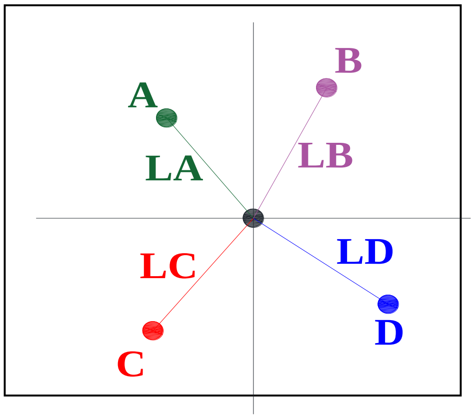
3- U.S. National Weather Service: An alternate method for filling in missing precipitation data has been developed, the method requires data for four index stations A, B, C, and D each located closest to the station X of interest, and in each of four quadrants delimited by north-south and east-west lines drawn through station X. the estimated precipitation value at station X is the weighted average of the values at the four index stations. For each station, the applicable weight is the reciprocal of the square of its distance L to station X.



$$P_X = \frac{\sum_{i=1}^{4}\left(\frac{P_i}{L_i^2}\right)}{\sum_{i=1}^{4}\left(\frac{1}{L_i^2}\right)}$$

Where: P = precipitation,

L = distance between index stations and station X.

4- Apparent trends in Observed data: from several years records it may seem that annual rainfall is, declining. It is important to know that this trend is independent of the gauging, and is due only to meteorological conditions. This may be checked by plotting a double mass curve.

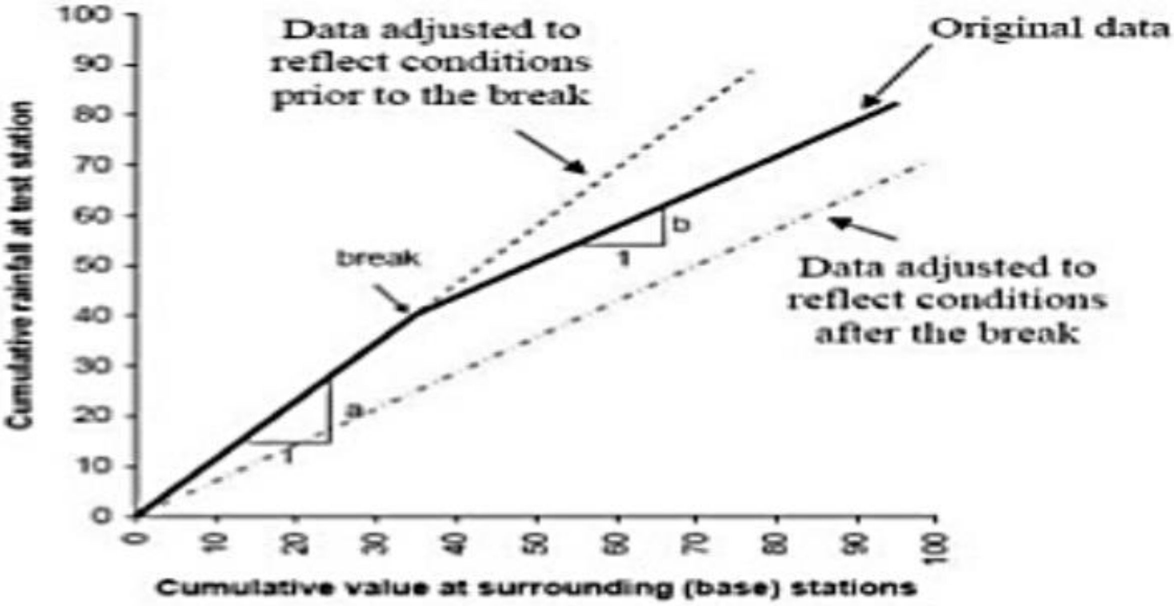
A sudden divergence from the straight line correlation indicated by the dashed line in the figures, indicates that a change has occurred in gauging and that the meteorology of the region is probably not the cause of the decline. Such a change might be due to the erection of a building or fence near the gauge which changes the wind pattern round the gauge, the planting of tress, the replacement of one measuring vessel by another, even the changing of an observer who uses different procedures.

In hydrology, a method called double-mass analysis can be used to evaluate the records compiled
at a gage station.
Steps of examples solution:
1- Prepare accumulation annual precipitation of station X with the surrounding years.
2- Prepare accumulated annual precipitation of surrounding stations.
3- Plot the data of step (1) on Y-axis and the data of step (2) on X – axis.
4- To adjusted the data after the point of inconsistency should be adjusted by following equation:

P_{new} of X station= P_{old} of X station * $\frac{slope\ 1}{slope 2}$

5- To adjusted the data before the point of inconsistency should be adjusted by following equation: P_{new} in X station= P_{old} of X station * $\frac{slope\ 2}{slope 1}$

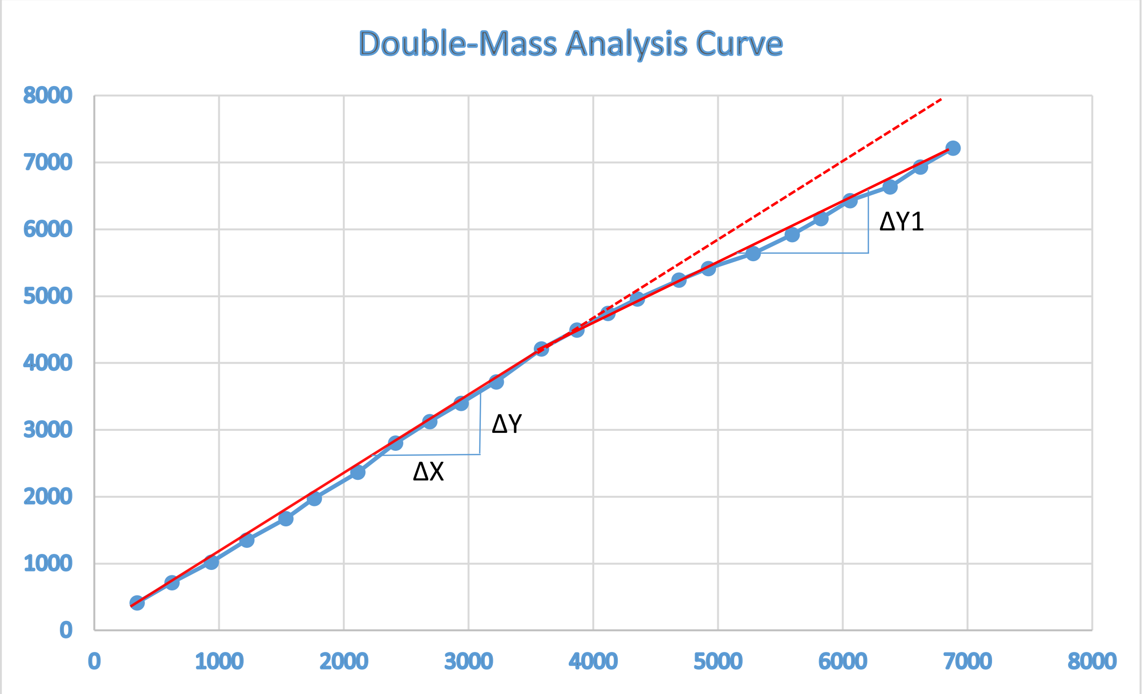
Figure (3.29) is summarized the double mass analysis method and all steps of solution



Example 1.14: yearly precipitation for station X and average yearly precipitation for 20 stations around the station X shown in table below from 1960. Check the observed data for station X. change the observed data, then find the average yearly precipitation for 24 years.

year	Station X	for 20 Station	X Cumulative	For 20 years Cumulative	Correction = 1.17/0.9= 1.3
1937	414	343	414	343	
1938	302	280	716	623	
1939	308	315	1024	938	
1940	328	284	1352	1222	
1941	320	312	1672	1534	
1942	305	228	1977	1762	
1943	389	350	2366	2112	
1944	437	302	2803	2414	
1945	322	274	3125	2688	
1946	274	252	3399	2940	
1947	320	282	3719	3222	
1948	493	361	4212	3583	
1949	284	284	4496	3867	284*1.3 = 369
1950	246	251	4742	4118	246 * 1.3 = 320
1951	218	236	4960	4354	283
1952	282	333	5242	4687	367
1953	173	234	5415	4921	225
1954	223	360	5638	5281	390
1955	284	312	5922	5593	370
1956	241	231	6163	5824	313
1957	269	234	6432	6058	250

1958	206	321	6638	6379	268
1959	295	242	6933	6621	384
1960	284	264	7217	6885	369



Average yearly precipitation for station X = $\frac{Cummlative\ for\ 24\ year}{24}$

Cumulative from 1937-1948 = 4212 mm

Corrected cumulative 1949-1960 = 3906.5 mm

Total cumulative = 4214 + 3906.5 = 8118.5 mm

Average yearly X = $\frac{8118.5}{24} = 338.27\ mm$

1.17 Measuring of precipitation or precipitation gages:

The amount of precipitation is expressed as the depth in (mm, cm, and inch) which falls on a level surface. It can be measured by rainfall gages.

*** Types of rainfall gages:**

a) Non- Recording gages

b) Recording gages

a) Non- recording gages.

The standard gage of the U.S. National weather service has a collector (receiver) of 8-in (20.3 cm) diameter.

Rain passes from the collector into a cylindrical measuring tube inside the overflow can. The measuring tube has a cross sectional area one- tenth that of the collector so that a 0.1 in rainfall will fill the tube to a depth of 1 inch with a measuring stick marked in tenths of an inch, rainfall can be measured to the nearest 0.01 inches (0.25). The collector and tube are removed when snow is expected. The snow caught in the other container, or overflow can, is melted, poured into the measuring tube, and measured.

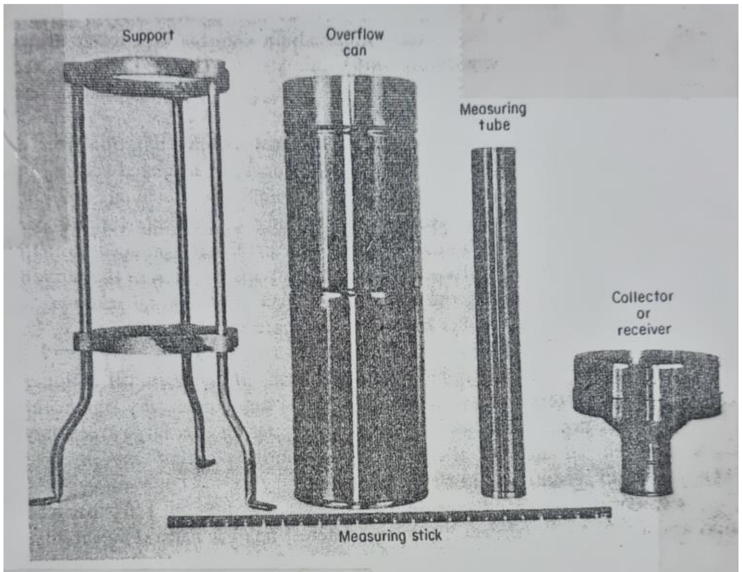


FIGURE 3-1
Standard 8-in. precipitation gage. (*U.S. National Weather Service.*)

b) Recording gages:

There are three types of recording precipitation gages in uses:

1) Tipping- bucket gage: The water caught in the collector is funneled into a two-compartment bucket; 0.01 in (or 0.1 mm) of rain will fill one compartment and overbalance the bucket so that it tips, emptying into a reservoir and moving the second compartment into beneath the funnel. As the bucket is tipped; it actuates an electric circuit, causing a pen to mark on a revolving drum. This type of gage is not suitable for measuring snow without heating the collector.

Advantages:

- Compute rainfall intensity directly.
- Computes the intensity of any time.
- It operates for 1 one month without servicing.

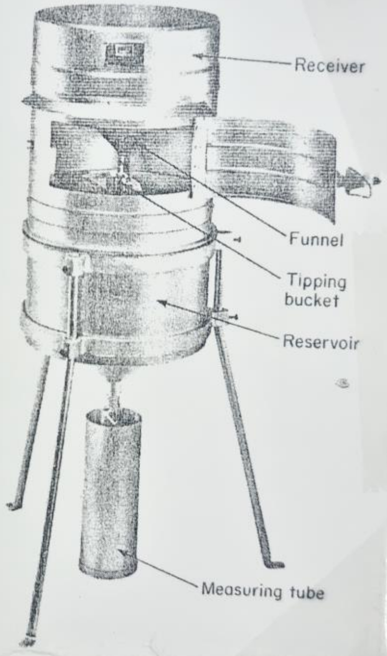


FIGURE 3-2
Tipping-bucket rain gage. (*Belfort Instrument Co.*)

2) Weighing-type gage: weighs the rain or snow which falls in to bucket set on a platform of a spring or lever balance. The increasing weigh of the bucket and its contents is recorded on a chart. The record thus shows the accumulation of precipitation.

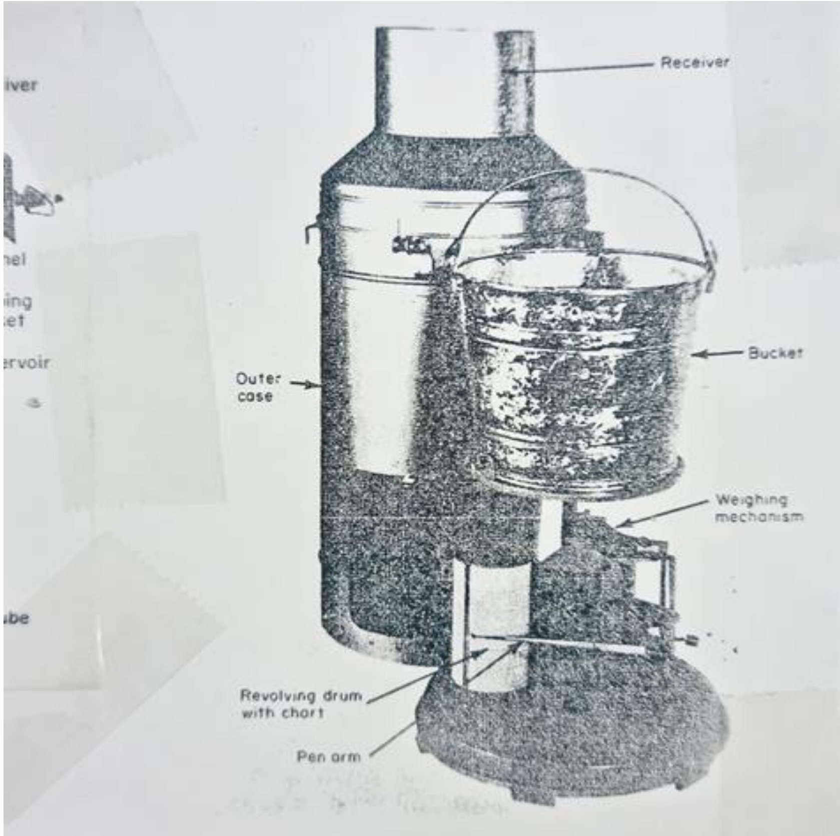


FIGURE 3-3
Weighing-type precipitation gage, 12-in. dual traverse. (*Belfort Instrument Co.*)

3) Float Recording Gages: the raise of the float with increasing catch of rainfall is recorded on a chart. Some gages must empty manually, while others are emptied automatically by self-starting siphons. In most gages the float is placed in the receiver, but in some the receiver rests in a bath of oil or mercury and the float measures the rise of the oil or mercury displaced by the increasing weight of the receiver as the rainfall catch freezes.

Sources of errors:

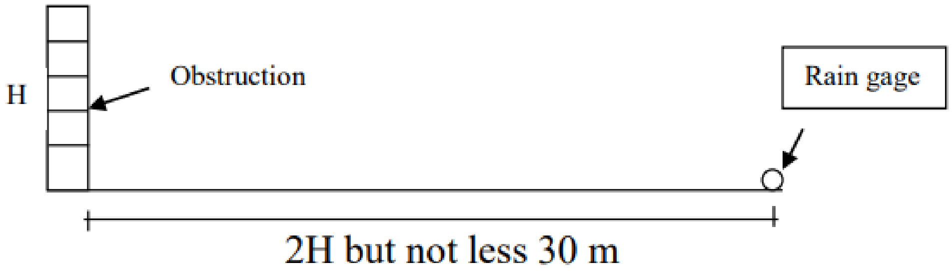
1- Frictional effects in weighing mechanism and also in the linkage with pen.

2- When rain starts, a portion of it is spent in to wetting the receiving area, this cause error about 25 mm per year.

3- Dent in receiving area, splash of rain from receiving area cause error.

Site selection of gages: following points must be considered

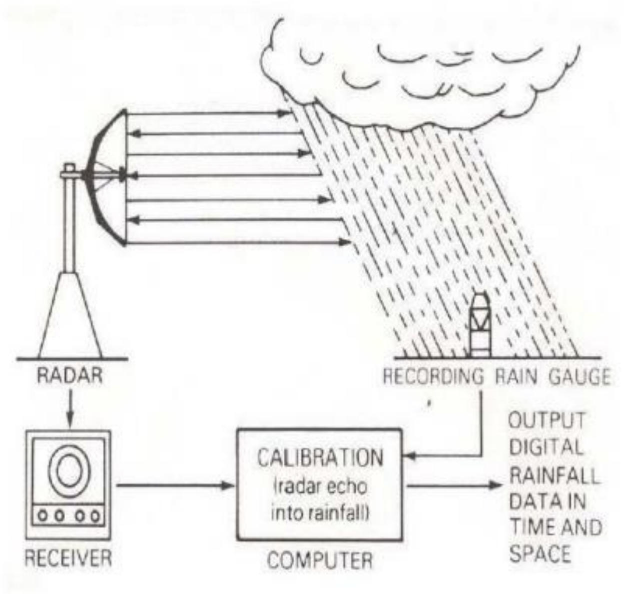
1- Site must be selected away from obstruction.
This includes fencing also.



2- Gages must be fixed on level ground.
3- On hills where no level space can be found, it should be protected from high wind and should be fixed at places where does not cause eddies.

Radar measurement of rainfall:

The most important advantage of using radar for precipitation measurement is, radar provided of a large area with high spatial and temporal resolution. It can provide rainfall estimate for time intervals as small as 5 minutes and spatial resolution as small as 1 km^2. A single radar can cover an area of more than 10000 km^2.



Satellite measurement of rainfall:

A standard procedure for estimating rainfall from satellite infrared imagery is the temperature threshold method.