LQ cans Call this **{ C }**	**1.8 + 2.1 + 1.6 + 2.1 + 1.9 + 1.9 + 1.6 + 1.8 + 1.8** **=16.6 mm**	
Average depths in LQ cans Call this **{ D }**	**= [C] ÷ by [LQ]** **= 16.6 ÷ 9 = 1.84 mm**	
Convert to 'per hour' figure **LQ average per hour**	[D] ÷ minutes of test x 60 **= 1.84 ÷ 60 x 60** = 1.84 mm/h	

DU% = Multiply by 100	[D/h] ÷ MAR = 1.84 ÷ 2.9 = 0.63 = 63 %	

How long to irrigate

	Example	Your data
RAW for this crop MAR calculated earlier If the system was 100% efficient the time to apply the RAW would be	say 21 mm = 2.9 mm/h RAW ÷ MAR = 21 ÷ 2.9 = 7.2 hours	

	Example	Your data
Time calculated for 100% efficiency Adjusted irrigation time to compensate for the DU	= 7.2 hours = 7.2 ÷ 0.63 = 11.4 hours	

Calculating the pressure variation

		Example	Your data
Add the maximum and minimum pressures.	=	max + min	
	=	**300 + 270**	
	=	**570**	
Divide the result by two.	=	**570 ÷ 2**	
This gives the midpoint pressure.	=	**285 kPa**	
To calculate the pressure variation			
Take the midpoint from the maximum.	=	**max – midpoint**	
	=	**300 - 285 kPa**	
		15 kPa	
Divide the difference by the midpoint.		**15 ÷ 285**	
	=	**0.0526**	
Multiply by 100 to get a percentage.		**0.0526 x 100**	
	=	**5.26 % close enough to 5%**	
Pressure variation is:	=	**± 5%**	

In the above example the pressure variation is ± 5.% A variation of more than ± 10% is unacceptable and indicates either a poor system design or that the valve unit has a problem.

Calculating flow variation

		Example	Your data
Add the maximum and minimum flow.	=	**Max + min**	
	=	**36.4+ 34.1**	
	=	**70.5**	
Divide the result by two to give the midpoint.	=	**70.5 ÷ 2**	
Midpoint flow is	=	**35.25 L/min**	
Take the midpoint from the maximum.		**Max – midpoint**	
	=	**36.4– 35.25**	
		= 1.15	
Divide the difference by the midpoint.		**1.15 ÷ 35.25**	
	=	**0.033**	
Multiply by 100 to get a percentage.	=	**0.033 x 100**	
Flow variation is written as a ± %.	=	**± 3.3 %**	

If the variation is more than ± 5% it is unacceptable.