CE 3354 Engineering Hydrology
Exercise Set 2

Exercises

1. A raingage is located in a 2.5 acre impervious watershed with non initial abstraction. The gage records a catch of 1.0 inches of precipitation in one hour. The maximum intensity was 2.4 inches per hour for 10 minutes. Assume that 10 minutes is the characteristic time for which all parts of the watershed can contribute runoff to a discharge point.

   Determine:

   a) Volume of rainfall in cubic feet for the watershed.

   b) Maximum (peak) discharge rate for the watershed.

   Solution(s):

   a) Find volume of rainfall in cubic feet as product to total depth and wassershed area.

$$V = A \times \ D = 2.5\ ac \cdot \frac{43560\ ft^2}{1\ ac} \cdot 1.0\ in \cdot \frac{1\ ft}{12\ in} = 9,074\ ft^3 \tag{1}$$

   b) Apply rational runoff equation to estimate peak discharge.

$$Q_{peak} = C \cdot i \cdot A = (1.0)(2.4)(2.5) = 6.0\ cfs \tag{2}$$

   Where:
   Q = peak discharge in cfs
   C = runoff coefficient (1.0 for impervious surfaces, given)
   i = rainfall intensity (2.4 in/hr, given maximum 10-min intensity) for the time of concentration (10 minutes, given)
   A = area in acres (2.5 ac., given)

2. Consider the rainfall data in Table 1

Table 1: Somewhere USA Precipitation Data

Time (minutes)	Cumulative Depth (inches
0.00	0.00
30.0	0.04
60.0	0.38
90.0	1.07
120.	1.44
150.	1.62
180.	1.70

Determine:

a) A depth (cumulative inches) hyetograph in 30 minute intervals (plot).

b) An intensity (inches/hour) hyetograph in 30 minute intervals (plot).

Solution(s): Both items above are shown on Figure 1

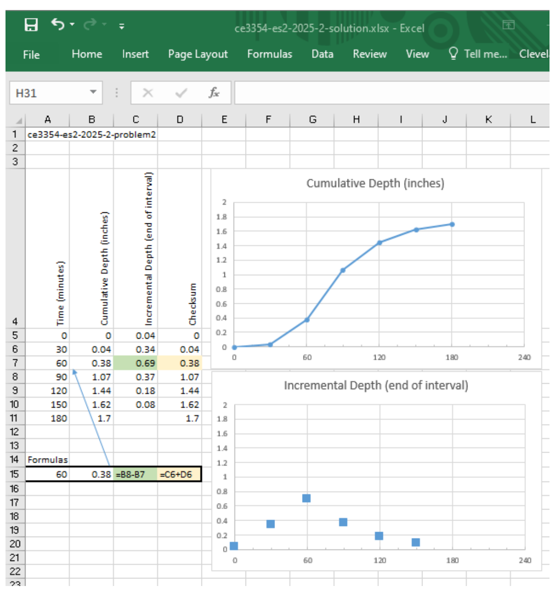

Figure 1: Excel screen capture for ES2-2 (both parts)

3. The intersection of US 408 and US 417 in Orange County, Florida at 28°32'51.2"N 81°15'28.5"W is the approximate centroid of that county. Using NOAA Atlas 14 (use the online PFDS tool)

   Determine:

   a) The 1-hr rainfall depth for a 100-yr Annual Recurrance Interval (ARI).

   b) The 1-hr average rainfall intensity for a 100-yr Annual Recurrance Interval (ARI).

   c) The 6-hr rainfall depth for a 100-yr Annual Recurrance Interval (ARI).

   d) The 6-hr average rainfall intensity for a 100-yr Annual Recurrance Interval (ARI).

   Solutions:

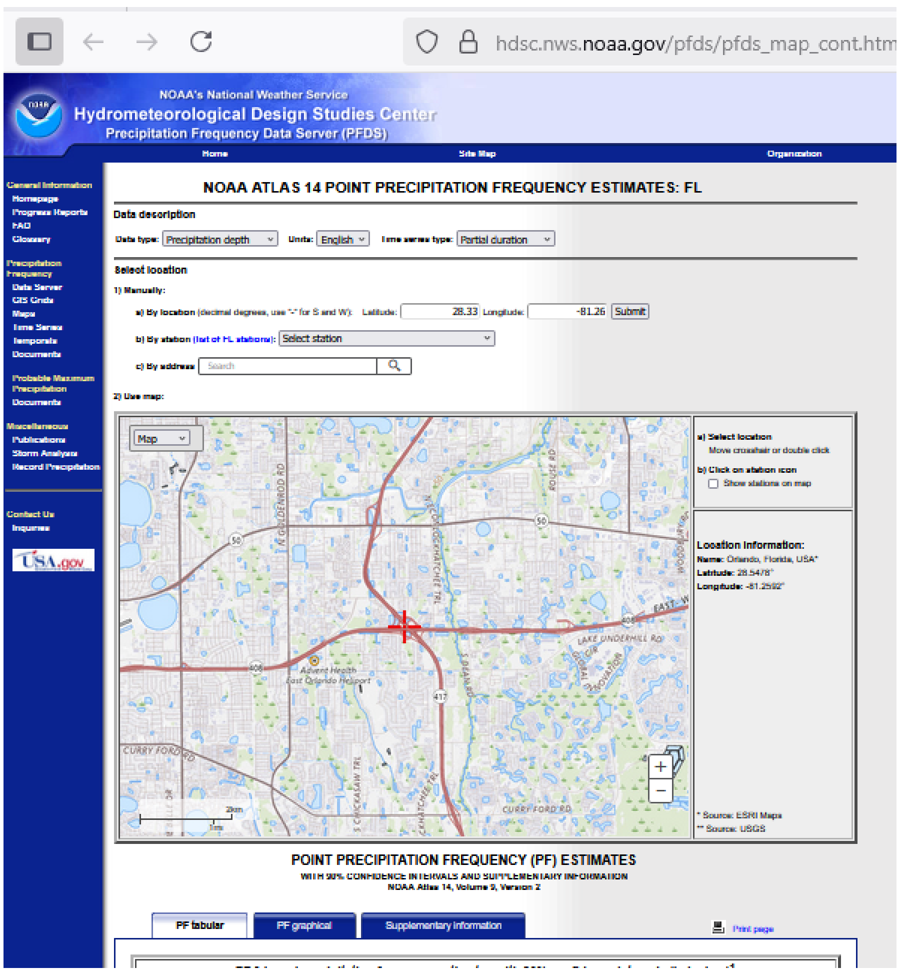

Figure 2: NOAA PFDS Locating the place of interest

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 9, Version 2

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.456** (0.385-0.554)	**0.528** (0.444-0.641)	**0.639** (0.536-0.779)	**0.726** (0.605-0.891)	**0.839** (0.667-1.06)	**0.920** (0.713-1.19)	**0.996** (0.742-1.34)	**1.07** (0.758-1.49)	**1.16** (0.784-1.68)	**1.22** (0.803-1.82)
10-min	**0.668** (0.563-0.811)	**0.772** (0.650-0.939)	**0.935** (0.784-1.14)	**1.06** (0.886-1.30)	**1.23** (0.976-1.56)	**1.35** (1.04-1.75)	**1.46** (1.09-1.96)	**1.56** (1.11-2.18)	**1.69** (1.15-2.46)	**1.78** (1.18-2.67)
15-min	**0.815** (0.687-0.989)	**0.942** (0.793-1.14)	**1.14** (0.956-1.39)	**1.30** (1.08-1.59)	**1.50** (1.19-1.90)	**1.64** (1.27-2.13)	**1.78** (1.32-2.39)	**1.91** (1.35-2.66)	**2.06** (1.40-3.00)	**2.17** (1.43-3.25)
30-min	**1.39** (1.17-1.69)	**1.59** (1.34-1.94)	**1.91** (1.60-2.33)	**2.15** (1.79-2.64)	**2.48** (1.97-3.14)	**2.71** (2.10-3.51)	**2.93** (2.18-3.93)	**3.13** (2.22-4.38)	**3.39** (2.30-4.93)	**3.56** (2.36-5.34)
60-min	**1.87** (1.58-2.27)	**2.15** (1.81-2.62)	**2.59** (2.17-3.16)	**2.93** (2.44-3.60)	**3.37** (2.68-4.28)	**3.69** (2.86-4.79)	**3.99** (2.97-5.35)	**4.26** (3.02-5.96)	**4.60** (3.12-6.69)	**4.83** (3.19-7.24)
2-hr	**2.35** (2.00-2.84)	**2.71** (2.30-3.28)	**3.27** (2.76-3.97)	**3.71** (3.11-4.53)	**4.27** (3.41-5.38)	**4.67** (3.64-6.02)	**5.04** (3.78-6.73)	**5.40** (3.85-7.48)	**5.82** (3.97-8.40)	**6.10** (4.06-9.08)
3-hr	**2.56** (2.18-3.08)	**2.96** (2.51-3.56)	**3.59** (3.04-4.34)	**4.09** (3.44-4.97)	**4.74** (3.80-5.96)	**5.21** (4.08-6.70)	**5.66** (4.26-7.54)	**6.09** (4.36-8.43)	**6.62** (4.53-9.53)	**6.98** (4.66-10.4)
6-hr	**2.92** (2.50-3.49)	**3.37** (2.87-4.03)	**4.10** (3.49-4.92)	**4.72** (3.98-5.69)	**5.57** (4.52-7.02)	**6.24** (4.93-8.03)	**6.91** (5.25-9.22)	**7.60** (5.50-10.5)	**8.52** (5.90-12.3)	**9.23** (6.20-13.6)
12-hr	**3.35** (2.88-3.98)	**3.80** (3.26-4.52)	**4.62** (3.95-5.50)	**5.37** (4.56-6.44)	**6.52** (5.37-8.30)	**7.48** (5.99-9.70)	**8.53** (6.56-11.4)	**9.67** (7.08-13.5)	**11.3** (7.91-16.3)	**12.6** (8.53-18.5)
24-hr	**3.82** (3.30-4.50)	**4.32** (3.72-5.09)	**5.28** (4.54-6.26)	**6.23** (5.31-7.42)	**7.73** (6.46-9.89)	**9.06** (7.32-11.8)	**10.5** (8.17-14.1)	**12.2** (8.99-16.9)	**14.6** (10.3-21.0)	**16.5** (11.3-24.1)
2-day	**4.35** (3.78-5.09)	**4.98** (4.32-5.84)	**6.20** (5.36-7.30)	**7.38** (6.34-8.74)	**9.26** (7.77-11.8)	**10.9** (8.86-14.1)	**12.7** (9.92-16.9)	**14.7** (11.0-20.4)	**17.7** (12.6-25.3)	**20.1** (13.8-29.0)
3-day	**4.79** (4.17-5.59)	**5.50** (4.78-6.41)	**6.83** (5.92-8.00)	**8.10** (6.98-9.55)	**10.1** (8.51-12.8)	**11.9** (9.67-15.2)	**13.8** (10.8-18.3)	**15.9** (11.9-21.9)	**19.0** (13.6-27.1)	**21.6** (14.9-31.1)
4-day	**5.19** (4.53-6.04)	**5.93** (5.17-6.90)	**7.31** (6.35-8.54)	**8.62** (7.44-10.1)	**10.7** (9.00-13.4)	**12.5** (10.2-15.9)	**14.4** (11.3-19.1)	**16.6** (12.4-22.8)	**19.7** (14.1-28.0)	**22.3** (15.4-32.1)
7-day	**6.25** (5.48-7.23)	**7.03** (6.15-8.13)	**8.46** (7.38-9.83)	**9.80** (8.50-11.5)	**11.9** (10.0-14.8)	**13.7** (11.2-17.3)	**15.6** (12.3-20.4)	**17.7** (13.3-24.1)	**20.8** (15.0-29.3)	**23.3** (16.2-33.3)
10-day	**7.22** (6.34-8.31)	**8.04** (7.06-9.28)	**9.55** (8.35-11.1)	**10.9** (9.50-12.7)	**13.0** (11.0-16.1)	**14.8** (12.1-18.6)	**16.7** (13.2-21.7)	**18.8** (14.1-25.4)	**21.8** (15.7-30.5)	**24.2** (16.8-34.4)
20-day	**10.1** (8.90-11.5)	**11.2** (9.87-12.8)	**13.0** (11.5-15.0)	**14.7** (12.8-17.0)	**17.0** (14.3-20.5)	**18.8** (15.5-23.3)	**20.7** (16.4-26.5)	**22.7** (17.1-30.2)	**25.4** (18.4-35.2)	**27.6** (19.3-39.0)
30-day	**12.6** (11.1-14.3)	**13.9** (12.3-15.9)	**16.2** (14.3-18.5)	**18.0** (15.8-20.8)	**20.6** (17.3-24.6)	**22.5** (18.5-27.6)	**24.4** (19.4-31.0)	**26.4** (19.9-34.8)	**29.0** (21.0-39.8)	**30.9** (21.7-43.5)
45-day	**15.8** (14.1-18.0)	**17.5** (15.6-19.9)	**20.3** (17.9-23.1)	**22.4** (19.7-25.8)	**25.3** (21.3-30.0)	**27.4** (22.5-33.2)	**29.3** (23.3-36.9)	**31.3** (23.7-40.9)	**33.6** (24.4-45.8)	**35.3** (25.0-49.5)
60-day	**18.7** (16.6-21.1)	**20.7** (18.4-23.5)	**23.8** (21.2-27.1)	**26.3** (23.2-30.1)	**29.4** (24.8-34.7)	**31.6** (26.1-38.2)	**33.6** (26.7-42.1)	**35.5** (26.9-46.2)	**37.7** (27.4-51.1)	**39.2** (27.8-54.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

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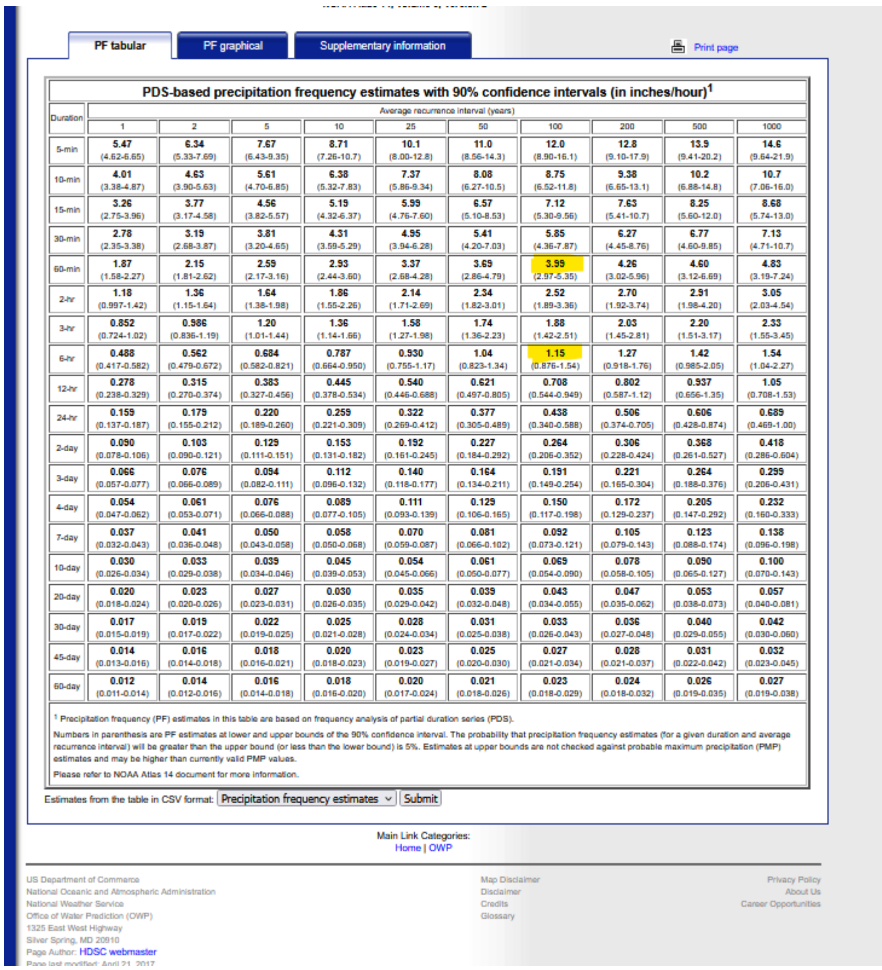
Figure 3: Depth for different reurrance intervals



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PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	5.47 (4.62-6.65)	6.34 (5.33-7.69)	7.67 (6.43-9.35)	8.71 (7.26-10.7)	10.1 (8.00-12.8)	11.0 (8.56-14.3)	12.0 (8.90-16.1)	12.8 (9.10-17.9)	13.9 (9.41-20.2)	14.6 (9.64-21.9)
10-min	4.01 (3.38-4.87)	4.63 (3.90-5.63)	5.61 (4.70-6.85)	6.38 (5.32-7.83)	7.37 (5.86-9.34)	8.08 (6.27-10.5)	8.75 (6.52-11.8)	9.38 (6.65-13.1)	10.2 (6.88-14.8)	10.7 (7.06-16.0)
15-min	3.26 (2.75-3.96)	3.77 (3.17-4.58)	4.56 (3.82-5.57)	5.19 (4.32-6.37)	5.99 (4.76-7.60)	6.57 (5.10-8.53)	7.12 (5.30-9.56)	7.63 (5.41-10.7)	8.25 (5.60-12.0)	8.68 (5.74-13.0)
30-min	2.78 (2.35-3.38)	3.19 (2.68-3.87)	3.81 (3.20-4.65)	4.31 (3.59-5.29)	4.95 (3.94-6.28)	5.41 (4.20-7.03)	5.85 (4.36-7.87)	6.27 (4.45-8.76)	6.77 (4.60-9.85)	7.13 (4.71-10.7)
60-min	1.87 (1.58-2.27)	2.15 (1.81-2.62)	2.59 (2.17-3.16)	2.93 (2.44-3.60)	3.37 (2.68-4.28)	3.69 (2.86-4.79)	3.99 (2.97-5.35)	4.26 (3.02-5.96)	4.60 (3.12-6.69)	4.83 (3.19-7.24)
2-hr	1.18 (0.997-1.42)	1.36 (1.15-1.64)	1.64 (1.38-1.98)	1.86 (1.55-2.26)	2.14 (1.71-2.69)	2.34 (1.82-3.01)	2.52 (1.89-3.36)	2.70 (1.92-3.74)	2.91 (1.98-4.20)	3.05 (2.03-4.54)
3-hr	0.852 (0.724-1.02)	0.986 (0.836-1.19)	1.20 (1.01-1.44)	1.36 (1.14-1.66)	1.58 (1.27-1.98)	1.74 (1.36-2.23)	1.88 (1.42-2.51)	2.03 (1.45-2.81)	2.20 (1.51-3.17)	2.33 (1.55-3.45)
6-hr	0.488 (0.417-0.582)	0.562 (0.479-0.672)	0.684 (0.582-0.821)	0.787 (0.664-0.950)	0.930 (0.755-1.17)	1.04 (0.823-1.34)	1.15 (0.876-1.54)	1.27 (0.918-1.76)	1.42 (0.985-2.05)	1.54 (1.04-2.27)
12-hr	0.278 (0.238-0.329)	0.315 (0.270-0.374)	0.383 (0.327-0.456)	0.445 (0.378-0.534)	0.540 (0.446-0.688)	0.621 (0.497-0.805)	0.708 (0.544-0.949)	0.802 (0.587-1.12)	0.937 (0.656-1.35)	1.05 (0.708-1.53)
24-hr	0.159 (0.137-0.187)	0.179 (0.155-0.212)	0.220 (0.189-0.260)	0.259 (0.221-0.309)	0.322 (0.269-0.412)	0.377 (0.305-0.489)	0.438 (0.340-0.588)	0.506 (0.374-0.705)	0.606 (0.428-0.874)	0.689 (0.469-1.00)
2-day	0.090 (0.078-0.106)	0.103 (0.090-0.121)	0.129 (0.111-0.151)	0.153 (0.131-0.182)	0.192 (0.161-0.245)	0.227 (0.184-0.292)	0.264 (0.206-0.352)	0.306 (0.228-0.424)	0.368 (0.261-0.527)	0.418 (0.286-0.604)
3-day	0.066 (0.057-0.077)	0.076 (0.066-0.089)	0.094 (0.082-0.111)	0.112 (0.096-0.132)	0.140 (0.118-0.177)	0.164 (0.134-0.211)	0.191 (0.149-0.254)	0.221 (0.165-0.304)	0.264 (0.188-0.376)	0.299 (0.206-0.431)
4-day	0.054 (0.047-0.062)	0.061 (0.053-0.071)	0.076 (0.066-0.088)	0.089 (0.077-0.105)	0.111 (0.093-0.139)	0.129 (0.106-0.165)	0.150 (0.117-0.198)	0.172 (0.129-0.237)	0.205 (0.147-0.292)	0.232 (0.160-0.333)
7-day	0.037 (0.032-0.043)	0.041 (0.036-0.048)	0.050 (0.043-0.058)	0.058 (0.050-0.068)	0.070 (0.059-0.087)	0.081 (0.066-0.102)	0.092 (0.073-0.121)	0.105 (0.079-0.143)	0.123 (0.088-0.174)	0.138 (0.096-0.198)
10-day	0.030 (0.026-0.034)	0.033 (0.029-0.038)	0.039 (0.034-0.046)	0.045 (0.039-0.053)	0.054 (0.045-0.066)	0.061 (0.050-0.077)	0.069 (0.054-0.090)	0.078 (0.058-0.105)	0.090 (0.065-0.127)	0.100 (0.070-0.143)
20-day	0.020 (0.018-0.024)	0.023 (0.020-0.026)	0.027 (0.023-0.031)	0.030 (0.026-0.035)	0.035 (0.029-0.042)	0.039 (0.032-0.048)	0.043 (0.034-0.055)	0.047 (0.035-0.062)	0.053 (0.038-0.073)	0.057 (0.040-0.081)
30-day	0.017 (0.015-0.019)	0.019 (0.017-0.022)	0.022 (0.019-0.025)	0.025 (0.021-0.028)	0.028 (0.024-0.034)	0.031 (0.025-0.038)	0.033 (0.026-0.043)	0.036 (0.027-0.048)	0.040 (0.029-0.055)	0.042 (0.030-0.060)
45-day	0.014 (0.013-0.016)	0.016 (0.014-0.018)	0.018 (0.016-0.021)	0.020 (0.018-0.023)	0.023 (0.019-0.027)	0.025 (0.020-0.030)	0.027 (0.021-0.034)	0.028 (0.021-0.037)	0.031 (0.022-0.042)	0.032 (0.023-0.045)
60-day	0.012 (0.011-0.014)	0.014 (0.012-0.016)	0.016 (0.014-0.018)	0.018 (0.016-0.020)	0.020 (0.017-0.024)	0.021 (0.018-0.026)	0.023 (0.018-0.029)	0.024 (0.018-0.032)	0.026 (0.019-0.035)	0.027 (0.019-0.038)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

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Figure 4: Intensity for different recurrance intervals

Table 2: Summary Florida Depths and Intensity for the intersection of US 408 and US 417 in Orange County, Florida

Duration (hours)	Value	ARI (years)
1.0	3.55 inches	100
1.0	3.55 inches/hour	100
6.0	6.91 inches	100
6.0	1.15 inches/hour	100

4. 55 mm of rain is recorded for a 6-hour storm by a raingage for a 10 km^2 watershed. The runoff from the storm indicates that only 45 mm of rain fell on the entire area.

   a) The areal reduction factor (ARF).

   b) Compare the result to Central Texas areal reduction factors

   Solution(s):

   Figure 5

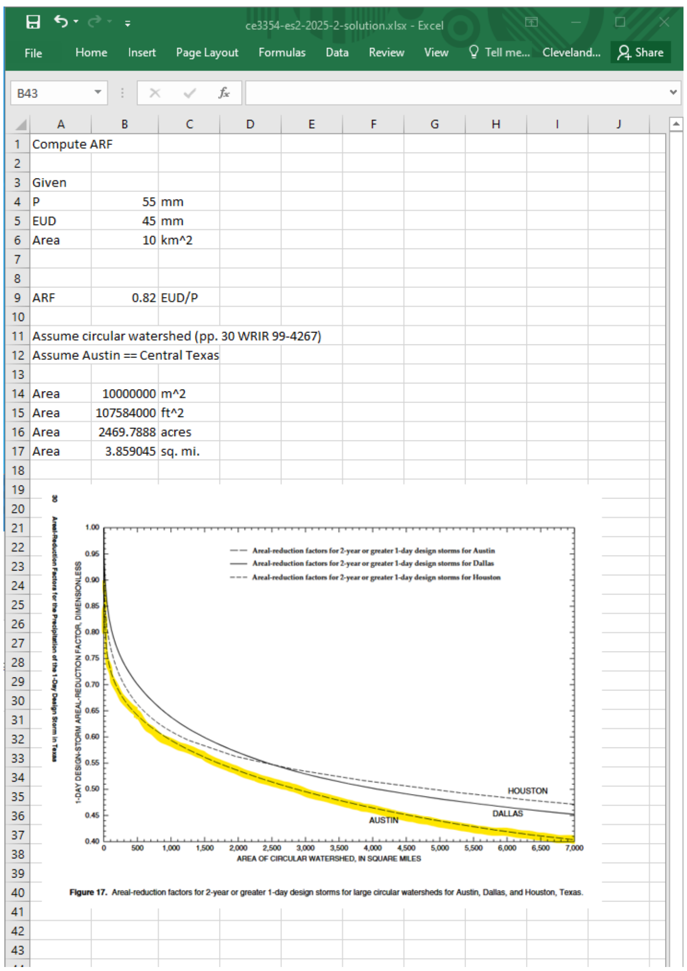


Figure 5: ARF computation and comparison to Central Texas

The reported ARF is consistent with plotted ARF for the Austin curve, but the reported is smaller than anticipated with Central Texas behavior.

5. Table 3 is precipitation data for a 6-hour storm in Somewhere Else USA.

Table 3: Somewhere Else USA Precipitation Data – End of Interval Catch

Time (hours)	Cumulative Depth (inches
0.00	0.00
0.25	0.10
0.50	0.21
0.75	0.33
1.00	0.48
1.25	0.64
1.50	0.81
1.75	1.08
2.00	1.38
2.25	2.46
2.50	3.60
2.75	3.90
3.00	4.20
3.25	4.44
3.50	4.68
3.75	4.86
4.00	5.01
4.25	5.16
4.50	5.28
4.75	5.40
5.00	5.52
5.25	5.64
5.50	5.76
5.75	5.88
6.00	6.00

Determine:

a) The average rainfall intensity (inches/hour) from hour 3:00 to hour 4:00.

b) The average rainfall intensity (inches/hour) for the first half of the storm.

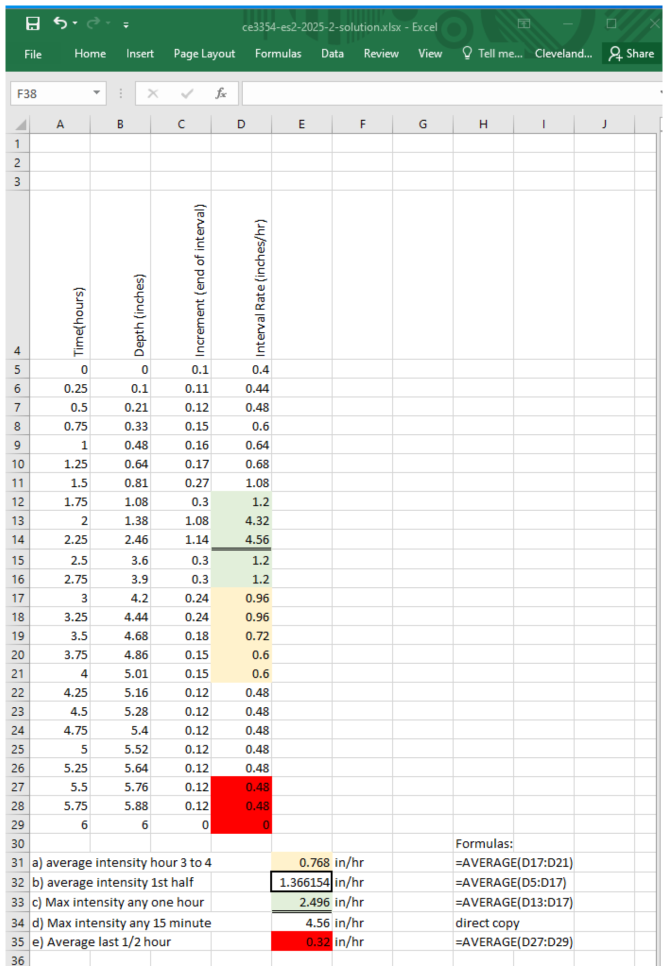
c) The maximum rainfall intensity (inches/hour) in any one hour.

d) The maximum rainfall intensity (inches/hour) in any 15-minute interval.

e) The average rainfall intens10ity (inches/hour) for the last half hour of the storm.

Solution(s):

Figure 6 is a screen capture with the various storm values; formulas used are shown in the figure.



	A	B	C	D	E	F	H
4	Time(hours)	Depth (inches)	Increment (end of interval)	Interval Rate (inches/hr)			
5	0	0	0.1	0.4			
6	0.25	0.1	0.11	0.44			
7	0.5	0.21	0.12	0.48			
8	0.75	0.33	0.15	0.6			
9	1	0.48	0.16	0.64			
10	1.25	0.64	0.17	0.68			
11	1.5	0.81	0.27	1.08			
12	1.75	1.08	0.3	1.2			
13	2	1.38	1.08	4.32			
14	2.25	2.46	1.14	4.56			
15	2.5	3.6	0.3	1.2			
16	2.75	3.9	0.3	1.2			
17	3	4.2	0.24	0.96			
18	3.25	4.44	0.24	0.96			
19	3.5	4.68	0.18	0.72			
20	3.75	4.86	0.15	0.6			
21	4	5.01	0.15	0.6			
22	4.25	5.16	0.12	0.48			
23	4.5	5.28	0.12	0.48			
24	4.75	5.4	0.12	0.48			
25	5	5.52	0.12	0.48			
26	5.25	5.64	0.12	0.48			
27	5.5	5.76	0.12	0.48			
28	5.75	5.88	0.12	0.48			
29	6	6	0	0			
30							Formulas:
31	a) average intensity hour 3 to 4				0.768	in/hr	=AVERAGE(D17:D21)
32	b) average intensity 1st half				1.366154	in/hr	=AVERAGE(D5:D17)
33	c) Max intensity any one hour				2.496	in/hr	=AVERAGE(D13:D17)
34	d) Max intensity any 15 minute				4.56	in/hr	direct copy
35	e) Average last 1/2 hour				0.32	in/hr	=AVERAGE(D27:D29)

Figure 6: Various storm averages from Somewhere Else USA

6. Using the NRCS Type III rainfall distribution

   Determine:

   a) The cumulative rainfall depth (inches) for half-hour increments for a 10 inch total depth, 24-hour storm.

   b) The rainfall intensity (inches/hour) for each half-hour increment of the storm.

   c) The maximum rainfall intensity (inches/hour) in any 30-minute interval.

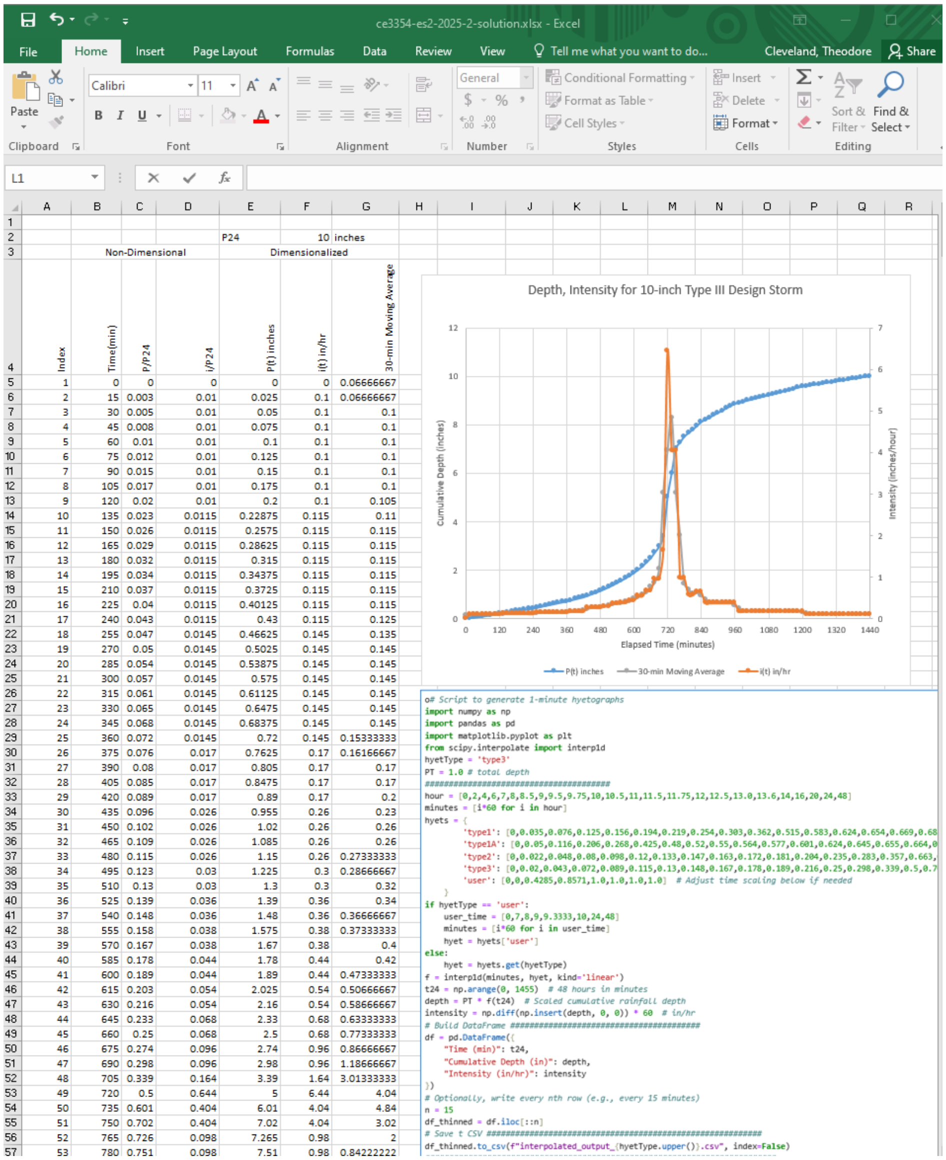
   Solution(s):

   The python script below should interpolate the hyetographs onto the desired 15-minute space. Copy the output file into an Excel spreadsheet, and complete the exercise.

```
# Script to generate 1-minute hyetographs
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d
hyetType = 'type3'
PT = 1.0 # total depth - change to suit problem
########################################
hour = [0,2,4,6,7,8,8.5,9,9.5,9.75,10,10.5,11,11.5,11.75,12,12.5,13.0,13.6,14,16,20
minutes = [i*60 for i in hour]
hyets = {
        'type1': [0,0.035,0.076,0.125,0.156,0.194,0.219,0.254,0.303,0.362,
        0.515,0.583,0.624,0.654,0.669,0.682,0.706,0.727,0.748,0.767,0.83,0.926,1,1]
        'type1A': [0,0.05,0.116,0.206,0.268,0.425,0.48,0.52,0.55,0.564,0.577,
        0.601,0.624,0.645,0.655,0.664,0.683,0.701,0.719,0.736,0.8,0.906,1,1],
        'type2': [0,0.022,0.048,0.08,0.098,0.12,0.133,0.147,0.163,0.172,0.181,
        0.204,0.235,0.283,0.357,0.663,0.735,0.772,0.799,0.82,0.88,0.952,1,1],
        'type3': [0,0.02,0.043,0.072,0.089,0.115,0.13,0.148,0.167,0.178,0.189,
        0.216,0.25,0.298,0.339,0.5,0.702,0.751,0.785,0.811,0.886,0.957,1,1],
        'user': [0,0,0.4285,0.8571,1.0,1.0,1.0,1.0]  # Adjust time scaling below if
    }
if hyetType == 'user':
    user_time = [0,7,8,9,9.3333,10,24,48]
    minutes = [i*60 for i in user_time]
    hyet = hyets['user']
else:
    hyet = hyets.get(hyetType)
f = interp1d(minutes, hyet, kind='linear')
```

```
t24 = np.arange(0, 1455)  # 48 hours in minutes
depth = PT * f(t24)  # Scaled cumulative rainfall depth
intensity = np.diff(np.insert(depth, 0, 0)) * 60  # in/hr
# Build DataFrame ########################################
df = pd.DataFrame({
    "Time (min)": t24,
    "Cumulative Depth (in)": depth,
    "Intensity (in/hr)": intensity
})
# Optionally, write every nth row (e.g., every 15 minutes)
n = 15
df_thinned = df.iloc[::n]
# Save to CSV ##########################################################
df_thinned.to_csv(f"interpolated_output_{hyetType.upper()}.csv", index=False)
###########################################################################
```

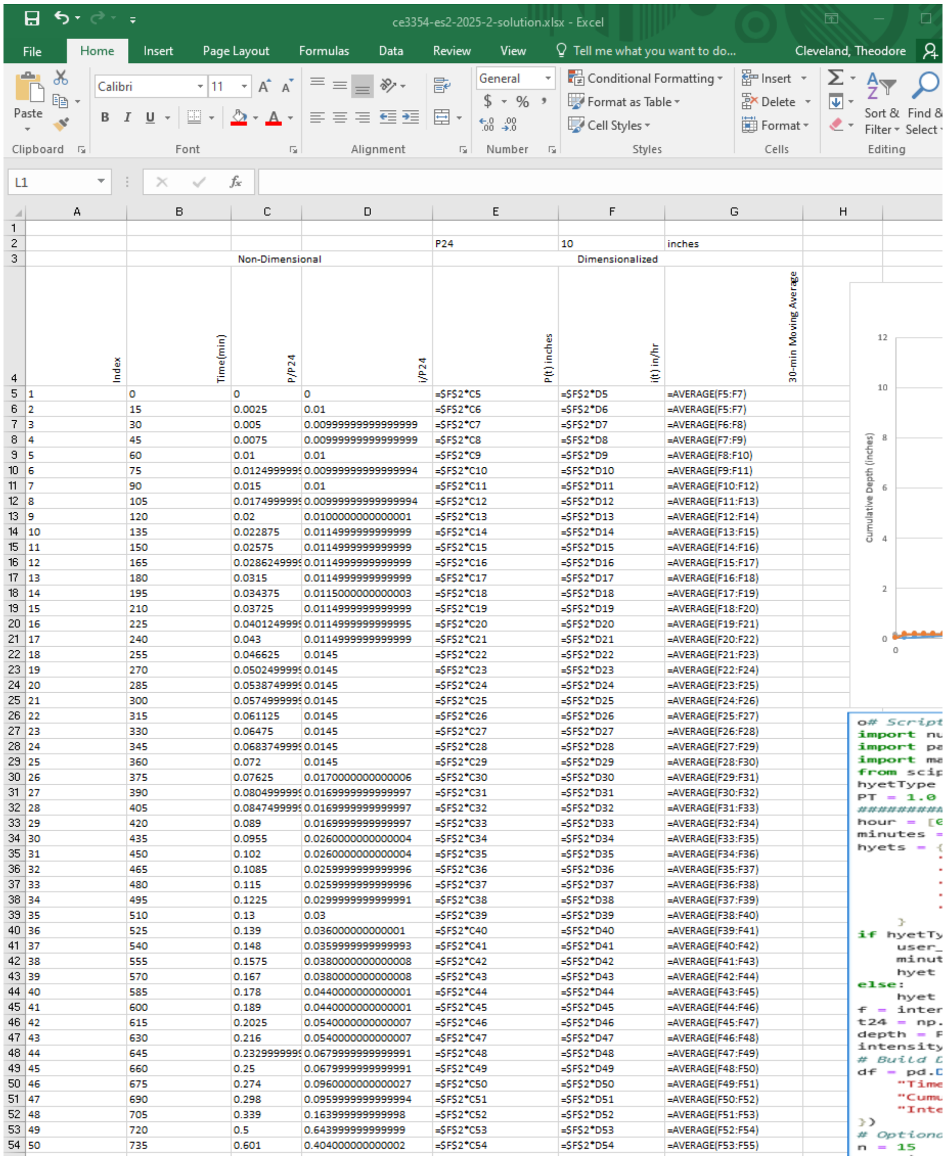
Figures 7 and 8 are spreadsheet fragments to illustrate the building of the tool. Once the tool(s) are built simply query arrays as needed to complete the exercise.



				P24	10	inches
	Non-Dimensional			Dimensionalized		
Index	Time(min)	P/P24	i/P24	P(t) inches	i(t) in/hr	30-min Moving Average
1	0	0	0	0	0	0.06666667
2	15	0.003	0.01	0.025	0.1	0.06666667
3	30	0.005	0.01	0.05	0.1	0.1
4	45	0.008	0.01	0.075	0.1	0.1
5	60	0.01	0.01	0.1	0.1	0.1
6	75	0.012	0.01	0.125	0.1	0.1
7	90	0.015	0.01	0.15	0.1	0.1
8	105	0.017	0.01	0.175	0.1	0.1
9	120	0.02	0.01	0.2	0.1	0.105
10	135	0.023	0.0115	0.22875	0.115	0.11
11	150	0.026	0.0115	0.2575	0.115	0.115
12	165	0.029	0.0115	0.28625	0.115	0.115
13	180	0.032	0.0115	0.315	0.115	0.115
14	195	0.034	0.0115	0.34375	0.115	0.115
15	210	0.037	0.0115	0.3725	0.115	0.115
16	225	0.04	0.0115	0.40125	0.115	0.115
17	240	0.043	0.0115	0.43	0.115	0.125
18	255	0.047	0.0145	0.46625	0.145	0.135
19	270	0.05	0.0145	0.5025	0.145	0.145
20	285	0.054	0.0145	0.53875	0.145	0.145
21	300	0.057	0.0145	0.575	0.145	0.145
22	315	0.061	0.0145	0.61125	0.145	0.145
23	330	0.065	0.0145	0.6475	0.145	0.145
24	345	0.068	0.0145	0.68375	0.145	0.145
25	360	0.072	0.0145	0.72	0.145	0.15333333
26	375	0.076	0.017	0.7625	0.17	0.16166667
27	390	0.08	0.017	0.805	0.17	0.17
28	405	0.085	0.017	0.8475	0.17	0.17
29	420	0.089	0.017	0.89	0.17	0.2
30	435	0.096	0.026	0.955	0.26	0.23
31	450	0.102	0.026	1.02	0.26	0.26
32	465	0.109	0.026	1.085	0.26	0.26
33	480	0.115	0.026	1.15	0.26	0.27333333
34	495	0.123	0.03	1.225	0.3	0.28666667
35	510	0.13	0.03	1.3	0.3	0.32
36	525	0.139	0.036	1.39	0.36	0.34
37	540	0.148	0.036	1.48	0.36	0.36666667
38	555	0.158	0.038	1.575	0.38	0.37333333
39	570	0.167	0.038	1.67	0.38	0.4
40	585	0.178	0.044	1.78	0.44	0.42
41	600	0.189	0.044	1.89	0.44	0.47333333
42	615	0.203	0.054	2.025	0.54	0.50666667
43	630	0.216	0.054	2.16	0.54	0.58666667
44	645	0.233	0.068	2.33	0.68	0.63333333
45	660	0.25	0.068	2.5	0.68	0.77333333
46	675	0.274	0.096	2.74	0.96	0.86666667
47	690	0.298	0.096	2.98	0.96	1.18666667
48	705	0.339	0.164	3.39	1.64	3.01333333
49	720	0.5	0.644	5	6.44	4.04
50	735	0.601	0.404	6.01	4.04	4.84
51	750	0.702	0.404	7.02	4.04	3.02
52	765	0.726	0.098	7.265	0.98	2
53	780	0.751	0.098	7.51	0.98	0.84222222

```
o# Script to generate 1-minute hyetographs
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d
hyetType = 'type3'
PT = 1.0 # total depth
#####################################
hour = [0,2,4,6,7,8,8.5,9,9.5,9.75,10,10.5,11,11.5,11.75,12,12.5,13.0,13.6,14,16,20,24,48]
minutes = [i*60 for i in hour]
hyets = {
        'type1': [0,0.035,0.076,0.125,0.156,0.194,0.219,0.254,0.303,0.362,0.515,0.583,0.624,0.654,0.669,0.68
        'type1A': [0,0.05,0.116,0.206,0.268,0.425,0.48,0.52,0.55,0.564,0.577,0.601,0.624,0.645,0.655,0.664,0
        'type2': [0,0.022,0.048,0.08,0.098,0.12,0.133,0.147,0.163,0.172,0.181,0.204,0.235,0.283,0.357,0.663,
        'type3': [0,0.02,0.043,0.072,0.089,0.115,0.13,0.148,0.167,0.178,0.189,0.216,0.25,0.298,0.339,0.5,0.7
        'user': [0,0,0.4285,0.8571,1.0,1.0,1.0,1.0]  # Adjust time scaling below if needed
    }
if hyetType == 'user':
    user_time = [0,7,8,9,9.3333,10,24,48]
    minutes = [i*60 for i in user_time]
    hyet = hyets['user']
else:
    hyet = hyets.get(hyetType)
f = interp1d(minutes, hyet, kind='linear')
t24 = np.arange(0, 1455)  # 48 hours in minutes
depth = PT * f(t24)  # Scaled cumulative rainfall depth
intensity = np.diff(np.insert(depth, 0, 0)) * 60  # in/hr
# Build DataFrame #########################################
df = pd.DataFrame({
    "Time (min)": t24,
    "Cumulative Depth (in)": depth,
    "Intensity (in/hr)": intensity
})
# Optionally, write every nth row (e.g., every 15 minutes)
n = 15
df_thinned = df.iloc[::n]
# Save t CSV ##############################################################
df_thinned.to_csv(f"interpolated_output_{hyetType.upper()}.csv", index=False)
```

Figure 7: Type III Storm Spreadsheet



	A	B	C	D	E	F	G
1							
2					P24	10	inches
3		Non-Dimensional			Dimensionalized		
4	Index	Time(min)	P/P24	i/P24	P(t) inches	i(t) in/hr	30-min Moving Average
5	1	0	0	0	=$F$2*C5	=$F$2*D5	=AVERAGE(F5:F7)
6	2	15	0.0025	0.01	=$F$2*C6	=$F$2*D6	=AVERAGE(F5:F7)
7	3	30	0.005	0.00999999999999999	=$F$2*C7	=$F$2*D7	=AVERAGE(F6:F8)
8	4	45	0.0075	0.00999999999999999	=$F$2*C8	=$F$2*D8	=AVERAGE(F7:F9)
9	5	60	0.01	0.01	=$F$2*C9	=$F$2*D9	=AVERAGE(F8:F10)
10	6	75	0.012499999	0.00999999999999994	=$F$2*C10	=$F$2*D10	=AVERAGE(F9:F11)
11	7	90	0.015	0.01	=$F$2*C11	=$F$2*D11	=AVERAGE(F10:F12)
12	8	105	0.017499999	0.00999999999999994	=$F$2*C12	=$F$2*D12	=AVERAGE(F11:F13)
13	9	120	0.02	0.0100000000000001	=$F$2*C13	=$F$2*D13	=AVERAGE(F12:F14)
14	10	135	0.022875	0.0114999999999999	=$F$2*C14	=$F$2*D14	=AVERAGE(F13:F15)
15	11	150	0.02575	0.0114999999999999	=$F$2*C15	=$F$2*D15	=AVERAGE(F14:F16)
16	12	165	0.028624999	0.0114999999999999	=$F$2*C16	=$F$2*D16	=AVERAGE(F15:F17)
17	13	180	0.0315	0.0114999999999999	=$F$2*C17	=$F$2*D17	=AVERAGE(F16:F18)
18	14	195	0.034375	0.0115000000000003	=$F$2*C18	=$F$2*D18	=AVERAGE(F17:F19)
19	15	210	0.03725	0.0114999999999999	=$F$2*C19	=$F$2*D19	=AVERAGE(F18:F20)
20	16	225	0.040124999	0.0114999999999995	=$F$2*C20	=$F$2*D20	=AVERAGE(F19:F21)
21	17	240	0.043	0.0114999999999999	=$F$2*C21	=$F$2*D21	=AVERAGE(F20:F22)
22	18	255	0.046625	0.0145	=$F$2*C22	=$F$2*D22	=AVERAGE(F21:F23)
23	19	270	0.050249999	0.0145	=$F$2*C23	=$F$2*D23	=AVERAGE(F22:F24)
24	20	285	0.053874999	0.0145	=$F$2*C24	=$F$2*D24	=AVERAGE(F23:F25)
25	21	300	0.057499999	0.0145	=$F$2*C25	=$F$2*D25	=AVERAGE(F24:F26)
26	22	315	0.061125	0.0145	=$F$2*C26	=$F$2*D26	=AVERAGE(F25:F27)
27	23	330	0.06475	0.0145	=$F$2*C27	=$F$2*D27	=AVERAGE(F26:F28)
28	24	345	0.068374999	0.0145	=$F$2*C28	=$F$2*D28	=AVERAGE(F27:F29)
29	25	360	0.072	0.0145	=$F$2*C29	=$F$2*D29	=AVERAGE(F28:F30)
30	26	375	0.07625	0.0170000000000006	=$F$2*C30	=$F$2*D30	=AVERAGE(F29:F31)
31	27	390	0.080499999	0.0169999999999997	=$F$2*C31	=$F$2*D31	=AVERAGE(F30:F32)
32	28	405	0.084749999	0.0169999999999997	=$F$2*C32	=$F$2*D32	=AVERAGE(F31:F33)
33	29	420	0.089	0.0169999999999997	=$F$2*C33	=$F$2*D33	=AVERAGE(F32:F34)
34	30	435	0.0955	0.0260000000000004	=$F$2*C34	=$F$2*D34	=AVERAGE(F33:F35)
35	31	450	0.102	0.0260000000000004	=$F$2*C35	=$F$2*D35	=AVERAGE(F34:F36)
36	32	465	0.1085	0.0259999999999996	=$F$2*C36	=$F$2*D36	=AVERAGE(F35:F37)
37	33	480	0.115	0.0259999999999996	=$F$2*C37	=$F$2*D37	=AVERAGE(F36:F38)
38	34	495	0.1225	0.0299999999999991	=$F$2*C38	=$F$2*D38	=AVERAGE(F37:F39)
39	35	510	0.13	0.03	=$F$2*C39	=$F$2*D39	=AVERAGE(F38:F40)
40	36	525	0.139	0.036000000000001	=$F$2*C40	=$F$2*D40	=AVERAGE(F39:F41)
41	37	540	0.148	0.0359999999999993	=$F$2*C41	=$F$2*D41	=AVERAGE(F40:F42)
42	38	555	0.1575	0.0380000000000008	=$F$2*C42	=$F$2*D42	=AVERAGE(F41:F43)
43	39	570	0.167	0.0380000000000008	=$F$2*C43	=$F$2*D43	=AVERAGE(F42:F44)
44	40	585	0.178	0.0440000000000001	=$F$2*C44	=$F$2*D44	=AVERAGE(F43:F45)
45	41	600	0.189	0.0440000000000001	=$F$2*C45	=$F$2*D45	=AVERAGE(F44:F46)
46	42	615	0.2025	0.0540000000000007	=$F$2*C46	=$F$2*D46	=AVERAGE(F45:F47)
47	43	630	0.216	0.0540000000000007	=$F$2*C47	=$F$2*D47	=AVERAGE(F46:F48)
48	44	645	0.232999999	0.0679999999999991	=$F$2*C48	=$F$2*D48	=AVERAGE(F47:F49)
49	45	660	0.25	0.0679999999999991	=$F$2*C49	=$F$2*D49	=AVERAGE(F48:F50)
50	46	675	0.274	0.0960000000000027	=$F$2*C50	=$F$2*D50	=AVERAGE(F49:F51)
51	47	690	0.298	0.0959999999999994	=$F$2*C51	=$F$2*D51	=AVERAGE(F50:F52)
52	48	705	0.339	0.163999999999998	=$F$2*C52	=$F$2*D52	=AVERAGE(F51:F53)
53	49	720	0.5	0.643999999999999	=$F$2*C53	=$F$2*D53	=AVERAGE(F52:F54)
54	50	735	0.601	0.404000000000002	=$F$2*C54	=$F$2*D54	=AVERAGE(F53:F55)

Figure 8: Type III Storm Spreadsheet (as formulas)

a) The cumulative rainfall depth (inches) for half-hour increments for a 10 inch total depth, 24-hour storm. The column labeled **P(t) inches** is the cumulative depth for the design storm.

b) The rainfall intensity (inches/hour) for each half-hour increment of the storm. The column labeled **i(t) in/hr** is the intensity for the design storm.

c) The maximum rainfall intensity (inches/hour) in any 30-minute interval. The largest average of any 3 three adjacent rows would be the maximum 30-minute intensity. In the image its the column labeled 30-minute moving average. The largest value is 4.84 in/hr at time 735 minutes.(12:15 from the storm start)

7. Table 4 is intensity duration data for Somewhere USA.

Table 4: Somewhere USA Intensity-Duration

Duration (minutes)	Intensity (inches/hour)
10.0	4.00
15.0	3.20
20.0	2.70
30.0	1.90
60.0	1.20
120.	0.80
180.	0.60

Determine:

a) Plot the intensity duration on the plot type that produces a straight line.

b) An equation (model) of the ”best” straight line for these values.

Solution(s):

The attached spreadsheet in Figure 9 shows the analysis.

In this case the data, when plotted on log-log axes, align closely along a straight line. This suggests that the relationship between variables follows a power-law form of the type:

$y = ax^b$

In a log-log plot, such relationships appear linear because:

$log(y) = log(a) + b \cdot log(x)$

This linearity in the transformed space indicates that a power-law model may be the most appropriate choice for describing the underlying behavior of the data.

The equation based on the plot (using Excel Trendline) is

$$I_{in/hr} = 18.925 \cdot T_{c~min}^{0.665} \tag{3}$$

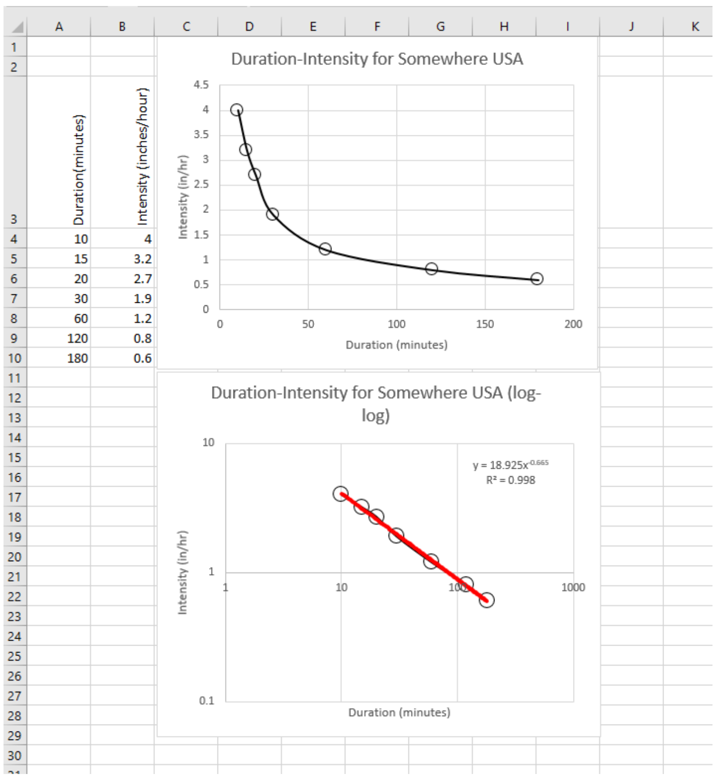


Figure 9: Spreadsheet screen capture with arithmetic and double log plots.

8. Table 5 is a measured 1-hour hyetograph for Baltimore, Maryland.

Table 5: Baltimore, Maryland Rainfall Data

Time (minutes)	Intensity (cm/hour)
0.00 - 10.0	2.00
10.0 - 20.0	6.00
20.0 - 30.0	12.00
30.0 - 40.0	8.00
40.0 - 50.0	6.00
50.0 - 60.0	3.00

Determine:

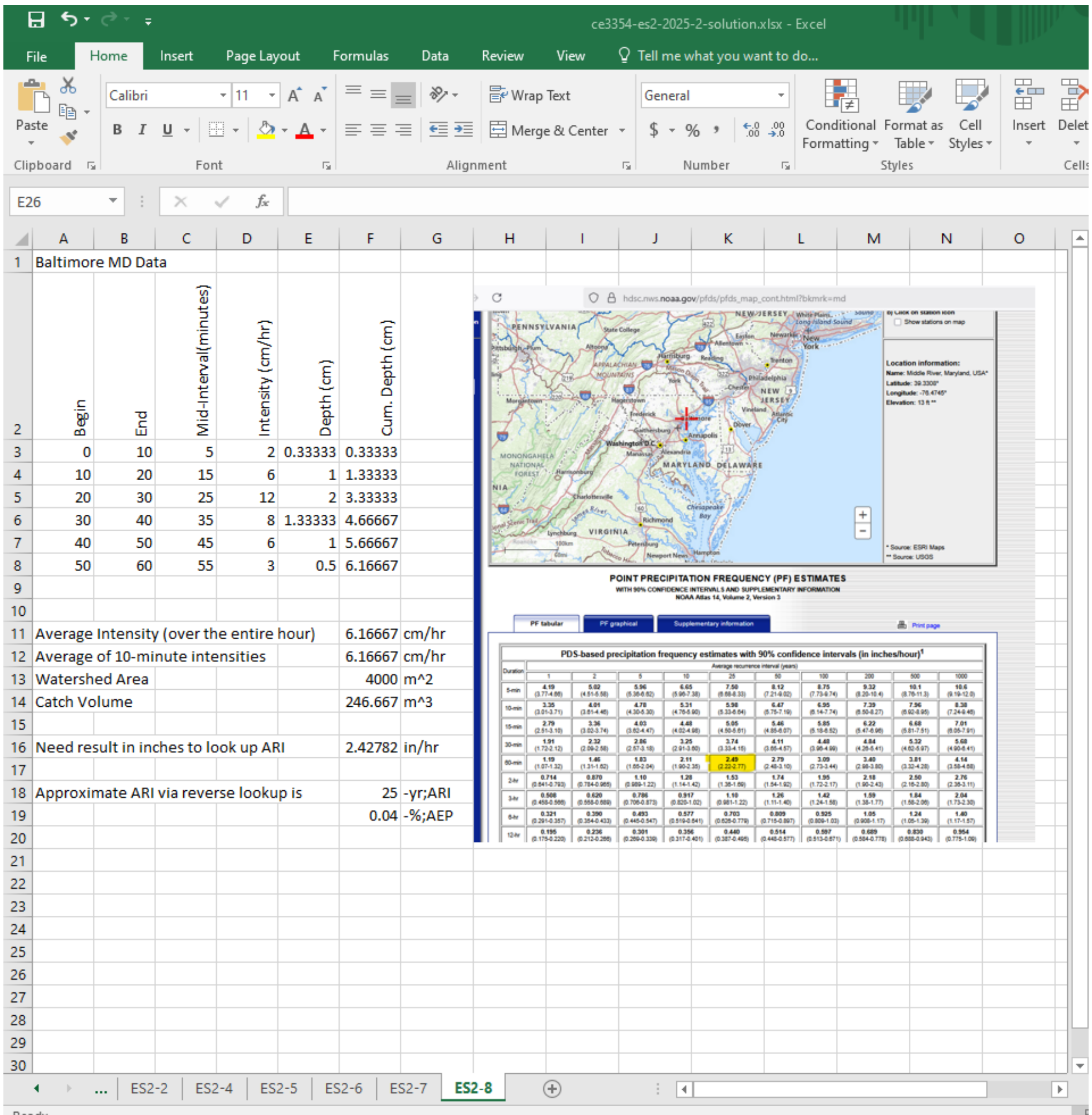
a) The average intensity in cm/hr.

b) The net volume of rainfall in m^3 and liters if the watershed is 4,000 m^2

c) An approximate Annual Recurrance Interval (ARI) for the measured event, using NOAA Atlas 14.

Solution(s):

a), b), and c) are shown in the spreadsheet in Figure 10 and the formulas used are in Figure 11



	A	B	C	D	E	F	G
1	Baltimore MD Data						
2	Begin	End	Mid-Interval(minutes)	Intensity (cm/hr)	Depth (cm)	Cum. Depth (cm)	
3	0	10	5	2	0.33333	0.33333	
4	10	20	15	6	1	1.33333	
5	20	30	25	12	2	3.33333	
6	30	40	35	8	1.33333	4.66667	
7	40	50	45	6	1	5.66667	
8	50	60	55	3	0.5	6.16667	
11	Average Intensity (over the entire hour)					6.16667	cm/hr
12	Average of 10-minute intensities					6.16667	cm/hr
13	Watershed Area					4000	m^2
14	Catch Volume					246.667	m^3
16	Need result in inches to look up ARI					2.42782	in/hr
18	Approximate ARI via reverse lookup is					25	-yr;ARI
19						0.04	-%;AEP

Figure 10: Baltimore, MD intensity data analysis

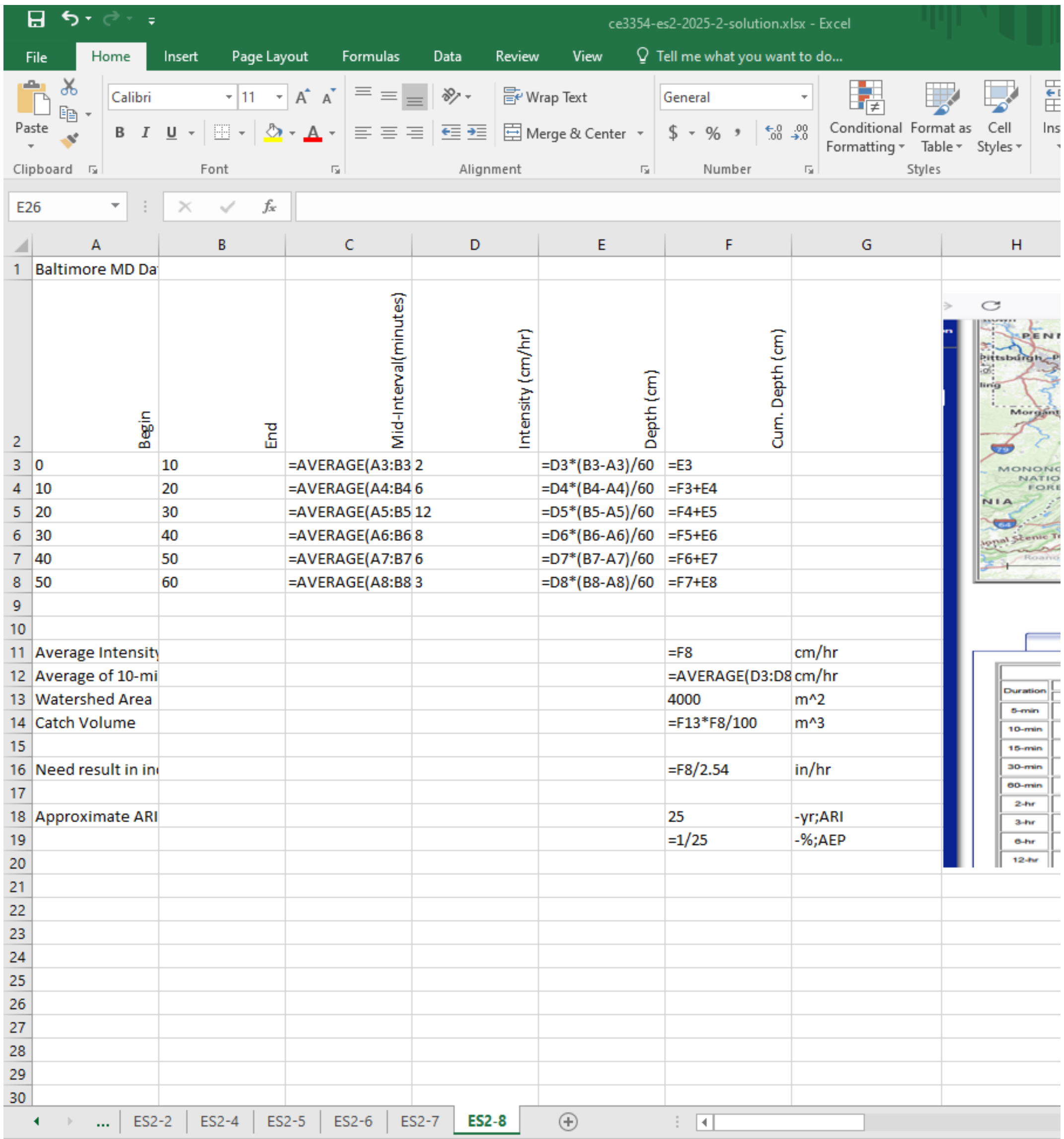


Figure 11: Baltimore, MD intensity data analysis (Excel formulas)

9. The map in Figure 12 shows the location of 6 rain gages and a watershed boundary. The rainfall depths for a certain storm are shown by each gage. An isohyetal map is displayed on the figure as is a linear distance scale.

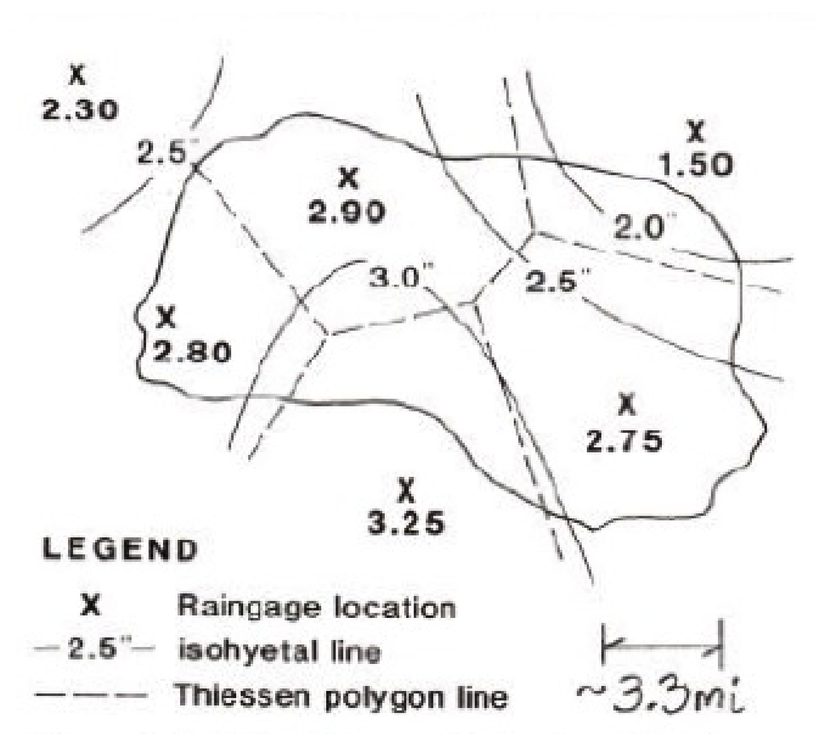


Figure 12: Raingages

Determine:

a) The Theissen polygon boundaries – verify if the gage in the upper left corner is included in the polygon boundaries in the picture (i.e determine your own boundaries for the gages, do they agree with the drawing?).

b) The polygon areas and compute the Theissen weights.

c) The average weighted precipitation over the watershed (using the Theissen weights).

d) The average weighted precipitation (using the Isoheyets).

Solution(s):

For this problem the solution documents workflow using 'ImageJ' software, which is free to download. It has way more useful stuff than simple map measuring, but reflective of the kind of software that will have some durability.

1) Download and extract, install using the imageJ.exe file in the download folder, when extracted, move the folder to somewhere on your computer (or leave in Downloads).

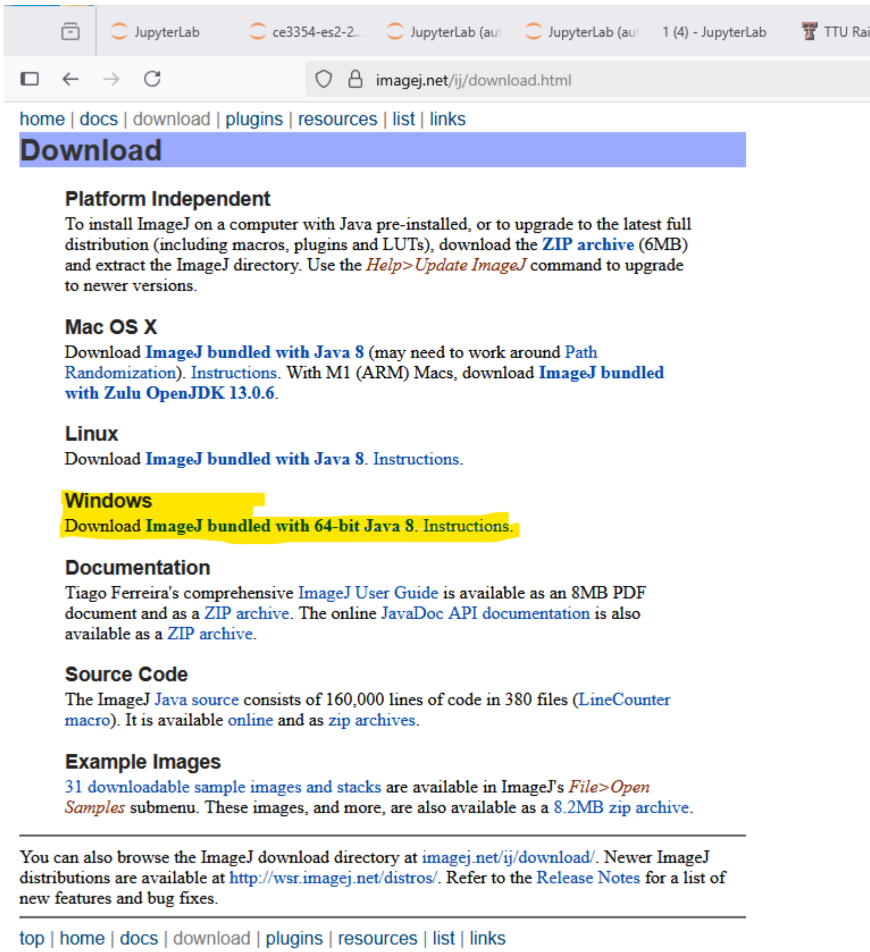


Figure 13: ImageJ Download Landing Page (note the URL)

2) Start ImageJ and open the image file (in this case clip from the assignment)

Calibrate scale using a known distance on the map (in **Analyze** menu item set the scale after drawing a line on the 3.3 mi. scale bar. In the Set Scale dialog, enter 3.3 as the known distance)

3) Use **Polygon** tool to draw amd measure various polygons.

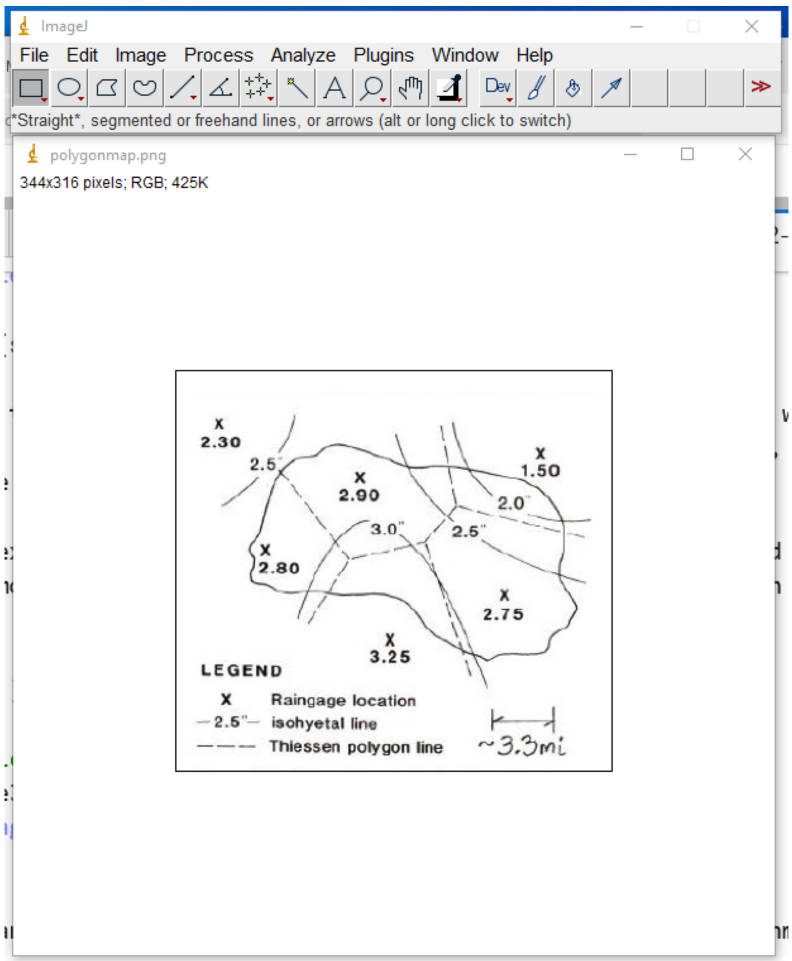


Figure 14: Image to process in ImageJ tool.

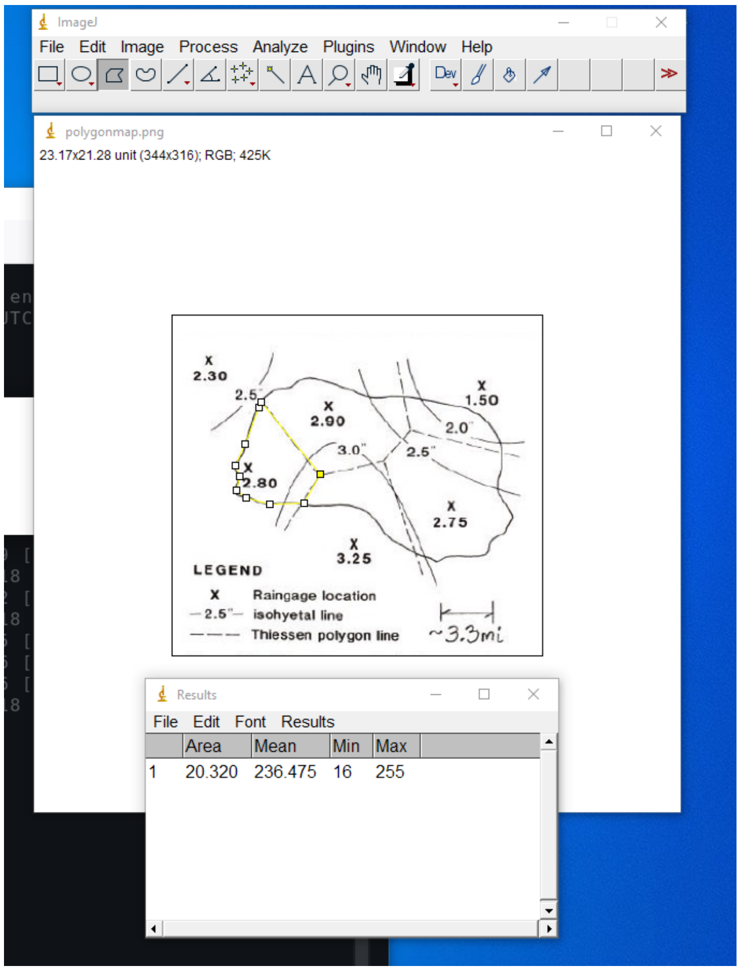
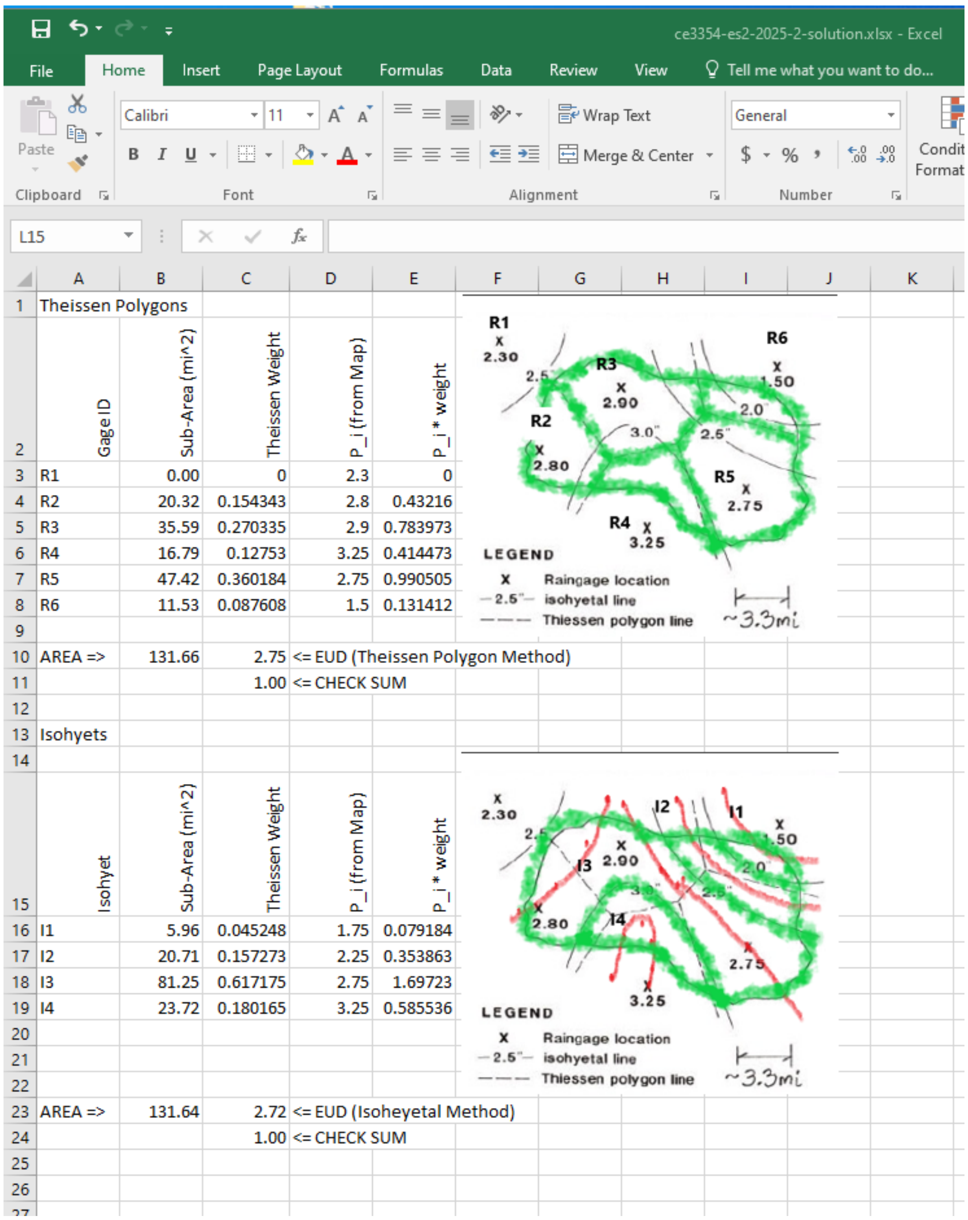


Figure 15: Polygon drawn and measurement completed.

4) Repeat 3) above until have the entire polygon field, record in a spreadsheet.

a), b), c), d) are shown in Figures 16 and 17 using measurements made in ImageJ by the workflow depicted above.



Theissen Polygons

Gage ID	Sub-Area (mi^2)	Theissen Weight	P_i (from Map)	P_i * weight
R1	0.00	0	2.3	0
R2	20.32	0.154343	2.8	0.43216
R3	35.59	0.270335	2.9	0.783973
R4	16.79	0.12753	3.25	0.414473
R5	47.42	0.360184	2.75	0.990505
R6	11.53	0.087608	1.5	0.131412
AREA =>	131.66	2.75	<= EUD (Theissen Polygon Method)	
		1.00	<= CHECK SUM	

Isohyets

Isohyet	Sub-Area (mi^2)	Theissen Weight	P_i (from Map)	P_i * weight
I1	5.96	0.045248	1.75	0.079184
I2	20.71	0.157273	2.25	0.353863
I3	81.25	0.617175	2.75	1.69723
I4	23.72	0.180165	3.25	0.585536
AREA =>	131.64	2.72	<= EUD (Isoheyetal Method)	
		1.00	<= CHECK SUM	

Figure 16: Excel spreadsheet showing EUD calculations.

	A	B	C	D	E
2	Gage ID	Sub-Area (mi^2)	Theissen Weight	P_i (from Map)	P_i * weight
3	R1	0	=B3/$B$10	2.3	=D3*C3
4	R2	20.32	=B4/$B$10	2.8	=D4*C4
5	R3	35.591	=B5/$B$10	2.9	=D5*C5
6	R4	16.79	=B6/$B$10	3.25	=D6*C6
7	R5	47.42	=B7/$B$10	2.75	=D7*C7
8	R6	11.534	=B8/$B$10	1.5	=D8*C8
9					
10	AREA =>	=SUM(B3:B8)	=SUM(E3:E8)	<= EUD (Theissen Po	
11			=SUM(C3:C8)	<= CHECK SUM	
12					
13	Isohyets				
14					
15	Isohyet	Sub-Area (mi^2)	Theissen Weight	P_i (from Map)	P_i * weight
16	I1	5.956216	=B16/$B$23	1.75	=D16*C16
17	I2	20.70572	=B17/$B$10	2.25	=D17*C17
18	I3	81.25411	=B18/$B$10	2.75	=D18*C18
19	I4	23.719598	=B19/$B$10	3.25	=D19*C19
20					
21					
22					
23	AREA =>	=SUM(B16:B21)	=SUM(E16:E21)	<= EUD (Isoheyetal N	
24			=SUM(C16:C21)	<= CHECK SUM	
25					
26			=AVERAGE(D3:D8)	<=EUD (Arithmetic N	
27					

Figure 17: Excel spreadsheet showing EUD calculations (formulas)

10. The map in Figure 18 shows the location of 8 rain gages and the watershed boundary. The rainfall depths for a certain storm are in Table 6. Use the Thiessen polygon method to determine the mean rainfall depth over the watershed for this storm event.

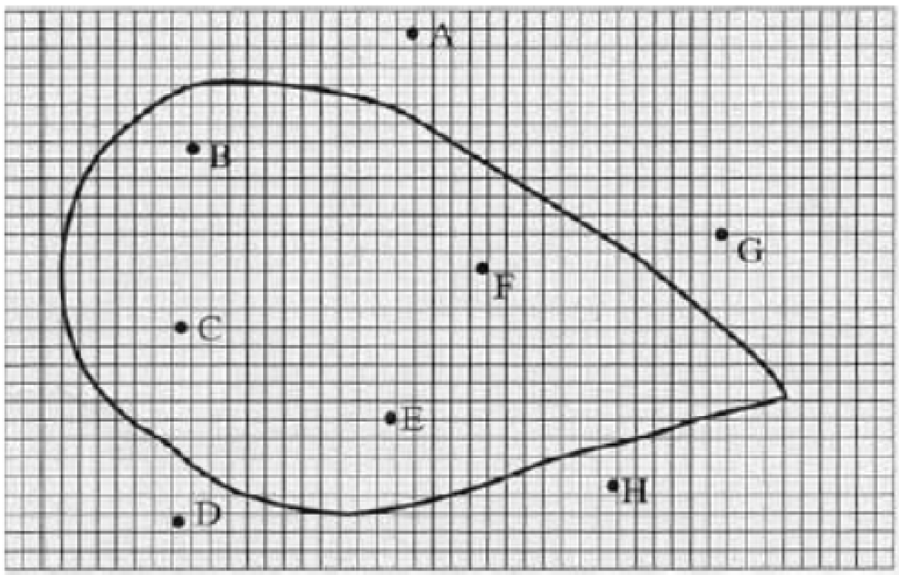


Figure 18: Nowhere Watershed Active Raingages

Table 6: Nowhere Watershed Precipitation

Gage	Cumulative Depth (millimeters)
A	25.00
B	18.00
C	92.00
D	95.00
E	192.0
F	175.0
G	152.0
H	168.0

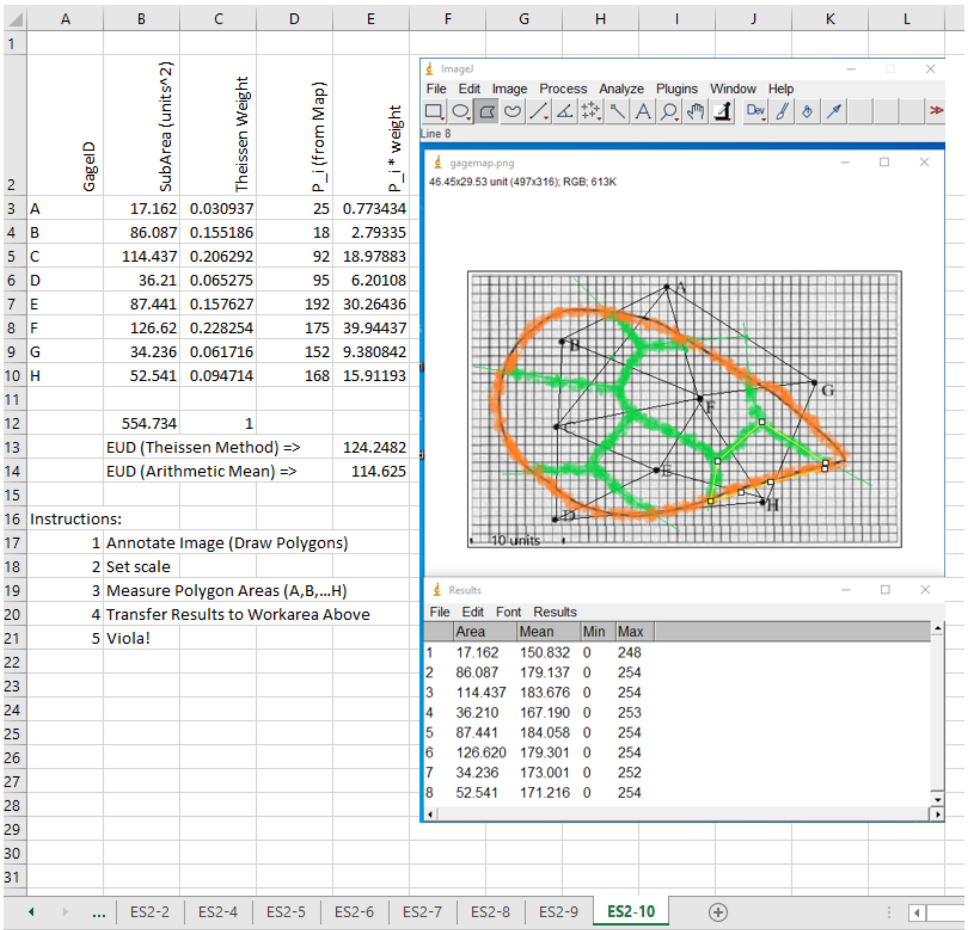
Determine:

a) The mean rainfall depth over the watershed for this storm event using the arithmetic mean.

b) The mean rainfall depth over the watershed for this storm event using the Thiessen polygon method.

Solution(s):

Again using ImageJ software to measure areas the results are displayed on Figures 19 and 20 below.



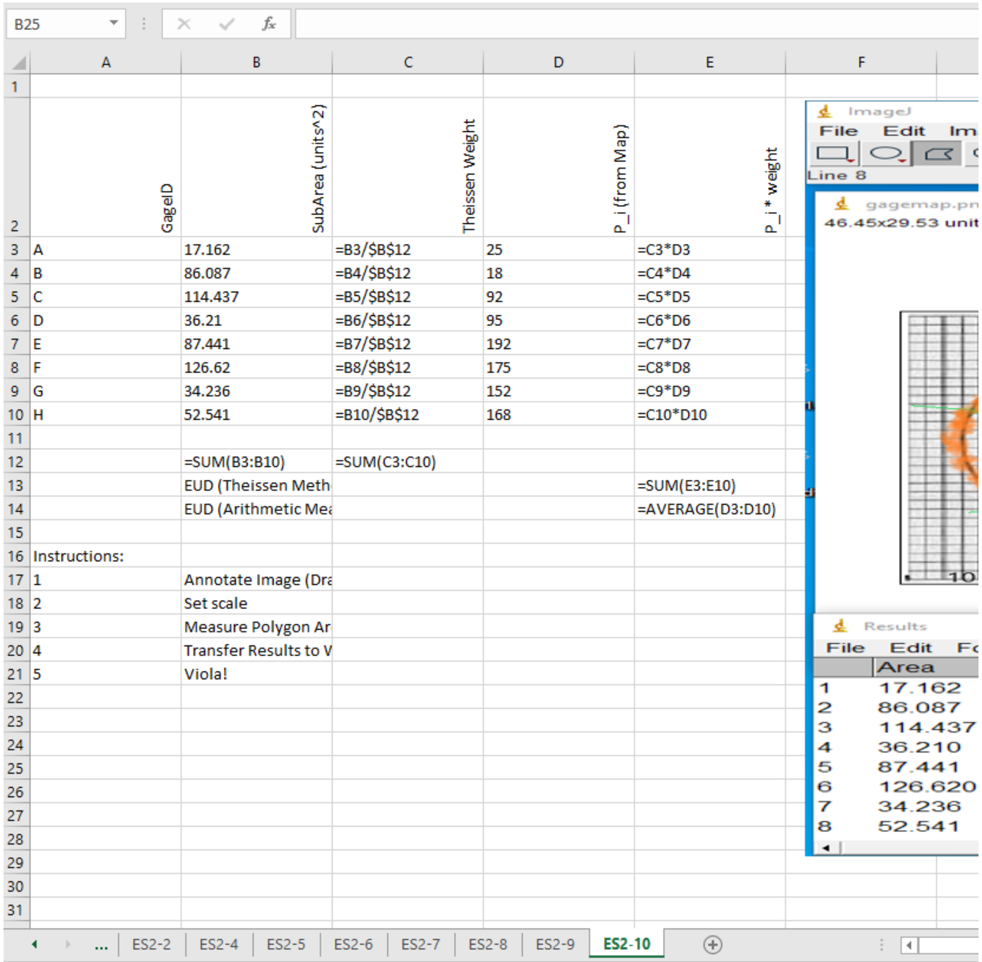
GageID	SubArea (units^2)	Theissen Weight	P_i (from Map)	P_i * weight
A	17.162	0.030937	25	0.773434
B	86.087	0.155186	18	2.79335
C	114.437	0.206292	92	18.97883
D	36.21	0.065275	95	6.20108
E	87.441	0.157627	192	30.26436
F	126.62	0.228254	175	39.94437
G	34.236	0.061716	152	9.380842
H	52.541	0.094714	168	15.91193
	554.734	1		
	EUD (Theissen Method) =>			124.2482
	EUD (Arithmetic Mean) =>			114.625

Instructions:

1 Annotate Image (Draw Polygons)
2 Set scale
3 Measure Polygon Areas (A,B,...H)
4 Transfer Results to Workarea Above
5 Viola!

	Area	Mean	Min	Max
1	17.162	150.832	0	248
2	86.087	179.137	0	254
3	114.437	183.676	0	254
4	36.210	167.190	0	253
5	87.441	184.058	0	254
6	126.620	179.301	0	254
7	34.236	173.001	0	252
8	52.541	171.216	0	254

Figure 19: Excel spreadsheet showing EUD calculations.



B25

	A	B	C	D	E
1					
2	GageID	SubArea (units^2)	Theissen Weight	P_i (from Map)	P_i * weight
3	A	17.162	=B3/$B$12	25	=C3*D3
4	B	86.087	=B4/$B$12	18	=C4*D4
5	C	114.437	=B5/$B$12	92	=C5*D5
6	D	36.21	=B6/$B$12	95	=C6*D6
7	E	87.441	=B7/$B$12	192	=C7*D7
8	F	126.62	=B8/$B$12	175	=C8*D8
9	G	34.236	=B9/$B$12	152	=C9*D9
10	H	52.541	=B10/$B$12	168	=C10*D10
11					
12		=SUM(B3:B10)	=SUM(C3:C10)		
13		EUD (Theissen Meth			=SUM(E3:E10)
14		EUD (Arithmetic Mea			=AVERAGE(D3:D10)
15					
16	Instructions:				
17	1	Annotate Image (Dra			
18	2	Set scale			
19	3	Measure Polygon Ar			
20	4	Transfer Results to V			
21	5	Viola!			

Figure 20: Excel spreadsheet showing EUD calculations (formulas)

11. The map excerpt in Figure 21, shows a stream gage labeled as U.S.G.S. no. 1. Various rain gages are shown as rectangles surrounding the catch for the gage for some time interval.

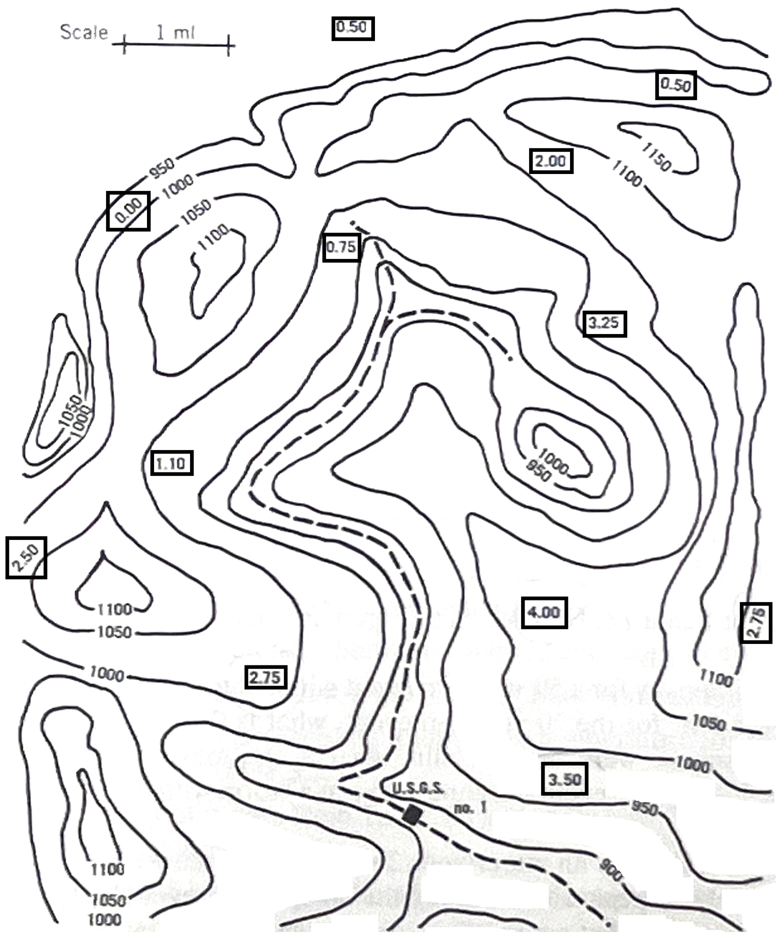


Figure 21: U.S.G.S. No. 1 Area Map

Determine:

a) The drainage area boundary using watershed delineation principles.

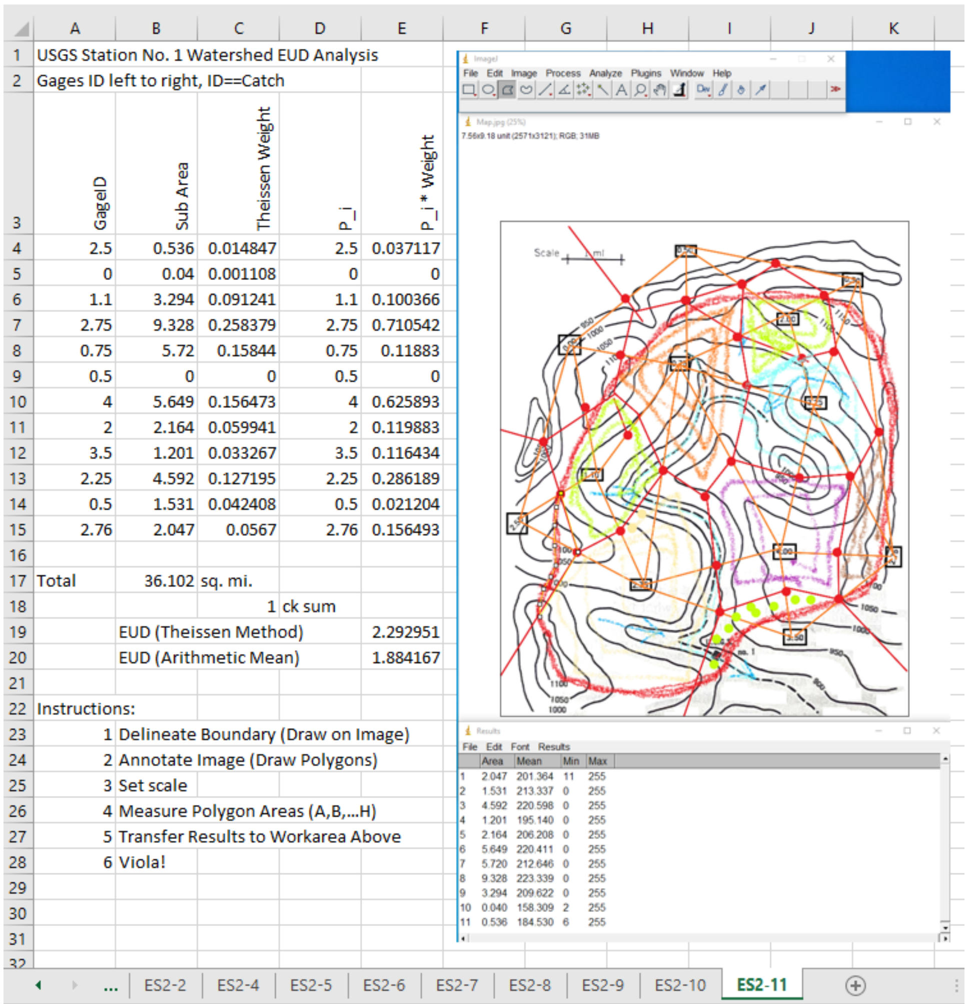
b) The drainage area in square miles.

c) The average precipitation over the area by arithmetic mean.

d) The average precipitation over the area by Thiessen polygon method.

Solution(s):

Again using ImageJ software to measure areas the results are displayed on Figures 22 and 23 below.



	A	B	C	D	E
1	USGS Station No. 1 Watershed EUD Analysis				
2	Gages ID left to right, ID==Catch				
3	GageID	Sub Area	Theissen Weight	P_i	P_i * Weight
4	2.5	0.536	0.014847	2.5	0.037117
5	0	0.04	0.001108	0	0
6	1.1	3.294	0.091241	1.1	0.100366
7	2.75	9.328	0.258379	2.75	0.710542
8	0.75	5.72	0.15844	0.75	0.11883
9	0.5	0	0	0.5	0
10	4	5.649	0.156473	4	0.625893
11	2	2.164	0.059941	2	0.119883
12	3.5	1.201	0.033267	3.5	0.116434
13	2.25	4.592	0.127195	2.25	0.286189
14	0.5	1.531	0.042408	0.5	0.021204
15	2.76	2.047	0.0567	2.76	0.156493
16					
17	Total	36.102	sq. mi.		
18			1	ck sum	
19		EUD (Theissen Method)			2.292951
20		EUD (Arithmetic Mean)			1.884167
21					
22	Instructions:				
23	1	Delineate Boundary (Draw on Image)			
24	2	Annotate Image (Draw Polygons)			
25	3	Set scale			
26	4	Measure Polygon Areas (A,B,...H)			
27	5	Transfer Results to Workarea Above			
28	6	Viola!			

	Area	Mean	Min	Max
1	2.047	201.364	11	255
2	1.531	213.337	0	255
3	4.592	220.598	0	255
4	1.201	195.140	0	255
5	2.164	206.208	0	255
6	5.649	220.411	0	255
7	5.720	212.646	0	255
8	9.328	223.339	0	255
9	3.294	209.622	0	255
10	0.040	158.309	2	255
11	0.536	184.530	6	255

Figure 22: Excel spreadsheet showing EUD calculations.

	A	B	C	D	E	F
1	USGS Station No. 1 W					
2	Gages ID left to right					
3	GageID	Sub Area	Theissen Weight	P_i	P_i * Weight	
4	2.5	0.536	=B4/$B$17	2.5	=D4*C4	
5	0	0.04	=B5/$B$17	0	=D5*C5	
6	1.1	3.294	=B6/$B$17	1.1	=D6*C6	
7	2.75	9.328	=B7/$B$17	2.75	=D7*C7	
8	0.75	5.72	=B8/$B$17	0.75	=D8*C8	
9	0.5	0	=B9/$B$17	0.5	=D9*C9	
10	4	5.649	=B10/$B$17	4	=D10*C10	
11	2	2.164	=B11/$B$17	2	=D11*C11	
12	3.5	1.201	=B12/$B$17	3.5	=D12*C12	
13	2.25	4.592	=B13/$B$17	2.25	=D13*C13	
14	0.5	1.531	=B14/$B$17	0.5	=D14*C14	
15	2.76	2.047	=B15/$B$17	2.76	=D15*C15	
16						
17	Total	=SUM(B4:B15)	sq. mi.			
18			=SUM(C4:C15)	ck sum		
19		EUD (Theissen Meth			=SUM(E4:E15)	
20		EUD (Arithmetic Mea			=AVERAGE(D4:D15)	
21						
22	Instructions:					
23	1	Delineate Boundary				
24	2	Annotate Image (Dra				
25	3	Set scale				
26	4	Measure Polygon Ar				
27	5	Transfer Results to V				
28	6	Viola!				
29						
30						
31						

... ES2-2 ES2-4 ES2-5 ES2-6 ES2-7 ES2-8 ES2-9 ES2-10 ES2-11

Figure 23: Excel spreadsheet showing EUD calculations (formulas)