CE361a : Assignment 1

Due Date: Friday, September 8, 2017

The questions to be solved are marked in the attached scanned pages from the reference book 'Engineering Hydrology' by K. Subramanya.

References

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7. Rakecha, P.K. and Deshpande, N.R., Precipitation Network Design, *Jal Vigyan Sameeksha (Hydrology Review),* Vol. II, No. 2, Dec. 1987, pp. 56–75.
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10. Ram Babu et al. *Rainfall Intensity-Duration-Return Period Equations and Nomographs of India,* Bull. No. 3, CSWCRTI, Dehradun, India, 1979.

Revision Questions

2.1 Describe the different methods of recording of rainfall.

2.2 Discuss the current practice and status of rainfall recording in India.

2.3 Describe the salient characteristics of precipitation on India.

2.4 Explain the different methods of determining the average rainfall over a catchment due to a storm. Discuss the relative merits and demerits of the various methods.

2.5 Explain a procedure for checking a rainfall data for consistency.

2.6 Explain a procedure for supplementing the missing rainfall data.

2.7 Explain briefly the following relationships relating to the precipitation over a basin:

(a) Depth-Area Relationship

(b) Maximum Depth-Area-Duration Curves

(c) Intensity Duration Frequency Relationship.

2.8 What is meant by Probable Maximum Precipitation (PMP) over a basin? Explain how PMP is estimated.

2.9 Consider the statement: The 50 year-24 hour maximum rainfall at Bangalore is 160 mm. What do you understand by this statement?

Problems

2.1 A catchment area has seven raingauge stations. In a year the annual rainfall recorded by the gauges are as follows:

Station	*P*	*Q*	*R*	*S*	*T*	*U*	*V*
Rainfall (cm)	130.0	142.1	118.2	108.5	165.2	102.1	146.9

For a 5% error in the estimation of the mean rainfall, calculate the minimum number of additional stations required to be established in the catchment.

2.2 The normal annual precipitation of five raingauge stations *P, Q, R, S* and *T* are respectively 125, 102, 76, 113 and 137 cm. During a particular storm the precipitation recorded by stations *P*, *Q*, *R*, and *S* are 13.2, 9.2, 6.8 and 10.2 cm respectively. The instrument at station *T* was inoperative during that storm. Estimate the rainfall at station *T* during that storm.

2.3 Test the consistency of the 22 years of data of the annual precipitation measured at station *A*. Rainfall data for station *A* as well as the average annual rainfall measured at a group of eight neighbouring stations located in a meteorologically homogeneous region are given as follows.

Year	Annual Rainfall of Station A (mm)	Average Annual Rainfall of 8 Station groups (mm)	Year	Annual Rainfall of Station A (mm)	Average Annual Rainfall of 8 Station groups (mm)
1946	177	143	1957	158	164
1947	144	132	1958	145	155
1948	178	146	1959	132	143
1949	162	147	1960	95	115
1950	194	161	1961	148	135
1951	168	155	1962	142	163
1952	196	152	1963	140	135
1953	144	117	1964	130	143
1954	160	128	1965	137	130
1955	196	193	1966	130	146
1956	141	156	1967	163	161

(a) In what year is a change in regime indicated?

(b) Adjust the recorded data at station *A* and determine the mean annual precipitation.

2.4 In a storm of 210 minutes duration, the incremental rainfall at various time intervals is given below.

Time since start of the storm (minutes)	30	60	90	120	150	180	210
Incremental rainfall in the time interval (cm)	1.75	2.25	6.00	4.50	2.50	1.50	0.75

(a) Obtain the ordinates of the hyetograph and represent the hyetograph as a bar chart with time in chronological order in the *x*-axis.

(b) Obtain the ordinates of the mass curve of rainfall for this storm and plot the same. What is the average intensity of storm over the duration of the storm?

2.5 Assuming the density of water as 998 kg/m^3, determine the internal diameter of a tubular snow sample such that 0.1 *N* of snow in the sample represents 10 mm of water equivalent.

2.6 Represent the annual rainfall data of station *A* given below as a bar chart with time in chronological order. If the annual rainfall less than 75% of long term mean is taken to signify meteorological drought, identify the drought years and suitably display the same in the bar chart.

Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Annual rain (mm)	760	750	427	380	480	620	550	640	624	500
Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Annual rain (mm)	400	356	700	580	520	102	525	900	600	400

2.7 For a drainage basin of 600 km^2, isohyetals drawn for a storm gave the following data:

Isohyetals (interval) (cm)	15–12	12–9	9–6	6–3	3–1
Inter-isohyetal area (km^2)	92	128	120	175	85

Estimate the average depth of precipitation over the catchment.

2.8 There are 10 raingauge stations available to calculate the rainfall characteristics of a catchment whose shape can be approximately described by straight lines joining the following coordinates (distances in kilometres):
(30, 0), (80, 10), (110, 30), (140, 90), (130, 115), (40, 110), (15, 60). Coordinates of the raingauge stations and the annual rainfall recorded in them in the year 1981 are given below.

Station	**1**	**2**	**3**	**4**	**5**
Co-ordinates	(0, 40)	(50, 0)	(140, 30)	(140, 80)	(90, 140)
Annual Rainfall (cm)	132	136	93	81	85
Station	**6**	**7**	**8**	**9**	**10**
Co-ordinates	(0, 80)	(40, 50)	(90, 30)	(90, 90)	(40, 80)
Annual Rainfall (cm)	124	156	128	102	128

Determine the average annual rainfall over the catchment.

2.9 Figure 2.25 shows a catchment with seven raingauge stations inside it and three stations outside. The rainfall recorded by each of these stations are indicated in the figure. Draw the figure to an enlarged scale and calculate the mean precipitation by (a) Thiessen-mean method, (b) Isohyetal method and by (c) Arithmetic-mean method.

2.10 Annual rainfall at a point M is needed. At five points surrounding the point M the values of recorded rainfall together with the coordinates of these stations with respect to a set of axes at point M are given below. Estimate the annual rainfall at point M by using the USNWS method.

Station	**Rainfall** P **(cm)**	**Coordinates of station (in units)**	
		X	Y
A	102	2.0	1.0
B	120	2.0	2.0
C	126	3.0	1.0
D	108	1.5	1.0
E	131	4.5	1.5

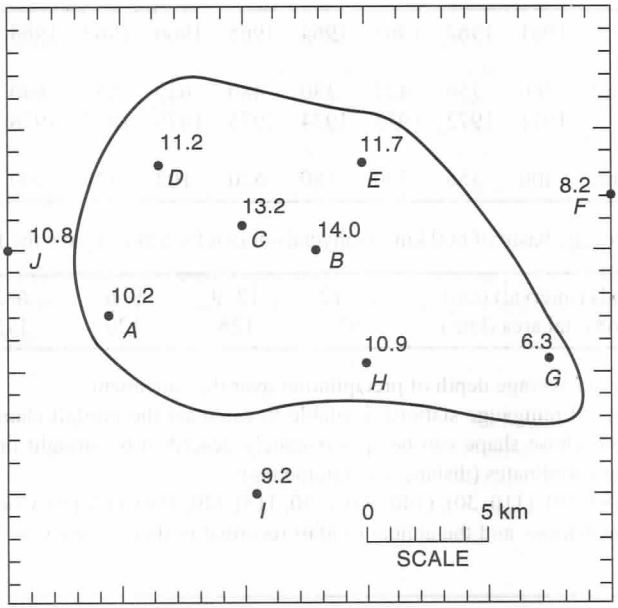

Fig. 2.25 Problem 2.9

[**Hint:** In the US National Weather Service (USNWS) method the weightage to the stations are inversely proportional to the square of the distance of the station from the station M. If the co-ordinate of any station is (x, y) then $D^2 = x^2 + y^2$ and weightage $W = 1/D^2$. Then rainfall at $M = P_m = \dfrac{\Sigma PW}{\Sigma W}$].

2.11 Estimate from depth-area curve, the average depth of precipitation that may be expected over an area of 2400 Sq. km due to the storm of 27th September 1978 which lasted for 24 hours. Assume the storm centre to be located at the centre of the area. The isohyetal map for the storm gave the areas enclosed between different isohyetes as follows:

Isohyet (mm)	21	20	19	18	17	16	15	14	13	12
Enclosed area (km^2)	54 3	134 5	203 0	254 5	295 5	328 0	353 5	371 0	388 0	391 5

2.12 Following are the data of a storm as recorded in a self-recording rain gauge at a station:

Time from the beginning of storm (minutes)	10	20	30	40	50	60	70	80	90
Cumulative rainfall (mm)	19	41	48	68	91	124	152	160	166

(a) Plot the hyetograph of the storm.
(b) Plot the maximum intensity-duration curve of the storm.

2.13 Prepare the Maximum depth-duration curve for the 90 minute storm given below:

Time (minutes)	0	10	20	30	40	50	60	70	80	90
Cumulative rainfall (mm)	0	8	15	25	30	46	55	60	64	67

2.14 The mass curve of rainfall in a storm of total duration 90 minutes is given below. (a) Draw the hyetograph of the storm at 10 minutes time step. (b) Plot the Maximum intensity-duration curve for this storm. (c) Plot the Maximum depth-duration curve for the storm.

Time (Minutes)	0	10	20	30	40	50	60	70	80	90
Cumulative rainfall (mm)	0	2.1	6.3	14.5	21.7	27.9	33.0	35.1	36.2	37.0

2.15 The record of annual rainfall at a place is available for 25 years. Plot the curve of recurrence interval *vs* annual rainfall magnitude and by suitable interpolation estimate the magnitude of rainfall at the station that would correspond to a recurrence interval of (a) 50 years and (b) 100 years.

Year	Annual Rainfall (cm)	Year	Annual Rainfall (cm)
1950	113.0	1963	68.6
1951	94.5	1964	82.5
1952	76.0	1965	90.7
1953	87.5	1966	99.8
1954	92.7	1967	74.4
1955	71.3	1968	66.6
1956	77.3	1969	65.0
1957	85.1	1970	91.0
1958	122.8	1971	106.8
1959	69.4	1972	102.2
1960	81.0	1973	87.0
1961	94.5	1974	84.0
1962	86.3		

2.16 The annual rainfall values at a station *P* for a period of 20 years are as follows:

Year	Annual Rainfall (cm)	Year	Annual Rainfall (cm)
1975	120.0	1985	101.0
1976	84.0	1986	109.0
1977	68.0	1987	106.0
1978	92.0	1988	115.0
1979	102.0	1989	95.0
1980	92.0	1990	90.0
1981	95.0	1991	70.0
1982	88.0	1992	89.0
1983	76.0	1993	80.0
1984	84.0	1994	90.0

Determine

(a) The value of annual rainfall at *P* with a recurrence interval of 15 years.

(b) The probability of occurrence of an annual rainfall of magnitude 100 cm at station *P*.

(c) 75% dependable annual rainfall at the station.

[**Hint:** If an event (rainfall magnitude in the present case) occurs more than once, the rank m = number of times the event is equalled + number of times it is exceeded.]

2.17 Plot the three-year and the five-year moving means for the data of Problem 2.15. Comment on the effect of increase in the period of the moving mean. Is there any apparent trend in the data?

2.18 On the basis of isopluvial maps the 50 year-24 hour maximum rainfall at Bangalore is found to be 16.0 cm. Determine the probability of a 24 h rainfall of magnitude 16.0 cm occurring at Bangalore:

(a) Once in ten successive years.
(b) Twice in ten successive years.
(c) At least once in ten successive years.

2.19 A one-day rainfall of 20.0 cm at a place X was found to have a period of 100 years. Calculate the probability that a one-day rainfall of magnitude equal to or larger than 20.0 cm:

(a) Will not occur at station X during the next 50 years.
(b) Will occur in the next year.

2.20 When long records are not available, records at two or more stations are combined to get one long record for the purposes of recurrence interval calculation. This method is known as *Station-year method.*

The number of times a storm of intensity 6 cm/h was equalled or exceeded in three different rain gauge stations in a region were 4, 2 and 5 for periods of records of 36, 25 and 48 years. Find the recurrence interval of the 6 cm/h storm in that area by the *station–year method.*

2.21 Annual precipitation values at a place having 70 years of record can be tabulated as follows:

Range (cm)	Number of years
< 60.0	6
60.0–79.9	6
80.0–99.9	22
100.0–119.9	25
120.0–139.9	8
> 140.0	3

Calculate the probability of having:

(a) an annual rainfall equal to or larger than 120 cm,
(b) two successive years in which the annual rainfall is equal to or greater than 140 cm,
(c) an annual rainfall less than 60 cm.

Objective Questions

2.1 A tropical cyclone is a

(a) low-pressure zone that occurs in the northern hemisphere only
(b) high-pressure zone with high winds
(c) zone of low pressure with clockwise winds in the northern hemisphere
(d) zone of low pressure with anticlockwise winds in the northern hemisphere.

2.2 A tropical cyclone in the northern hemisphere is a zone of

(a) low pressure with clockwise wind
(b) low pressure with anticlockwise wind
(c) high pressure with clockwise wind
(d) high pressure with anticlockwise wind.