

Appendix 1: Evaluation method for centre pivot irrigators

WaterWise on the Farm

Evaluating a Centre Pivot Irrigation System



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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Equipment needed

To measure sprinkler coverage:

- Catchcans
- Weights to prevent catchcans blowing away
- A shovel to smooth catchcan area, and where necessary for partially burying the cans
- A measuring cylinder or jug with graduations in millilitres
- A 30-metre measuring tape; and possibly a short ruler
- Pegs or markers
- A calculator, a pen and evaluation sheets (you may need extra copies of the data sheets)
- Manufacturer's sprinkler performance charts

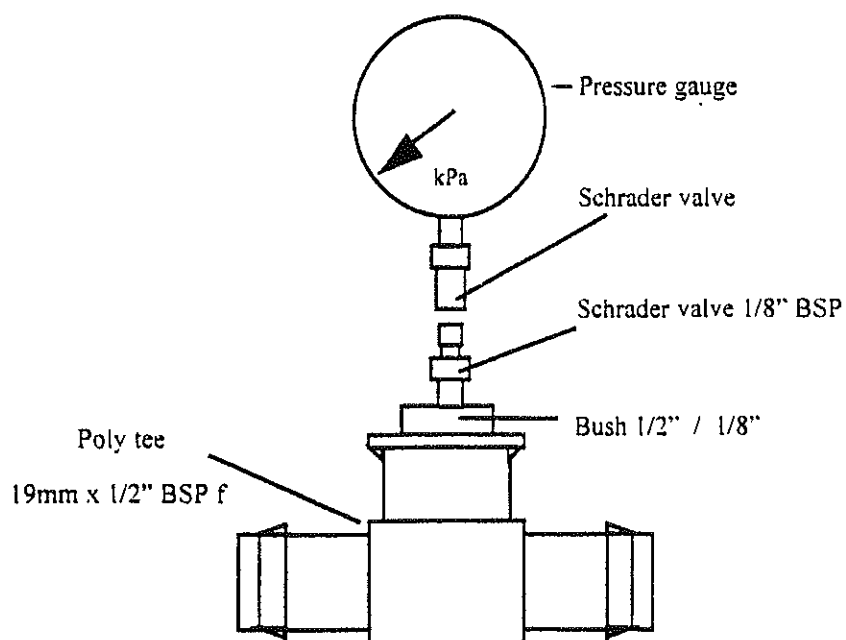
To measure flow:

- A container of known volume eg. 10 L bucket
- Stop watch

To measure pressure:

- An accurate pressure gauge with an appropriate scale so it works mid-range at normal pressures (say 0 to 400 kPa) to 1000 kPa
- Tees and fittings to install above pressure regulators (eg. Figure 1), sufficient for several emitters

Figure 1: Fittings and Schrader Valve



Evaluation method

To assess the performance of centre pivot irrigation system, it is necessary to measure the pressure at various points in the system, its operating speed and the output of the emitters using catchcans. To do this, work through the following procedure.

1. Record wind speed and direction (see Table 1). Field tests are ideally done in zero wind conditions and should not be done if the wind is stronger than a light breeze.
2. Fill out the first sections of the centre pivot data sheet with details about the crop, soils and the centre pivot. Measure the length of each span and the distance from the centre to the outer wheel track (where the travel speed will be measured).

Water output measurement

3. Choose a suitable location for the test so that catchcans may be placed across the pathway of the centre pivot. If possible, the location should be flat and level, and far enough ahead of the boom so that no water enters the catchcans before they are all set up. (For long pivots, the catchcans under the first one or two spans need not be recorded, as the time to pass over them is too great. There will be little effect on the calculations. However, the catchcan positions under these spans **must** be noted and the catch volume recorded as an 'X'.)
4. Ideally, two rows of catch cans, with rows no more than 50m apart, should be used to check variation along the direction of travel.
5. Set out the catchcans no more than 5 metres apart. (For greater accuracy, use International Standard ISO 11545 maximum 3m apart.)
 - Ensure that the cans are in a straight line and that none will be displaced as the irrigator moves past.
 - Add at least two extra containers at the end to allow for changes in wind speed or direction.
 - If rain is likely, place another can away from the boom to record rain during the test. Any rain must be deducted from the amount caught in **each** catchcan.
6. When the irrigator has completely passed over all of the catchcans, measure and record the volumes in **each** container. Each volume **MUST** be written in the correct space on the field record sheet. If there is no catch can or no reading at a position, record it as an 'X'.
7. Measure and record the tyre sizes and pressures.
8. Measure and record the width (or diameter) of the wetting pattern near the end drive unit. Placing a peg or marker at the limits of throw, then measuring the distance between after the machine has passed is the simplest way.

Speed measurement

Note that the pivot must be moving (at its normal speed) throughout the test, otherwise the difference in flow rates between the inboard and outboard sprinklers will give incorrect results.

9. Record the control panel settings/readings.
10. Measure the pivot's speed by staking out a measured distance (say 10 m) around the **outer** wheel track and recording the time required for the end drive unit to travel between the stakes.

Measuring pressure and flow

11. Attach tees and fittings (figure 1) above the pressure regulator and emitter at selected emitters for measuring the pressure. Select several, at least one on the first span, one on the last span and one in between, or you can measure a known emitter from each span, say the 3rd last emitter of each span.
12. Record the make, model, nozzle size or colour of each emitter tested, and its span and position number.
13. When the system is operating, record the pressure of the selected emitters using the pressure gauge. Take a reading at the centre too.
14. When the system is operating, measure the flow rate by holding the large container of known volume under one emitter and timing how long it takes to fill. Record measurements from at least one emitter per span and note the span and emitter position numbers. If a flow meter is fitted, take a reading at the centre too.

Calculating the results

15. After taking all measurements, complete the calculations. As the calculations for a centre pivot are quite complex, it is best to put the figures into a computer spreadsheet and let the computer work out the results. These may be available from your irrigation advisor or agency. For those who prefer to avoid the use of the computer, the full procedure is detailed in these notes.
16. Rank the volumes starting with the lowest amount, (1st, 2nd 3rd, and so forth). Do this for about one third of the cans.
17. Calculate the "weighted catch" by multiplying the volume collected in the catchcan by the position number of that catchcan. Follow the steps in your field record sheet.
18. Calculate the Average Application Depth per pass of your system using the Average Application Depth Table. Record the results in the Application Results table.
19. Calculate the Distribution Uniformity (DU) of your system using the DU Table. Record the results in the Application Results table.

Table 1: Wind Speed

Wind speed guide		
Visible effect	Wind description	Speed (knots)
Calm. Smoke rises vertically.	Calm.	00
Direction of wind shown by smoke drift but not wind vane.	Light air.	02
Wind felt on face. Leaves rustle. Vane moved by wind.	Light breeze.	05
Leaves and small twigs in constant motion. Wind extends light flag.	Gentle breeze.	09
Raises dust and loose paper. Small branches are moved.	Moderate breeze.	13
Small trees in leaf begin to sway. Crested wavelets on inland waters.	Fresh breeze.	18
Large branches in motion. Whistling heard in telegraph wires.	Strong breeze.	24
Whole trees in motion. Inconvenience felt when walking against wind.	Moderate gale.	30
Breaks twigs off trees. Generally impedes progress.	Fresh gale.	37
Slight structural damage occurs.	Strong gale.	44
Trees uprooted. Considerable structural damage. Seldom experienced inland.	Whole gale.	52
Very rarely experienced. Accompanied by widespread damage.	Storm. Hurricane.	60 68

Source: Bureau of Meteorology

Centre pivot data sheet – example

Property name: Roundabout		Date of field test: 16/8/00	
Crop	Lucerne		
Location/block	Paddock 2 block 3		
Soil texture of Block	Sandy loam over sand		
Effective root depth	1.0	metres	
Rootzone RAW	48	mm	
Max. infiltration rate	60	mm/h	
Irrigator make	Dizzy Lizzy		
Designed Flow Rate	840 USGPM 53.0 L/s 0.19 ML/hr		
Designed pressure (at centre)	25	psi	175 kPa
Number of Spans	6		
Total length of spans (pivot radius to outer tower)	324	metres	
Emitter make	Nelson		
Emitter model	R3000 Rotators		
Number of emitters along span	20		
Length of overhang	25	metres	
Wetted width (diameter) – end span	8	m	
Number of emitters on overhang	8 sprinklers		
End gun present	Yes	No	
End gun radius	0		
Pressure regulated?	Yes	No	
Wind direction and speed during test	Light Breeze		
Catchcan Diameter	113	mm	
Catchcan spacing	6	metres	
Speed setting and depth applied – control panel			
Time to travel test distance	12	minutes	9 seconds
Distance travelled	10	metres	

Centre pivot data sheet

Property name:

Date of field test:

Crop			
Location/block			
Soil texture of Block			
Effective root depth	metres		
Rootzone RAW	mm		
Max. infiltration rate	mm/h		
Irrigator make			
Designed Flow Rate	USGPM	L/s	ML/hr
Designed pressure (at centre)	psi	kPa	
Number of Spans			
Total length of spans (pivot radius to outer tower)	metres		
Emitter make			
Emitter model			
Number of emitters along span			
Length of overhang	metres		
Wetted width (diameter) – end span	metres		
Number of emitters on overhang			
End gun present	Yes	No	
End gun radius	metres		
Pressure regulated?	Yes	No	
Wind direction and speed during test			
Catchcan Diameter	mm		
Catchcan spacing	metres		
Speed setting and depth applied – control panel			
Time to travel test distance	minutes	seconds	
Distance travelled	metres		

Irrigation System Calculations – example

Wetted area	$= \pi \times (\text{radius})^2 \div 10,000$ $\approx 3.14 \times (\text{pivot radius} + \text{length of overhang} + \text{end gun radius})^2 \div 10,000$ $\approx 3.14 \times (324 + 25 + 0)^2 \div 10,000$ $\approx 3.14 \times (349)^2 \div 10,000$ $\approx 3.14 \times 121,801 \div 10,000$ $\approx 38.2 \text{ ha}$	WA
Distance Travelled	10 metres	A
Time for distance travelled	12 minutes 9 seconds = 729 seconds	B
Travel Speed = Distance travelled	+ Test Duration (seconds) x 3600	
	$= A \div B \times 3600$ $= 10 \div 729 \times 3600$ $= 49.4 \text{ metres per hour}$	C
Pivot Radius (length to outer track)	324 metres	R
Circumference (outer wheel track)	= 2 x π x pivot radius	
Circumference	$= 6.28 \times R$ $= 6.28 \times 324$ $= 2,035 \text{ metres}$	E
2 x $\pi \approx 6.28$		
Time for one revolution = Circumference	÷ Travel speed	
	$= E \div C$ $= 2,035 \div 49.4$ $= 41.2 \text{ hours}$	F

Irrigation System Calculations

Wetted area	$= \pi \times (\text{radius})^2 \div 10,000$ $\approx 3.14 \times (\text{pivot radius} + \text{length of overhang} + \text{end gun radius})^2 \div 10,000$ $\approx 3.14 \times (\quad + \quad + \quad)^2 \div 10,000$ $\approx 3.14 \times \quad \div 10,000$ $\approx \quad \text{ha}$	WA
Distance Travelled	metres	A
Time for distance travelled	minutes seconds	B
Travel Speed = Distance travelled	\div Test Duration (seconds) x 3600	
	$= A \div B \times 3600$ $= \quad \div \quad \times 3600$ $= \quad \text{metres per hour}$	C
Pivot Radius (length to outer track)	metres	R
Circumference (outer wheel track)	$= 2 \times \pi \times \text{pivot radius}$	
Circumference	$= 6.28 \times R$ $= 6.28 \times \quad$ $= \quad \text{metres}$	E
Time for one revolution = Circumference	\div Travel speed	
	$= E \div C$ $= \quad \div \quad$ $= \quad \text{hours}$	F

Checking System Capacity

System Capacity or	= Daily pump flow rate (L/day) ÷ Field irrigated area (m ²) = Pump flow rate (ML/day) x 100 ÷ Field irrigated area (ha)	
Daily pump flow rate	= L/s = x 3600 secs x 24 hrs L/day = L/day = ML/day	
System Capacity	= ÷ m ² = mm/day	

Max daily crop water use = Max daily Point Potential ETo x Crop Coefficient (Kc)		
Max daily PPETO	mm/day	ETo
Peak Kc		Kc
Max daily crop water use (CWU)	= ETo x Kc = x = mm/day	CWU

Allowance must be made for:

- Pump Utilisation Ratio (P.U.R) – the proportion of the total possible time that pumping is actually occurring. This may be reduced for spraying, cultivating, machine and pump maintenance, dry movement of lateral move, refuelling, etc.
- Application Efficiency (Ea) – loss of water between the nozzle and root zone

This is the **Managed** System Capacity, and it should be at least equal to max. daily CWU.

Pump Utilisation ratio:		PUR
Application Efficiency:		Ea
Managed System Capacity	= System Capacity x P.U.R x Ea = x x =	
Is Managed System Capacity adequate?		

Check tyre pressures

Tyre size:		
Tyre pressures – recommended	kPa	psi
Tyre pressures – measured	kPa	psi

Field Record Sheet – example

If there is access to a computer program, only fill in columns A and B of this table. The computer will do the rest.

For Centre Pivots, DU must be calculated using **weighted** catch can readings. The following procedure uses weighted readings.

If you use a computer spreadsheet, ensure it uses weighted catch can readings.

Span #	Catchcan position number	Volume collected in can (mL)	Ranked volume	Weighted catch A x B
	A	B		C
1	1	X		
1	2	X		
1	3	X		
1	4	X		
1	5	X		
1	6	X		
1	7	X		
1	8	X		
1	9	X		
2	10	183		1830
2	11	221		2431
2	12	202		2424
2	13	209		2717
2	14	175	11	2450
2	15	206		3090
2	16	183		2928
2	17	177		3009
2	18	168	10	3024
3	19	143	6	2717
3	20	197		3940
3	21	177		3717
3	22	237		5214
3	23	197		4531
3	24	211		5064
3	25	189		4725
3	26	206		5356
3	27	191		5157
4	28	157	7	4396
4	29	210		6090
4	30	238		7140
4	31	250		7750
4	32	330		10560

4	33	272		8976
4	34	167	8	5678
4	35	259		9065
4	36	244		8784
5	37	142	5	5254
5	38	184		6992
5	39	208		8112
5	40	230		9200
5	41	224		9184
5	42	227		9534
5	43	212		9116
5	44	176		7744
5	45	189		8505
6	46	136	4	6256
6	47	168	9	7896
6	48	191		9168
6	49	194		9506
6	50	175	12	8750
6	51	224		11424
6	52	221		11492
6	53	187		9911
6	54	227		12258
O'hang	55	115	1	6325
O'hang	56	187		10472
O'hang	57	136	3	7752
O'hang	58	133	2	7714
	59			
	60			
	61			
Totals: TN = 1,666			TC =	325,328

Conversion from Volume into depth

In order to convert Volume into depth (millimetres) a conversion factor is needed. The conversion factors are listed in the table on this page. Select the conversion factor by measuring the diameter of the mouth of the catchcan

For instance, if the diameter of the catchcan is 110 mm then the conversion factor from Table 2 will be 9.5 (circled).

If the cans collected 674 mL, then the conversion is the volume divided by the conversion factor;

$$674 \text{ mL} \div 9.5 = 71 \text{ mm}$$

Therefore the depth of water applied was 71 mm.

For catch-cans of 110 to 115 mm diameter across the top, dividing the collected amount by 10 to get mm of irrigation is likely to be accurate enough.

For instance if you collected 674 mL, this approximates closely to a depth of 67.4 mm.

Table 2. Converting mL to mm

Diameter of catchcan (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, use

$$\text{"water collected in mL"} \div 40 = \text{..... mm}$$

Calculating Average Application Depth and Average Application Rate – example

Average Application	= Total of weighted catch cans ÷ Total of catch can numbers ÷ Conversion factor	
Total of catchcan numbers Add up the numbers in Column A where water was collected in the can. Ignore empty can numbers.	1,666	TN
Total of weighted catches Add up the numbers in Column C.	325,328	TC
Conversion Factor (Table 2) Our catchcans were 113 mm diameter	10.0	CF
Average Application Depth (AAD) per pass	$= \text{TC} \div \text{TN} \div \text{CF}$ $= 325,328 \div 1,666 \div 10.0$ $= 19.5 \text{ mm}$	AAD
Wetted width – end span	8 metres	WW
Average Application Rate (AAR) = emitter flow (L/h) ÷ (wetted width x emitter spacing)		
Emitter spacing2.7..... metres	ES
Emitter flow for Span: 6 Emitter no.: 1200.83..... L/s	EF
AAR	$= (\text{EF} \times 3600) \div (\text{WW} \times \text{ES})$ $= (0.83 \times 3600) \div (8 \times 2.7)$ $= 2988 \text{ L/h} \div 21.6$ $= 138 \text{ mm/h}$	AAR

Transfer the AAD figure to the Application Results Table (earlier).

AAR should be compared to the infiltration rate of the soil. If the AAR at the outer end of centre pivot is much greater than the infiltration rate, runoff will occur. Methods of reducing this problem should be investigated eg. installing outlets with a larger wetted diameter, increasing soil organic matter, using soil conditioners, etc.

Calculating Average Application Depth and Average Application Rate

Average Application	=	Total of weighted catch cans	÷	Total of catch can numbers	÷	Conversion factor	
Total of catchcan numbers Add up the numbers in Column A where water was collected in the can. Ignore empty can numbers.							TN
Total of weighted catches Add up the numbers in Column C.							TC
Conversion Factor (Table 2) Our catchcans were 113 mm diameter							CF
Average Application Depth (AAD) per pass	=	TC	÷	TN	÷	CF	AAD
	=		÷		÷		
	=					mm	
Wetted width							WW
Average Application Rate (AAR) = emitter flow (L/h) ÷ (wetted width x emitter spacing)							
Emitter spacing			 metres			ES
Emitter flow for Span: ____ Emitter no.: ____			 L/s			EF
AAR	=	(EF x 3600)	÷	(WW x ES)			AAR
	=	(x 3600)	÷	(x)			
	=		÷			L/h	
	=					mm/h	

Transfer the AAD figure to the Application Results Table (earlier).

AAR should be compared to the infiltration rate of the soil. If the AAR at the outer end of centre pivot is much greater than the infiltration rate, runoff will occur. Methods of reducing this problem should be investigated eg. installing outlets with a larger wetted diameter, increasing soil organic matter, using soil conditioners, etc.

Calculating the Distribution Uniformity (DU)

For Centre Pivots, DU must be calculated using weighted catch can readings. The following procedure uses weighted readings.

If you use a computer spreadsheet, ensure it uses weighted catch can readings.

- Step 1** Determine the lowest quarter limit (LQ limit)
 where LQ limit = Cumulative catchcan No. (TN) ÷ 4
- Step 2** Use the Lowest Quarter Catch table to add up the figures in column C of the Field record sheet, starting at the lowest volume rank (1st).
- Step 3** Continue to add the weighted catch until the total exceeds the figure for LQ limit. Use the figure before this, so the total is less than LQ limit.
- Step 4** The figures you have added are your LQ catches – shade or highlight them on your Field record sheet
- Step 5** Follow the steps in the Distribution Uniformity Table
- Step 6** Record your results in the Application Results Table

Lowest Quarter Catch Can Table – example

Rank	Catchcan position No.	Cumulative Catchcan No.	Weighted Catch C	Cumulative Weighted Catch
1	55	55	6325	6325
2	58	113	7714	14039
3	57	170	7752	21791
4	46	216	6256	28047
5	37	253	5254	33301
6	19	272	2717	36018
7	28	300	4396	40414
8	34	334	5678	46092
9	47	381	7896	53988
10	18	399	3024	57012
11	14	413	2450	59462
12	50	463	8750	68212
13				
14				

$$\begin{aligned}
 \text{LQ limit is Cumulative Catchcan No.} &= \text{TN} \div 4 \\
 &= 1,666 \div 4 \\
 &= 416.5
 \end{aligned}$$

413 is the closest to this, so the rank 11 catch, catch can no. 14, is the last LQ amount (highlighted above).

Thus the Low Quarter Weighted Catch is 59,462.

Lowest Quarter Catch Can Table

Rank	Catchcan position No.	Cumulative Catchcan No.	Weighted Catch C	Cumulative Weighted Catch
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

LQ limit is Cumulative Catchcan No. = $TN \div 4$
 = $\quad \div 4$
 =

_____ is the closest to this, so the rank _____ catch, catch can no. _____ is the last LQ amount (highlighted above).

Thus the Low Quarter Weighted Catch is _____

Distribution Uniformity – example

Lowest quarter Limit	= TN ÷ 4	
	= 1,666 ÷ 4	LQ Limit
	= 416.5	
Lowest quarter Depth	= Total Lowest quarter weighted volumes ÷ Total lowest quarter can positions ÷ conversion factor	
From the LQ Table, find the Cumulative Catchcan Number closest to LQ Limit.	= 413	TNLQ
From the LQ Table, find Cumulative Weighted Catch for TNLQ.	= 59,462	TCLQ
Lowest quarter depth	= TCLQ ÷ TNLQ ÷ CF = 59,462 ÷ 413 ÷ 10 = 14.4 mm	LQ depth
Distribution Uniformity	= LQ Depth ÷ AAD x 100	
	= 14.4 ÷ 19.5 x 100 = 0.74 x 100 = 74 %	DU
Transfer the DU figure to the Application Results Table (earlier).		

Distribution Uniformity

Lowest quarter Limit	$= \text{TN} \div 4$	
	$= \div 4$	LQ Limit
Lowest quarter Depth	$= \frac{\text{Total Lowest quarter weighted volumes}}{\text{Total lowest quarter can positions}} \div \text{conversion factor}$	
From the LQ Table, find the Cumulative Catchcan Number closest to LQ Limit.	$=$	TNLQ
From the LQ Table, find Cumulative Weighted Catch for TNLQ.	$=$	TCLQ
Lowest quarter depth	$= \frac{\text{TCLQ} \div \text{TNLQ}}{\text{CF}}$ $=$ $= \text{mm}$	LQ depth
Distribution Uniformity	$= \frac{\text{LQ Depth}}{\text{AAD}} \times 100$	
	$= \div \times 100$ $= \times 100$ $= \%$	DU
Transfer the DU figure to the Application Results Table (earlier).		