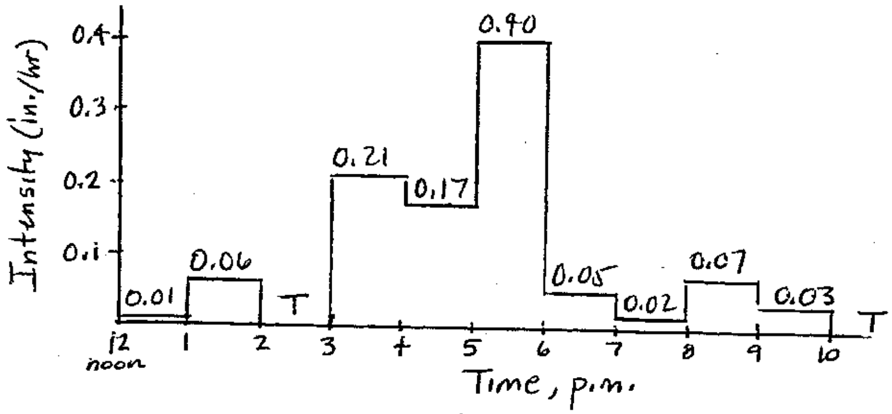
CHAPTER 2

Solutions for Review Questions

Question	Answer
1	D
2	E
3	E
4	B
5	A
6	A
7	B
8	C
9	B
10	D
11	A
12	C
13	B
14	D
15	D
16	A
17	C
18	A
19	C
20	E
21	B
22	B

2-1



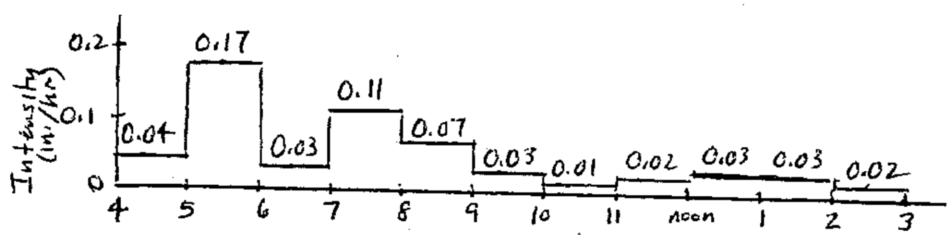
Total depth = (0.01 + 0.06 + 0.21 + 0.17 + 0.40 + 0.05 + 0.02 + 0.07 + 0.03)
= 1.02 inches

Maximum hourly rate = 0.40 in./hr.

Maximum 2-hr. rate = (0.40 + 0.17) in./2 hr. = 0.285 in./hr.

Volume = $10\ \text{mi}^2 * \dfrac{640\ ac}{mi^2} * 1.02\ in. * \dfrac{ft}{12\ in.} = 544\ ac\text{-}ft$

2-2



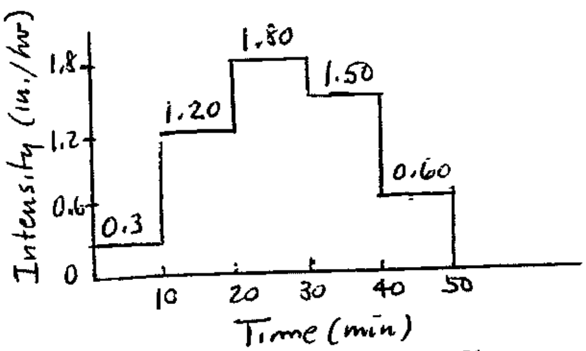
Total depth = (0.04 + 0.17 + 0.03 + 0.11 + 0.07 + 0.03 + 0.01 + 0.02 + 0.03 + 0.03 + 0.02)
= 0.57 in.

Maximum hourly rate = 0.17 in./hr.

Maximum 3-hr. rate = (0.17 + 0.03 + 0.11) in./hr./3 hr. = 0.103 in./hr.

Volume = $50\ \text{ac} * 0.57\ \text{in.} * \dfrac{1\ ft}{12\ in.} = 2.375\ ac\text{-}ft$

2-3

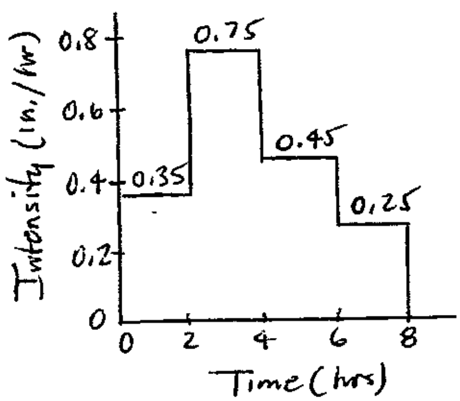


To convert the depths to intensities, divide by the interval and include conversion factors; for example, (0.05 in./10 min.) * (60 min./hr.) = 0.30 in./hr.
The maximum 30-min. intensity occurs during the middle three ordinates:

d_{30} = (0.20 + 0.30 + 0.25) in. = 0.75 in.

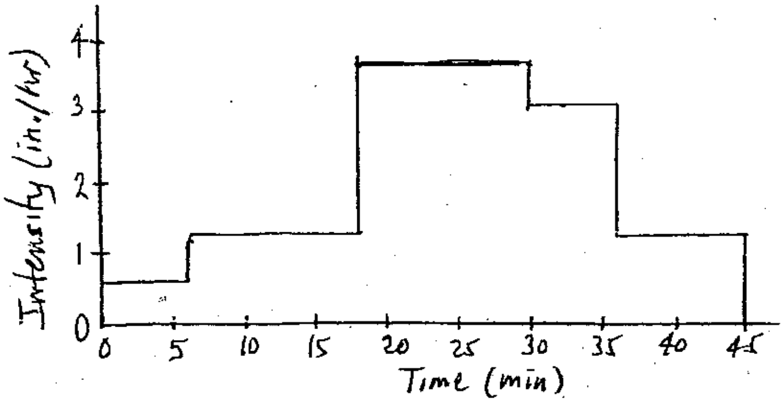
$$i_{30} = \frac{0.75\ in.}{30\ \text{min.}} * \frac{60\ \text{min.}}{hr.} = 1.5\ in./hr.$$

2-4



To convert the depths to intensities, divide the depths by the time interval; for example, 0.7 in./2 hr. = 0.35 in./hr.
The maximum 4-hour intensity is: $\frac{(1.5 + 0.9)\ in.}{4\ hours} = 0.60\ in./hr.$

2-5



Total depth = 0.06 + 0.24 + 0.18 + 0.54 + 0.30 + 0.18 ≐ 1.5 inches
Maximum intensity = 3.6 in./hr.

2-6

(a) $\frac{1.5\ in.}{30\ min.} * \frac{60\ min.}{hr.} = 3\ \frac{in.}{hr.}$

(b) $\frac{45\ ac\text{-}ft}{40\ min.} * \frac{60\ min.}{hr.} * \frac{12\ in.}{ft} * \frac{1}{0.5\ mi^2} * \frac{1\ mi^2}{640\ ac} = 2.53\ \frac{in.}{hr.}$

2-7

(a) $3\ in. * 0.25\ mi^2 * \frac{ft}{12\ in.} * \frac{640\ ac}{1\ mi^2} = 40\ ac\text{-}ft$

(b) $0.6\ \frac{in.}{hr.} * 90\ min. * \frac{hr.}{60\ min.} * \frac{ft}{12\ in.} * 10\ ac = 0.75\ ac\text{-}ft$

(c) $0.9\ in. * 1\ mi^2 * \frac{640\ ac}{mi^2} * \frac{ft}{12\ in.} = 48\ ac\text{-}ft$

2-8

(a)

City	Depth (in.)	Intensity (in./hr.)
New York	2.45	1.225
Atlanta	3.25	1.625
Chicago	2.40	1.20
Dallas	3.75	1.875
Denver	1.65	0.825
Seattle	0.70	0.35

(b)

City	Depth (in.)	Intensity (in./hr.)
Boston	6.5	0.271
Cleveland	4.4	0.183
New Orleans	13.0	0.542
Miami	12.0	0.5
Houston	12.0	0.5
Phoenix	3.6	0.15

2-9

City	Depth (in.)	Intensity (in./hr.)
Frostburg	2.75	0.115
Washington, DC	3.46	0.144
Dover	3.50	0.146

2-10

Intensity (in./hr)	Depth (in.)	Duration (hr)	Return Period (yrs)
2.4	1.8	0.75	5
0.67	4.0	6.0	25
8.0	2.0	0.25	100
5.0	2.5	0.5	50
0.3	7.2	24	100
4.0	2.67	0.667	50

2-11

Intensity (in./hr)	Depth (in.)	Duration (hr)	Return Period (yrs)
2.0	4.0	**2**	**100**
0.2	4.8	24	**9**
0.81	**4.86**	6	75
6.99	0.58	0.083	**6**
0.3	**3.6**	12	**6**

2-12

While more accurate equations can be developed using least squares, the two-point method is as follows:

for D < 2 hr:

t (hr.)	i (in./hr.)
1/6	6.3
2	1.3

The two simultaneous equations are:

$$\frac{1}{6.3} = f + g\left(\frac{1}{6}\right)$$

$$\frac{1}{1.3} = f + g(2)$$

Solving for f and g yields g = 0.7326 and f = 0.03663.
Solving for a and b of Eq. 2-2a gives a = 3, b = 0.31.

Therefore: $i = \dfrac{3}{D + 0.31}$

for D > 2 hr:

t (hr.)	i (in./hr.)
4	0.8
10	0.4

The two simultaneous equations are:

log (0.8) = h + d log (4)
log (0.4) = h + d log (10)

Solving yields d = -0.7565, h = 0.35853. Therefore, $C = 10^{0.35853} = 2.283$. The resulting relationship is: $i = 2.283\ D^{-0.7565}$

2-13

for D < 2 hr:

t (hr.)	i (in./hr.)
0.25	8
2	2

The two simultaneous equations are:

$$\frac{1}{8} = f + g(0.25)$$
$$\frac{1}{2} = f + g(2)$$

Solving for f and g yields g = 0.2143, h = 0.07143.
Solving for a and b yields a = 4.667, b = 0.333.
There, i = 4.667/(D + 0.333)

for D > 2 hr:

t (hr.)	i (in./hr.)
10	0.6
5	1

The two simultaneous equations are:

log (0.6) = h + d log (10)
log (1) = h + d log (5)

Solving yields h = 0.5151, d = -0.737; therefore C = 3.274 and $i = 3.274\ D^{-0.737}$

2-14 Solution not provided. Solution is unique to locality.

2-15 From Figure 2-4, the intensity is 0.58 in./hr. Therefore, the depth is 0.58 in./hr. (6 hr.) = 3.48 inches. The depth-area adjustment factor from Fig. 2-7 is 0.86. Therefore the depth is:

3.48 in. (0.86) = 2.993 in.

The volume is:

$$2.993 \text{ in.} * \frac{1\ ft}{12\ in.} * 150\ mi^2 * \frac{640\ ac}{1\ mi^2} = 23{,}944\ ac\text{-}ft$$

2-16 From Figure 2-4, the intensity is 0.44 in./hr. Therefore, the depth is 0.44 in./hr. (12 hr.) = 5.28 inches. The depth-area adjustment factor from Fig. 2-7 is 0.88. Therefore, the depth is:

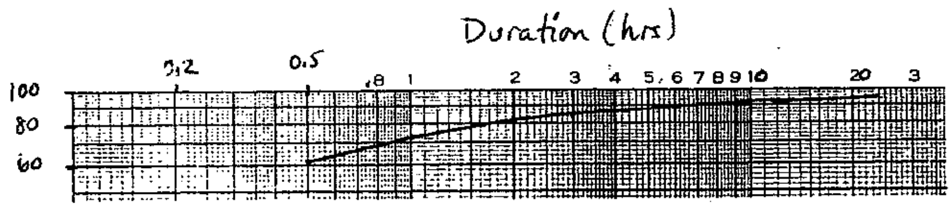
5.28 in. (0.88) = 4.646 in.

The volume is:

$$4.646\ in. * \frac{1\ ft}{12\ in.} * 250\ mi^2 * \frac{640\ ac}{mi^2} = 61{,}947\ ac\text{-}ft$$

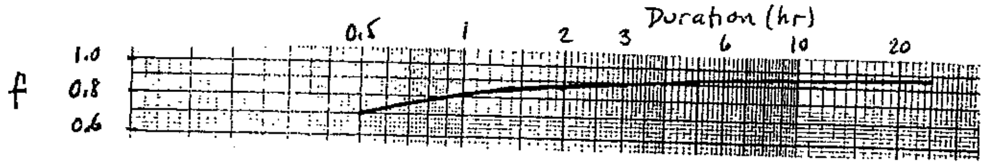
2-17

D(hrs)	24	12	6	3	2	1	0.5
factor	93.1	91.0	88.5	84.6	81.4	72.1	61.2

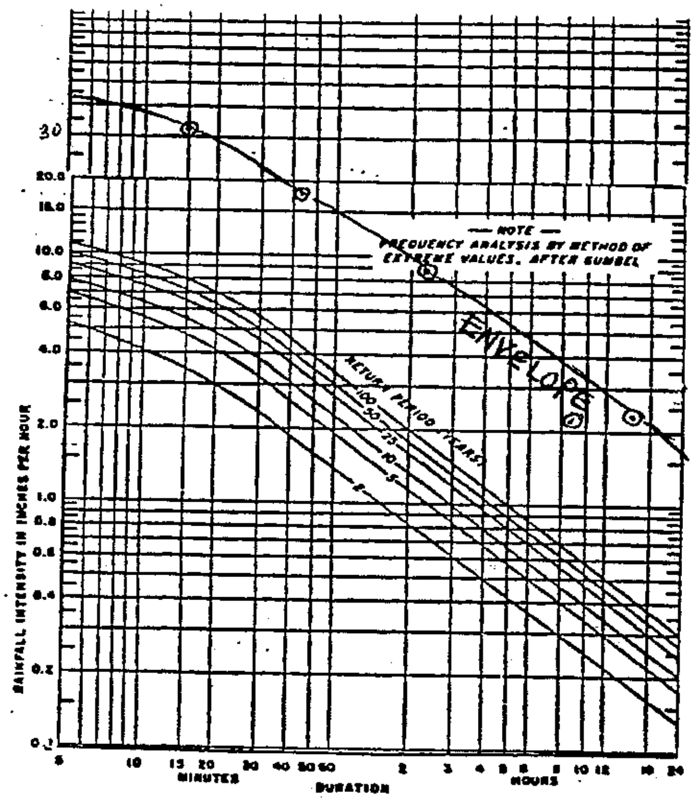


2-18

D(hrs)	24	12	6	3	2	1	0.5
factor	95.2	94.3	92.5	89.8	86.9	80.8	70.1



2-19



The curve of extremes is too far above the 100-yr curve to place a return period on the curve.

2-20

$$\bar{P} = \frac{1}{4}(2.1 + 2.7 + 3.4 + 2.5)\ in. = 2.675\ in.$$

2-21 $\bar{P} = \frac{1}{5}(5.1 + 5.4 + 5.3 + 5.7 + 5.2)\ in. = 5.34\ in.$

2-22 Assume a 5% level of significance for testing the hypotheses, H_o: $\mu = 6$ in., H_A: $\mu < 6$ in. The mean and standard deviation of the measured data are 5.34 in. and 0.230 in., respectively. The t-test yields:

$$t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}} = \frac{5.34 - 6.0}{0.230/\sqrt{5}} = -6.42$$

The critical t value for n-1 = 4 degrees of freedom is -2.132. Therefore, reject the null hypothesis and conclude that the newscaster overstated the rainfall.

2-23 10% of the annual catch at the gage of interest is 3.2 inches. Thus, the station-average method can be used since all annual catches are within 10% of the catch at the gage of interest: 28.8 to 35.2 inches.

$$\bar{P} = \frac{1}{4}(1.3 + 2.7 + 1.8 + 1.9) = \frac{7.7}{4} = 1.925\ inches$$

2-24 $$\bar{P} = \sum_{i=1}^{4}\left(\frac{A_x}{A_i n}\right)P_i = \frac{A_x}{n}\sum_{i=1}^{4}\frac{P_i}{A_i} = \frac{32}{4}\left[\frac{1.3}{29.1} + \frac{2.7}{34.4} + \frac{1.8}{30.9} + \frac{1.9}{30.2}\right]$$

= 1.955 inches

Relative difference = $\frac{1.925 - 1.955}{1.955} = -0.0153\ or\ -1.5\%$

2-25 The station average method is the same, 1.925 inches. The normal-ratio estimate is:

$$\bar{P} = \frac{38}{4}\left[\frac{1.3}{29.1} + \frac{2.7}{34.4} + \frac{1.8}{30.9} + \frac{1.9}{30.2}\right] = 2.322\ inches$$

Relative difference = $\frac{1.925 - 2.322}{2.322} = -0.171\ or\ -17.1\%$

The normal-ratio method should provide the more accurate estimate since it accounts for the regional effects of the gage locations.

2-26 Station-average $\bar{P} = \frac{1}{5}(0.6 + 1.2 + 1.1 + 1.5 + 0.8) = \frac{5.2}{5} = 1.04 \textit{ inches}$

Normal-ratio $\bar{P} = \frac{24}{5}\left(\frac{0.6}{17.5} + \frac{1.2}{26.8} + \frac{1.1}{23.2} + \frac{1.5}{31.1} + \frac{0.8}{27.4}\right) = 0.979 \textit{ inches}$

Relative difference = (1.04 - 0.979) / 0.979 = 0.062 or 6.2%

The difference reflects the disparity between the annual catch at the site of the missing data (24 in.) and the high variability of the annual catches at the five sites, 17.5 to 31.1 inches. The normal-ratio method should be more accurate because it attempts to account for the effect of the spatial variation of the rainfall at the gages.

2-27 Station-average $\bar{P} = \frac{1}{3}(4.3 + 5.1 + 5.5) = \frac{14.9}{3} = 4.967 \textit{ inches}$

Normal-ratio $\bar{P} = \frac{23}{3}\left(\frac{4.3}{33.7} + \frac{5.1}{36.4} + \frac{5.5}{40.8}\right) = 3.086 \textit{ inches}$

Relative difference = (4.967 - 3.086) / 3.086 = 0.610 or 61%

The difference reflects the disparity between the annual catch at the site of the missing data (23 in.) and the high variability of the annual catches at the three sites (33.7 to 40.8).

The normal-ratio method should be more accurate because it attempts to account for the effect of the spatial variation of the rainfall at the gages.

2-28 Using Eq. 2-12, $\bar{p} = 0.13$ and n = 1. Therefore, $P_i/A_i = 0.13$ and P = 0.13

A = 0.13(36) = 4.68 inches.

2-29 Using Eqs. 2-10 and 2-11:

$$\hat{P} = \sum_{i=1}^{n} w_i P_i = \sum_{i=1}^{n}\left(\frac{A_x}{nA_i}\right) P_i = \sum_{i=1}^{n}\left(\frac{A_x}{n}\right)\left(\frac{P_i}{A_i}\right)$$

Since A_x and n are constants, they can be taken outside the summation:

$$\hat{P} = \frac{A_x}{n}\sum\left(\frac{P_i}{A_i}\right)$$

Therefore,

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

2-30

At (41° 9.30', 104° 51.44'): $\hat{P} = 4.4 \pm 0.2$ inches
At (41° 11.27', 104° 49.53'): $\hat{P} = 4.4 \pm 0.3$ inches

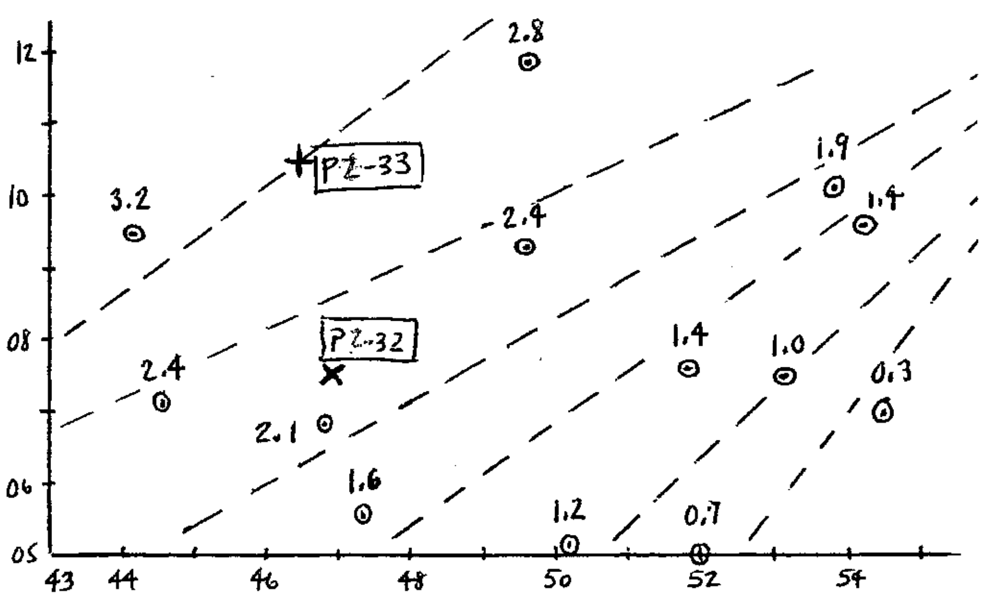
The value at the first point is more accurate because the isohyets are closer together and more straight. At the second point, the isohyets diverge and are curvilinear. Therefore, it is more difficult to take an accurate reading.

2-31

At Routes 80 and 25: $\hat{P} = 2.0 \pm 0.05$ inches
At the airport: $\hat{P} = 6.2 \pm 0.3$ inches

At the highway interchange, the estimate seems very accurate because the isohyet passes through the center of the interchange. At the airport, the estimate is less accurate because the isohyets diverge and there seems to be a flat area.

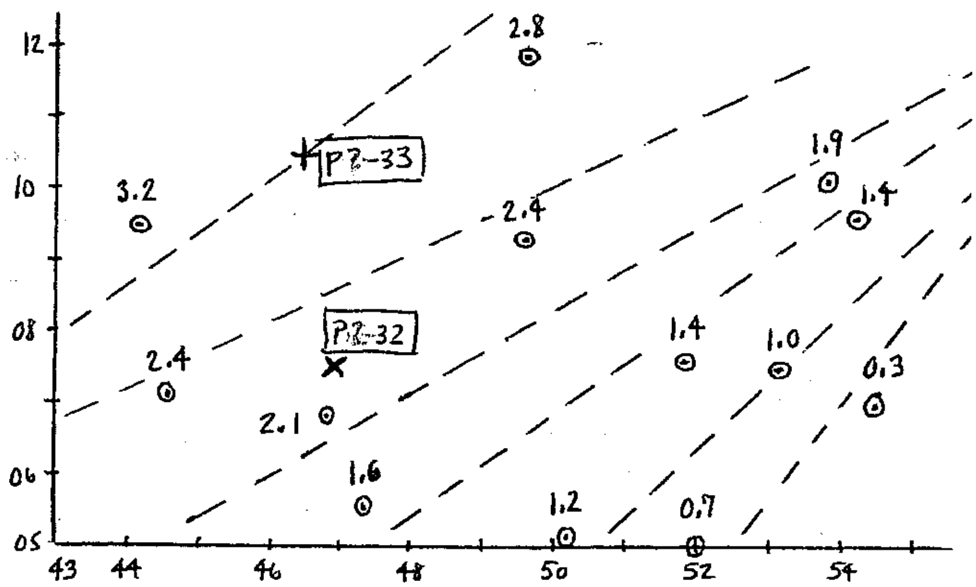
2-32



Numerous isohyetal maps could be developed, each a reasonable representation of the data. Based on the isohyets shown on the map of the region, the estimated value is 2.2 ± 0.1 inches.

The accuracy of the estimate is based on the assumption that the isohyets are correct. The expected error would be much larger if one includes the expected inaccuracy of the isohyets.

2-33



Numerous isohyetal maps could be developed, each a reasonable representation of the data. Based on the isohyets shown on the map of the region, the estimated value is 3.0 ± 0.1 inches. The accuracy of the estimate is based on the assumption that the isohyets are correct. The expected error would be much larger if one includes the expected inaccuracy of the isohyets.

2-34 From Eq. 2-15,

$$D = \sum_{i=1}^{4} 1/d_i^2 = \frac{1}{(12.3)^2} + \frac{1}{(7.9)^2} + \frac{1}{(10.3)^2} + \frac{1}{(8.6)^2} = 0.04558$$

$$w_1 = \frac{1/d_1^2}{D} = \frac{1/(12.3)^2}{0.04558} = 0.145 \qquad w_2 = \frac{1/(7.9)^2}{0.04558} = 0.352$$

$$w_3 = \frac{1/(10.3)^2}{0.04558} = 0.207 \qquad w_4 = \frac{1/(8.6)^2}{0.04558} = 0.296$$

$$\hat{P} = \Sigma w_i P_i = 0.145(3.6) + 0.352(5.2) + 0.207(4.4) + 0.296(4.7)$$
$$= 4.654 \text{ inches}$$

2-35

$$D = \sum_{i=1}^{4} 1/d_i^2 = \frac{1}{(14.7)^2} + \frac{1}{(9.2)^2} + \frac{1}{(5.4)^2} + \frac{1}{(18.6)^2} = 0.05363$$

$$w_1 = \frac{1/d_1^2}{D} = \frac{1/(14.7)^2}{0.05363} = 0.087 \qquad w_2 = \frac{1/(9.2)^2}{0.05363} = 0.220$$

$$w_3 = \frac{1/(5.4)^2}{0.05363} = 0.639 \qquad w_4 = \frac{1/(18.6)^2}{0.05363} = 0.054$$

$$\hat{P} = \Sigma w_i P_i = 0.087(1.9) + 0.220(2.2) + 0.639(1.4) + 0.054(2.5)$$
$$= 1.679 \text{ inches}$$

$$\text{Station average} = \frac{1}{4}(1.9 + 2.2 + 1.4 + 2.5) = \frac{8.0}{4} = 2.0 \textit{ inches}$$

$$\text{Relative difference} = \frac{2.0 - 1.679}{1.679} = 0.191 \textit{ or } 19.1\%$$

The estimate made from the quadrant method is most likely the more accurate method because it gives more weight to the gages closer to the location of the estimate.

2-36

Coordinates					
N-S	E-W	Quadrant	Distance	Gage Selected	Catch
12	5	1	13.0	*	2.9
16	17	1	23.3		
-5	22	2	22.6		
-6	8	2	10.0	*	3.3
-19	6	2	19.9		
-14	-16	3	21.3	*	1.9
13	-6	4	14.3	*	2.1
9	-13	4	15.8		

$$D = \Sigma 1/d_i^2 = \frac{1}{(13)^2} + \frac{1}{(10)^2} + \frac{1}{(21.3)^2} + \frac{1}{(14.3)^2} = 0.02301$$

$$w_1 = \frac{1/(13)^2}{0.02301} = 0.257 \qquad w_2 = \frac{1/(10)^2}{0.02301} = 0.435$$

$$w_3 = \frac{1/(21.3)^2}{0.02301} = 0.096 \qquad w_4 = \frac{1/(14.3)^2}{0.02301} = 0.212$$

$$\hat{P} = \Sigma w_i P_i = 0.257(2.9) + 0.435(3.3) + 0.096(1.9) + 0.212(2.1) = 2.808 \text{ inches}$$

2-37

Coordinates N-S	E-W	Quadrant	Distance	Gage Selected	Catch
15	6	1	16.2		
8	14	1	16.1	*	4.5
-8	7	2	10.6	*	3.9
-8	14	2	16.1		
10	-9	4	13.5	*	5.6
7	-18	4	19.3		
19	-15	4	24.2		

$$D = \Sigma\, 1/d_i^2 + \frac{1}{(16.1)^2} + \frac{1}{(10.6)^2} + \frac{1}{(13.5)^2} = 0.01824$$

$$w_1 = \frac{1/(16.1)^2}{0.01824} = 0.211 \qquad w_2 = \frac{1/(10.6)^2}{0.01824} = 0.488$$

$$w_3 = \frac{1/(13.5)^2}{0.01824} = 0.301$$

$$\hat{P} = 0.211(4.5) + 0.488(3.9) + 0.301(5.6) = 4.538 \textit{ inches}$$

2-38

Lat	Long	Catch (in.)	Difference Lat	Difference Long	Quadrant	Difference Lat (min)	Difference Long (min)	Distance (mi) Lat	Distance (mi) Long	Distance from gage	Gage selected
40° 07.6	103° 51.8	1.4	+	+	1	0.2	4.9	0.23	4.25	4.25	
05.0	52.0	0.7	-	+	2	2.4	5.1	2.80	4.42	5.23	
05.1	50.2	1.2	-	+	2	2.3	3.3	2.68	2.86	3.92	
06.8	45.8	2.1	-	-	3	0.6	1.1	0.70	0.95	1.18	*
07.1	43.6	2.4	-	-	3	0.3	3.3	0.35	2.86	2.88	
05.5	47.3	1.6	-	+	2	1.9	0.4	2.22	0.35	2.24	*
09.3	49.6	2.4	+	+	1	1.9	2.7	2.22	2.34	3.22	*

07.5	53.1	1.0	+	+	1	0.1	6.2	0.12	5.38	5.38	
09.5	44.1	3.2	+	-	4	2.1	2.8	2.45	2.43	3.45	*
11.9	49.6	2.8	+	+	1	4.5	2.7	5.25	2.34	5.75	
09.6	54.2	1.4	+	+	1	2.2	7.3	2.57	6.33	6.83	
10.2	53.8	1.9	+	+	1	2.8	6.9	3.27	5.98	6.82	
07.0	54.5	0.3	-	+	2	0.4	7.6	0.47	6.59	6.61	

From Figure 4-5, 1 minute of latitude = 1.167 mi
1 minute of longitude = 0.867 mi

$$D = \Sigma\ 1/d_i^2 = \frac{1}{(1.18)^2} + \frac{1}{(2.24)^2} + \frac{1}{(3.22)^2} + \frac{1}{(3.45)^2} = 1.0979$$

$$w_1 = \frac{1/(1.18)^2}{1.0979} = 0.654 \qquad w_2 = \frac{1/(2.24)^2}{1.0979} = 0.182$$

$$w_3 = \frac{1/(3.22)^2}{1.0979} = 0.088 \qquad w_4 = \frac{1/(3.45)^2}{1.0979} = 0.076$$

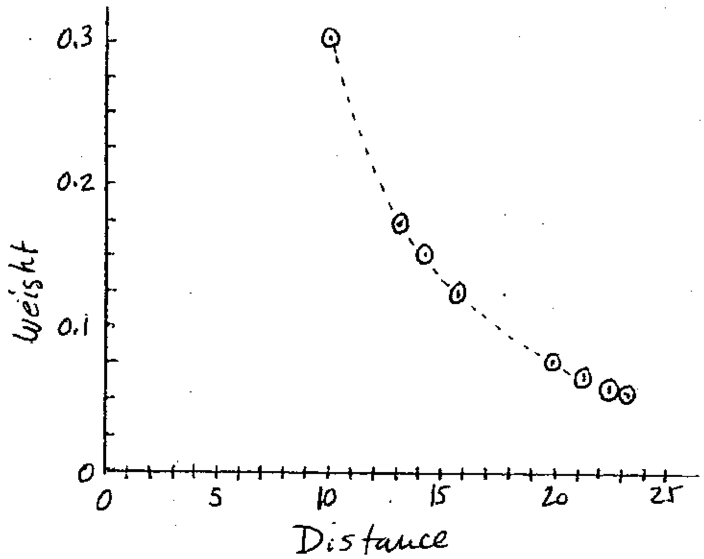
$$\hat{P} = 0.654(2.1) + 0.182(1.6) + 0.088(2.4) + 0.076(3.2)$$
$$= 2.119 \text{ inches}$$

2-39

Coordinates				
N-S	E-W	Quad.	Distance	Catch
12	5	1	13.0	2.9
16	17	1	23.3	2.8
-5	22	2	22.6	2.0
-6	8	2	10.0	3.3
-19	6	2	19.9	2.3
-14	-16	3	21.3	1.9
13	-6	4	14.3	2.1
9	-13	4	15.8	1.8

$$D = \sum_{i=1}^{8} 1/d_i^2 = 0.03334 \qquad w_i = \frac{1/d_i^2}{D}$$

$w_1 = 0.177$ $w_2 = 0.055$ $w_3 = 0.059$
$w_4 = 0.300$ $w_5 = 0.076$ $w_6 = 0.066$
$w_7 = 0.147$ $w_8 = 0.120$



Generally, a weighted average of eight sample values is more accurate than that from four sample values; however, if the points are not independent of each other, they can bias the final estimate, thus making it less accurate.

2-40

Year	W + X + Y + Z	Σ	ΣA
1977	83	83	17
78	107	190	41
79	113	303	66
80	97	400	88
81	81	481	104
82	81	562	124
83	90	652	148
84	71	723	168
85	72	795	190
86	86	881	215

1977 - 82: Slope = $S_1 = \dfrac{124 - 0}{562 - 0} = 0.2206$

1983 - 86: Slope = $S_2 = \frac{215 - 124}{881 - 562} = 0.2853$

To adjust the 1983 - 86 period to have a lower slope equal to the slope of the 1977 - 82 period, the adjustment factor equals $S_1/S_2 = 0.2206/0.2853 = 0.7732$. Therefore, the catches at A are adjusted:

1983: $A_a = 24(0.7732) = 18.56$ in.
1984: $A_a = 20(0.7732) = 15.46$ in.
1985: $A_a = 22(0.7732) = 17.01$ in.
1986: $A_a = 25(0.7732) = 19.33$ in.

To check: $\Sigma A_a = 70.36$ in.

$$S_a = \frac{70.36}{881 - 562} = 0.2206$$

2-41

Year	A+B+C	Σ	ΣX	Year	A+B+C	Σ	ΣX
1970	120	120	43	1978	104	1021	371
71	129	249	89	79	122	1143	417
72	109	358	129	80	124	1267	457
73	113	471	171	81	114	1381	493
74	121	592	216	82	128	1509	532
75	122	714	259	83	130	1639	574
76	102	816	296	84	126	1765	612
77	101	917	334	85	110	1875	646

1970 - 1979: Slope = $S_1 = \frac{417 - 0}{1143 - 0} = 0.3648$

1980 - 1985: Slope = $S_2 = \frac{646 - 417}{1875 - 1143} = 0.3128$

To adjust the values for the 1980 - 1985 period to have a higher slope equal to that of the slope of the 1970 - 1979 period, the adjustment factor R equals $S_1/S_2 = 0.3648/0.3128 = 1.166$. Therefore, the adjusted catches are:

1980: 40 R = 46.65
1981: 36 R = 41.98
1982: 39 R = 45.48
1983: 42 R = 48.98
1984: 38 R = 44.31
1985: 34 R = 39.65
267.55

To check the adjusted slope: $S_a = \frac{267.55}{1875 - 1143} = 0.3655$

2-42

Year	F+G+H	Σ	ΣT
1973	80	80	25
74	94	174	54
75	97	271	84
76	101	372	115
77	88	460	141
78	81	541	171
79	100	641	207
80	107	748	245
81	94	842	281
82	84	926	312
83	72	998	340
84	82	1080	370
85	98	1178	407
86	103	1281	444

1973-1977: Slope $= S_1 = \frac{141}{460} = 0.3065$

1978-1986: Slope $= S_2 = \frac{444-141}{1281-460} = 0.3691$

To adjust the 1973-1977 values to have the higher slope equal to that of the slope for 1978-1986, the adjustment ration R equals $S_2/S_1 = 0.3691/0.3065 = 1.204$. Therefore, the adjusted catches are:

1973:	25R = 30.10
1974:	29R = 34.92
1975:	30R = 36.12
1976:	31R = 37.33
1977:	26R = 31.30
	169.77

To check the adjusted slope: $S_a = \frac{169.77}{460} = 0.3691$

2-43

The adjustment factor is the ratio of two slopes. For adjusting the latter part of the curve, the adjustment ratio is b_o/b_2. Therefore, $Y_a = (b_o/b_2)\ Y_i$. For the data of Problem 2 - 40:

$$Y_a = \begin{cases} 0.2206\ X & \text{for } 1973 - 1979 \\ -36.34 + 0.2853\ X & \text{for } 1980 - 1985 \end{cases}$$

The adjustment ratio is: R = 0.2206/0.2853 = 0.7732 and the adjusted values are:

1983: 18.56 in.
1984: 15.46 in.
1985: 17.01 in.
1986: 19.33 in.

2-44

The adjustment factor is the ratio of the two slopes. For adjusting the lower part of the curve, the adjustment ratio is b_2/b_0. Therefore, $Y_a = (b_2/b_0)\ Y_i$. For the data of Problem 2-42:

$$Y_a = \begin{cases} 0.3229\ X \\ -30.36 + 0.3703\ X \end{cases}$$

The adjustment ratio R is = 0.3703/0.3229 = 1.147. Therefore, the adjusted catches are:

1973: 28.67
1974: 33.25
1975: 34.40
1976: 35.55
1977: 29.81
1978: 34.40
1979: 41.28

2-45

To calculate the adjustment ratio combine the consistent parts of the record:

Year	(F+G+H)	Σ	P	ΣP
1973	80	80	24	24
74	94	174	28	52
75	97	271	29	81
76	101	372	30	111
77	88	460	26	137
1982	84	544	25	162

83	72	616	22	184
84	82	698	25	209
85	98	796	29	238
86	103	899	31	269
1978	81	980	28	297
79	100	1080	35	332
80	107	1187	37	369
81	94	1281	33	402

$$\text{Slope}_1 = S_1 = \frac{269 - 0}{899 - 0} = 0.2992$$

$$\text{Slope}_2 = S_2 = \frac{402 - 269}{1281 - 899} = 0.3482$$

To adjust the second slope to the lower slope of the first section, use the adjustment ratio $R = S_1/S_2 = 0.2992/0.3482 = 0.8593$. Therefore, the four adjusted catches are:

1978: $P_a = 28\,R = 24.06$
1979: $P_a = 35\,R = 30.07$
1980: $P_a = 37\,R = 31.79$
1981: $P_a = 33\,R = \underline{28.36}$
114.28

Therefore, the adjusted slope is: $\frac{114.28}{1281 - 899} = 0.2992$

2-46

$$\bar{P} = \frac{1}{4}(1.2 + 0.9 + 1.3 + 1.7) = \frac{5.1}{4} = 1.275 \text{ inches}$$

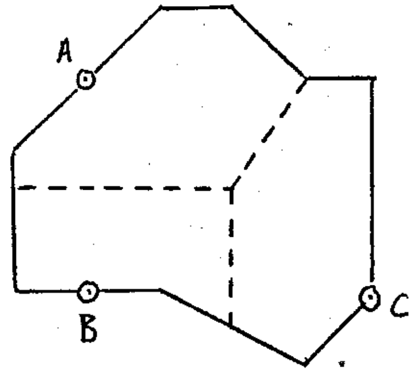
$$\text{Volume} = 1.275 \text{ in.} * 15 \text{ mi}^2 * \frac{640 \; ac}{mi^2} * \frac{ft}{12 \; in.} = 1020 \; ac\text{-}ft$$

2-47

$$\bar{P} = \frac{1}{7}(0.8 + 1.8 + 2.2 + 1.4 + 3.1 + 2.5 + 1.6) = \frac{13.4}{7} = 1.914 \text{ inches}$$

Volume = 1.914 in. * 240 mi² * 640 ac/mi² * 1 ft/12 in.
= 24503 ac-ft

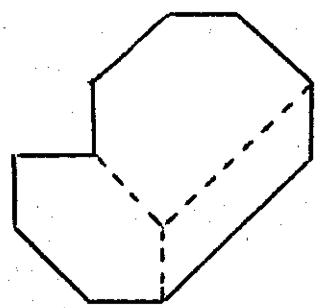
2-48



Gage	Area	P	A * P	f
A	6.84375	3.6	24.64	0.3802
B	4.75000	4.5	21.37	0.2639
C	6.40625	5.1	32.67	0.3559
	18		78.68	1.0000

$$\bar{P} = \frac{\sum A*P}{\sum A} = 4.371 \text{ inches}$$

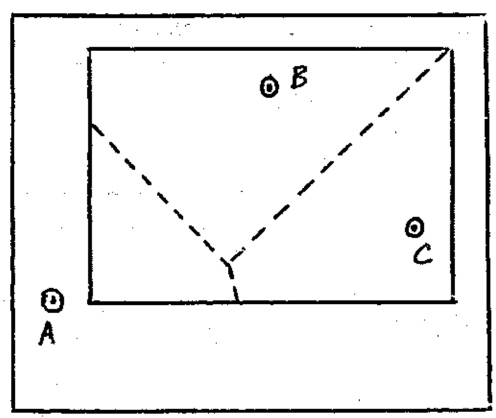
2-49



Gage	A	P	A * P
X	5.5	2.8	15.4
Y	3.0	3.6	10.8
Z	2.0	4.8	9.6
	10.5		35.8

$$\bar{P} = \frac{35.8}{10.5} = 3.410 \text{ inches}$$

2-50



Gage	Area	E_i	$A_i E_i$	
A	12.1	38	459.8	.0986
B	34.0	66	2244.0	.4812

(Continued)

C	23.9	82	1959.8	0.4202
	70.0		4663.6	

$$\bar{E} = \frac{\Sigma E_i A_i}{\Sigma A_i} = \frac{4663.6}{70.0} = 66.62 \ tons/ac/yr$$

Total erosion = 66.62 tons/ac/yr * 700 ft * 1000 ft * $\frac{1 \ ac}{43560 \ ft^2}$
= 1071 tons/yr.

2-51

P	$\bar{P}$	A	A * $\bar{P}$	
4.4				
	4.7	3.5	16.45	0.3186
5.0				
	4.5	3.5	15.75	0.3051
4.0				
	3.5	3.75	13.125	0.2542
3.0				
	2.8	2.25	6.300	0.1220
2.6				
		13.00	51.625	1.0000

$$\bar{P} = \frac{\Sigma A * \bar{P}}{\Sigma A} = 3.971 \ in.$$

2-52

P	$\bar{P}$	A	A * $\bar{P}$	
5.4				
	5.7	4.0	22.8	0.3468
6.0				
	6.5	3.75	24.375	0.3708
7.0				
	6.75	2.75	18.5625	0.2824
6.5				
		10.50	65.7375	1.0000

$$\bar{P} = \frac{\Sigma A * \bar{P}}{\Sigma A} = \frac{65.74}{10.5} = 6.261 \ in.$$

2-53

(a)

P	$\bar{P}$	A	A * $\bar{P}$
0			
	0.25	500	125
0.5			
	0.75	720	540
1.0			
	1.25	2100	2625
1.5			
	1.75	1150	2012.5
2.0			
	2.25	1080	2430
2.5			
	2.75	250	687.5
3.0			
		5800	8420

$$\bar{P} = \frac{\Sigma A * \bar{P}}{\Sigma A} = \frac{8420}{5800} = 1.452 \ in.$$

(b)

P_i	$\bar{P}_I$	A_i	$\bar{P}_I$*A
0			
	0.5	1220	610
1			
	1.5	3250	4875
2			
	2.5	1330	3325
3			
		5800	8810

$$\bar{P} = \frac{\Sigma A_i * \bar{P}_i}{\Sigma A_i} = \frac{8810}{5800} = 1.519 \ in.$$

The difference between the two estimates (1.452 and 1.519) reflects the loss of information content using the less detailed rainfall scale. For example, in part (a) 2100 acres receives an average of 1.25 in. and 1150 acres receives an average of 1.75 in.; thus, approximately two-thirds of these areas receives less than 1.5 inches (actually 1.25 in.). When cells are combined (part b), the entire 3250 acres is assumed to be covered with 1.5 inches of rainfall.

2-54

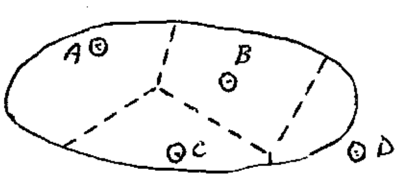
P_i	$\bar{P}_i$	A_i	$\bar{P}_i * A_i$
0			
	0.5	12	6.0
1			
	1.5	29	43.5
2			
	2.25	36	81.0
2.5			
	2.75	26	71.5
3			
	3.25	14	45.5
3.5			
	4.25	8	34
5			
		125	281.5

$$\bar{P} = \frac{\Sigma \bar{P}_i * A_i}{\Sigma A_i} = \frac{281.5}{125} = 2.252 \ in.$$

2-55

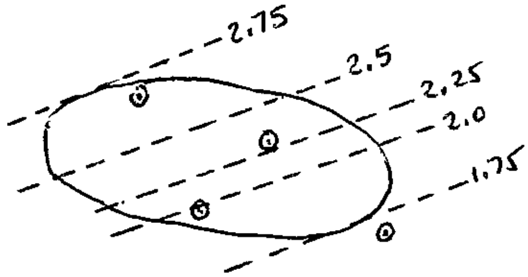
$$\text{Station average} = \frac{1}{4}(2.7 + 2.3 + 1.9 + 1.7) = \frac{8.6}{4} = 2.15 \ inches$$

Theissen:



Gage	A_i	$p_i = A_i/A_T$	P_i	$p_i * P_i$
A	151	0.3082	2.7	0.8321
B	166	0.3388	2.3	0.7792
C	111	0.2265	1.9	0.4303
D	62	0.1265	1.7	0.2150
	490	1.0000		2.2568

$\bar{P}$ = 2.257 inches



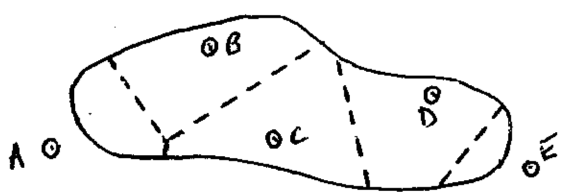
Numerous isohyets could be drawn.

P_i	$\bar{P}_i$	A_i	p_i	$p_i * \bar{P}_i$
1.75				
	1.875	119	0.2429	0.4554
2.00				
	2.125	95	0.1938	0.4118
2.25				
	2.375	136	0.2776	0.6593
2.50				
	2.625	140	0.2857	0.7500
2.75				
		490	1.0000	2.2765

$\bar{P}$ = 2.276 inches

2.-56

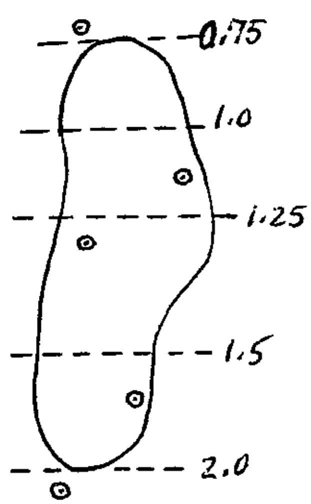
Station average $\bar{P} = \frac{1}{5}(0.7 + 1.2 + 1.3 + 1.6 + 2.1) = \frac{6.9}{5} = 1.38\ in.$



Theissen:

Gage	A_i	$p_i=A_i/A_T$	P_i	$p_i * P_i$
A	70	0.1114	0.7	0.0780
B	175	0.2787	1.2	0.3344
C	185	0.2946	1.3	0.3830
D	168	0.2675	1.6	0.4280
E	30	0.0478	2.1	0.1004
	628	1.0000		1.3238

$\bar{P}$ = 1.324 inches



Isohyetal:

P_i	$\bar{P}_i$	A_i	p_i	$p_i * \bar{P}_i$
0.75				
	0.875	111	0.1768	0.1547
1.00				
	1.125	150	0.2388	0.2686
1.25				
	1.375	226	0.3599	0.4949
1.50				
	1.750	141	0.2245	0.3929
2.00				
		628	1.0000	1.3111

$\bar{P}$ = 1.311 inches

2-57

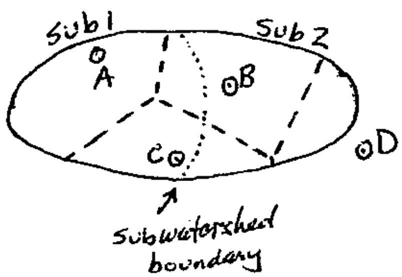
Station-average:

$$\bar{P}_1 = \frac{1}{2}(2.7 + 1.9) = 2.3 \text{ } in.$$

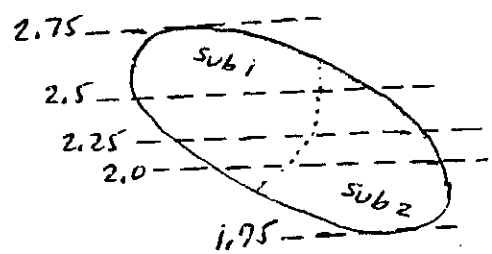
$$\bar{P}_2 = \frac{1}{2}(2.3 + 1.7) = 2.0 \text{ } in.$$

Theissen:

Sub	Gage	A_i	P_i	P_i	$P_i * P_i$
1	A	151	0.5763	2.7	1.556
	B	34	0.1298	2.3	0.299
	C	77	0.2939	1.9	0.558
		262	1.0000		$2.413 = \bar{P}_1$
2	B	132	0.5790	2.3	1.332
	C	34	0.1491	1.9	0.283
	D	62	0.2719	1.7	0.462
		228			$2.077 = \bar{P}_2$



Sub	P_i	$\bar{P}_i$	A_i	p_i	$p_i * \bar{P}_i$
1	1.90				
		1.950	11	0.0417	0.081
	2.00				
		2.125	35	0.1326	0.282
	2.25				
		2.375	88	0.3333	0.792
	2.50				
		2.625	130	0.4924	1.293
	2.75				
			264	1.0000	$2.447 = \bar{P}_1$
2	1.75				
		1.875	108	0.4779	0.896
	2.00				
		2.125	60	0.2655	0.564
	2.25				
		2.375	48	0.2124	0.504
	2.50				
		2.550	10	0.0442	0.113
	2.60				
			226	1.0000	$2.077 = \bar{P}_2$

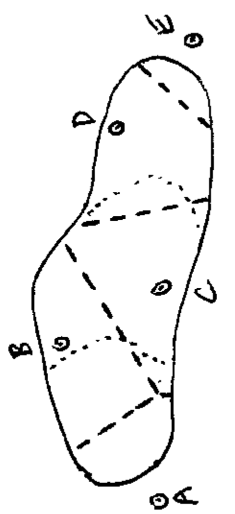


2-58

$$\bar{P}_1 = 0.5(0.7 + 1.2) = 0.95 \text{ in.}$$

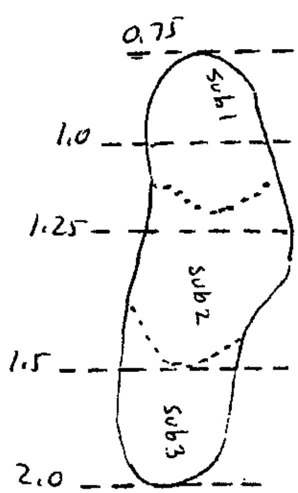
$$\bar{P}_2 = 0.5(1.2 + 1.3) = 1.25 \text{ in.}$$

$$\bar{P}_3 = 0.5(1.6 + 2.1) = 1.85 \text{ in.}$$



Theissen

Sub	Gage	A_i	$p_i = A_i/A_T$	P_i	$p_i * P_i$
1	A	70	0.3889	0.7	0.2722
	B	100	0.5556	1.2	0.6667
	C	10	0.0555	1.3	0.0721
		180	1.0000		$1.0111 = \bar{P}_1$
2	B	75	0.2641	1.2	0.3169
	C	172	0.6056	1.3	0.7873
	D	37	0.1303	1.6	0.2085
		284	1.0000		$1.3127 = \bar{P}_2$
3	C	3	0.0183	1.3	0.0238
	D	131	0.7988	1.6	1.2781
	E	30	0.1829	2.1	0.3841
		164	1.0000		$1.6860 = \bar{P}_3$



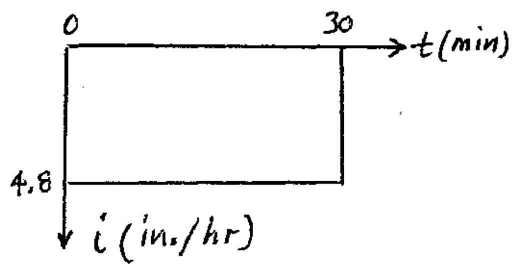
Isohyetal

Sub	P_i	$\bar{P}_i$	A_i	p_i	$p_i * P_i$
1	0.75				
		0.875	111	0.6167	0.5396
	1.00				
		1.125	69	0.3833	0.4312
	1.25				
			180	1.0000	$0.9708 = \bar{P}_1$
2	1.00				
		1.125	81	0.2852	0.3208
	1.25				
		1.375	203	0.7148	0.9829
	1.50				
			284	1.0000	$1.3037 = \bar{P}_2$
3	1.25				
		1.375	23	0.1402	0.1928

1.50				
	1.75	141	0.8598	1.5047
2.0				
		164	1.0000	$1.6975 = \bar{P}_3$

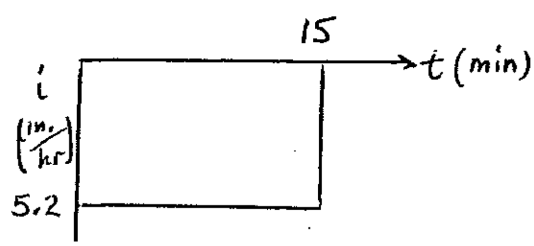
2-59

From Fig. 2-4, the 50-yr, 30-min. rainfall intensity is 4.8 in./hr. Thus, the design storm is:



2-60

From Figure 2-4, the 10-yr, 15-min. rainfall intensity is 5.2 in./hr. Thus, the design storm is:



2-61

Solution dependent on IDF curve.

2-62

Solution dependent on IDF curve.

2-63

From Problem 4-12, the IDF curve for 10-yr storms can be represented by the equation:

$$i = \frac{3}{D + 0.31}$$

Based on this, i can be computed for 10-min. increments.

Duration (min)	i (in./hr.)	Depth (in.)	Incremental depth (in.)	Design storm (in.)	Cumulative Dimensionless storm	Dimensionless storm
10	6.3	1.05	1.05	0.13	0.057	0.057
20	4.7	1.57	0.52	0.28	0.179	0.122
30	3.7	1.85	0.28	1.05	0.638	0.459
40	3.07	2.05	0.20	0.52	0.865	0.227
50	2.62	2.18	0.13	0.20	0.952	0.087
60	2.29	2.29	0.11	0.11	1.000	0.048
			2.29			

2-64

From Problem 4-13 the 100-yr IDF curve can be represented by the following equations:

$$i = \begin{cases} 4.667/(D + 0.333) & for\ D < 2\ hr. \\ 3.274\ D^{-0.737} & for\ D > 2\ hr. \end{cases}$$

Based on this, i can be computed for 3-hr. increments.

Duration (hr.)	i (in/hr)	Depth (in.)	Incremental (in.)	Design storm (in.)	Dimensionless storm	Cumulative storm
3	1.460	4.38	4.38	0.29	0.038	0.038
6	0.874	5.24	0.86	0.38	0.050	0.088
9	0.648	5.84	0.60	0.60	0.079	0.167
12	0.524	6.29	0.45	4.38	0.580	0.747
15	0.445	6.67	0.38	0.86	0.114	0.861
18	0.389	7.00	0.33	0.45	0.064	0.925
21	0.347	7.29	0.29	0.33	0.044	0.969
24	0.315	7.55	0.26	0.26	0.034	1.003
			7.55			(round-off)

2-65

Solution dependent on IDF curve.

2-66

From Figure 2-4, the rainfall intensity is 0.24 in./hr., which gives a depth of 5.76 in.

Time (hr.)	Type II	Cum. Storm (inches)	Design Storm (in.)
3	0.0347	0.200	0.200
6	0.0797	0.459	0.259
9	0.1467	0.845	0.386
12	0.6632	3.820	2.975
15	0.8538	4.918	1.098
18	0.9206	5.303	0.385
21	0.9653	5.560	0.257
24	1.0000	5.760	0.200
			5.760

2-67

Solution dependent on IDF curve.

2-68

For 200-mi^2 the depth-area factor (Figure 2-7) is 0.67. Therefore, the ordinates of the design storm are:

$$0.13\,(0.67) = 0.09$$
$$0.28\,(0.67) = 0.19$$
$$1.05\,(0.67) = 0.70$$
$$0.52\,(0.67) = 0.35$$
$$0.20\,(0.67) = 0.13$$
$$0.11\,(0.67) = 0.07$$

2-69

For 225 mi^2, the depth-area factor (Figure 2-7) is 0.91. Therefore, the ordinates of the design storm are:

$$0.29\,(0.91) = 0.26$$
$$0.38\,(0.91) = 0.35$$
$$0.60\,(0.91) = 0.55$$
$$4.38\,(0.91) = 3.99$$
$$0.86\,(0.91) = 0.78$$
$$0.45\,(0.91) = 0.41$$
$$0.33\,(0.91) = 0.30$$
$$0.26\,(0.91) = 0.24$$

2-70

Solution dependent on IDF curve.
