Estimation of Missing Rainfall Data

- Rainfall data are generally collected at point locations (mainly at meteorological stations)
- However, rainfall data might be incomplete. Missing data therefore could be attributed to:
  i. Malfunctioning التقصير
  ii. Mismanagement سوء لادارة
  iii. Inability to take the measurement عدم القدرة لاخذ القياس
  iv. Vandalism تخريب متعمد
- Therefore, when part of rainfall data is missing, then estimation of missing data should be made

1- Station – Average Method

- Consider n rain gages present in a region with measured data for a given storm event
- The data at station X are missing for a storm event
- Then

$$P_x = \frac{1}{n} \sum_{i=1}^{n} (P_i)$$

- Use this method when the annual rainfall of any station is within the 10% of the average annual rainfall from the gages

Example: Find the missing rainfall data at station D for the following storm events given the average annual rainfall data,

Gage	Rainfall (in)	
	Annual	Storm
A	42	2.6
B	41	3.1
C	39	2.3
D	41	?

Solution: The average annual rainfall at the four gages is 40.7 in and thus all the annual readings are within 10% of the average

10% of the average annual rainfall from the gages = 40.7+ (40.7 * 10/100) = 44.77

Annual rainfall < 44.77

36.63 | 40.7 | 44.77

$$P_D = \frac{1}{3} \text{ x } (2.6 + 3.1 + 2.3) = 2.67 \text{ in}$$

2- Normal – Ratio Method

In regions where the annual average rainfall differs considerably between locations, the normal – ratio method is preferred

$$P_x = \sum_{i=1}^{n} \frac{A_x}{nA_i}(P_i)$$

Px: missing rainfall data at x

Ax: annual rainfall at station x

Ai: annual rainfall at station i

n: No. of stations (known precipitation)

Example : Find the missing rainfall data at station D for the following storm events given the average annual rainfall data

Gage	Rainfall (in)	
	Annual	Storm
A	41	2.4
B	37	2.3
C	46	3.1
D	40	?

$$P_x = \sum_{i=1}^{n} \frac{A_x}{nA_i}(P_i)$$

$$P_D = \frac{40}{3x41} \text{ x } 2.4 + \frac{40}{3x37} \text{ x } 2.3 + \frac{40}{3x46} \text{ x } 3.1 = 2.51 \text{ in}$$

- Use the flowing equation when the annual rainfall of any station is greater than the 10% of the average annual rainfall from the gages

$P_X = N_X/3*[P_A/N_A + P_B/N_B + P_C/N_C]$

where:

A,B,C = rainfall for each station is know

X= missing data station

N= average annual rainfall for station

P = rainfall for station during limit time

Example: One of four monthly reading gages on a catchment area develops a fault in a month when the other three gages record, respectively (**122, 89, 107**) mm. If the average annual precipitation of these three gages are (**935, 1120, 979**) mm, respectively and (**1200mm**) of the broken gage. Estimate the missing monthly precipitation at the later station?

Solution:

$(N_A-N_X)/N_X*100 = (935-1200)/1200*100= 22\%$

$(N_B-N_X)/N_X*100 = (1120-1200)/1200*100= 7\%$ **<10%**

$(N_C-N_X)/N_X*100 = (979-1200)/1200*100= 18\%$ **> 10%**

$P_X = N_X/3*[P_A/ N_A+ P_B/ N_B+ P_C/ N_C]$

$= 1200/3[122/935+89/1120+107/979]$

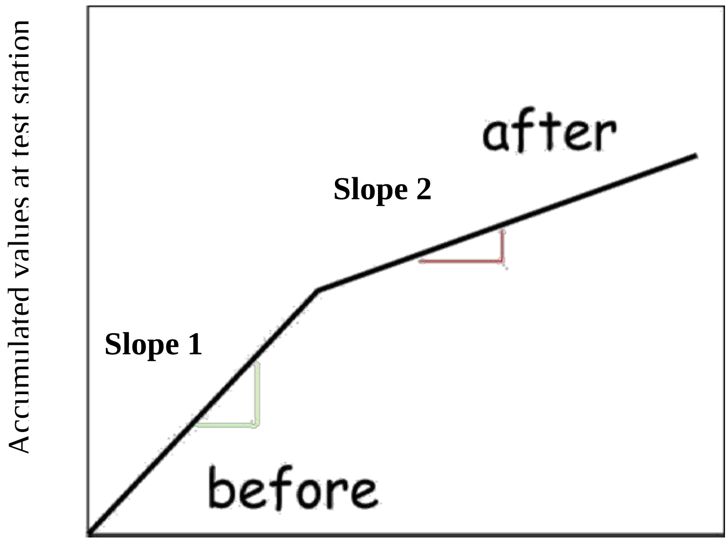
$=127.7$ mm

Testing of Consistency of precipitation Records.

Numerous factors could affect the consistency of the record at a given station.

- damage and replacement of a rain gage
- change in measurement procedure, or
- human, mechanical, or electrical error in taking readings
- Changes in type, location, and/or environment of the gage are common
- Trees may grow up or buildings may be constructed around a gage

- So it is important for a hydrologist to determine if the precipitation record is affected by such artificial alterations of measurement conditions and to correct them if they are present
- The most common technique for detecting and correcting the inconsistent precipitation data is the **double-mass curve**
- The double-mass curve is a plot of the successive cumulative annual precipitation collected at a gage where measurement conditions may have changed significantly versus the successive cumulative of average annual precipitation for the same period of years collected at several gages in the same region
- A change in the proportionality between the measurements at the suspect station and those of the region is reflected in a change in the slope of the trend of the plotted points



Correction Factor

K = slope (after) / slope (before)

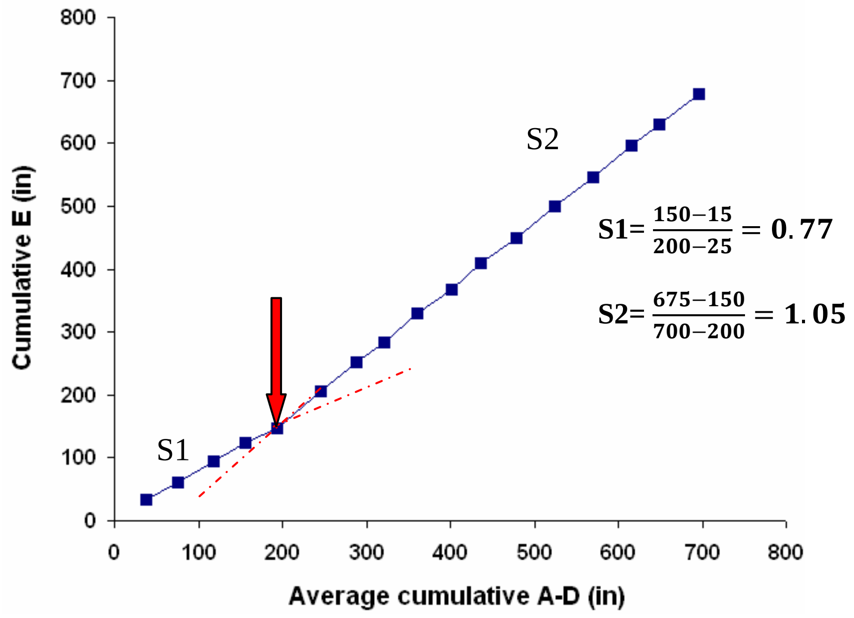
EX:

- The problem is in station E
- Find the average for stations A to D and then the cumulative
- Find the cumulative for station E

Year	A	B	C	D	E
1926	39.75	45.7	30.69	37.36	32.85
1927	39.57	38.52	40.99	30.87	28.08
1928	41.01	48.26	40.44	42	33.51
1929	41.39	34.64	32.49	39.92	29.58
1930	31.55	45.13	36.72	36.32	23.76
1931	55.54	53.28	62.35	36.61	58.39
1932	48.11	40.08	47.85	38.61	46.24
1933	39.85	29.57	32.74	26.89	30.34
1934	45.4	41.68	36.13	32.44	46.78
1935	44.89	48.13	30.73	41.56	38.06
1936	32.64	39.48	35.4	31.32	42.82
1937	45.87	44.11	39.16	44.14	37.93
1938	46.05	38.94	43.27	50.62	50.67
1939	49.76	41.58	49.85	41.09	46.85
1940	47.26	49.66	47.86	39.01	50.52
1941	37.07	31.92	32.15	34.45	34.38
1942	45.89	38.16	52.39	47.32	47.6

Year	Average A-D	Cumulative A-D	Cumulative E
1926	38.375	38.38	32.85
1927	37.4875	75.86	60.93
1928	42.9275	118.79	94.44
1929	37.11	155.90	124.02
1930	37.43	193.33	147.78
1931	51.945	245.28	206.17
1932	43.6625	288.94	252.41
1933	32.2625	321.20	282.75
1934	38.9125	360.11	329.53
1935	41.3275	401.44	367.59
1936	34.71	436.15	410.41
1937	43.32	479.47	448.34
1938	44.72	524.19	499.01
1939	45.57	569.76	545.86
1940	45.9475	615.71	596.38
1941	33.8975	649.61	630.76
1942	45.94	695.55	678.36

- Apparently, there is a slope difference
- The slope before the change is 0.77 while after the change it is 1.05
- To reflect the conditions that exist before the break then multiply by 0.77/1.05 all the records after change
- To reflect the conditions that exist after the break then multiply by 1.05/0.77 all the records before the change



E (adjusted)
44.80
38.29
45.70
40.34
32.40

<u>Double Mass Curve Analysis</u> **<u>(Consistency Test):</u>*****<u>DMC</u>***

<u>DMC</u>: is a plot of accumulative totals for each year at the gage against the sum of accumulative totals for the same years at a number of adjacent gages.

<u>DMC</u>: is used to check if trended in rainfall data of a certain gage is due to Meteorological condition only.

Example: Annual precipitation at rain gage (**X**) and the annual precipitation at (**15**) surrounding rain gages are listed in the following table:

a. Examine the consistency of st. (**X**) data;

b. When did a change in regime occur?

c. Adjust the data and determine what difference this makes to the **33** year annual average precipitation at st. (**X**).

Year	Annual precipitation (mm)	
	St.(X)	(15) Sts.
1938	13.4	13.9
1939	10.7	9.9
1940	10.9	10.1
1941	12	13.7
1942	13.3	13.1
1943	14.6	13.2
1944	9.0	10.9
1945	11.8	11.4
1946	9.7	10.2
1947	15.4	13.9
1948	12.5	13.0
1949	11.5	13.1
1950	11.5	13.1
1951	13.9	10.9
1952	14.1	13.2
1953	10.4	10.0
1954	7.9	8.8
1955	13.3	9.6
1956	16.3	10.2
1957	22.7	15.9
1958	13.9	10.9
1959	14.7	10.2
1960	14	10.3
1961	11.4	10.2
1962	13.8	11.8
1963	10.0	9.2
1964	10.5	10.2
1965	16.7	14.0
1966	9.3	8.4
1967	18.4	11.5
1968	14.1	9.0
1969	19.8	13.0
1970	17.1	13.1
1971	16.0	10.7

Rainfall Classification

- Very light — < 0.25 mm/hr
- Light — 0.25 mm/hr - 1.0 mm/hr
- Moderate — 1.0 mm/hr - 4.0 mm/hr
- Heavy — 4.0 mm/hr - 16.0 mm/hr
- Very heavy — 16.0 mm/hr – 50 mm/hr
- Extreme — > 50.0 mm/hr