The 6th Jordanian International Civil Engineering Conference (JICEC)

Jordan Engineers Association

CONSOLIDATED CONSULTANTS GROUP

HIGH QUALITY WATER USING ZERO ENERGY AT URBAN AREAS OF JORDAN

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Jordan is classified among few countries of the world with limited water resources and it is one of the lowest on a per capita basis.

The available water resources per capita are falling as a result of population growth. They are projected to fall from less than 160 m^3/capita/year (2006) to about 90 m^3/capita/year (2025); this is putting Jordan in the category of an absolute water shortage.

The water demand is exceeded the supply at all levels of consumption and specially the domestic use.

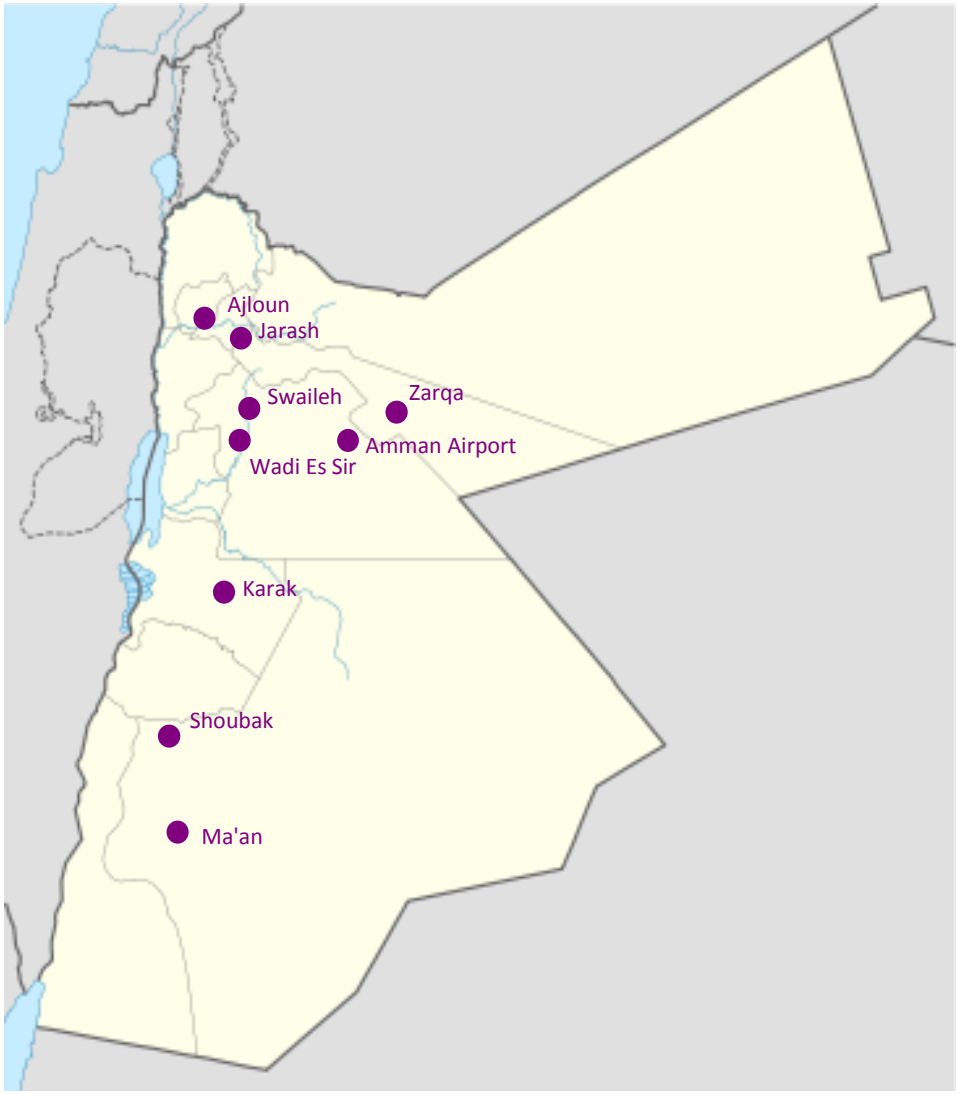
The rainwater harvesting could be an attractive option to be implemented in order to close the deficit gap of the drinking water.

The climate in study area varies from dry sub-humid Mediterranean in the northwest of the country with rainfall of about 630 mm to desert conditions with less than 50 mm over distance of only 100 km.

The study area is covered by nine rainfall stations along Jordan.

The country is divided into three parts, which are the north with two stations at two major cities; Ajloun and Jarash, the middle part with four stations at the two largest cities in the kingdom; Amman and Zarqa, and the south part with three stations at three major southern cities; Karak, Shoubak and Ma’an.

“Rainfall Stations at Major Cities of Jordan”

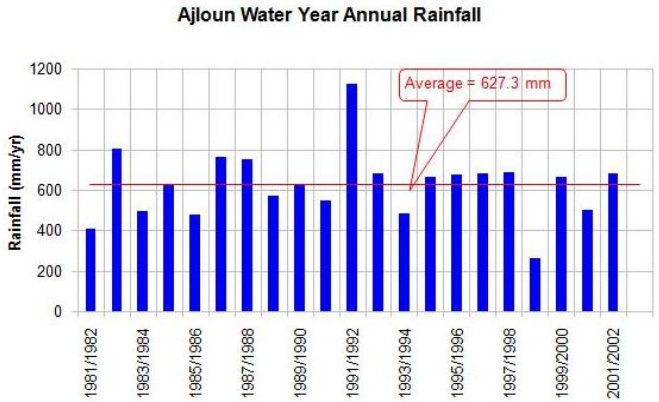


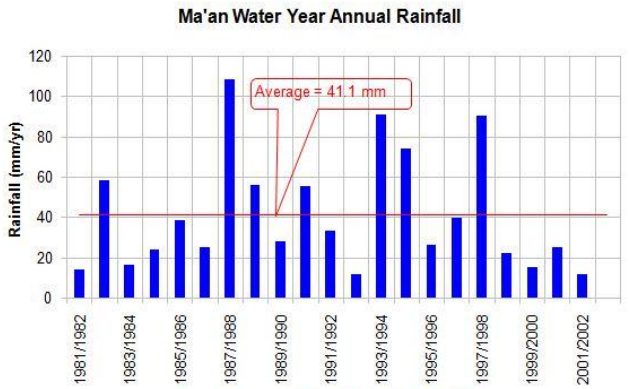
Methodology and Results

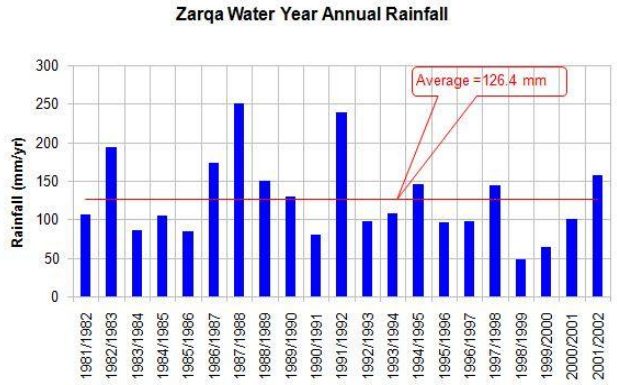
Longer daily rainfall records are reviewed and tested for consistency in order to find the proper continuous period of records.

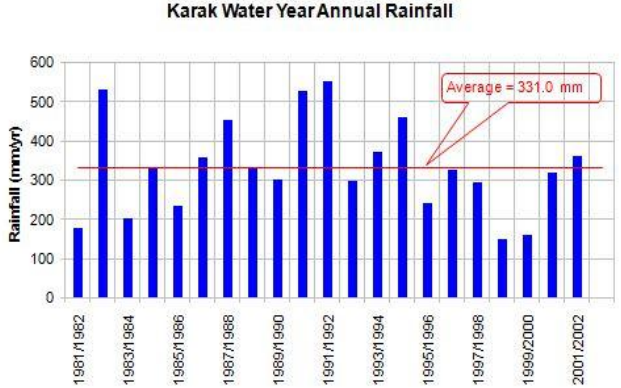
The period between 1982 and 2002 is found consistent and continuous for the nine rainfall stations. The monthly and annual rainfalls are developed at each station.

"Annual Rainfall with Average at Major Cities for 20 Years (1982-2002)"









Methodology and Results

The method developed by Soil Conservation Service (SCS) (1972) for computing abstractions from storm rainfall is used to find the runoff for different curve numbers based on the three Antecedent Moisture Condition (AMC) classifications,

Curve number for different roofs sizes and hydrologic soil group are used for urban district. CN 95 is used for commercial and business lots for hydrologic soil group D.

SCS method is well known as abstracting procedure to obtain the runoff out of the rainfall using storm-by-storm analysis.

The runoff at each storm is developed according to SCS method, which leads to the monthly and annual runoff for five different curve numbers. Accordingly, the runoff coefficients are estimated.

"Runoff Curve Number for Urban Areas"

Cover Type and Hydrologic Condition	CN for Hydrologic Soil Group
Commercial and Business	95 D
500m^2 or less (Town House)	85 B and 90 C
Residential of lot size 2000m^2	80 C and 85 D
Residential of lot size 1000m^2	75 B

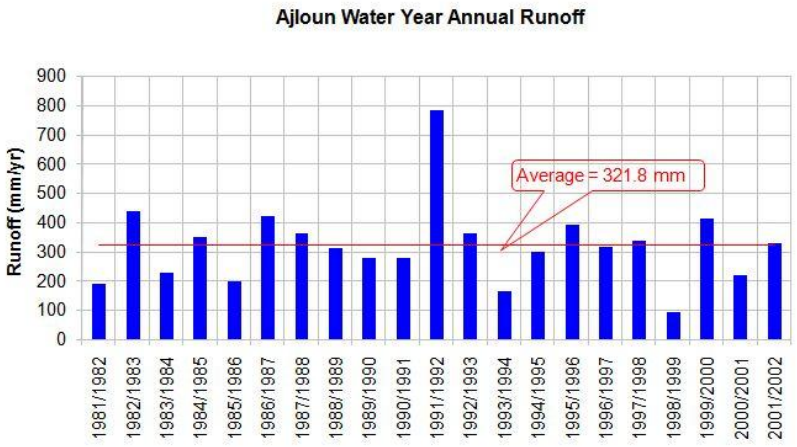
Methodology and Results

Ajloun rainfall station receives the highest annual rainfall with an average of 627mm, while Ma'an gets the lowest of 41mm.

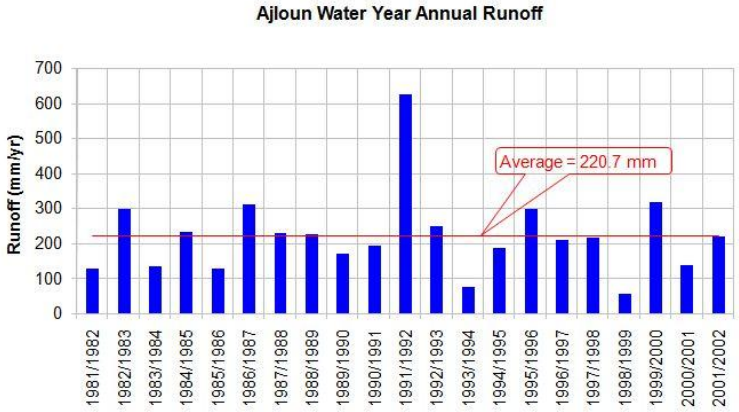
Relationship between rainfall and runoff with different curve number values are investigated for each rainfall station.

The trend of the relationship is differing according to the curve number due to the abstracting depth differences.

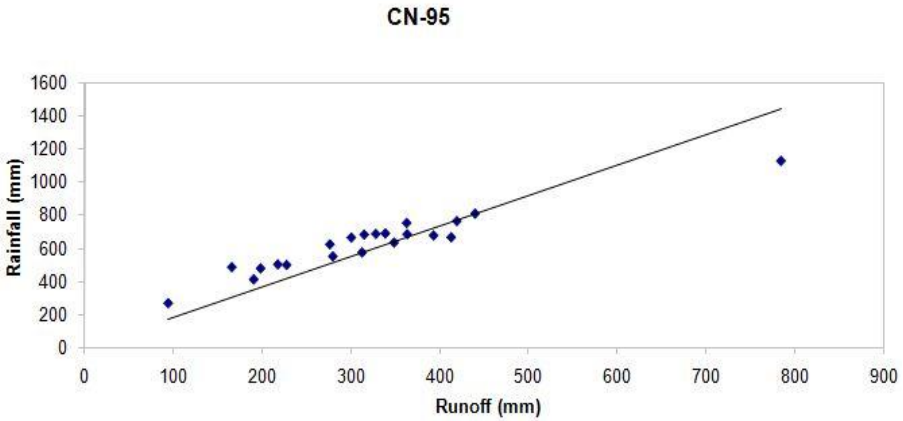
"Annual Runoff for Ajloun Rainfall Station with CN 95"



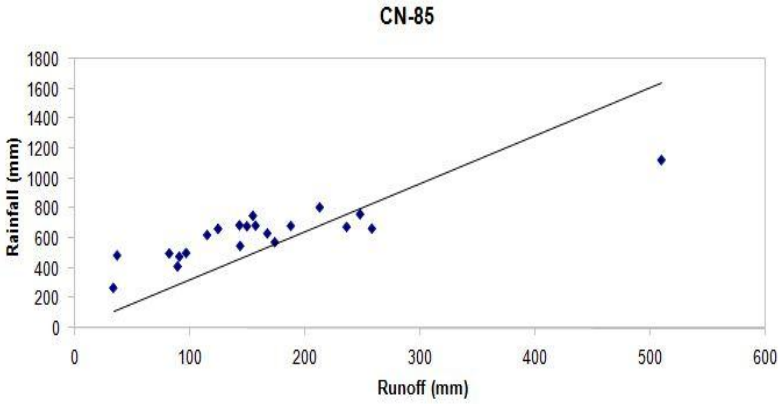
"Annual Runoff for Ajloun Rainfall Station with CN 90"



Methodology and Results



"Annual Rainfall vs. Annual Rainfall for Ajloun at CN-95"



"Annual Rainfall vs. Annual Rainfall for Ajloun at CN-85"

Methodology and Results

Storms' numbers per year are affecting the annual runoff since the annual rainfall will be distributed among the storms.

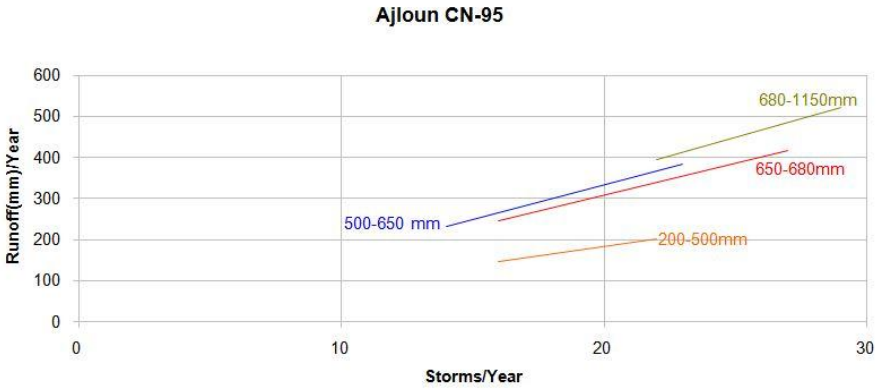
Higher number of storms will lead to less annual runoff for the same annual rainfall.

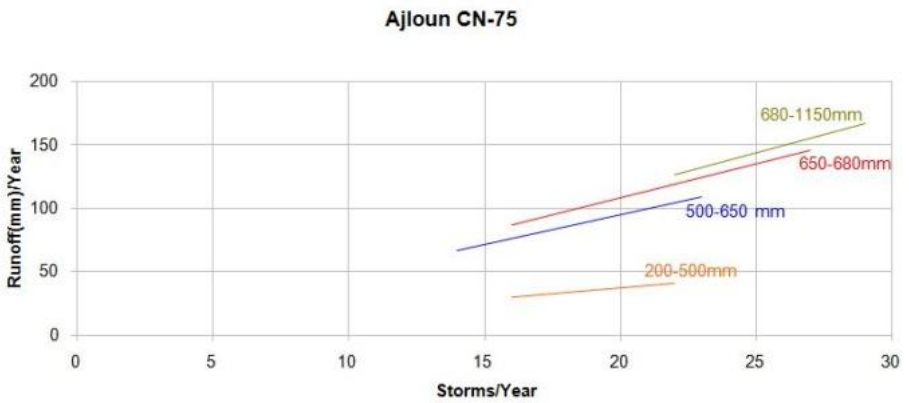
The runoff values increase when rainfall values do, nevertheless, in some cases runoff values do not correspond with rainfall values' increment such as in Ajloun, Shoubak and Karak.

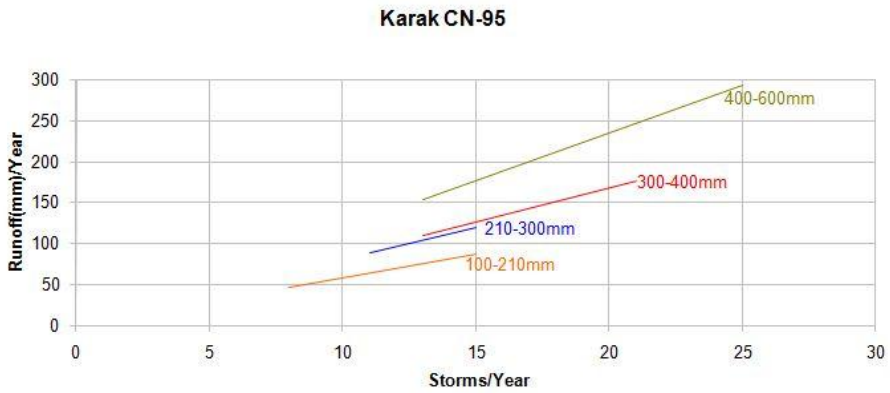
The runoff values resulted from the interval (500-650) mm of rainfall are higher than those resulted from the interval 650-680 mm of rainfall when the curve number is CN 75 and vice versa for CN 95. The figure shows the same results for Karak rainfall station.

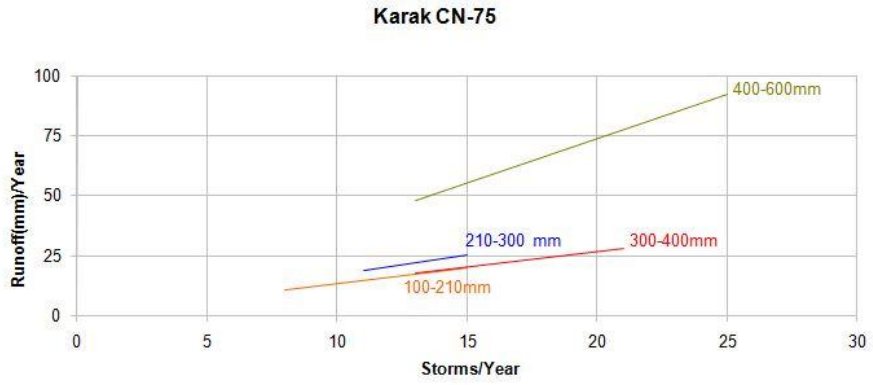
Methodology and Results

"Annual Runoff vs. Annual Number of Storms at Different Ranges of Annual Rainfall"









Discussion and Recommendation

The selected nine rainfall stations are at seven major cities in Jordan. The major population intensities are in Amman and Zarqa and the rest divided into two parts one at north and the other at south.

The intensity at north is higher than at south. The north cities are Ajloun and Jarash while the south cities are Karak, Shoubak, and Ma'an. These seven cities contain more than 85% of the Jordan population.

The daily runoff should be used to generate the annual runoff out of storm-by-storm analysis but in this research the average annual runoff coefficients are developed for different curve numbers at all nine rainfall stations over Jordan.

"Runoff Coefficient according to Stations at different Curve Numbers"

Station	Av Rainfall (mm/yr)	Runoff Coef*	Curve Number (CN)				
			95	90	85	80	75
Ajloun	625	0.500	0.496	0.334	0.244	0.185	0.143
Jarash	350	0.355	0.352	0.205	0.134	0.092	0.065
Zarqa	125	0.115	0.112	0.037	0.017	0.009	0.005
Amman Airport	240	0.240	0.238	0.115	0.067	0.043	0.029
Sweilih	485	0.430	0.427	0.268	0.184	0.132	0.097
Wadi Es-Sir	450	0.460	0.457	0.295	0.207	0.150	0.111
Karak	330	0.445	0.442	0.283	0.198	0.144	0.107
Shoubak	275	0.320	0.315	0.166	0.098	0.061	0.039
Ma'an	40	0.055	0.053	0.015	0.006	0.002	0.001

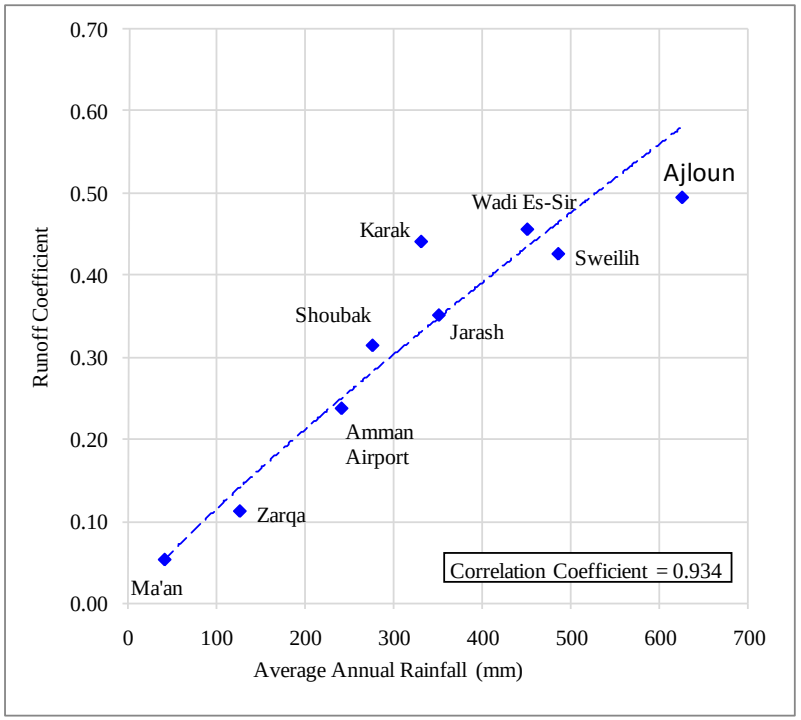
* Runoff coefficient for paved impermeable roofs (CN=98).

Discussion and Recommendation

The runoff coefficients can be used for different surface or roof covers starting from paved roof down to permeable surfaces. This will help in estimating the runoff out of a certain type of surface using the average annual rainfall.

The runoff coefficient for paved roof is highly correlated to the average annual rainfall with correlation coefficient of 0.934. A power equation is developed to solve for the runoff coefficient for paved roof out of the average annual rainfall at the area with coefficient of determination at 0.960. The maximum error is not more than ± 25% with average error around ± 10%. The parameter of the equation is 1.932×10^{-3} and the power is 0.8866.

"Runoff Coefficient vs. Average Annual Rainfall at Major Cities of Jordan"



Discussion and Recommendation

As an example, the CN for commercial 100m^2 paved roof located at Sweilih is 95, and by using the average annual rainfall of 485mm/yr for Sweilih the amount of annual runoff that can be harvested out of this roof will be about 21m^3/year.

0.21m^3/year can be harvested from the same roof if it was located at Ma'an. This leads to unfeasible construction of rain water harvesting system at areas of low precipitation.

Thank You