ARTIFICIAL CATCHMENTS FOR RAIN WATER HARVESTING IN DESERTS OF PAKISTAN

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Summary. *An experiment on rain water harvesting was conducted in Thal desert to assess the efficiency of different treatments of the catchment plots to induce maximum runoff. The results showed that mud plaster (soil + wheat straw) was the most effective and economical treatment for rain water harvesting as it induced on an average maximum runoff, 11.03 m^3 per catchment plot, about 78.14% of total rainfall received by the catchment plot. The next better treatments are mudplaster (soil + cowdung). Polythene sheet cover and sodium carbonate spray which produced 10.43 m^3, 10.36 m^3 and 9.99 m^3 runoff respectively.*

While cement plaster, asphalt cover, lime concretion cover, mechanical stabilization and natural grass cover proved ineffective in increasing the runoff, as these collected only 7.75 m^3, 7.83 m^3, 7.1 m^3, 8.79 m^3 and 7.89 m^3 water respectively as compared to control which also gave 6.98 m^3 runoff.

Mudplaster is also the cheapest treatment as it costs about Rs. 4,000 per hectare as compared to the next best treatments, polythene sheet cover and sodium carbonate spray, their expenditure being Rs. 30,000 and Rs. 10,000 per hectare respectively.

Introduction. More than half of the earth surface is arid, semi arid or subject to the scarcity of moisture. It is estimated that 66% of earth land surface does not receive adequate and reliable rainfall, while 31% may be classified as arid not including tundra and cold deserts. The hot dry deserts of the world cover one third earth surface. More than 80% area of Pakistan is arid or semi arid (S. Ahmad 1955). Over major part of Pakistan it is extremely hot and dry in summer and dry and cold in winter. Beginning from 1860, large tracts of arid wastelands have been colonized and cultivated with canal irrigation. Pakistan at present has one of the largest canal irrigation system in the world. Still about 30,352,500 hectares are classified as waste land and produce practically nothing except some scrub vegetation which has been badly destroyed and overgrazed in the past. Low rainfall and high summer temperature is the characteristic climate of most of the area of Pakistan (M.I.R. Khan 1954).

With increase in population demand for food, fuel and fodder is growing. It is essential that extensive waste land should be utilized and made productive. Even otherwise, planting of wildlands is important because denudation in the

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past has led to large scale soil and wind erosion. Of all the factors connected with the plant growth in the arid land water is by far the most important and the over all limiting factor. For successful afforestation, it is necessary that all measures for complete conservation of moisture are fully understood and practised.

In addition, in some parts of the country, rain water is the only source for drinking purposes for human population, domestic animals and wildlife. In these areas there are no rivers, streams or springs and the underground water cannot be utilized due to difficult geological structures or its unsuitability for drinking and irrigation. Rain water is collected in ponds during the rainy season and utilized for drinking purposes during the dry periods.

In some range areas such as Cholistan in Punjab and Kohistan deserts in Sind province, semi covered water ponds are being constructed to collect maximum rain water for the grazing animals. In fact the animals have to be shifted when the water ponds get dry during dry season. There is need for developing techniques for harvesting maximum rain water and conserving it for drinking and irrigation purposes.

Though rain in arid areas is infrequent, it comprises considerable amount of water; 10 mm of rain equals 100,000 litres of water per hectare. Harvesting this rain water can provide water for regions where other sources are too distant or too costly or where wells are impracticable because of unfavourable geology or excessive drilling cost. Rainwater harvesting is practically suited to supplying water for small villages, schools, house holds, small gardens, livestock and wildlife.

Ancient people used to harvest rain water by redirecting the water running down hill slopes into the fields. The system is still being adopted in some parts of Pakistan. Kenyon, 1929 reported a catchment area of 2400 m^2 in arid part of Australia (300 mm average annual rainfall) provided adequate water for 6 persons, and 160 animals even during the years of lowest rainfall.

Research is being conducted in different countries to increase water runoff by modifying the surface of the soil. Although some times rainfall runoff can be collected from untouched catchment but often the catchment needs modification, usually by making the soil surface more impermeable to increase the amount of runoff. In some cases all that is needed to collect and convey runoff water are ditches or rock wall along hill side contours (Evenari 1971). In Negev after clearing rocks and vegetation gravel mounds and strips are used to increase the rain water harvest. Conduits and channels are organized so that each drains a small catchment. The system divides over all runoff into small streams, thereby avoiding erosion and presenting the farmers with small easy to handle flows (Tadmor 1969).

In 1950 a rain water harvesting system was designed in Western Australia (Annon 1974). Catchments were graded and rolled and shed water with a minimum rainfall of 7.6 mm. They were designed so that for only 4.45 cm of runoff

1.6 hectare of catchment will provide 800 m^3 of water. Catchments were cambered so that rainfall runoff quickly goes to the side of the road where ditch conveys it to the main collector drain and thence through silt trap to the storage tank. Carder in 1971 developed a modern rain water harvesting catchment in south of the Stirling Range in Western Australia. Natural ground surface was sandy with a clay subsoil. The sand was moved into rows, the clay exposed by roading process was shaped and spread to cover the whole surface. The ridges discharged runoff into a channel which conveyed it to the square tank (capacity 3000 m^3). The main advantage are that the system uses the existing soil and can be built by readily available equipment.

A promising method for rain water harvesting is to treat the catchment area with chemicals that fill pores or make soil water repellent.

Sodium salts have been used to increase run off (Annon 1974). These salts cause the soil to break down into small particles partially sealing the soil pores and cracks. Cluff (1966) treated the catchment area with sodium chloride which proved promising to increase the runoff. Sodium salts are useful as soil sealant because of their low cost, ready availability and retardation of weed growth.

Asphalt offers promise for building low cost, impermeable catchment particularly because it can be easily applied by spraying. In U.S.A. hill slope catchments have been cleared of vegetation, smoothed, treated with soil sterilant and two coats of asphalt to make rain water catchment.

Approximately 240 hectares of asphalt or asphalt-concrete catchments have been constructed to furnish water for 32 small towns in Western Australia (Kellshell 1962).

Paraffin wax had been used as soil sealant in United States. Granulor wax spread on the ground melts in the sun and flows into the pores to produce a surface that increases the runoff. In tests (Fink 1973) wax treated plots yielded an average of 90% of rainfall as runoff compared to 30% from the untreated plots. Runoff water from the wax plots had low salt contents and almost undetectable organic matter.

Plastic sheet cover is used for low cost rainfall catchment but they are easily damaged by wind and temperature variation. Polythene sheet covered with gravel (C.B. Cluff 1971) proved more successful. The gravel protects the underlying membrance against radiation and wind damage. It was reported that these catchments if properly constructed and maintained, can be durable with a projected life of more than 20 years. They are useful where gravel is readily available and maximum runoff is not required as the gravels retain some of the water.

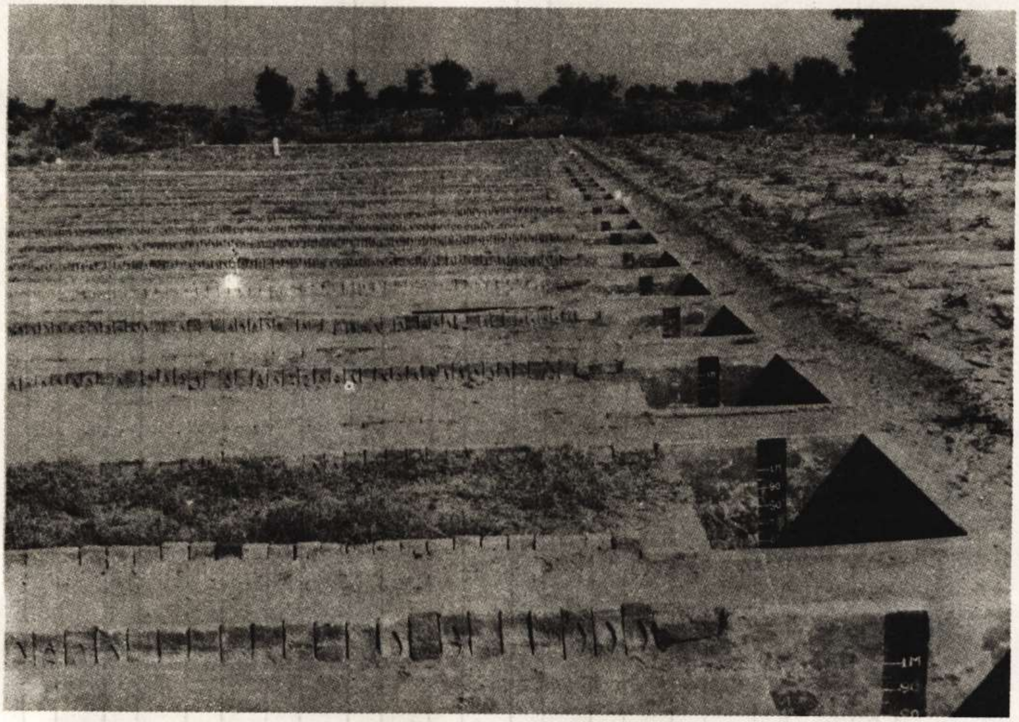
Murthy (1978) studied the inter relationship between rainfall-runoff of treated catchments in arid zone of Rajastan. He explained the statistical verification of developed techniques to generate maximum surface water yield from treated catchments under prevailing rainfall conditions. Various impervious and water proofing surface covers were tested on a catchment model and their efficiency for generating more surface runoff worked out. The mathematical model developed establishes a dynamic relationship between the two major parameters.

No work has been done on rain water harvesting in Pakistan. The present study was initiated to assess the efficiency of different water proofing treatments to the catchment plots for producing maximum runoff of rain water in arid areas.

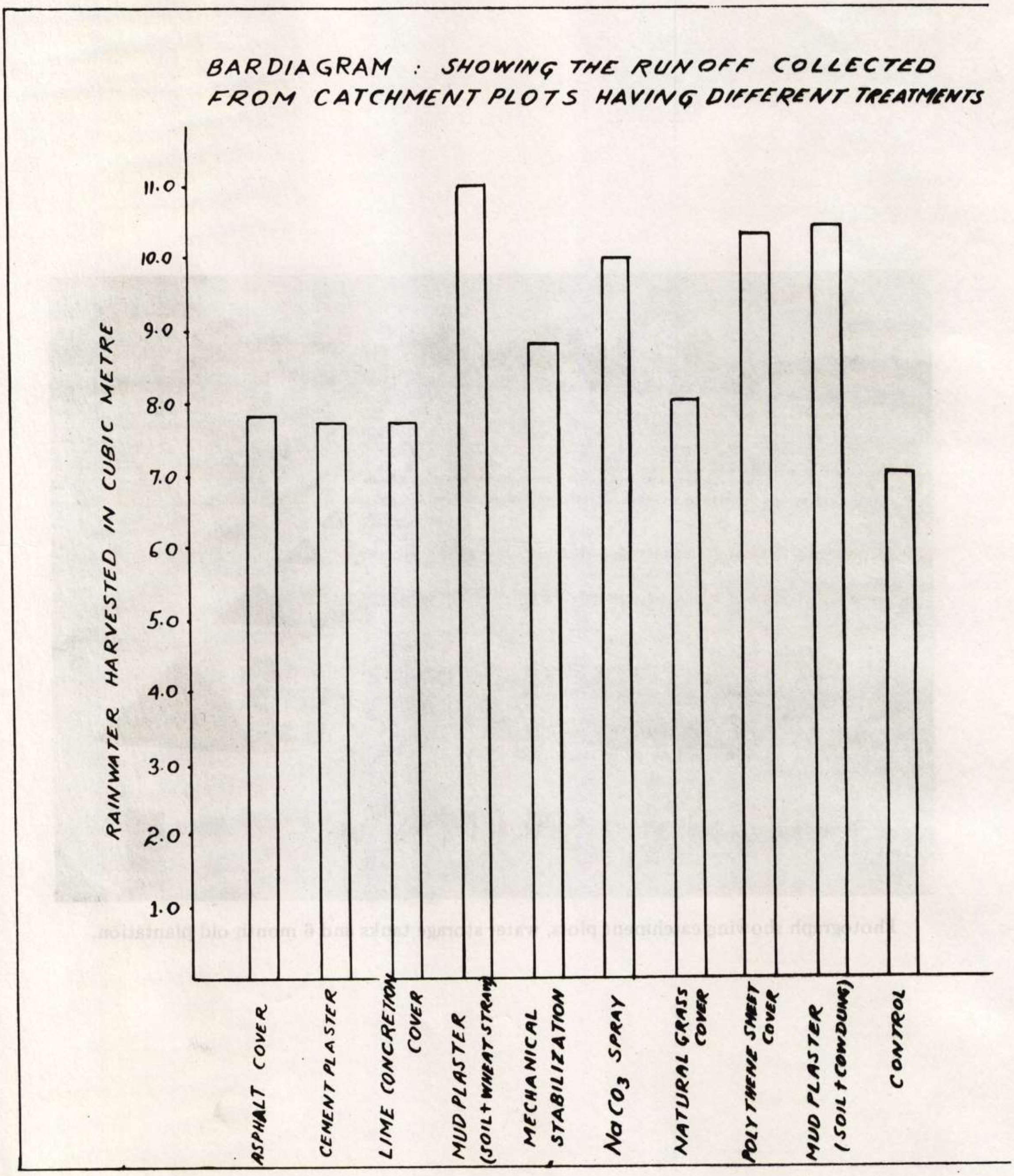
Material and Method. The experiment was conducted at Rakh Dagar Kotli (Bhakkar Range Management Division) situated in Thal desert which is a scientifically managed grazing land. The annual average rainfall of the area is about 180-200 mm which is mostly received in summer months (monsoon season). The mean summer temperature is about 32°C and mean winter temperature is 17.7°C. The soil is constituted of Indus alluvium, wind resorted to rolling longitudinal ridgy sands oriented NW-SE with rolling streamers consisting of long moderately steep sand ridges, some 200 m wide and separated by nearby level somewhat sandy valleys of approximately same extent.

The experiment was laid out in August/September 1980. Thirty catchment plots of 20 x 2 metres were prepared, demarcated by 15 cm brick birms. A slope of 1 in 40 was given to each catchment plot. For the collection of runoff water from the catchment plots water storage tank of 2 x 1 x 1 metre dimension were constructed of brick masonary with cement plaster. Each tank size is 2 x 1 x 1 m and thus the capacity of storing 2 m^3 water. One metre scale was painted on the wall of each water tank for the measurement of runoff collected from each catchment plot (Photograph). The following treatments were given to the catchment plots.

	Treatments	Specification
1.	Asphalt (coaltar) cover	1 cm thick
2.	Cement (8% mixed with sand)	1.25 cm thick
3.	Lime concretion (cankers)	3.00 cm thick compacted
4.	Mudplaster (soil+wheat straw)	1.25 cm thick layer
5.	Mechanical stabilization	Stabilized upto 10 cm thickness
6.	Sodium carbonate spray	2 kg per 10 m^2 over compacted soil
7.	Natural grass cover	Grass tufts planted at 15 x 15 cm
8.	Polythene sheet cover	300 guage thickness, white transparent



Photograph showing catchment plots, water storage tanks and 6 month old plantation.


BARDIAGRAM : SHOWING THE RUNOFF COLLECTED FROM CATCHMENT PLOTS HAVING DIFFERENT TREATMENTS
RAINWATER HARVESTED IN CUBIC METRE
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ASPHALT COVER
CEMENT PLASTER
LIME CONCRETION COVER
MUD PLASTER (SOIL + WHEAT STRAW)
MECHANICAL STABILIZATION
$NaCO_3$ SPRAY
NATURAL GRASS COVER
POLYTHENE SHEET COVER
MUD PLASTER (SOIL + COWDUNG)
CONTROL

9. Mudplaster (soil+cowdung) 1.25 cm thickness
10. Control No treatment.

The experiment was arranged in a complete Randomized Block Design, with three replications. The polythene was spread during rainy season and rolled up during dry periods to avoid damage from wind and radiation.

Twelve plants, six each of *Acacia modesta* and *Eucalyptus camaldulensis* were planted in two rows in front of each tank in March 1981. Planting was done at 2 x 2 m spacing in pits.

Plants are being irrigated by the rain water collected in the storage tanks to find the effect of the quality of water thus collected on the survival and growth of plants.

A rain guage was installed in the centre of the experimental plot.

Results and Discussion. In one year, seventeen rainfalls were received in the experimental plot. The rainfall received and the rain water harvested from each catchment plot was recorded. The data so collected was compiled and is represented in table No. 1. From the table it can be seen that a maximum of 11.05 m^3 rain water was harvested from the catchment plot treated with mud plaster (soil + wheat husk), while untreated catchment plot produced minimum runoff, 6.98 m^3.

Next to the best treatments were mud plaster (soil + cowdung), polythene sheet cover and sodium carbonate spray yielding 10.43 m^3, 10.36 m^3 and 9.99 m^3 runoff respectively. The mechanical stabilization, asphalt cover, cement plaster, natural grass cover and lime concretion cover did not prove much effective as these treatments resulted only in 8.79, 7.82, 7.75, 7.98 and 7.1 cubic metre rain water harvest per catchment plot respectively.

The bar diagram shows the comparative picture of rain water harvested from the catchment plots having different treatments.

The data were analysed statistically and ANOVA carried out.

Source	ANOVA			
	df	SS	MS	F
Replications	2	19.3515	9.6757	
Treatments	9	70.7651	7.8628	2.5549
Error	18	55.3961	3.0776	

Tabulated value of F = 2.46 at 5%
3.60 at 1%

The calculated F value of treatments is 2.5549 which is more than 2.46 and less than 3.60. So differences in the effects of treatments is significant at 5% level.

To know the differences between the effects of individual treatments t-test was applied which revealed that mud plaster (soil + wheat husk) is the best, highly significantly better than control and significant at 5% level as compared to asphalt cover, cement plaster, lime concretion and natural grass cover.

Next to best are mud plaster (soil + cowdung), polythene sheet cover and sodium carbonate spray which have no significant difference amongst themselves but are significantly better than cement plaster, asphalt cover, lime concretion cover, natural grass cover and control. While there is no significant difference betweeen asphalt cover, cement plaster, lime concretion, mechanical stabilization, natural grass cover and control.

A total of 353.5 mm rainfall was received which means that each 20 x 2 metre plot received 14.14 m^3 rain water. The catchment plots treated with mud plaster (soil + wheat husk) yielded 78.14% rain water as runoff as compared to untreated catchment plots which produced only 49.36% runoff. The other treatments mud plaster (soil + cowdung), polythene sheet cover, sodium carbonate spray, mechanical stabilization, natural grass cover, asphalt cover, cement plaster and lime concretion resulted in 73.76%, 73.76%, 70.65%, 62.16%, 56.42%, 55.3%, 54.80% and 50.21% runoff respectively out of the total rainfall received in each catchment plot.

The results of the experiment show that mud plaster (soil + husk), mud plaster (soil + cowdung), polythene sheet cover and sodium carbonate spray are the most efficient treatments for producing maximum runoff.

If the cost of the treatments is considered, polythene sheet cover is the most expensive treatment. For covering a hectare with polythene sheet it costs about Rs. 30,000 because polythene sheet is available at the rate of Rs. 6/- metre having a width of 2 metres. The cost of sodium carbonate spray is Rs. 10,000 per hectare treated at the rate of 2 kg per 10 m^2 area without considering the labour cost. While the cost of mud plastering is only Rs. 4,000 per hectare because only labour cost is involved, the material (soil + wheat straw) are available free of cost. Two labourers (at the rate of Rs. 10/- per day) can easily treat 50 m^2 area with mud plaster in a day.

In one year's time polythene sheet had to be replaced thrice because it was damaged by wind and heat which resulted in the increase of cost three times. Cluff (1973) covered the plastic sheet with gravels for saving it from wind and radiation damage but in deserts gravels are not available locally and have to be transported from distant places and will increase the expenditure. Secondly the gravels also retain rain water and decrease the runoff. Sodium carbonate is costlier but sodium chloride is much cheaper as it is available at the rate of Rs. 1.50

per kg in Pakistan. The cost of treating a hectare with sodium chloride will be only Rs. 3,000. Sodium chloride was applied to catchment area by Cluff (1966) at experimental Ranch near Tuscan, Arizona, USA which proved promising to increase the runoff.

Sodium salts can only be used for treating catchment areas where the soil is clayey but these will not be effective in pure sandy soil as in Thal, Cholistan, Kohistan deserts.

It is concluded that mud plaster (soil + wheat husk) is the cheapest and efficient treatment for catchment areas for harvesting maximum rain water in conditions prevailing in Pakistan.

In areas where there is scarcity of drinking water for human beings and domestic animals, the technique of harvesting rain can be used and water stored in artificial tanks. The technique can be used in areas like Cholistan in Punjab, Kohistan desert in Sind Province and many areas in Baluchistan Province where water points are being developed in range lands for the grazing animals.

Measures for reducing evaporation losses can be adopted in storage tanks. The rain so harvested can be utilized for drinking as well as for irrigating plantations in the arid areas.

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Table 1

Rain Water harvested from different catchment plots from October, 1980-September, 1981

Rain water harvested in m^3 from 20 x 2m catchment plots in 3 replications.

Date	Rainfall (mm)	TREATMENTS OF CATCHMENT PLOTS: Coaltar cover	Cement plaster	Lime Concretion cover	Mud plaster (Soil + wheat husk)	Mechanical stabilization	Na CO_3 solution spray	Natural grass cover	Polythene sheet cover	Mud plaster (Soil + Cowdung)	Control
10-10-80	18	0.36	—	0.04	0.92	0.25	0.34	0.44	0.22	0.44	0.18
1-11-80	25.0	0.72	0.78	0.34	1.00	0.80	0.92	0.66	1.44	1.30	0.60
4-1-81	8.2	—	—	0.06	0.15	—	0.14	0.03	0.07	—	0.05
24-1-81	2.2	0.18	—	—	0.34	0.24	0.16	0.12	0.36	0.20	0.14
25-1-81	9.9	0.32	0.24	0.12	0.56	0.40	0.56	0.32	0.48	0.50	0.28
3-2-81	15.1	0.20	0.26	0.26	0.68	0.40	0.62	0.50	0.62	0.58	0.46
20-3-81	24.0	1.10	0.40	0.38	1.94	1.04	2.04	0.88	1.44	2.36	0.98
31-3-81	4.1	0.32	0.24	0.10	0.32	0.40	0.28	0.56	0.40	0.30	0.22
8-5-81	7.0	0.18	0.18	0.08	0.10	0.26	0.34	0.22	0.40	0.20	0.12
14-5-81	5.0	0.12	0.10	0.02	0.06	0.24	0.26	0.14	0.30	0.14	0.08
15-7-81	36.0	3.60	3.40	3.40	5.30	3.00	3.40	3.40	5.10	4.20	3.40
24-7-81	68.0	5.20	5.04	5.44	5.70	5.24	5.50	4.20	6.00	5.30	5.74
30-7-81	21.0	1.86	0.94	2.06	3.10	2.64	2.18	1.74	3.26	2.80	1.30
8-8-81	34.0	1.90	1.90	2.60	3.22	2.66	3.50	2.60	3.00	3.60	2.20
22-8-81	9.0	1.00	0.66	0.54	1.34	1.08	1.36	0.84	0.88	1.68	0.62
29-8-81	22.0	1.70	1.60	1.46	2.70	2.40	2.60	1.90	2.00	2.70	1.40
3-9-81	45.0	4.70	4.50	4.40	5.72	5.36	5.80	5.40	5.40	5.00	3.16
Total:	353.5	23.46	20.24	21.30	33.15	26.38	29.99	23.95	31.07	31.30	20.93
Average	=	7.82	7.75	7.1	11.05	8.79	9.99	7.98	10.36	10.43	6.98
% run off		55.3%	54.80	50.21	78.14%	62.16%	70.65%	56.42%	73.26%	73.76%	49.36%