Example: *X and Y are two neighboring rainfall stations. Station X has complete records and station Y has some missing values. Find the linear correlation equation between the two series as mentioned in columns 2 and 3 of the following table (8) and then check the correlation by computing both the correlation and regression coefficients, showing the correlation line on an X-Y diagram? Using the derived equation, find the missing data of Y if the observed data at X for the same years are (110, 170 and 166 mm).*

Table (6): Annual precipitation amounts as recorded by stations X and Y.

No.	***X***	***Y***
1	*200*	*145*
2	*225*	*155*
3	*190*	*148*
4	*230*	*152*
5	*205*	*153*
6	*150*	*140*
7	*167*	*138*

Table (7): Annual precipitation amounts as recorded by stations X and Y. (continued)

8	*196*	*145*
9	*112*	*128*
10	*125*	*130*

11	*135*	*133*

Solution: Let us compute (a) and (b) first. To do so, the following table (4) should be completed.

Step 1: preparing of table (9):

Table (8): Computations of the Components to be Used in the Least Squares Method

No.	**X**	**Y**	**X*Y**	**X^2**	**Y^2**
1	200	145	29000	40000	21025
2	225	155	34875	50625	24025
3	190	148	28120	36100	21904
4	230	152	34960	52900	23104
5	205	153	31365	42025	23409
6	150	140	21000	22500	19600
7	167	138	23046	27889	19044
8	196	145	28420	38416	21025
9	112	128	14336	12544	16384
10	125	130	16250	15625	16900
11	135	133	17955	18225	17689
Total	**1935**	**1567**	**279327**	**356849**	**224109**

Step 2: Computation of the slope of the line:

In order to compute (**b**) in the linear equation we have to follow the following computations:

$$b = \frac{N * (\sum X * Y) - (\sum X * \sum Y)}{N * (\sum X^2) - (\sum X)^2}$$

$$b = \frac{11 * 279327 - 1935 * 1567}{11 * 356849 - 1935 * 1935}$$

$$b = \frac{3072597 - 3032145}{3925339 - 3744225}$$

$$b = \frac{40452}{181114}$$

$$b = 0.22335$$

Step 2: Computation of the intercept of the line:

For the computation of (**a**) in the linear equation we have to follow the following computations:

$$a = \frac{\sum Y - b * \sum X}{N}$$

$$a = \frac{1567 - 0.22335 * 1935}{11}$$

$$a = \frac{1567 - 432.18225}{11}$$

$$a = \frac{1134.81775}{11}$$

$$a = 103.165$$

As a result, the linear equation can be written as:

$$Y = 103.17 + 0.2334 * X$$

Step 3: Computation of the correlation coefficient of the line:

For the computation of (**r**) in the linear equation we have to follow the following computations:

$$r = \frac{N * (\sum X * Y) - (\sum X) * (\sum Y)}{\sqrt{\{[N * (\sum X^2) - (\sum X)^2] * [N * (\sum Y^2) - (\sum Y)^2]\}}}$$

$$r = \frac{11 * 279327 - 1935 * 1567}{\sqrt{\{[11 * 356849 - 1935 * 1935] * [11 * 224109 - 1567 * 1567}}}$$

$$r = \frac{3072597 - 3032145}{\sqrt{\{[3945139 - 3744225] * [2465199 - 2455489}}}$$

$$r = \frac{40452}{\sqrt{\{[181114] * [9710]}}}$$

$$r = \frac{40452}{41935.867}$$

$$r = 0.96676$$

Step 4: Computation of the regression coefficient of the line:

For the computation of (**r^2**) in the linear equation we have to follow the following computations:

$$r^2 = \frac{a*(\sum Y) + b*(\sum X*Y) - \frac{1}{N}*(\sum Y)^2}{\sum Y^2 - \frac{1}{N}(\sum Y)^2}$$

$$r^2 = \frac{103.165*1567 + 0.22335*279327 - 0.09091*2455489}{224109 - 0.09091*2455489}$$

$$r^2 = \frac{161659.555 + 62387.685 - 223228.505}{224109 - 223228.505}$$

$$r^2 = \frac{818.05}{880.495}$$

$$r^2 = 0.929$$

$r^2 \approx$ 0.93 , which is the square of the value of **(r)**

Step 5: Filling the missing values at station Y using the regression equation:

The derived equation was:

$$Y = 103.17 + 0.2334 * X$$

From the observed precipitation values at station X, *110, 170 and 166 mm,* we can have the computed values at station Y as follows:

Y_1 = 103.17+ 0.2334*110 = 127.7 mm

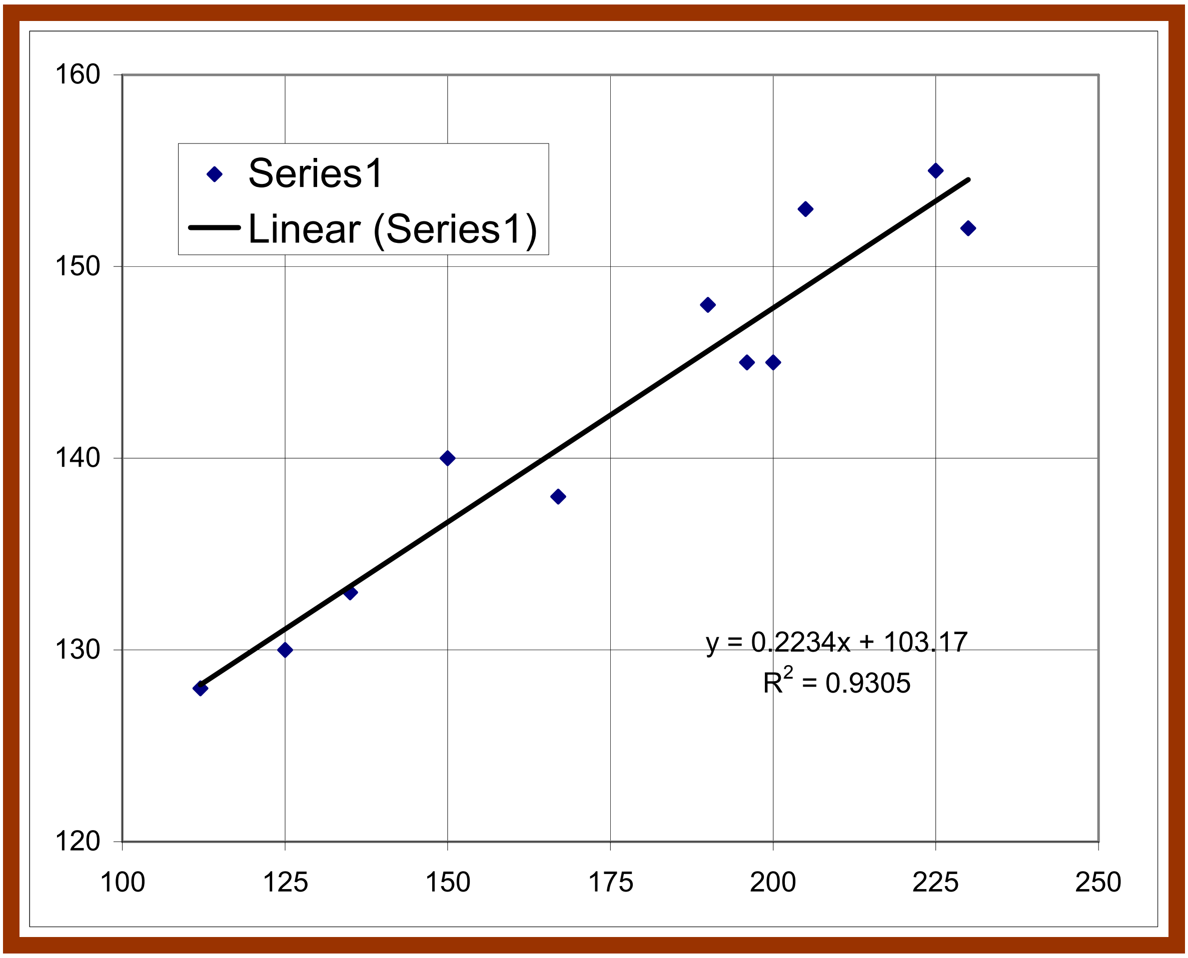
Y_2 = 103.17+ 0.2334*170 = 142.8 mm

Y_3 = 103.17+ 0.2334*166 = 141.9 mm

Step 6: Drawing of the regression line:

The regression line can be represented as shown in the following figure (8).

Figure (8): The regression line between the precipitation values of the rainfall stations X and Y



Example: *Annual precipitation at rain gauge X and the average annual precipitation at twenty surrounding stations are listed in the following table:*

a. *Examine the consistency of station X*
b. *When did a change in regime occur? Discuss possible causes.*
c. *Adjust the data and determine what difference this makes to the 36-year annual average at station X.*

Table (9): *Observed annual precipitation values at Station X and computed average annual precipitation for twenty nearby stations*

Year	***Annual precipitation (mm)***		***Year***	***Annual precipitation (mm)***	
	Gauge X	***20-Station Average***		***Gauge X***	***20-Station Average***
1992	*188*	*264*	**1974**	*245*	*302*
1991	*185*	*228*	**1973**	*280*	*360*
1990	*310*	*386*	**1972**	*315*	*340*
1989	*295*	*330*	**1971**	*300*	*290*
1988	*208*	*330*	***1970***	*250*	*370*
1987	*287*	*380*	**1969**	*290*	*275*
1986	*183*	*310*	**1968**	*315*	*255*
1985	*304*	*400*	**1967**	*310*	*255*
1984	*228*	*234*	**1966**	*338*	*225*
1983	*216*	*325*	**1965**	*350*	*235*

Table (9): *Observed annual precipitation values at Station X and computed average annual precipitation for twenty nearby stations*

(continued)

Year	***Annual precipitation (mm)***		***Year***	***Annual precipitation (mm)***	
	Gauge X	***20-Station Average***		***Gauge X***	***20-Station Average***
1982	*224*	*330*	**1964**	*450*	*270*
1981	*203*	*300*	**1963**	*333*	*300*
1980	*284*	*312*	**1962**	*325*	*200*
1979	*295*	*375*	**1961**	*350*	*275*
1978	*185*	*301*	**1960**	*345*	*210*
1977	*269*	*333*	**1959**	*318*	*222*
1976	*210*	*360*	**1958**	*313*	*225*
1975	*260*	*400*	**1957**	*400*	*280*

Solution: Let us first compute the cumulative values of the precipitation amounts tabulated in the above-mentioned table (9). To do so, the following table (10) should be completed.

Step 1: Preparing of table (10):

Both the observations of the X gauge and the data of the average of the surrounding 20 stations are being accumulated on year basis as shown in the following table (10).

Step 2: Plotting the accumulating data against each other where the accumulated precipitation of X gauge on the ordinate and the accumulated average of the surrounding 20 stations on the abscissa.

Step 3: Computing of the linear equations of fitting lines and finding the different slopes.

Step 4: Finding the averages of the recent data presented by the recent line for both variables and then, finding the ratio between them.

Step 5: Finding the annual means of the records of the whole period for both variables, which was found as 282.25 mm and 299.64 mm for the station X and the series of average of the 20 stations respectively.

.

Table (10): The cumulative data calculation of the precipitation data of station X and the average of the 22 surrounding stations

Year	*Cumulative Annual precipitation (mm)*		*Year*	*Cumulative Annual precipitation (mm)*	
	Gauge X	*20-Station Average*		*Gauge X*	*20-Station Average*
1992	*188*	*264*	1974	*4579*	*6200*
1991	*373*	*492*	1973	*4859*	*6560*
1990	*683*	*878*	1972	*5174*	*6900*
1989	*978*	*1208*	1971	*5474*	*7190*

1988	*1186*	*1538*	*1970*	*5724*	*7560*
1987	*1473*	*1918*	1969	*6014*	*7835*
1986	*1656*	*2228*	1968	*6329*	*8090*
1985	*1960*	*2628*	1967	*6639*	*8345*
1984	*2188*	*2862*	1966	*6977*	*8570*
1983	*2404*	*3187*	1965	*7327*	*8805*
1982	*2628*	*3517*	1964	*7777*	*9075*
1981	*2831*	*3817*	1963	*8110*	*9375*
1980	*3115*	*4129*	1962	*8435*	*9575*
1979	*3410*	*4504*	1961	*8785*	*9850*
1978	*3595*	*4805*	1960	*9130*	*10060*
1977	*3864*	*5138*	1959	*9448*	*10282*
1976	*4074*	*5498*	1958	*9761*	*10507*
1975	*4334*	*5898*	1957	*10161*	*10787*

a. The cumulative values are drawn in figure (9). There is inconsistency in the data after the year of 1970.

b. The cause of the inconsistency could be a change in the gauge location or in the exposure affected by the conditions surrounding the station such as outcropping of trees or construction of buildings nearby the station, with which a rain gauge samples the rainfall in the particular area.

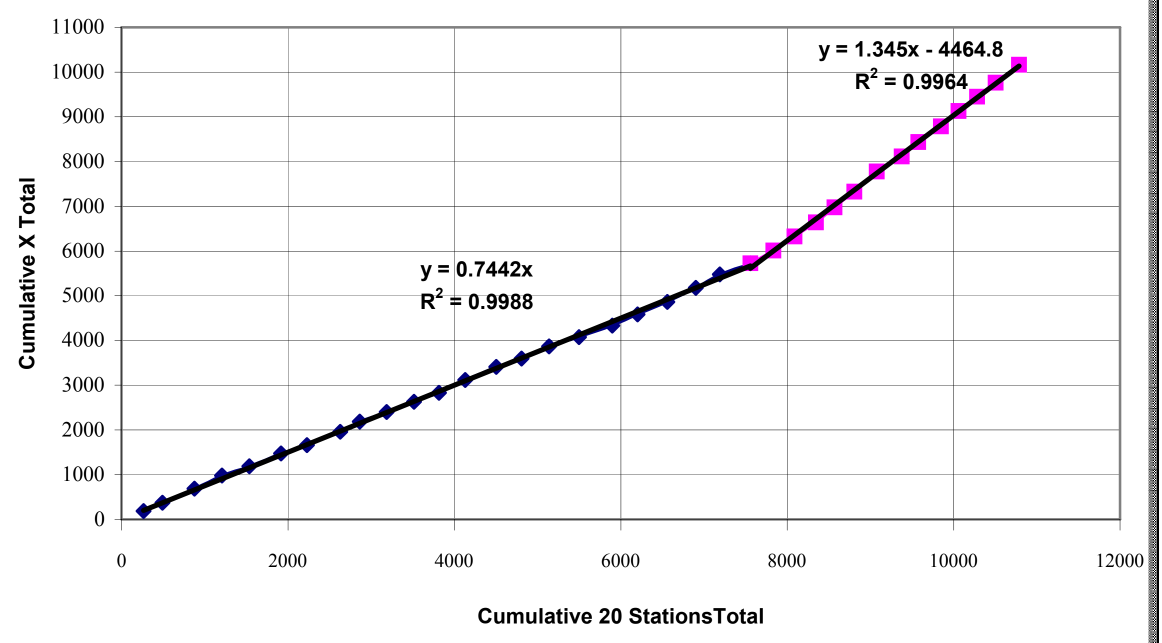
For example, moving a gauge from one part of a roof to another can affect the catch of the gage greatly, even though the gauge is moved only a few meters. Also construction a tall building in the vicinity of the gauge changes wind direction and affects thermal air currents, thus influencing the catch in the rain gauge.

c. If the earlier period is correct, then for the period of 1957-1970 the ratio between the average precipitation will be:

$$\frac{Gauge \qquad X \qquad Average}{20 \qquad Stations \qquad average} \approx 1.303$$

This ratio applied to the whole gauge X record gives an annual average over 36 years of 334.79 mm instead of the existing average of 282.25 mm.

Figure (9): Double Mass Curve for consistency of Precipitation Data

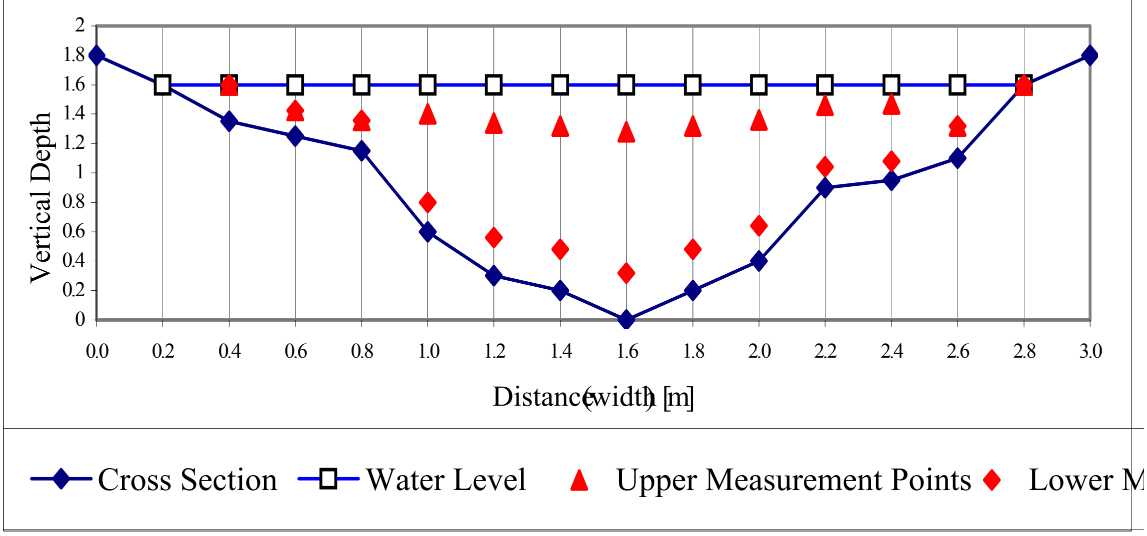


Example: *an irregular cross section of 3.0 m width and 1.8 m maximum depth has a maximum depth of water equals to 1.6 m that was measured by a standard current meter. The velocities was rated to be as indicated in the following table (25).*

Distance from Right Edge [m]	*Vertical Depth [m]*	*Method Used*	*Velocity-1 [m^3/s]*	*Velocity-2 [m^3/s]*
0				
0.2	0		0	
0.4	0.25	S.V	0.02	
0.6	0.35	0.6 D	0.032	
0.8	0.45	0.6 D	0.036	
1	1	0.2 D, 0.8 D	0.018	0.102
1.2	1.3	0.2 D, 0.8 D	0.022	0.118
1.4	1.4	0.2 D, 0.8 D	0.027	0.123
1.6	1.6	0.2 D, 0.8 D	0.03	0.13
1.8	1.4	0.2 D, 0.8 D	0.027	0.123
2	1.2	0.2 D, 0.8 D	0.019	0.111
2.2	0.7	0.2 D, 0.8 D	0.02	0.08
2.4	0.65	0.2 D, 0.8 D	0.018	0.072
2.6	0.5	0.6 D	0.036	
2.8	0		0	
3				

Table (25): Current Meter Measurements in a Cross-Section X

Fig (13): Cross Section for Current Meter Measu



Solution:

Step 1: *Averaging the Velocities by Applying the equations indicated for the methods to be used, as in table (24) taking into consideration the depth of water. Column 4 of table (26).*

Step 2: *Computation of Partial Areas, by multiplying the average width with the depth. Column 5 of table (26).*

Step 3: *Computation of partial Q for each vertical partial section, by multiplying the partial area with its related average velocity. Column 6 of table (26).*

Step 4: *Finding the average velocity of the flow, by dividing the total of the column 6 to column 5 as follows:*

$$\overline{V} = \frac{\sum Q}{\sum A} = \frac{0.13618}{2.18} = 0.063$$

Table (36): Discharge Computation by Current Meter Measurement

Distance from Right Edge [m]	***Vertical Depth [m]***	***Method Used***	***Corrected Velocity [m/s]***	***Partial Areas [m^2]***	***Discharge Q [m^3/s]***
Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*
0					
0.2	0		0	0	0
0.4	0.25	S.V	0.017	0.05	0.00085
0.6	0.35	0.6 D	0.032	0.07	0.00224
0.8	0.45	0.6 D	0.036	0.09	0.00324
1	1	0.2 D, 0.8 D	0.06	0.2	0.012
1.2	1.3	0.2 D, 0.8 D	0.07	0.26	0.0182
1.4	1.4	0.2 D, 0.8 D	0.075	0.28	0.021
1.6	1.6	0.2 D, 0.8 D	0.08	0.32	0.0256
1.8	1.4	0.2 D, 0.8 D	0.075	0.28	0.021
2	1.2	0.2 D, 0.8 D	0.065	0.24	0.0156
2.2	0.7	0.2 D, 0.8 D	0.05	0.14	0.007
2.4	0.65	0.2 D, 0.8 D	0.045	0.13	0.00585
2.6	0.5	0.6 D	0.036	0.1	0.0036
2.8	0		0	0	0
3					
			Σ	**2.16**	**0.13618**

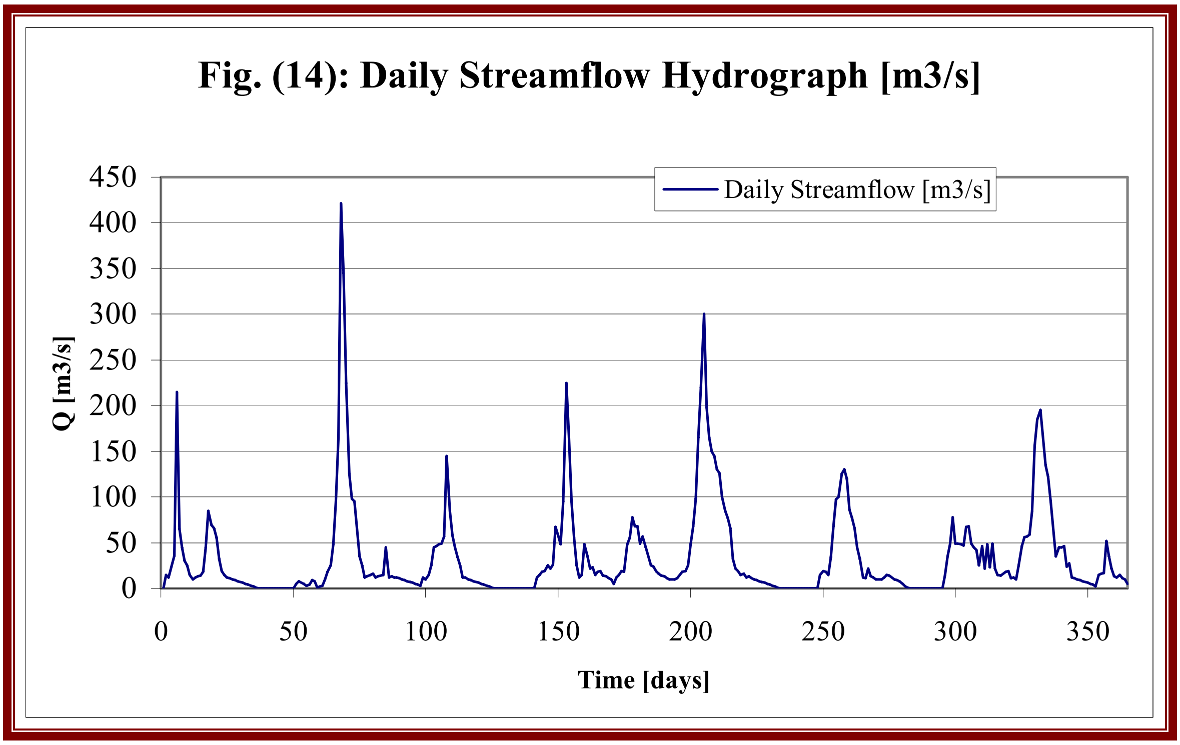


Fig. (14): Daily Streamflow Hydrograph [m3/s]
Daily Streamflow [m3/s]
Q [m3/s]
Time [days]
0
50
100
150
200
250
300
350
400
450

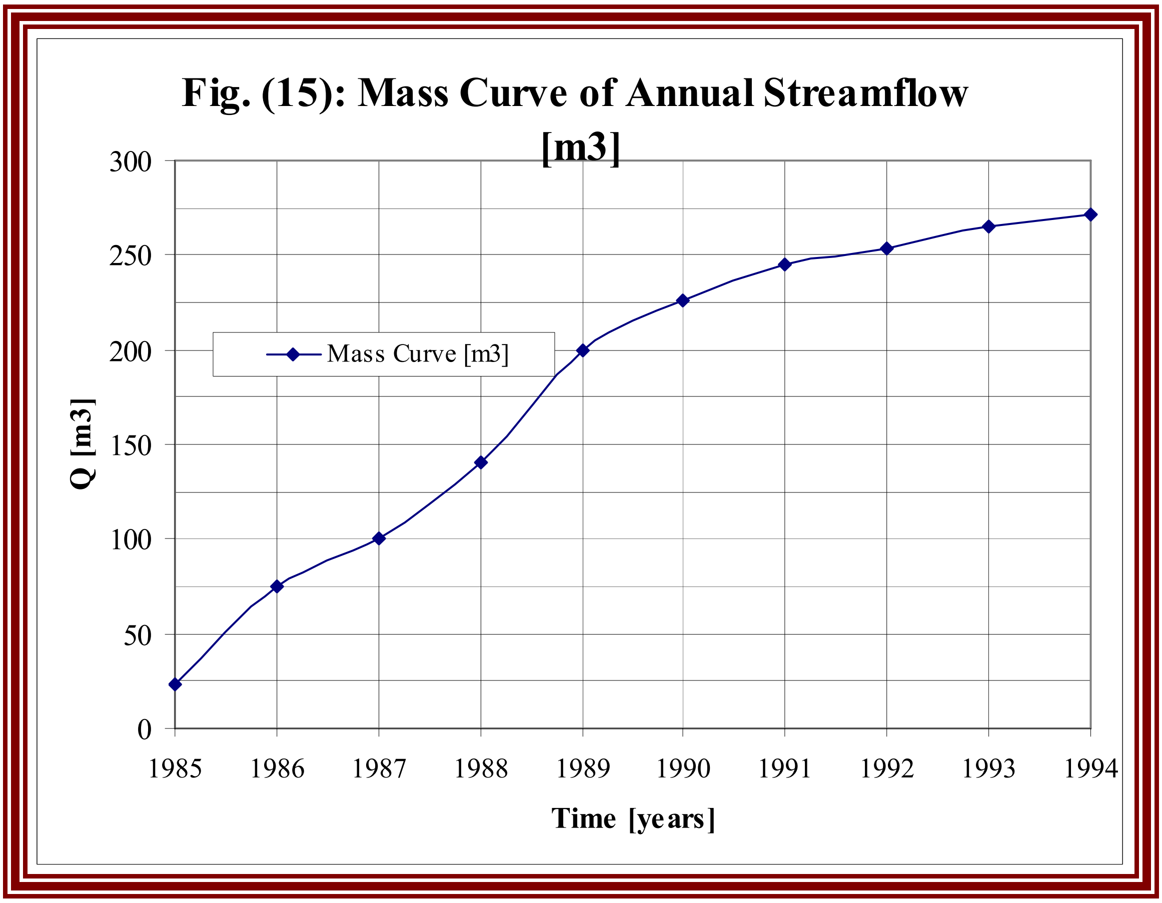


Fig. (15): Mass Curve of Annual Streamflow [m3]
Mass Curve [m3]
Q [m3]
Time [years]
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
0
50
100
150
200
250
300

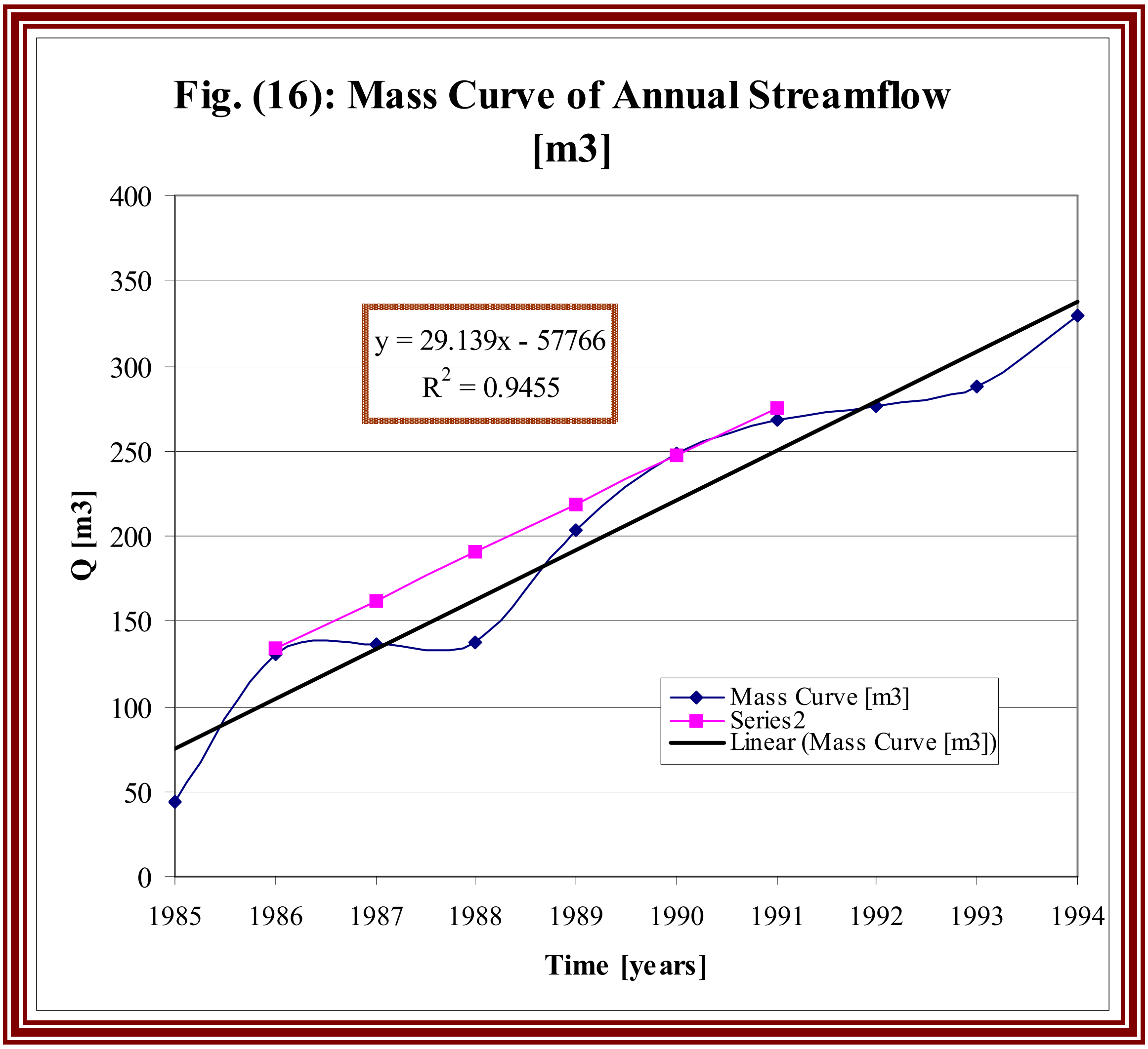


Fig. (16): Mass Curve of Annual Streamflow [m3]
y = 29.139x - 57766
R2 = 0.9455
Q [m3]
400
350
300
250
200
150
100
50
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
Time [years]
Mass Curve [m3]
Series2
Linear (Mass Curve [m3])

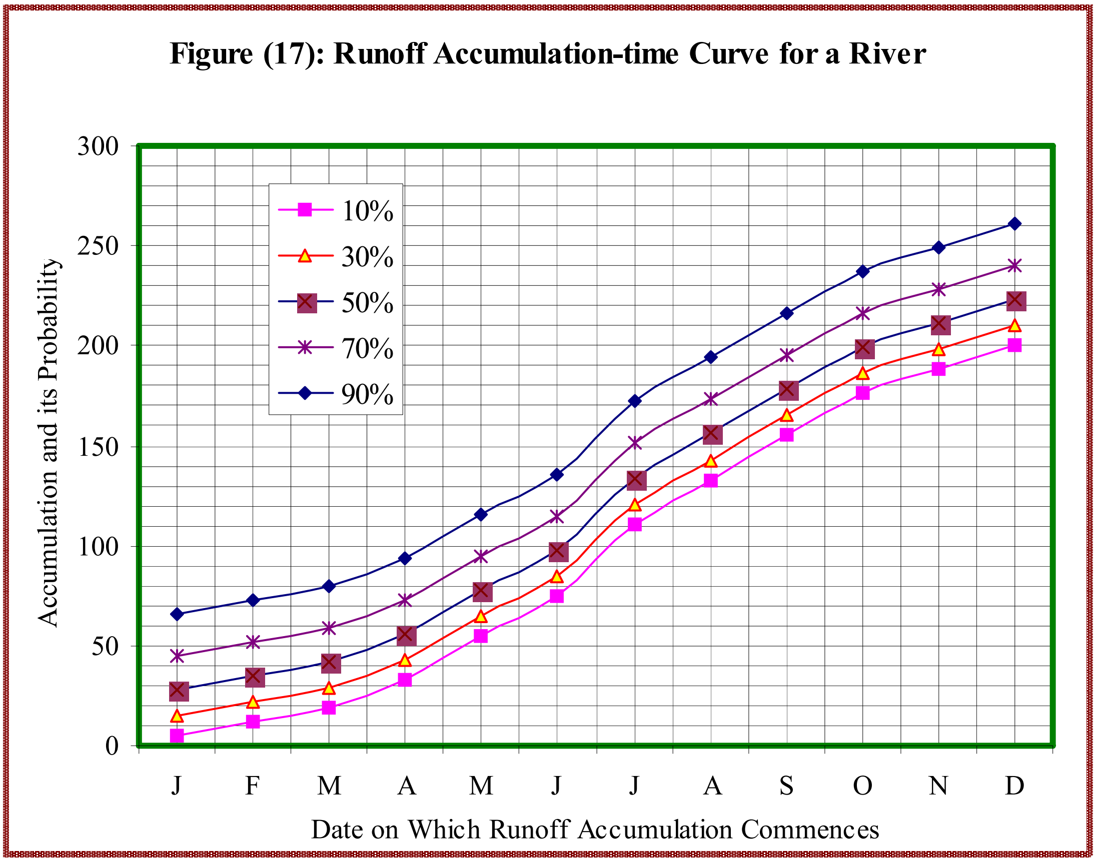


Figure (17): Runoff Accumulation-time Curve for a River
300
250
200
150
100
50
0
Accumulation and its Probability
10%
30%
50%
70%
90%
J
F
M
A
M
J
J
A
S
O
N
D
Date on Which Runoff Accumulation Commences

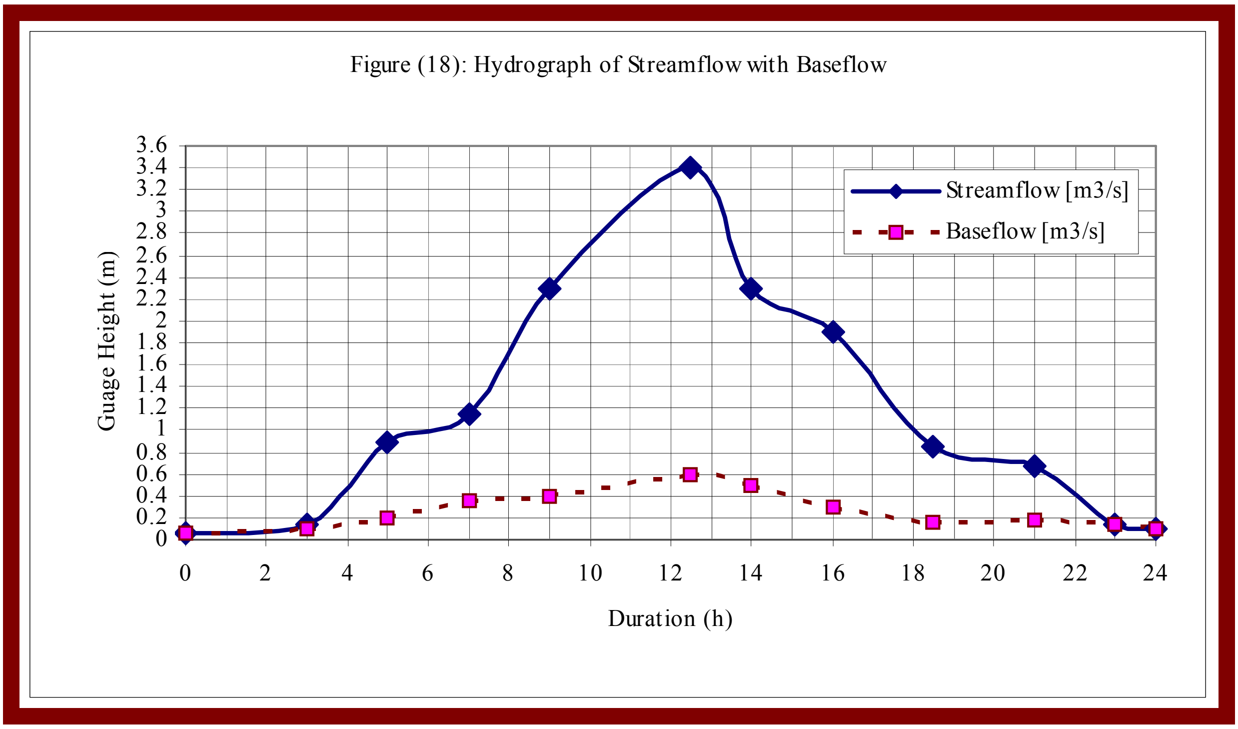


Figure (18): Hydrograph of Streamflow with Baseflow
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Guage Height (m)
Streamflow [m3/s]
Baseflow [m3/s]
0
2
4
6
8
10
12
14
16
18
20
22
24
Duration (h)