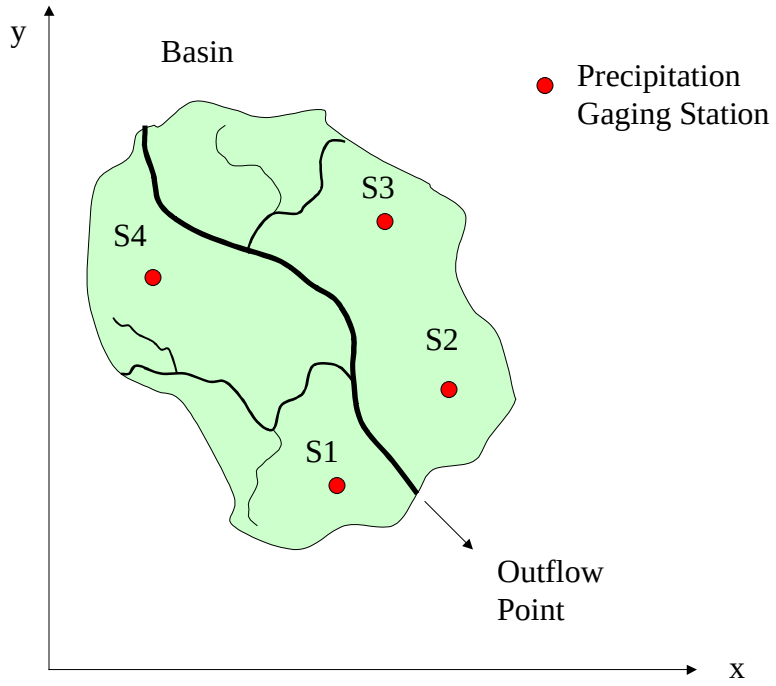
Lecture – 3: Areal Estimation of Precipitation

1. Introduction:

One important aspect of hydrologic modeling is the estimation of the total precipitation and its distribution within a watershed. This problem is commonly referred to as "areal estimation of precipitation" and is best described as follows:

Given the coordinates of m precipitation stations along with their respective recorded precipitation values (P_i; $i = 1,\ldots,m$), how can we determine the area-averaged (P_{avg}) precipitation from these limited stations?

This problem is illustrated below, where P_{avg} across the entire basin has to be estimated from measured P_1, P_2, P_3, and P_4.



We will discuss four methods:

1) Arithmetic Average, 2) Theissen Polygons, 3) Isohyetal Method, and 4) Grid Method.

2. Arithmetic Average:

The simplest approach is to assume that

$$P_{avg} = \frac{\sum_{i=1}^{m} P_i}{m} = \frac{P_1 + P_2 + P_3 + P_4}{4};$$

This method will give reasonable results if the variability among P_i is not too large. A "rule of thumb" is that if the standard deviation of P_i is < 10% of P_{avg}, then the arithmetic average will be an accurate estimator of P_{avg}.

The standard deviation (σ_p) is given by

$$\sigma_p = \sqrt{\frac{\sum_{i=1}^{m} \left(P_i - P_{avg}\right)^2}{m}}$$

where P_{avg} is given by the arithmetic average.

Hence, the arithmetic average will be accurate when $\frac{\sigma_p}{P_{avg}}$<0.1.

3. Theissen Polygons:

The Theissen polygon method assumes that each precipitation gage does not get the same weight as in the arithmetic method.

$$P_{avg} = \sum_{i=1}^{m} w_i P_i$$

where $\sum_{i=1}^{m} w_i$ =1. The Theissen polygon method REDUCES to the arithmetic method if $w_i = \frac{1}{m}$.

In the Theissen polygon method,

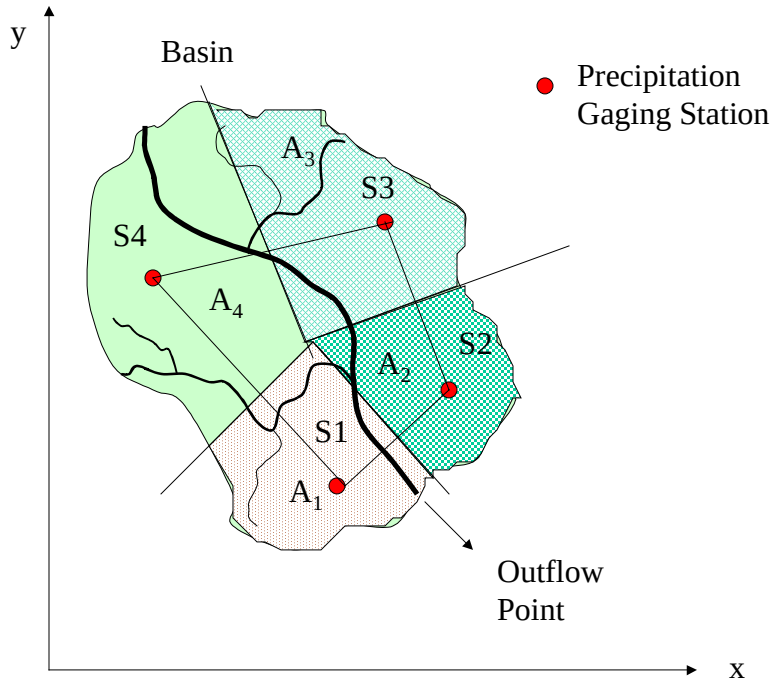
$w_i = \frac{A_i}{A_T}$; where

A_T = Total basin or watershed area.

A_i = Area defined by the Theissen polygons.

To determine A_i, use the following procedure:

1. Join adjacent station locations with straight lines
2. Take the PERPENDUCALR BISECTORS to those lines.
3. Define the polygons bounding each station and compute its area.



If we apply this algorithm to each of the example shown in the INTRODUCTION section, we obtain the above figure. The areas $A_1 \ldots A_4$ are shaded. The total area is $A_T = A_1 + A_2 + A_3 + A_4$.

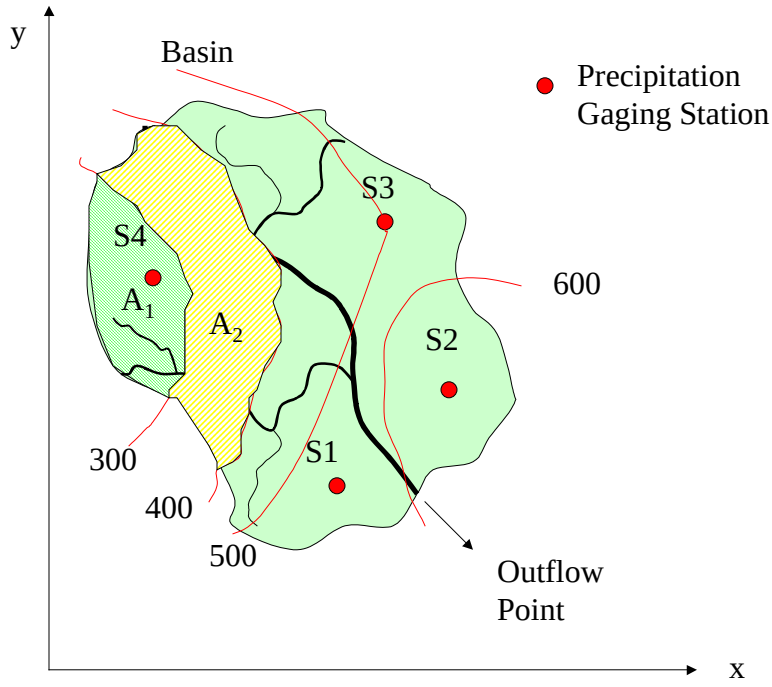
How to compute the polygon areas becomes a major challenge in this method.

4. Isohyetal Method

The basic formulation is also

$$P_{avg} = \sum_{i=1}^{m} w_i P_i \text{, where } \sum_{i=1}^{m} w_i = 1$$

but the weights are defined by the contour map area as shown below and P_i is the representative contour.



$$P_{avg} = \frac{A_1 \times 300 + A_2 \times \frac{300+400}{2} + ...}{A_T}$$

where the 300, 400, …. are contour lines of precipitation.