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RAINFALL HARVESTING TO ESTABLISH TREES AND SHRUBS ON FLAT, SANDY SOIL IN THE ARID ZONE

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Abstract

Seven surface materials on man-made rainfall catchments for single trees were evaluated as to their effect on collecting rainfall run-off to aid tree and shrub establishment on flat sandy soils in arid zones. The aim being to develop a catchment system that can substitute entirely for supplementary watering in arid zones.

Large variability in run-off occurred. After nine months residual herbicides were ineffective and weed germination broke up the surface materials and reduced run-off. Dry soil at the time of application of the surface materials also may have reduced their effectiveness. However, catchments sealed with cut-back bitumen tended to give more run-off than those sealed with a cement render or silicon products (silicone emulsion plus polymer latex, and sodium methyl siliconate). The 1.2 l/m² rate of cut-back bitumen tended to be giving more run-off than the 0.6 l/m² rate.

A catchment size of 4 m² treated with 1.2 l/m² of cut-back bitumen potentially substituted for three hand waterings, representing nett cost savings. Also, with this treatment, 2 mm of rain was sufficient to give a benefit to plants in the first year of its application, by shedding 3–4 l of run-off, providing it falls close to a few other small events or one larger one.

The practicality of applying the different surface treatments and the future directions are discussed.

Introduction

Making water available to plants is one of the most costly exercises of tree planting in the arid zone. If trees and shrubs are to be established in areas where piped water is not available, then water has to be carted to the trees. The contract cost of such watering was estimated to be 50¢ per plant per watering in 1985 (Kealley 1987). Various watering formulas are practised in the arid zone. Sandell *et al.* (1986) followed a program that meant up to 14 waterings in the first six months, but Kealley (1987) only used 8 waterings in the first year. Therefore, allowing for inflation, the minimum watering cost would be $6.56 per plant per year (1993 dollars), but in most situations it is likely to be far more than this.

Water can be made available to plants by watering, mulching, weed removal, fallowing and rainfall harvesting.

Dalton (1992) proposed that the most economical means of supplying seedlings with water is likely to be a combination of weed control with waterings during extended dry periods. This was tested using the following formula: water with 40 litres every 28 days, but if 25 mm or more rain occurs within a two day period, then defer the watering until 28 days after this rain. Plants did not do well when watering was reduced below this level (Dalton, unpublished data). Long term rainfall records from Port Augusta indicate that this formula would require an average of 8 waterings per plant per year (Bureau of Meteorology, Adelaide).

[1] We acknowledge the assistance of Tony Johnson, Parks Superintendent, City of Port Augusta and the funding provided by ETSA and the City of Port Augusta to enable the realisation of this trial.

Mulching is of known benefit in conserving moisture in heavy textured soils (Handreck & Black 1984), but is of little benefit on sandy soils, which are often 'self-mulching'. Organic mulch was of negligible benefit on a sandy soil at the Australian Arid Lands Botanic Park (AALBP) in a seedling planting trail in 1986 (Dalton 1992). Vermiculite plus paint or bitumen improved emergence of salt bushes (Malcolm & Swaan 1985), but the benefit is only for emergence and not long term growth.

Thus, the effects of watering, weed control and mulching on seedling survival and growth in arid zones is largely understood. Fallowing and rainfall harvesting have not been evaluated.

From the aspect of water storage, there is little to be gained from fallowing deep sands (French *et al.* 1968). Rainfall harvesting to concentrate water run-off at the seedling is used extensively in Israel, even in areas with as little rainfall as 80 mm per annum (Wilson 1980), but mainly on sites that are sloping and have a high run-off factor (either naturally or induced). Sandy and relatively flat sites would have to be formed into sloping catchments and possibly sealed to induce run-off and prevent erosion.

The aim of this work was to evaluate man-made single tree rainfall catchments for plant establishment on a flat, sandy, arid site, in order to try and establish seedlings without watering. With such large areas of the world being arid and sandy, such techniques have a potentially large scope and cost savings.

Materials and methods

(i) *Trial site*

The site was at the AALBP, Port Augusta, South Australia; latitude 32°32'24"; longitude 137°46'50"; altitude 4.34 m; average maximum temperature 32°C; average minimum temperature 7.3°C; mean annual rainfall 257 mm; mean relative humidity (3 p.m.) 38.6%; mean annual pan evaporation 2500 mm.

The soil is a mainly structureless, apedal, red clayey sand of two metres deep. The existing vegetation consists of *Maireana sedifolia, Sclerolaena obliquicuspis, Atriplex holocarpa, Sida intricata, Carrichtera annua, Enneapogon avenaceus*, and a *Stipa* sp.

(ii) *Catchment surface materials*

Methods and compounds with which soil surfaces have been sealed to improve water run-off include non-permeable bitumen (Laing 1981), paraffin waxes (Frasier *et al.* 1979), sodium salts (which break down structure of heavy soils) and plastic sheets (Wilson 1980) and silicone compounds (Plueddemann 1975). Also, Hudson (1987) reviews the work of others who have used crude oil, compaction, compaction with added clay, and concrete.

For tree seedling establishment a catchment would have to remain effective for at least two years. Cut-back bitumen at the rate of 1.2 l/m² has given 65% run-off and was still 7.5% intact after four years (Laing 1981). Therefore, after two years it may still be giving beneficial amounts of run-off. The effectiveness of a lower rate of bitumen has not been assessed. Plueddemann (1975) found that silicon emulsion was effective when bound with a polymer latex to give stability on the soil. Plueddemann cites Hillel (1976) that sodium methyl siliconate on large areas was 'fairly effective and surprisingly durable over a three year period, but it allowed soil erosion'. Such erosion may not be a problem on small individual tree catchments.

Cement is a readily available material, that is comparable in cost to bitumen (Table 1). Spreading cement onto sand, lightly raking it in and watering it was tried but was difficult to mix evenly in situ. A 1:4 premix of cement and sand (plus water) rendered over the soil gave a sealed surface.

The other methods and products mentioned in the literature are unsuitable for use because of unavailability, lack of suitability to the soil type under investigation, practicality of application, run-off effectiveness and price.

The following surface treatments and their costs are detailed below:

Product	Cost per m²
Bare soil	$0.00
Silicone emulsion (Dow Corning® HV 490) plus polymer latex binder at 1:3 ration, diluted to 3% silicone solids and applied at 0.25 l/m²	$0.29
Silicone emulsion (Dow Corning® HV 490) plus polymer latex binder at 1:3 ration, diluted to 1.5% silicone solids and applied at 0.25 l/m²	$0.46
Sodium methyl siliconate (Dow Corning® 772) at 3% solids and applied at 0.25 l/m²	$0.29
Cement render (5–8 mm)	$0.58
Cut-back bitumen (Shell AMC 00) at 0.6 l/m²	$0.30
Cut-back bitumen (Shell AMC 00) at 1.2 l/m²	$0.60

Table 1. Cost of products (1993 Australian dollars)[2]

(iii) *Catchment formation*

Rainfall data was used to help decide the catchment area. The rainfall data at the Port Augusta power station (2 km from the trial site), had been kept from July 1985 to June 1988 (Table 2). It is doubtful whether the falls of 2 mm or less (62% of the total falls) would be worth harvesting because of evaporation and surface tension. Falls of 24 mm or more would be useful (maybe even damaging if concentrated on one spot). Somewhere between 2 and 24 mm the falls would become useful, depending on the size of the catchment as well as environmental conditions.

Another factor determining the usefulness of a fall is the amount of water placed near a seedling considered to be of benefit to that seedling. This could arbitrarily be set at 20 litres. The volume of water harvested by rainfall event is described by the following formula:

Volume (l) = Rainfall (mm) × catchment area (m²) × percentage run-off

Using this formula, the information in Table 2, and (as an example) the 65% run-off achieved with cut-back bitumen (Laing 1981), the following can be calculated:

Catchment area (m²)	Rainfall required (mm) to harvest 20l	Number of rainfall events in which 20l or more is likely to be harvested
1	30.8	0
2	15.4	4.9
3	10.3	8
4	7.9	9

[2] Mention of a trade name does not imply preference of a product.

Obviously one m^2 catchments would be of no use. Two m^2 catchments are unlikely to be an effective substitute for waterings because it is unlikely with erratic rainfall distribution of arid zones that the 4.9 beneficial rainfall events will occur at times critical to seedling survival. Three or four m^2 catchments would increase the chance of sufficient water being harvested to substitute for hand watering; to maximise this chance, 4 m^2 was used.

The soil was formed into a slope using a road grader. A 7% slope was used as this minimises bitumen redistribution (Plueddemann 1975). After the soil was graded, 2 × 2 m catchments were delineated with 200 × 2 mm galvanised metal strips on three sides and roof guttering on the lowest side. This delineation helped avoid run-on from the upslope and it set and kept the catchment shape constant. A lip of the guttering sat on the soil surface so that surface materials could be sprayed onto it and create a continuous flat surface from the soil to the guttering (Fig. 1). Residual herbicide (oxyfluorfen at 1.2 kg/ha a.i. and oryzalin at 2.5 kg/ha a.i.) was applied to each catchment prior to applying the surface treatments. However, the ground was dry at the time of application, which is not ideal for residual herbicides. Glyphosate at 1.08 kg/ha a.i. was used to control weed germination on the plots after application of the surface materials.

The guttering directed the run-off water into 45 L collection tank which were in excavated pits. Soil collapse into the pits was prevented by lining the pits with steel cylinders. A rain gauge was installed in the centre of the trial area.

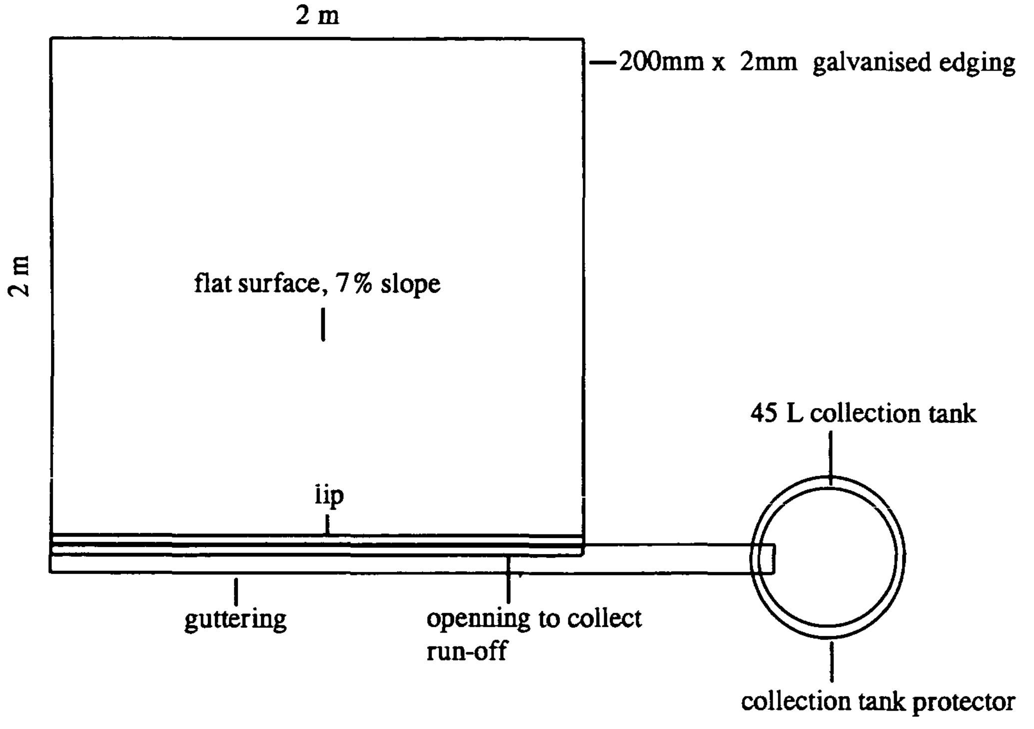

Fig. 1. Plan view of a 4 m^2 rainfall catchment showing edging, flat surface, guttering, lip, collection tank and collection tank protector.

(iv) *Design*

A randomised complete block design of three replicates, with two control treatments per replicate, was used. The rainfall reading and collection volume was measured at 9:00 a.m. daily, from the 1.v.1990 to the 28.ii.1991 to establish initial runoff, and from the 1.ii. to the 31.v.1992 to evaluate the effectiveness of the treatments after two years. Full collection tanks were recorded as 45+ l and less than 0.05 l was recorded as 0.

Rainfall range (mm)	Number of falls	Percentage of falls
< 1.0	40	48.8
1.1 - 2.0	10.3	12.6
2.1 - 3.0	7.3	8.9
3.1 - 4.0	4.7	5.7
4.1 - 5.0	4.3	5.2
5.1 - 6.0	2.0	2.4
6.1 - 7.0	2.7	3.3
7.1 - 8.0	1.7	2.1
8.1 - 9.0	0.3	0.4
9.1 - 10.0	0.7	0.9
10.1 - 12.0	1.7	2.1
12.1 - 14.0	0.7	0.9
14.1 - 16.0	0.7	0.9
16.1 - 18.0	0.7	0.9
18.1 - 20.0	1.3	1.6
20.01 - 22.0	0.3	0.4
22.1 - 24.0	0.3	0.4
>24.0	2.3	2.8
	82.0	

Table 2. Frequency of rainfall events of varying intensities (24 hour period). Average figures for the Port Augusta power station from July 1985 to June 1988.

Results and discussion

(i) *Effect of weeds*

Oxyfluorfen at 1.2 kg/ha a.i. (active ingredient) and oryzalin at 2.5 kg/ha a.i. controlled the weeds on the plots for nine months despite the dry soil at the time of application. After this large numbers of weeds emerged and broke up the bitumen, and to a lesser extent, the silicon crusts. Laing (1981, cited Kelsall 1968 and Laing & Prout 1975) reported that weed growth through bitumen catchments can destroy the catchment surface. The cement probably experienced less of a weed problem because it would have been more impermeable than other surface materials and too thick for weeds to penetrate, except through cracks.

(ii) *Annual rainfall*

A total of 175 mm of rain was recorded in the 12 months following the 1.v.1990. However, approximately 333 mm was recorded in the second 12 months. Fifty years of records from Port Augusta Post Office (1937 – June 1962 (2 km from trial site)) and Port Augusta Power Station (July 1962 – 1987) show that annual rainfalls of up to 175 mm only occur in 22% of years. Which means that higher rainfalls and greater run-off would have been received in 78% of years. Also, annual rainfalls of over 333 mm only occur in 12% of years (Bureau of Meteorology, Adelaide). The extremely wet second year of the trial may have contributed to an early deterioration of the surface materials.

(iii) *Initial poor treatments*

After four months measurements were discontinued on the silicon emulsion/latex treatments and the bare soil control plots because they were giving negligible run-off in comparison to the other treatments (Table 3). Poor results from these treatments may have been caused by permeability, or cracking in the surface before weed emergence became a problem, or surface tension withholding water. The silicon emulsion/latex treatments remained cracked from the start, possibly due to it being applied to dry soil. Attempts to seal the cracks with more silicon emulsion/latex were generally ineffective.

Plueddemann (1975) found that silicon emulsion was an effective surface sealant when bound with a polymer latex. However, his trial was conducted under controlled conditions.

Date		170590	210590	220590	230590	300590	120690	150690	160690	240690	300690
Rain (mm)		20	9	15	2	2	8.2	3	4	7.2	2.2
Rep	T										
1	1	45+	0.25	1.6	0	0	0.8	0.1	1.4	1.1	0
2	1	16.5	0.2	2.0	0	0	0.7	0.2	0.4	0.6	0
3	1	24.0	0	1.4	0	0	0.5	0	0.2	0	0
1	2	22.5	0.5	1.0	0.2	0.1	0.9	0.2	0.8	0.9	0.1
2	2	7.5	0.6	1.7	0	0	0.7	0.2	0.4	0.6	0
3	2	6.5	0.5	1.7	0	0	1.3	0.4	0.5	1.2	0
1	3	25.5	1.5	6.2	0.7	0	1.7	0.5	1.5	1.5	0
2	3	27.0	0.5	3.2	0	0	1.3	0.3	0.6	0.9	0
3	3	27.0	0.8	2.5	0.1	0	1.3	0.4	0.7	1.2	0
1	4	45+	10.5	36.0	2.0	1.0	9.0	2.6	5.8	9.2	1.0
2	4	45+	1.7	9.3	0.3	0.1	1.7	0.7	2.2	3.6	0.2
3	4	45+	3.3	8.0	0	1.1	5.8	1.9	5.0	10.5	1.2
1	5	45+	7.2	16.5	3.2	1.8	7.5	2.1	5.8	8.3	1.8
2	5	45+	6.8	18.3	3.3	2.5	10.6	2.7	7.3	11.2	2.5
3	5	45+	0.4	19.6	2.3	2.0	7.8	2.5	6.7	8.1	2.1
1	6	45+	12.2	28.0	2.5	1.5	7.5	1.8	2.5	6.6	1.4
2	6	45+	20.5	45+	3.6	2.4	7.8	3.3	6.2	9.6	2.4
3	6	45+	15.7	9.0	4.5	2.4	6.9	3.1	5.6	6.9	2.5
1	7	45+	32.0	45+	6.2	3.2	19.2	6.6	7.5	15.2	3.0
2	7	45+	21.3	45+	0.5	4.2	23.8	8.1	12.0	19.8	4.4
3	7	45+	4.0	9.2	4.4	3.1	17.5	4.0	6.7	13.8	3.2
1	8	29.5	0.3	1.5	0	0	0.9	0	1.1	0.6	0
2	8	45+	0.15	1.5	0	0	1.5	0.2	1.0	1.6	0
3	8	35.0	0.3	1.4	0	0	1.2	0	1.5	1.3	0

Table 3. Run-off (l) collected from each treatment and replicate for each rainfall event in the first year of the trial.

Note: 45 l is at over flow
Less than 50 ml is recorded as 0
Rep = replicate
T = Treatment:
1. Bare soil
2. Dow Corning® HV 490 (silicone emulsion) plus polymer latex binder at 1:3 ratio, diluted to 3% silicone solids.
3. Dow Corning® HV 490 (silicone emulsion) plus polymer latex binder at 1:3 ratio, diluted to 1.5% silicone solids.
4. Dow Corning® 772 (sodiummethyl siliconate) at 3% solids.
5. Cement render.
6. Cut-back bitumen at 0.6 l/m².
7. Cut-back bitumen at 1.2 l/m².
8. Bare soil.

DATE		020790	030790	070790	100790	120790	130790	200890	110990	071090	201090	091290	220191	230191
Rain (mm)		2	1.5	6	2	2.5	1	2.5	6.8	9	3	3	7	7
Rep	T													
1	1	0	0	0.4	0	0.1	0	0.1						
2	1	0	0	0.5	0	0.2	0	0.2						
3	1	0	0	0.6	0.1	0.2	0	0.2						
1	2	0.1	0	0.4	0.2	0.3	0.1	0.3						
2	2	0	0	0.2	0	0.2	0	0.2						
3	2	0.1	0	0.7	0.2	0.2	0	0.2						
1	3	0	0	0.25	0	0.3	0	0.3						
2	3	0	0	1.1	0	0.1	0	0.2						
3	3	0	0	0.5	0.1	0.2	0	0.2						
1	4	1.0	1.0	8.2	1.1	1.5	0	1.5	2.8	3.5	0	2.5	2.8	2.9
2	4	0.1	0	1.7	0.2	0.3	0.1	0.3	0	0.9	0	0.7	0.1	0.1
3	4	1.1	0.8	5.7	1.2	1.3	0.9	1.3	•	•	0	1.9	10.6	10.5
1	5	1.8	1.6	0.45	1.9	1.9	0	1.9	0	2.1	0	2.1	0.1	0.1
2	5	2.6	2.4	0.2	2.6	2.7	0	2.7	0.1	0.9	0	0.7	0.1	0.1
3	5	2.0	1.8	0.4	2.1	2.2	0	2.3	0.8	2.4	0	2.4	0.8	0.8
1	6	1.5	1.2	4.5	1.55	1.45	0.15	1.5	11.2	1.7	0	1.6	11.3	11.3
2	6	2.5	2.4	11.4	2.5	2.6	0.15	2.6	0.1	4.1	0	3.1	0.1	0.1
3	6	2.4	2.0	4.8	2.6	2.6	0.3	2.6	0.1	1.4	0	3.0	0.1	0.1
1	7	3.3	3.2	16.2	3.3	3.3	0.5	3.3	1.5	33.0	2.5	6.0	1.6	1.6
2	7	4.2	4.1	16.9	4.3	4.3	0.8	4.5	6.8	36.5	1.8	8.0	6.9	6.9
3	7	3.2	3.2	12.7	3.2	3.3	0.6	3.3	8.8	5.2	0	4.1	8.8	8.9
1	8	0	0	0.2	0	0	0	0.2						
2	8	0	0	0.2	0.1	0.1	0	0.1						
3	8	0	0	0.7	0.1	0.1	0	0.2						

Table 3 cont. Run-off (l) collected from each treatment and replicate for each rainfall event in the first year of the trial.

Note: 45 l is at over flow
Less than 50 ml is recorded as 0
Rep = replicate
T = Treatment:

1. Bare soil
2. Dow Corning® HV 490 (silicone emulsion) plus polymer latex binder at 1:3 ratio, diluted to 3% silicone solids.
3. Dow Corning® HV 490 (silicone emulsion) plus polymer latex binder at 1:3 ratio, diluted to 1.5% silicone solids.
4. Dow Corning® 772 (sodiummethyl siliconate) at 3% solids.
5. Cement render.
6. Cut-back bitumen at 0.6 l/m².
7. Cut-back bitumen at 1.2 l/m².
8. Bare soil.

DATE	COMMENTS	DATE	COMMENTS
220590	Steady misty rain, 15–20 knot wind.	200890	Misty showers, mild to warm.
300590	Rain fell in two minutes.	110990	This is the first data with unrequired plots omitted. Lid from bin 3 4 is missing - presumed stolen.
150690	Rain in one heavy shower.	071090	Lid on bin 3 4 still missing, but replaced from now on.
160690	Light misty rain over 12 hours.	301090	Max temp = 39°C, winds in excess of 70 mph (at powerstation), thundery showers from N-NW.
240690	3 l-soil eroded from inside gutter edge.	091290	Cold with light drizzly rain.
100790	Light misty rain.	220191	Temp = 38°C, high humidity.
130790	Sprayed roundup® on weeds; light misty rain.	230191	Temp = 31.5°, "cool change".

(iv) *Statistical analysis*

The coefficients of variation ranged from 114% to 160% for all treatments, precluding any mathematical model describing the percentage run-off in response to the rainfall amount. For this reason, all the data has been included in Table 3 & 4.

This variation may be caused by irregularity in rainfall distribution and/or evaporation over the trial area and/or leaks in some of the catchments and/or including varying degrees of damage due to weed emergence. Variation from one rainfall event to the next may be explained by different rainfall intensities or evaporation rates on the catchments and is illustrated in Tables 5.

Date		290292	010392	270392	060492	020592
Rain (mm)		14.5	99	5	15	20
Rep	Treatment					
1	4	1.7	45+	0.2	2.1	1.2
2	4	1.5	45+	0	1.4	0
3	4	3.2	45+	*	3.5	2.7
1	5	3.6	45+	1.4	4.7	5.5
2	5	8.3	45+	1.3	1.7	2.1
3	5	3.6	45+	1.9	11.1	4.8
1	6	2.4	45+	0	1.5	1.3
2	6	2.3	45+	0.2	2.6	2.2
3	6	2.2	45+	0.1	2.0	2.3
1	7	2.5	45+	0.9	4.6	1.6
2	7	7.8	45+	1.4	9.3	6.2
3	7	2.4	45+	0	2.5	1.5

Table 4. Run-off (l) collected from each treatment and replicate for each rainfall event in the last four months of the trial.

Note: 45 l is at over flow
Less than 50 ml is recorded as 0
Rep = replicate
Treatment:
4. Dow Corning® 772 (sodium methyl siliconate) at 3% solids.
5. Cement render.
6. Cut-back bitumen at 0.6 l/m².
7. Cut-back bitumen at 1.2 l/m².

Date	Rainfall (mm)	TREATMENT			
		Sodium methyl siliconate	Cement render	Bitumen @ 0.6l/m²	Bitumen @ 1.2l/m²
21/5/90	9	3.3	0.4	15.7	4.0
12/6/90	8.2	5.8	7.8	6.9	17.5

Table 5. Run-off volume harvested (l) from replicate 3 showing variability of results from one event to the next event of a similar rainfall quantity.

(v) *Cut-back bitumen effectiveness*

Despite the variation, cut-back bitumen at 1.2 l/m² tended to give more run-off than the other treatments. After the first four months there was a total of 51 measurements for each treatment (3 replicates × 17 rainfall events), 38 of which had cut-back bitumen at 1.2 L/m² returning the most run-off (Table 3). However, after two years the surface materials had deteriorated significantly, to the point where not even a 20 mm rainfall was giving the arbitrary target of approximately 20 l from any of the surface materials. The deterioration over time is illustrated by Table 6.

Date	Rainfall (mm)	Sodium methyl siliconate	TREATMENT		
			Cement render	Bitumen @ 0.6l/m²	Bitumen @ 1.2l/m²
22/5/90	15	17.7 (29.5%)	18.1 (30%)	27.3 (45.5%)	33.1 (55%)
29/2/92	14.5	2.1 (3.5%)	5.2 (9%)	2.3 (4%)	4.2 (7.25%)

Table 6. Run-off (l and %) means for the four best surface materials for rainfall events 21 months apart. Note the deterioration in run-off over time.

There were four events out of 23, between May 1990 and January 1991, which produced the arbitrary target of 20 l or more of run-off from the 1.2 l/m² cut-back bitumen catchments (Table 7). Despite being a drier than average year, according to Dalton's proposed watering formula[3], potentially three hand waterings would have been saved by using the 1.2 l/m² bitumen catchments (Table 7).

Although four events produced at least 20 l run-off, two of these events occurred in one month, resulting in only three hand waterings being saved. This represents a saving in hand-waterings to the value of $2.46 for that period (1993 dollars). Although the cost of treating one bitumen catchment @ 1.2 l/m² is $2.40 (1993 dollars) (Table 1), this still represents a potential saving of $0.06 per plant.

Despite only three hand waterings being saved directly, there would also still be a considerable benefit derived from the other run-offs of below 20 l. Therefore the potential savings and value could be higher.

With 100% run-off of the rainfall listed in Table 7 (125.9 mm) a total of 503.6 l would have been caught from one 4 m² catchment in the first year of the trial. However, an average of 240 l was caught from the 1.2 l/m² of cut-back bitumen catchments (Table 7), which is 48% of the maximum possible run-off. After 21 months this had been reduced to less than 10% (Table 6). This is less than Laing 1981, who found that cut-back bitumen at the rate of 1.2 l/m² was giving 65% run-off and was still 7.5% intact after four years.

The 0.6 l/m² cut-back bitumen, although it cannot be statistically verified, was not producing as much run-off as the higher rate (Table 3 & 4). However, it was producing more run-off than the sodium methyl siliconate and cement in the first year of the trial. The 0.6 l/m² cut-back bitumen catchments experienced only one month throughout the trial in which a hand watering could potentially be saved. As it costs $1.20 to treat one catchment with 0.6 l/m² of cut-back bitumen and only one watering was spared, at a saving of $0.82, then this treatment cost an extra $0.38 per plant to use.

The low rate of bitumen tended to get ant holes, and germination of weeds were worse than any other treatment. In December 1990 the surface was showing marked signs of breaking up.

(vi) *Run-off threshold*

Referring to Table 3, although 1 mm of rain was producing run-off in the first year from 1.2 l/m² of cut-back bitumen, the quantities were not considered to be useful. Two mm of rain most often produced 3–4 l of run-off in the first year, which would have a minor effect by itself. However, if (depending on intensity) it falls close to a few other small events or one large event then 2 mm would be of some use.

[3] As per Introduction: water with 40 litres every 28 days, but if 25 mm or more of rain occurs within a two day period, then defer the watering until 28 days after this rain.

(vii) *Catchment size*

Considering the value of 2 mm rainfall events, the four events which gave in excess of 20 L run-off in the first year and the potential for substantial cost savings with the 1.2 l/m² cut-back bitumen catchments, as well as the likelihood of better years of rainfall than that of the first year of the trial, the area of 4 m² for catchments appears to be satisfactory. The catchments could be even more effective if the first year's percentage run-off could be maintained for two years.

(viii) *Sodium methyl siliconate and cement effectiveness*

Although the sodium methyl siliconate water repellent is reasonably priced (Table 2) it is toxic to handle, which forces operators to wear fully protective clothing and equipment. This can make application of this product uncomfortable during warm weather conditions, which are common in the arid zone. Also, this product appears to give less run-off than the bitumen treatments from rainfalls of less than 15 mm (Table 3 & 4). After eight months the 772 plots were showing signs of soil erosion, which can be a problem with this treatment (Plueddemann 1975).

Creating the cement render means that a considerable amount of time and effort is spent on each cement catchment, making it impractical to use for most projects. The cost of the product (Table 2) on top of labour costs further limits its suitability. Also, cement generally seemed to give low levels of run-off in the first year of the trial, in comparison to bitumen. However, it was marginally more durable than 1.2 l/m² of cut-back bitumen over the two years, but still unsatisfactory (Table 4). However this result is supported by Hudson (1987), who also noted that cement gave poorer levels of run-off than expected. This may be caused by evaporation, water disappearing down cracks in the surface or unevenness in the surface retaining water.

Month	Rainfall mm	Run-off mean (l)	Hand-watering necessary considering: run-off	rainfall only
May	20	45		*
	9	19		
	15	33		
	2	3.7		
	2	3.5		
June	8.2	20		*
	3	6		
	4	9		
	7.2	16		
	2.2	3.5		
July	2	3.5	*	*
	1.5	3.5		
	6	15		
	2	3.5		
	2.5	3.5		
	1	<1		
August	2.5	3.5	*	*
September	6.8	5.7	*	*
October	9	25		*
	3	1.5		
November	-	-	*	*
December	3	6	*	*
January	7	6	*	*
	7	6		
February	-	-	*	*
March	-	-	*	*
TOTAL	**125.9**	**240**		

Table 7. The mean run-off from the 1.2 l/m² cut-back bitumen treatment for each rainfall event in the first year. It also indicates whether hand-watering would be necessary each month, on the basis of the formula proposed by Dalton[4], with and without the caught run-off, considering the amount of rainfall during each month and the arbitrary target of approximately 20 l from rainfall catchments, which are discussed above.

[4] As per Introduction: water with 40 litres every 28 days, but if 25 mm or more of rain occurs within a two day period, then defer the watering until 28 days after this rain.

Conclusions

Cut-back bitumen at 1.2 l/m² is the most promising treatment for enhancing run-off. While bitumen is costly to apply at this rate in comparison to most other treatments (Table 2) and is difficult to apply it still returned a potential nett cost saving during the period of the trial. Cut-back bitumen at 0.6 L/m² has doubtful potential for effective rainfall harvesting over two years.

Better weed control into the second year would have resulted in much less damage to the catchments and higher levels of run-off over two years, especially from the cut-back bitumen treatments. Dry soil at the time of the application of the surface treatments may have contributed to a more rapid degradation which could be expected of many of the surfaces.

If rainfall harvesting on sandy soil is to be a reliable method of reducing the cost of tree establishment in the arid zone, weed control must be maintained for two years and a damp soil surface should be ensured before application of surface treatments.

On the basis of low run-off, cost, toxicity, rapid degradation and impractical application the following treatments should be excluded from recommendations and further trials for catchment enhancement: sodium methyl siliconate, cement, cut-back bitumen at 0.6 l/m² and bare soil. Silicon emulsion/latex may give better results if applied to damp soil, therefore should not be excluded from future work.

For practical purposes, rainfall catchments should be made with a grader, such that when it is travelling, the blade is lowered then raised to form a 4 m² scoop of 7% slope which would direct run-off to one plant. Using a grader to make catchments would be less time consuming and cheaper than creating basins for water carting or installing driplines.

References

Dalton, G. (1992). Establishing Native Plants in the Arid Zone. *J. Adelaide Bot. Gard.* 15(1): 65–70.

Frasier, G.W., Cooly, K.R. & Griggs, J.R. (1979). Performance Evaluation of Water Harvesting Catchments. *J. of Range Management* 32(6): 453–456.

French, R.J., Matheson, W.E. & Clarke, A.L. (1968). Soils and Agriculture of the Northern and York Peninsula Region of South Australia. *Dept of Agric., Special Bull.* No. 1. 68.

Handreck, K.A. & Black, N.D. (1984). "Growing media for ornamental plants and turf". N.S.W. University Press, pp. 236.

Hudson, N.W. (1987). "Soil and water conservation in semi-arid areas". *FAO Soils Bull.* 57.

Kealley, I. (1987). Successful Tree Establishment in an Arid Environment. A paper presented to the Workshop on Environmental Management in the Goldfields, Kalgoorlie, May, 1987.

Kelsall, K.J. (1968). Construction of bituminous surfaces for water supply catchment areas in Western Australia. Duplicated notes, Public Works Department, Western Australia.

Laing, I.A.F. & Prout, A.L. (1975). Bitumen, oil and clay surfaces on a deep sand to increase run-off from catchments for excavated tanks in Western Australia. Proc. Water Harvesting Symp., Phoenix, Arizona, 63–75.

Laing, I.A.F. (1981). Evaluation of small catchment surface treatments. Australian Water Resources Council Technical Paper No. 61. (Australian Govt Publishing Service: Canberra).

Malcolm, C.V. & Swann, T.C. (1985). Soil mulches and sprayed coatings and seed washing to aid chenopod establishment on saline soil. *Aust. Rangel. J.* 7(1): 22–28.

Plueddemann, E.P. (1975). Soil treatment with silicones for water harvesting. Pro. Water Harvesting Symposium, Phoenix, Arizona, March 1974, pp. 76–83.

Sandell, P., Kube, P. & Chuk, M. (1986). Dryland Tree Establishment in Central Australia. *Forest Ecology & Management J.* 16: 411–422.

Wilson, G. (1980). Amenity planting in arid zones. Canberra College of Advanced Education, School of Environmental Design.