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Research Article

Yield Estimation from a Catchment in Afghanistan with Inadequate Data

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Abstract

Proper estimation of runoff is required for planning, efficient design and management of stream basin projects that deal with utilization and preservation of water for various purposes. The transformation of rainfall into runoff over a catchment is a complex hydrologic phenomenon and includes processes of infiltration, depression storage, interception, percolation and evaporation. Present study aims at estimating yield at Pashadan dam site across Karokh River in Afghanistan. The catchment area at dam site is about 1851 sq km. The available rainfall and runoff data in study area was collected. These data were analyzed for checking homogeneity. It was seen that runoff data is available for short time and rainfall data are available for relatively long period. In order to estimate the yield at dam site different methods are selected from those reported in literature. Comparison of results is made using criteria like closeness of observed data, matching of trend, ease of computations, comparison of deviation etc. Study is conducted to review the methods and select the one(s), which are applicable for present scenario. Results obtained were analyzed using above criteria. Soil conservation services curve number method with annual step is noticed to be most suitable for Pashadan site.

Keywords: *Water Yield Estimation, Rainfall Runoff Conversion, Inadequate data, Thomas Fiering model, SCS-CN Method, Correlation, Empirical Method*

1. Introduction

Water is the elixir of life and a precious gift of nature to the mankind. About 71% of the earth surface is covered by water out of which 97% of water is existing in sea. From remaining part, 2% of water is in North and South poles and Himalaya. Rest 1% of water, which is available in rivers, reservoir, lakes and subsurface, can be used for consumptive use. Water is a basic fundamental for sustaining the life and progresses of society. However in Afghanistan, out of the total geographical extent, three part of area is land and one part is water.

The major source of all water on the earth is precipitation. One of the main processes in the cycle is transformation of rainfall in to runoff. For designing of water project, the basic requirement is the estimation of runoff resulting from precipitation. Different approaches like statistical and deterministic method, empirical equation and rainfall-runoff models can be used for this purpose.

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1.1 Estimation of Water Yield

The actual physical processes to transform rainfall to runoff are both complex and highly variable. Through the use of simplifying assumptions and empirical data, there are various equations and mathematical models that can predict resultant runoff volume and simulate these processes with acceptable accuracy. The selection of suitable equation or model depends on the parameter to be studied, drainage area size, climate, data availability, the hydrological elements and the type of system to be modeled. These aspects are taken in to considerations to estimate runoff by different methods at Pashdan dam on Karokh River at Herat city Afghanistan.

2. Literature Review

Rainstorms generate runoff. The occurrence and quantity of runoff are dependent on the characteristics of the rainfall event, viz the intensity, duration and distribution. Apart from these rainfall characteristics, number of catchment specific factors have a direct effect on the occurrence and volume of runoff. These include soil type, vegetation cover, slope and catchment type. There are various case studies available for estimation of yield by rainfall records.

D.K Khopde *et al* has done estimation of runoff yield for Nira Deoghar catchment using different equations such as Bralow`s method, Stranges table, Inglis formula, SCS-CN method. In addition they used formula available with Dept. of Irrigation India. These computed values were compared and found that the available runoff derived from R-R relationship on Dhom dam and Veer dam is suitable.

P. Rajasekhar has done estimating rainfall-runoff relationship in Central Kabul sub basin using NRCS-CN and remote sensing. He used GIS with remote sensing to determine curve number by dividing catchment into five sections (Northern, Southern, Central, Eastern, and Western). By using NRCS-CN equation, he calculated runoff with use of different values of CN in each basin.

In this work various methods proposed by different investigators for estimation of runoff are applied. The results are reviewed with criteria like applicability, ease of application and accuracy of results obtained.

2.1 Selection and Review of the Methods

For estimating yield at Pashdan dam in Karokh river of Afghanistan possible combination of deterministic methods and statistical methods was used. We will select appropriate method for better satisfaction of given purpose. The available methods for the estimation of yield are listed below:

- Empirical formula and Table
- Stochastic method
- Soil conservation service method
- Rainfall Runoff modeling
- Artificial neural network
- Statistical Method

2.1.1 Empirical Formulae and Tables

The estimation of the water availability from the available hydrometeoroloic data for purposes of planning water-resource projects had been carried out with the help of empirical equations, which are based on available observation or data. Formulae like those developed by Inglis formula, Khosala`s method, Barlows Table, Strange's Tables, Binnies Formula and Rational method have taken into consideration conversion of rainfall into runoff through different processes.

2.1.2 Stochastic method

A stochastic model can be used for the generation of long term sequences of events or extension of existing short term sequence with the same statistical properties.

2.1.3 Soil conservation service method

The Curve Number method for estimation of storm runoff volume was developed in the 1950s by the USDA Soil Conservation Service or SCS and has been commonly used. SCS- CN provides an empirical relationship for estimating initial abstraction and runoff as a function of soil type and land use.

2.1.4 Rainfall runoff modeling

To Estimate runoff we can use simulations and computer models. These are useful for extending the observed flows records using available rainfall and runoff data. The estimation is done by hydrological models etc.

2.1.5 Artificial neural network

One of the intelligence techniques is to estimate runoff by relation between input and output. Input data is obtained from rain gauges as well as from temperature recording gauges, the output of the model being monthly flows.

2.1.6 Statistical Method

The Statistical method includes analyzing, collecting, and interpreting numerical data. It can be contrasted with deterministic method. Statistical analysis relates observed data to theoretical models using regression analysis.

2.2 Selection Criteria

The following criteria were considered for selecting methods.

A. Availability of Required Data
B. Applicability of the methods
C. Ease of Computations.

According to those criteria some empirical methods are not applicable in our catchment. Because they were developed for use in small catchment area [130 km^2] in the specific location. These include the following:

a) Barlows Table
b) Strange's Tables
c) Binnies Formula

Similarly, Inglis Formula is developed using data catchment in Western Ghats of India. Hence this was not considered in the present study.

Artificial Neural Network could not to be used due to reason of insufficient observed runoff and other data.

In contrast to above mentioned rejected methods the following methods are applicable to the study area because they are coming under selection criteria.

1) SCS CN Method
2) Rational Meth
3) Khosla's Methods
4) Regression Analysis between monthly observed values of Rainfall and Runoff
5) Thomas Fierring model

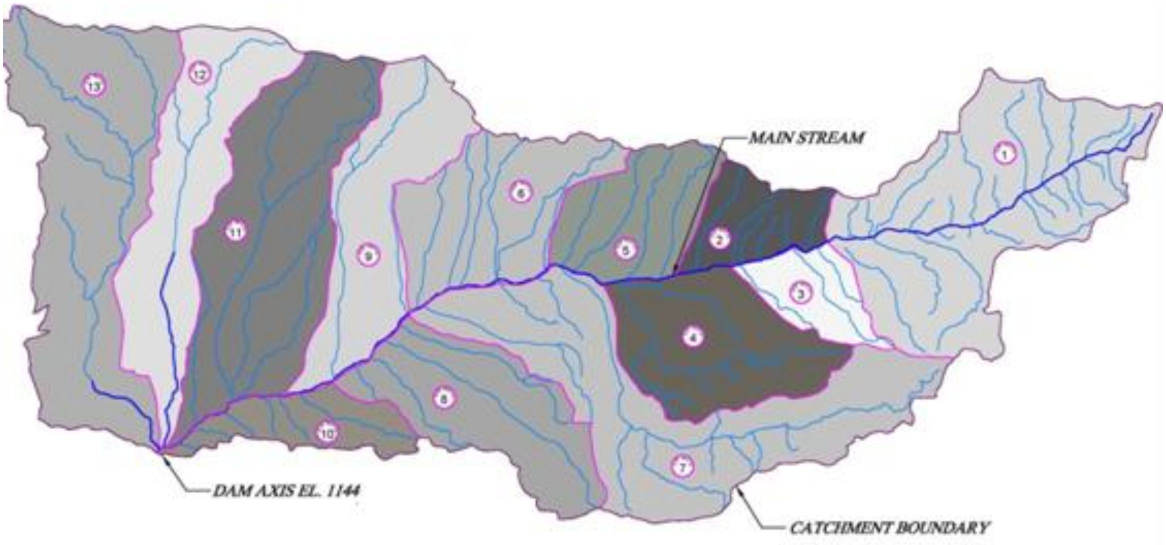

Figure 1- Karokh River Catchment at Pashdan Dam

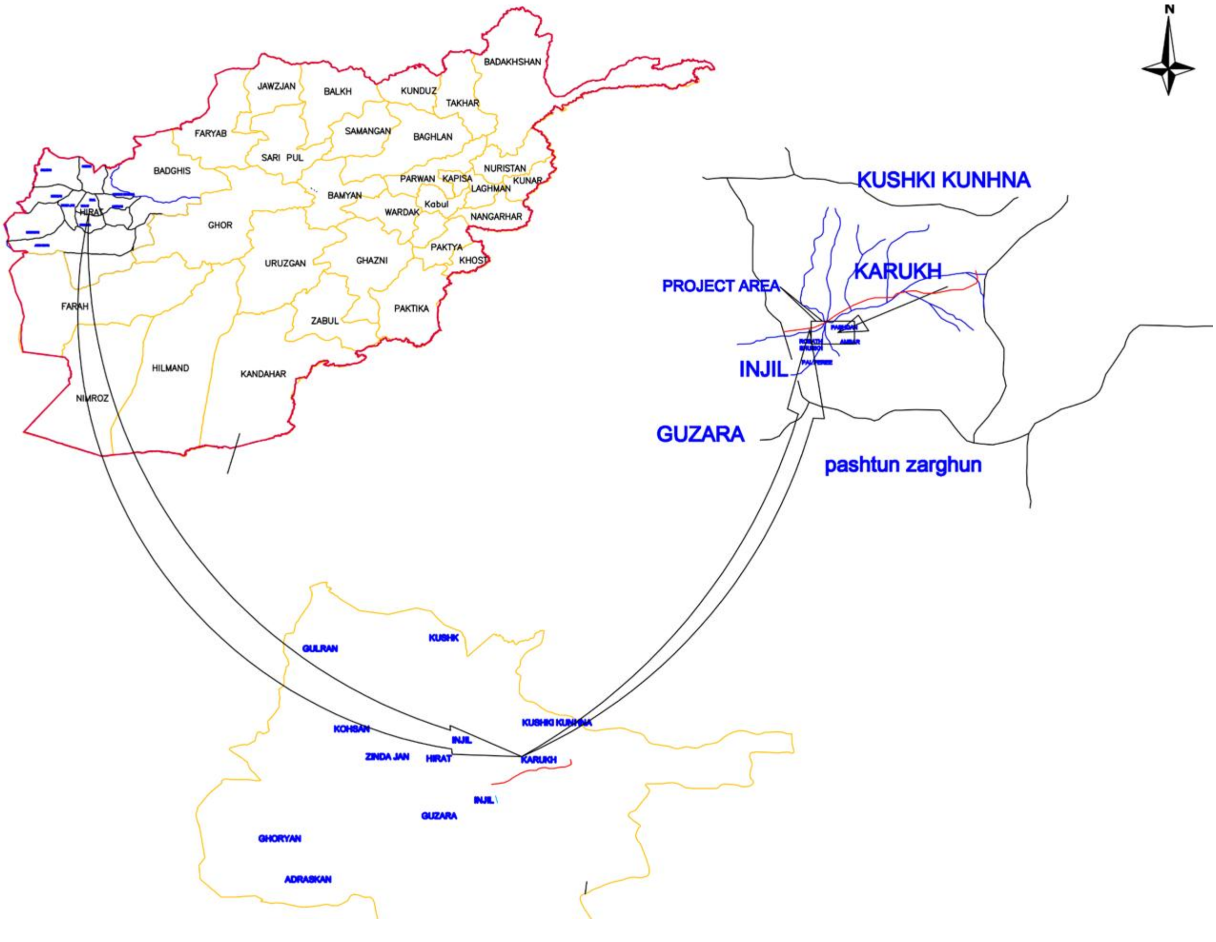

Figure 2- Location Map of River Karokh at Herat City

3. Study Area, Data Availability and Analysis

The Karokh River originates from the slopes of Koh-i-Bande Sabzak at an altitude of about 2,600 m. The catchment area of Karokh River up to the proposed dam site was computed as 1851 sq. km. The whole catchment area can be divided into thirteen sub catchments according to major tributaries which originate from different directions and areas. The location of the area study is illustrated in Figures 1 and 2.

For estimation of runoff in Pashdan dam with selected methods we need the data of rainfall, runoff, area of the catchment, type of the soil characteristics, temperature and vegetation cover.

Table 1- Mean Monthly Flows of Karokh River at Gauge Site (cumecs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	annual
1972-3	1.18	1.37	1.81	2.31	3.17	7.54	3.31	0.96	0.60	0.50	0.41	1.02	**24.18**
1973-4	1.30	1.40	1.45	2.23	3.24	6.57	6.06	1.15	0.40	0.50	0.60	0.72	**25.62**
1974-5	0.99	1.19	1.31	0.78	2.13	5.71	15.73	4.14	0.66	0.62	0.51	0.61	**34.38**
1975-6	1.23	1.30	1.57	1.54	5.63	17.75	17.47	13.73	0.90	1.00	0.95	0.90	**63.97**
1976-7	1.10	1.53	2.48	2.29	2.83	4.37	4.64	1.72	0.41	0.46	0.53	0.73	**23.09**
1978-9	1.28	1.42	5.71	2.14	3.28	4.57	2.35	1.46	0.36	0.29	0.11	0.10	**23.07**
Mean	**1.18**	**1.37**	**2.39**	**1.88**	**3.38**	**7.75**	**8.26**	**3.86**	**0.56**	**0.56**	**0.52**	**0.68**	32.385

Table 2- Mean Monthly Flows of Karokh River at Project Site (cumecs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1972-3	1.57	1.82	2.41	3.07	4.23	10.04	4.40	1.28	0.8	0.67	0.54	1.35	32.18
1973-4	1.73	1.87	1.92	2.97	4.31	8.74	8.07	1.52	0.53	0.67	0.8	0.95	34.08
1974-5	1.32	1.58	1.74	1.04	2.83	7.60	20.94	5.51	0.88	0.82	0.68	0.81	45.75
1975-6	1.64	1.73	2.08	2.05	7.49	23.64	23.26	18.28	1.20	1.34	1.26	1.20	85.17
1976-7	1.47	2.04	3.31	3.05	3.77	5.81	6.18	2.29	0.54	0.61	0.71	0.97	30.75
1977-8	1.57	1.83	3.18	2.51	4.45	10.32	11.00	5.14	0.738	0.748	0.69	0.902	43.07
1978-9	1.71	1.90	7.60	2.85	4.36	6.09	3.13	1.94	0.48	0.38	0.15	0.13	30.72
Mean	**1.57**	**1.82**	**3.18**	**2.51**	**4.49**	**10.32**	**11**	**5.14**	**0.74**	**0.75**	**0.69**	**0.9**	**43.1**

3.1 Stream flow / Runoff Data

A discharge measurement site (GS) is installed on Karokh River within the reservoir area at about 4.1 Km upstream of the Pashdan Dam axis. The catchment area of Karokh River up to the stream gauge site is 1390 Km^2. Monthly average flow data at the gauge site on Karokh River at Herat for the period of 1972-77 was available and additionally data for the period 1978-79 was taken from Ministry of Energy and Water. The mean monthly flows, computed through catchment area ratio (1851/1390 = 1.332), at the dam site vary from 0.69 to 11 cumecs, while the mean annual runoff for corresponding period is 43.10 cumecs. The gap for the year 1977-78 was filled by mean runoff values of all months.

3.2 Rainfall Data

Monthly rainfall data of Herat was adopted for the proposed studies as gauge is located within the catchment area of Pashdan dam site. The available data covering the period 1963-1988 and 2001-2010 (around 34 years) was subjected for further scrutiny before use in water availability studies, as there is gap in data from 1988 to 2001. The t test and F test were carried out to check homogeneity. The results indicated that the two sets are homogeneous as computed value of t (1.19) was less than the critical value (2.04) at 5% level of significance. Further, F value (4.87) was less than the critical value (5.28) at 1% level of significance. As such, the data in two parts can be considered to be homogenous. Hence, these were used in further studies. Mean monthly flow data was used to obtain annual runoff. The mean monthly rainfall for Herat varies from 0.0 to 55.3mm as shown in Figure 3.

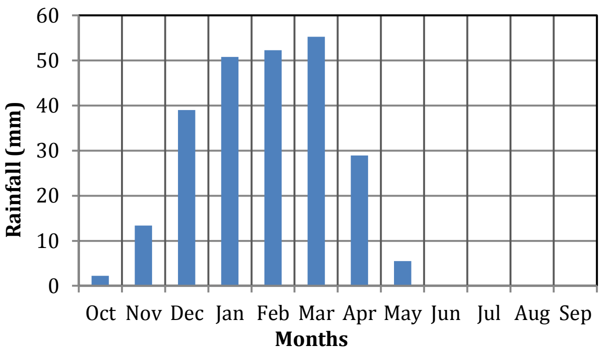

Figure 3- Mean Monthly Rainfall at Herat

3.3 Temperature Data

Mean monthly temperature in Herat city could not be readily available. Accordingly, the data from internet was used.

3.4 Soil Characteristics

The data of soils within the catchment and as well as data on vegetal cover is also required for the studies, The average gradation of suspended sediment particle according to size wise distribution is 11%, 60%, and 29% as sand, silt and clay. The vegetal cover as per visual observation taken during June 2015 shows straight row crops and had less cover.

4. Estimation of Runoff

4.1 SCS CN Method

Estimation of annual runoff in Pashdan dam is done by using different methods. One of these methods is Soil

Table 3- Estimated Runoff by using SCS-CN

Year	P in mm (annual)	(P - 0.2S)	$(P-0.2S)^2$	(P+0.8S)	Q = $(P-0.2S)^2$ / (P+0.8S) in MCM
1963-4	253.2	244.235	59650.833	289.059	381.976
1964-5	188.1	179.135	32089.42	223.959	265.216
1965-6	155.4	146.435	21443.268	191.259	207.527
1966-7	259.6	250.635	62818.003	295.459	393.544
1967-8	205.8	196.835	38744.096	241.659	296.762
1968-9	350.8	341.835	116851.304	386.659	559.386
1969-70	185	176.035	30988.392	220.859	259.711
1970-1	111.8	102.835	10575.078	147.659	132.565
1971-2	381.6	372.635	138856.992	417.459	615.687
1972-3	187.3	178.335	31803.444	223.159	263.795
1973-4	270.1	261.135	68191.593	305.959	412.547
1974-5	388.7	379.735	144198.822	424.559	628.68
1975-6	411.3	402.335	161873.613	447.159	670.07
1976-7	189.2	180.235	32484.727	225.059	267.171
1977-8	188.8	179.835	32340.699	224.659	266.46
1978-9	132.1	123.135	15162.277	167.959	167.096
1979-80	428.3	419.335	175842.01	464.159	701.233
1980-1	295.4	286.435	82045.124	331.259	458.449
1981-2	495	486.035	236230.216	530.859	823.688
1982-3	309.6	300.635	90381.523	345.459	484.272
1983-4	134.9	125.935	15859.675	170.759	171.916
1984-5	119	110.035	12107.745	154.859	144.721
1985-6	263.2	254.235	64635.537	299.059	400.056
1986-7	199	190.035	36113.377	234.859	284.621
1987-8	288.8	279.835	78307.739	324.659	446.461
2001-2	259	250.035	62517.601	294.859	392.459
2002-3	230	221.035	48856.56	265.859	340.156
2003-4	145.9	136.935	18751.249	181.759	190.959
2004-5	231.7	222.735	49610.969	267.559	343.213
2005-6	165.6	156.635	24534.586	201.459	225.423
2006-7	209.1	200.135	40054.098	244.959	302.663
2007-8	150.8	141.835	20117.224	186.659	199.492
2008-9	318.3	309.335	95688.266	354.159	500.111
2009-10	278.4	269.435	72595.327	314.259	427.59
Mean	246.494				371.343

Conservation Services- Curve Number, which is applied with annual and monthly rainfall. To decide CN, the hydrologic soil group of area is classified as group C type soil. The average gradation of suspended sediment particle according to size wise distribution is 11%, 60%, and 29% of sand, silt and clay respectively. These were compared with chapter 7 of hydrologic soil group and also straight row crops. Therefore for group C type soil and AMC-II type the CN number value for Karokh catchment is taken as CN = 85 from Table. The SCS curve number method has given the runoff equation as:

$$Q = (P-0.2S)^2 / (P+0.8S) \quad 4.1$$

$$S = (25400/ CN) - 254 \quad 4.2$$

Where,
Q is the actual runoff in mm
S is the potential maximum retention in mm = 44.824mm
P is the precipitation in mm

The result of annual runoff in SCS-CN is shown in Table 3.

4.2 Rational Method

The Rational method is an easy-to-use as empirical formula for estimating peak flows. According to the Karokh catchment the value of C=0.25, because it has sandy soil, the catchment area is 1851 sq. km. Runoff is predicted from the equation:

$$Q = C * A * P \quad 4.3$$

Where,
C is a runoff coefficient
A is the area of the watershed
P is the rainfall in mm

The result of annual runoff in Rational method is shown in Table 4 under column Rational.

4.3 Regression Analysis between monthly observed values of Rainfall and Runoff

For calculating annual runoff another method which is used regression analysis of observed data. By using runoff and rainfall of 7 years of observed data, we found the individual linear regression in form of

$y = a + bx$

and for second degree relation

$y = a + bx + cx^2$

between rainfall(x) and runoff(y). Also another relation was obtained with clubbing the 7 years of rainfall and runoff data. With comparison criteria like closeness of observed data, matching of curves, nature or type of equation and correlation coefficient, we selected appropriate equation for every month. By using these equations we obtained runoff for 34 years. For example, in month of October the equation of individual linear regression is
$y = -0.001x + 1.575$

and for linear regression for clubbed data in this month is

$y = 0.085x + 1.803$

And also in second degree regression the relation between rainfall- runoff is

$y = 0.003x^2 - 0.027x + 1.582$.

And for second degree regression for clubbed runoff-rainfall is

$y = -0.000x^2 + 0.103x + 1.694$.

Now out of the four equations, the suitable equation according to above criteria is selected. Thus, the equations used for estimation of runoff are given below:

Month	Equation used
October	Individual Linear
November	Individual Second degree
December	Individual Linear
January	Individual Linear
February	Individual Second degree
March	Individual Linear
April	Individual Linear
May	Individual Linear
June	Club second degree
July	Club second degree
August	Club second degree
September	Club second degree

We follow this procedure for all of the months to estimate runoff by using 34 years of rainfall. The result of annual runoff in Regression analysis is shown in Table 4 under column Regression.

4.4 Khosla Method

Khosla method was used in Karokh catchment for computing runoff by use of temperature data. Khosla has suggested this formula for runoff:

$R_m = P_m - L_m$ 4.4
$R_A = \Sigma R_m$ 4.5
$L_m = 5\ T_m$, for $T_m > 4.5^oC$ 4.6

Where,
RA is the annual runoff in mm
R_m is the monthly runoff in mm and $R_m \geq 0$
P_m is the monthly rainfall in mm
L_m is the monthly losses in mm
T_m is the mean monthly temperature of the catchment in ^{o} C

By using this formula the computed values of some monthly runoff were negative so as per Raghunath. it means no flow. The result of annual runoff in Khosla`s method is shown in Table 4 under column Khosla`s.

4.5 Thomas Fiering Model

The last selected method is Thomas Fiering model. The observed monthly flow series is used through stochastic-empirical hydrologic model in the review study to extend observed flow series in this study to 34 years using the seasonal stochastic Thomas Fiering Model at proposed project site. The method requires mean, standard deviation, lag one correlation coefficient, which were obtained from seven year data of observed runoff. The auto correlation coefficients for any lag k can be obtained by:

$$r_k = \frac{\sum_{t=1}^{n-k}(y_t - \bar{y})(y_{t+k} - \bar{y})/(n-k)}{\sum_{t=1}^{n}(y_t - \bar{y})^2/n}.$$

4.6

Where,
r_k is the auto correlation coefficient at lag k
y_i is the observed value at time i
$\bar{y}$ is the average of observed values
y_{i+k} is the observed value at time i + k
n is the number of observation
k is lag

Then, we started generating the data. The first value was assumed to be equal to the mean of first month. The second month in same year was computed by the formula:

$$X_{1,2} = \mu_2 + \rho_1 \frac{\sigma_2}{\sigma_1}(X_{1,1} - \mu_1) + t_{1,2}\sigma_2\sqrt{1-\rho_1^2}$$

4.7

Where,
$X_{1,2}$ is observed value for month 2 in year 1

μ_2 is the mean value of month 2
σ_1 is the standard deviation value of month 1
σ_2 is the standard deviation value of month 2
ρ_1 is the lag one correlation value of month 1
$t_{1,2}$ is the random number value month2 in year1
Like this, we keep on doing from second value we generated the third value and so on till end of the year. The value for last month was taken as previous value for first month of next year. We proceed and generate the time series of monthly flows.

In order to generateflows, we need random numbers. These were taken from function in the MS Excel. However, it is necessary to check whether these are really random. The test was carried out using correlogram analysis. The lag wise correlation coefficients are shown in Figure 3 and these were within the confidence band.

Total 16 sets of 7 years each were generated. Set wise mean was computed in a progressive manner. Thus, for first set 7 year data were used, for second set 14 year data were used. The results are illustrated in Figure 4.

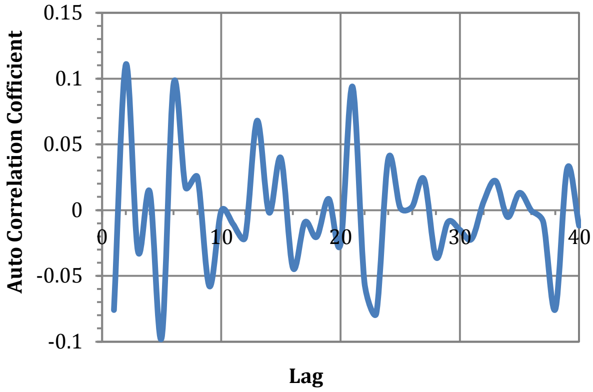

Figure 3 - Correlogram for Random Number

As we generated more, we have seen that generated mean goes closer to observed mean runoff for the respective month. The deviation from the observed mean was noticed to be within 10 % for the majority of rainfall months. The result of annual runoff in Thomas Feiring Model is shown in Table 4 under column Thomas.

Table 4- Comparison of Rainfall Observed with Different Estimated Runoff

Year	Annual rainfall (MCM)	Estimated Runoff (MCM)					
		SCS-CN annual	SCS-CN monthly	Rational	Regression	Khosla`s	Thomas
1963-4	468.673	381.976	150.067	117.168	89.359	107.728	1445.216
1964-5	348.173	265.216	169.583	87.043	75.994	171.218	1425.878
1965-6	287.645	207.527	59.335	71.911	66.698	67.191	1445.360
1966-7	480.52	393.544	180.646	120.13	103.269	86.442	1454.593
1967-8	380.936	296.762	99.372	95.234	89.142	41.462	1441.822
1968-9	649.331	559.386	317.515	162.333	95.887	261.176	1445.321
1969-70	342.435	259.711	142.718	85.609	79.527	77.742	1457.869
1970-1	206.942	132.565	68.828	51.735	73.544	6.479	1406.859
1971-2	706.342	615.687	363.816	176.585	124.98	338.918	1423.889
1972-3	346.692	263.795	126.805	86.673	64.116	79.963	1451.866
1973-4	499.955	412.547	227.29	124.989	82.655	194.725	1449.897
1974-5	719.484	628.68	346.134	179.871	114.771	267.47	1439.966
1975-6	761.316	670.07	325.988	190.329	148.307	264.323	1415.818
1976-7	350.209	267.171	132.243	87.552	73.789	90.144	1458.165
1977-8	349.469	266.46	89.441	87.367	61.693	62.194	1490.760
1978-9	244.517	167.096	62.171	61.129	61.092	30.542	1427.640
1979-80	792.783	701.233	368.727	198.196	101.276	443.685	1446.442
1980-1	546.785	458.449	189.576	136.696	102.821	201.574	1474.797
1981-2	916.245	823.688	467.418	229.061	292.897	428.507	1443.532
1982-3	573.07	484.272	244.03	143.267	73.376	130.31	1422.707
1983-4	249.7	171.916	88.068	62.425	71.985	24.248	1476.126
1984-5	220.269	144.721	55.455	55.067	68.791	16.474	1434.242
1985-6	487.183	400.056	188.512	121.796	92.63	166.96	1458.997
1986-7	368.349	284.621	192.141	92.087	93.982	119.39	1441.049
1987-8	534.569	446.461	278.828	133.642	97.577	254.327	1451.121
2001-2	479.409	392.459	252.643	119.852	88.167	166.59	1425.224
2002-3	425.73	340.156	134.412	106.433	82.194	65.711	1459.913
2003-4	270.061	190.959	111.749	67.515	61.416	92.55	1435.462
2004-5	428.877	343.213	265.72	107.219	53.256	243.036	1439.566
2005-6	306.526	225.423	93.019	76.631	104.671	34.429	1462.301
2006-7	387.044	302.663	165.651	96.761	55.826	94.401	1488.416
2007-8	279.131	199.492	119.581	69.783	80.158	41.277	1417.526
2008-9	589.173	500.111	220.269	147.293	112.615	116.613	1467.661
2009-10	515.318	427.59	172.011	128.83	90.434	181.213	1463.366
Mean	**456.261**	**371.343**	**190.287**	**114.065**	**92.026**	**146.147**	**1446.746**

Table 5- Comparison of Deviations

Year	Deviation %					
	SCS-CN annual	SCS-CN monthly	Rational	Khosla`s	Regression	Thomas
1963-4	18.50	67.98	75	77.01	80.93	-208.36
1964-5	23.83	51.29	75	50.82	78.17	-309.53
1965-6	27.85	79.37	75	76.64	76.81	-402.48
1966-7	18.10	62.41	75	82.01	78.51	-202.71
1967-8	22.10	73.91	75	89.12	76.6	-278.49
1968-9	13.85	51.10	75	59.78	85.23	-122.59
1969-70	24.16	58.32	75	77.30	76.78	-325.74
1970-1	35.94	66.74	75	96.87	64.46	-579.83
1971-2	12.83	48.49	75	52.02	82.31	-101.59
1972-3	23.91	63.42	75	76.94	81.51	-318.78
1973-4	17.48	54.54	75	61.05	83.47	-190.01
1974-5	12.62	51.89	75	62.82	84.05	-100.14
1975-6	11.99	57.18	75	65.28	80.52	-85.97
1976-7	23.71	62.24	75	74.26	78.93	-316.37
1977-8	23.75	74.41	75	82.20	82.35	-326.58
1978-9	31.66	74.57	75	87.51	75.02	-483.86
1979-80	11.55	53.49	75	44.03	87.23	-82.45
1980-1	16.16	65.33	75	63.13	81.2	-169.72
1981-2	10.10	48.99	75	53.23	68.03	-57.55
1982-3	15.50	57.42	75	77.26	87.2	-148.26
1983-4	31.15	64.73	75	90.29	71.17	-491.16
1984-5	34.30	74.82	75	92.52	68.77	-551.13
1985-6	17.88	61.31	75	65.73	80.99	-199.48
1986-7	22.73	47.84	75	67.59	74.49	-291.22
1987-8	16.48	47.84	75	52.42	81.75	-171.46
2001-2	18.14	47.30	75	65.25	81.61	-197.29
2002-3	20.10	68.43	75	84.57	80.69	-242.92
2003-4	29.29	58.62	75	65.73	77.26	-431.53
2004-5	19.97	38.04	75	43.33	87.58	-235.66
2005-6	26.46	69.65	75	88.77	65.85	-377.06
2006-7	21.80	57.20	75	75.61	85.58	-284.56
2007-8	28.53	57.16	75	85.21	71.28	-407.84
2008-9	15.12	62.61	75	80.21	80.89	-149.11
2009-10	17.02	66.62	75	64.83	82.45	-183.97
Mean	**18.61**	**58.29**	**75**	**67.97**	**79.83**	**-217.09**

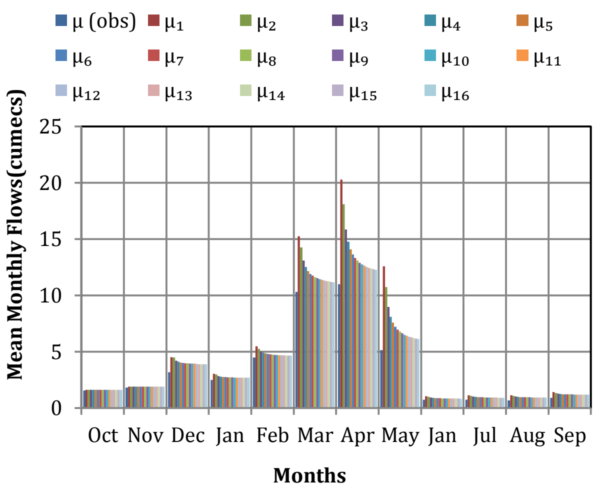

Figure 4- Comparison of Observed Runoff Mean with Generated Mean

5. Result and Discussion

To estimate runoff at the Pashdan dam on Karokh river five different methods are used. From these estimated annual runoff values annual yield of area can be calculated. These yields are compared with the available rainfall values of the Karokh catchment, as these were available for a longer period of 34 years than runoff data for 7 years. As such the computed values are expected to be lower side by the amount of losses. The quantum of losses would amongst other factors depend upon time of year, sequence of rainfall and vegetation growth stage. This aspect is to be kept in mind during the comparison exercise. The results are presented in Table 4.

The variation of the above results is shown in Figure 5.

Another comparison of deviation of all method is shown in Table 5.

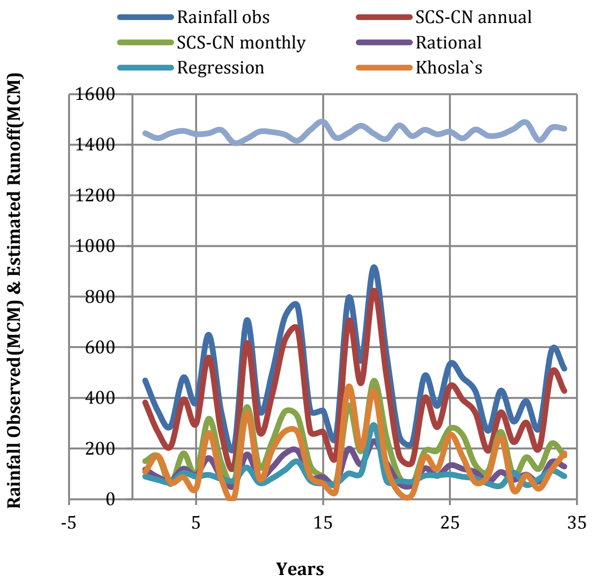

Figure 5 - Comparison of Runoff Values of Karokh Catchment

The variation of the above results is shown in Figure 6.

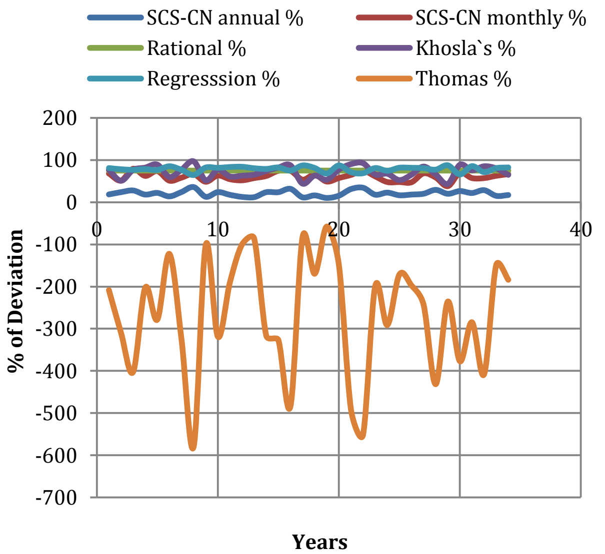

Figure 6 - Comparison of Rainfall with Deviation of the Methods

Now for deciding suitable method different aspects should be considered:

a) Applicability of method and availability of the required data
b) Ease of computation and available of time
c) Number of parameter used in computation
d) Closeness of observed value
e) Matching of trend curves

Review of available methods is taken and five methods viz Rational method, Khosla's method, Correlation, SCS-CN method and Thomas Fierring Model were selected in the present study. Five criteria were considered and review of results was carried out by comparing the trend and quantum of estimated runoff with long term rainfall data at the only rain gauge data at Herat. It is to be therefore kept in mind while reviewing the results that all estimated runoff volumes would be less than the rainfall values by the amount of loss. The loss is varying with time and location in the catchment. It was noticed in analysis of the results that

1) Out of the above methods, rational method is generally used for peak flow estimation. However, the method was selected to test the behavior while using method for long term rainfall. As expected, the results are not matching and thus show the inapplicability of the method. Other methods are also applied duly considering the limitations on account of inadequate data eg temperature data was not readily available for use in Khosla method. Similarly data on vegetation was collected through visual observations in June 2015. No such obvious limitations can be cited for correlation and Thomas Fierring Model (TFM).

2) Computational efforts are least in rational method and Khosla's method; next to these are correlation, SCS-CN and TFM.

3) Number of parameters is equal in rational method and Khosla method. These would vary in correlation depending on the role of parameter in phenomenon to be studied. Therefore, these would be equal to above method in case of linear relation and would increase if higher degree relation is required. Parameters for SCS-CN and TFM rank next in the sequence.

4) In the present study, % deviation of runoff from rainfall estimated by each method was determined. It was seen that the deviations change from minimum 10.1% in SCS-CN method to a maximum -579.83% in TFM method. As said above these deviations have to be discounted for loss as rainfall is used in the comparison against the runoff due to non availability of data. Since the loss rate is varying with time and space, an average value of 15 - 20 %, based on the experience of second author with other catchments, was considered in the study. Thus, all deviations would reduce by this amount. Thus, revised matrix of deviations would get improved and SCS-CN annual was noticed to tend towards acceptable limit of around 15%. It can be seen that the deviations are least for SCS-CN and maximum for TFM. The extreme trend in case of TFM could be due to tendency of approaching mean value. The others except rational method can be seen to be overlapping with each other and thus would have the same order of magnitude. Rational method shows a constant variation of 75% due to coefficient of 0.25 considered in the studies. This again highlights the limitation of the method.

5) The trend of estimations of all methods, except rational and TFM, is similar and show similarity with observed pattern Figure 5. Trend displayed by rational method is obvious due to constant loss coefficient

proposed in the method. Visual comparison of the results easily shows that SCS-CN annual is closest to rainfall pattern and these are followed by Khosala, Rational, Regression and TFM serially. Needless to say that TFM is behaving in its own way and has tendency to approach mean value. Detailed further work is necessary for analysis leading to improvements in estimation.

6) In order to have an overview of the comparison by combining all the criteria, a ranking matrix was framed as given below. Thus, GR1 refers to grade assigned to method as per Criteria 1 viz Applicability of method and availability of the required data. Similarly, grades GR2 to GR5 were assigned. Total grade and final rank could be easily determined.

Method	SCS-CN Annual	Regression	Khosla`s	Rational	TFM
GR1	4	3	2.5	3	2
GR2	3.5	3	4	5	1
GR3	3	3	4	4	2
GR4	5	2	4	3	1
GR5	5	2	4	3	1
Total Grade	20.5	14	18.5	18	7
Rank	**1**	**4**	**2**	**3**	**5**

7) A review of the rank matrix above, shows that SCS-CN annual method is most suitable for the yield estimation in case of Pashdan dam. The series thus derived can be used for estimation of yield of desired dependability to meet withdrawals and releases from Pashdan Dam's planned to serve for various uses including irrigation of canal command areas, domestic water supply and power generation.

Conclusion

Planning engineer is always faced with a dilemma of sizing of storage reservoir. Factors like spatial and temporal variation of rainfall add to the complexities that further increase due to low or no availability of data on runoff. It is therefore proposed to review the available methods for estimation of yield from a catchment with inadequate data. Review of available methods is taken and five methods viz Rational method, Khosla's method, Correlation, SCS-CN method and Thomas Fiering Model were selected in the present study. Available period runoff data and rainfall data were collected and analyzed for testing the homogeneity. The data passed t-test at 5% significance level. Five criteria were considered and review of results was carried out by comparing the trend and quantum of estimated runoff with long term rainfall data at the only rain gauge data at Herat. It is to be therefore kept in mind while reviewing the results that all estimated runoff volumes would be less than the rainfall values by the amount of loss. The loss is varying with time and location. The results were compared using the above criteria and grading was done to decide the rank of each method. The grading matrix shows the suitability of the methods for Pashadan catchment is as given below:

1) Soil Conservation Service Method
2) Khosalas Method
3) Rational Method
4) Regression Analysis Method
5) Thomas Fiering Method

The series of yield values derived by Soil Conservation Service Method annual can therefore be selected for estimation of yield of desired dependability.

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