CHAPTER 5.0 RAINFALL

5.1 Introduction

This chapter provides methods for obtaining rainfall data and generating rainfall design storms to be used for hydrologic runoff analysis within the County.

Rainfall data is based on the *National Oceanic and Atmospheric Administration Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8* (NOAA, 2013), which is referred hereinto as "NOAA Atlas 14." NOAA Atlas 14 is a precipitation frequency study released in 2013 for Colorado. It leverages over 30 years of additional precipitation data that has been recorded since the previous NOAA Atlas 2 studies were prepared in the 1970s. Approximately 15 rain gages within the County were used for NOAA Atlas 14 analysis, with various periods of record ranging from 1941 through 2011. NOAA Atlas 14 results are also readily available online using an interactive map to retrieve rainfall data at any location. MHFD and many other Colorado communities have adopted NOAA Atlas 14 since it was published.

The County Engineer may allow the use of other rainfall data if required by existing master drainage plans.

5.2 Retrieving Data from NOAA Atlas 14

Rainfall depth and intensity tables and graphs can be retrieved directly from the NOAA Atlas 14 website using the following procedures:

1. Go to the NOAA Atlas 14 website for Colorado. (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=co)
2. Select the project location by entering the latitude and longitude coordinates, address, or by using the point and click function on the interactive map.
3. Select either *Precipitation depth* (for developing design storms) or *Precipitation intensity* (for the intensity-duration-frequency curves) as the *Data type* and specify *Partial duration* as the *Time series type*. A partial duration series-based precipitation frequency estimates table appears below the map with 90% confidence intervals indicated.
4. Download the table of precipitation depth or intensity estimates, with or without 90% confidence intervals, by selecting the *Submit* button below the output table.
5. Use the *Print page* button to generate a report showing the rainfall data and location maps and provide that report with the submittals. An example of point precipitation data for an area near Red Feather Lakes is provided at the end of this chapter.

5.3 Intensity-Duration-Frequency

Rainfall intensity-duration-frequency data are needed for use in the Rational Method. NOAA Atlas 14 provides intensity values for storms of 5, 10, 15, 30, 60, and 120-minute duration (as well as longer) and return periods of 1, 2, 5, 10, 25, 50, 100, 200, 500 and 1000 years. The user

should interpolate between these values to obtain intensities for a storm duration falling in between those provided.

5.4 Design Storm Distributions

Design storms to be used with the Colorado Urban Hydrograph Procedure shall be generated according to procedures outlined in the *Rainfall* chapter of the MHFD Manual. The point-rainfall depths shall be obtained from NOAA Atlas 14 according to the procedures above. Note that depth-area-reduction factors may apply for contributing areas greater than 2 square miles. Table 5-1 below shows the 2-hour design storm distribution for 5-minute increments. The Excel-based workbooks CUHP-2000 and MHFD-Detention, both provided by MHFD, will automatically generate hyetographs for multiple return periods based on drainage area and one-hour point rainfall values. These workbooks are discussed in more detail in Chapter 6 *Runoff* and Chapter 14 *Detention* of the Standards.

Table 5-1. from MHFD Manual showing 2-hour design storm distributions based on 1-hour precipitation depths

Time Minutes	Percent of 1 Hour Precipitation Depth (%)				
	2-Year	5-Year	10-Year	25- and 50-Year	100- and 500-Year
5	2.0	2.0	2.0	1.3	1.0
10	4.0	3.7	3.7	3.5	3.0
15	8.4	8.7	8.2	5.0	4.6
20	16.0	15.3	15.0	8.0	8.0
25	25.0	25.0	25.0	15.0	14.0
30	14.0	13.0	12.0	25.0	25.0
35	6.3	5.8	5.6	12.0	14.0
40	5.0	4.4	4.3	8.0	8.0
45	3.0	3.6	3.8	5.0	6.2
50	3.0	3.6	3.2	5.0	5.0
55	3.0	3.0	3.2	3.2	4.0
60	3.0	3.0	3.2	3.2	4.0
65	3.0	3.0	3.2	3.2	4.0
70	2.0	3.0	3.2	2.4	2.0
75	2.0	2.5	3.2	2.4	2.0
80	2.0	2.2	2.5	1.8	1.2
85	2.0	2.2	1.9	1.8	1.2
90	2.0	2.2	1.9	1.4	1.2
95	2.0	2.2	1.9	1.4	1.2
100	2.0	1.5	1.9	1.4	1.2
105	2.0	1.5	1.9	1.4	1.2
110	2.0	1.5	1.9	1.4	1.2
115	1.0	1.5	1.7	1.4	1.2
120	1.0	1.3	1.3	1.4	1.2
Totals	115.7%	115.7%	115.7%	115.6%	115.6%

5.5 Example

Obtain the 5-year rainfall intensity value to use in the Rational Method for a 45-acre watershed in the Red Feather Lakes area. T_c = 17 minutes.

1. Go to the NOAA Atlas 14 website and select the location on the interactive map (Figure 5-1).

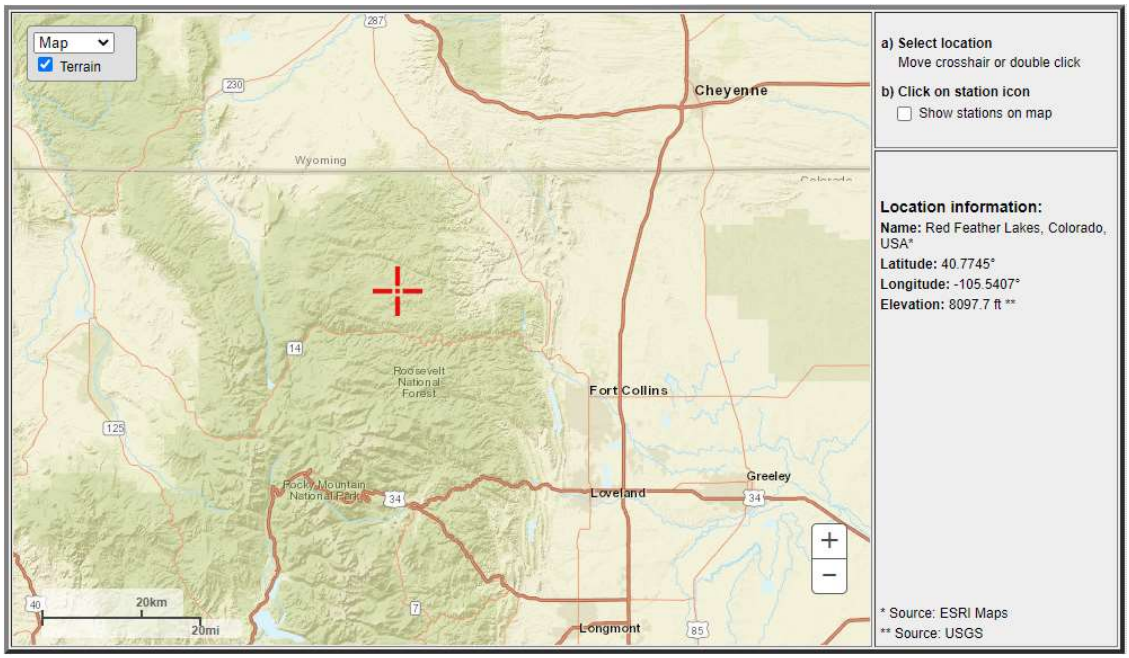

Figure 5-1. Location near Red Feather Lakes selected for point precipitation estimates using NOAA Atlas 14

2. Select Precipitation intensity, English units, and Partial duration time series.
3. Download the table of precipitation frequency estimates (Figure 5-2).
4. Create a graph of intensity-duration-frequency values (Figure 5-3).
5. Interpolate to find 5-year, 17-minute intensity.
    a. Find 5-year, 15-minute intensity and 5-year, 30-minute intensity from precipitation table downloaded from NOAA

Duration (minutes)	5-year Intensity (in/hr)
15	2.51
30	1.62

    b. Use Equation 1 for linear interpolation:

$$y = y_1 + (x - x_1)(y_2 - y_1)/(x_2 - x_1) \quad (1)$$

Where:

y = 5-year, 17-minute intensity
x = 17 minutes
x_1 = Duration 1
x_2 = Duration 2
y_1 = Intensity 1
y_2 = Intensity 2

c. I = 2.4 in/hr

PF tabular | PF graphical | Supplementary information | Print page

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	2.64 (2.03-3.43)	3.22 (2.47-4.19)	4.22 (3.23-5.51)	5.10 (3.89-6.71)	6.40 (4.75-8.87)	7.46 (5.41-10.5)	8.58 (6.02-12.5)	9.77 (6.60-14.7)	11.4 (7.44-17.8)	12.8 (8.08-20.1)
10-min	1.94 (1.49-2.51)	2.36 (1.81-3.07)	3.09 (2.36-4.04)	3.74 (2.85-4.91)	4.69 (3.48-6.49)	5.47 (3.96-7.69)	6.28 (4.41-9.13)	7.15 (4.83-10.8)	8.37 (5.44-13.0)	9.34 (5.91-14.7)
15-min	1.57 (1.21-2.05)	1.92 (1.47-2.50)	2.51 (1.92-3.28)	3.04 (2.32-3.99)	3.81 (2.83-5.28)	4.44 (3.22-6.26)	5.11 (3.58-7.42)	5.82 (3.93-8.74)	6.80 (4.43-10.6)	7.59 (4.80-12.0)
30-min	1.02 (0.782-1.32)	1.24 (0.950-1.61)	1.62 (1.24-2.12)	1.96 (1.49-2.57)	2.46 (1.83-3.41)	2.87 (2.08-4.04)	3.30 (2.32-4.80)	3.76 (2.54-5.66)	4.41 (2.87-6.86)	4.92 (3.11-7.77)
60-min	0.629 (0.483-0.817)	0.752 (0.578-0.979)	0.976 (0.748-1.27)	1.18 (0.900-1.55)	1.49 (1.12-2.09)	1.76 (1.28-2.49)	2.04 (1.44-2.98)	2.35 (1.59-3.55)	2.79 (1.82-4.36)	3.15 (2.00-4.97)
2-hr	0.374 (0.290-0.482)	0.443 (0.344-0.572)	0.571 (0.441-0.740)	0.692 (0.532-0.900)	0.879 (0.665-1.22)	1.04 (0.766-1.46)	1.22 (0.867-1.77)	1.41 (0.966-2.12)	1.69 (1.12-2.62)	1.92 (1.23-3.00)
3-hr	0.278 (0.217-0.357)	0.324 (0.252-0.416)	0.413 (0.321-0.532)	0.500 (0.386-0.647)	0.638 (0.488-0.887)	0.761 (0.564-1.07)	0.896 (0.643-1.30)	1.05 (0.723-1.57)	1.27 (0.843-1.96)	1.45 (0.934-2.25)
6-hr	0.171 (0.134-0.217)	0.194 (0.152-0.247)	0.242 (0.190-0.309)	0.291 (0.227-0.374)	0.373 (0.289-0.516)	0.446 (0.335-0.624)	0.529 (0.384-0.761)	0.623 (0.435-0.925)	0.761 (0.512-1.17)	0.877 (0.570-1.35)
12-hr	0.104 (0.083-0.131)	0.117 (0.093-0.148)	0.144 (0.114-0.183)	0.172 (0.135-0.219)	0.219 (0.171-0.300)	0.261 (0.198-0.361)	0.308 (0.226-0.439)	0.362 (0.255-0.532)	0.442 (0.300-0.669)	0.508 (0.334-0.773)
24-hr	0.062 (0.050-0.078)	0.071 (0.057-0.089)	0.088 (0.070-0.110)	0.105 (0.083-0.132)	0.132 (0.104-0.178)	0.156 (0.119-0.213)	0.183 (0.135-0.257)	0.213 (0.152-0.309)	0.257 (0.176-0.385)	0.294 (0.195-0.442)
2-day	0.036 (0.029-0.044)	0.042 (0.034-0.051)	0.052 (0.042-0.065)	0.062 (0.050-0.078)	0.078 (0.062-0.104)	0.092 (0.071-0.124)	0.107 (0.080-0.148)	0.124 (0.089-0.177)	0.148 (0.102-0.218)	0.167 (0.112-0.249)
3-day	0.026 (0.021-0.032)	0.030 (0.024-0.037)	0.037 (0.030-0.046)	0.044 (0.036-0.055)	0.055 (0.044-0.073)	0.065 (0.050-0.087)	0.075 (0.056-0.104)	0.087 (0.063-0.124)	0.104 (0.072-0.152)	0.118 (0.079-0.174)
4-day	0.021 (0.017-0.025)	0.024 (0.019-0.029)	0.029 (0.024-0.036)	0.035 (0.028-0.043)	0.043 (0.034-0.057)	0.050 (0.039-0.067)	0.058 (0.044-0.080)	0.067 (0.049-0.095)	0.080 (0.056-0.117)	0.091 (0.062-0.133)
7-day	0.014 (0.011-0.017)	0.016 (0.013-0.019)	0.019 (0.016-0.023)	0.022 (0.018-0.027)	0.027 (0.022-0.035)	0.031 (0.025-0.041)	0.036 (0.027-0.049)	0.041 (0.030-0.058)	0.048 (0.034-0.070)	0.054 (0.037-0.079)
10-day	0.011 (0.009-0.013)	0.012 (0.010-0.015)	0.015 (0.012-0.018)	0.017 (0.014-0.021)	0.021 (0.017-0.027)	0.024 (0.019-0.031)	0.027 (0.021-0.036)	0.031 (0.022-0.043)	0.036 (0.025-0.051)	0.040 (0.027-0.058)
20-day	0.007 (0.006-0.009)	0.008 (0.007-0.010)	0.010 (0.008-0.012)	0.011 (0.009-0.013)	0.013 (0.011-0.017)	0.015 (0.012-0.019)	0.016 (0.012-0.022)	0.018 (0.013-0.025)	0.020 (0.015-0.029)	0.022 (0.016-0.032)
30-day	0.006 (0.005-0.007)	0.007 (0.005-0.008)	0.008 (0.006-0.009)	0.009 (0.007-0.011)	0.010 (0.008-0.013)	0.011 (0.009-0.014)	0.013 (0.010-0.016)	0.014 (0.010-0.019)	0.015 (0.011-0.021)	0.017 (0.012-0.024)
45-day	0.005 (0.004-0.006)	0.005 (0.004-0.006)	0.006 (0.005-0.008)	0.007 (0.006-0.009)	0.008 (0.007-0.010)	0.009 (0.007-0.011)	0.010 (0.008-0.013)	0.011 (0.008-0.014)	0.012 (0.008-0.016)	0.013 (0.009-0.018)
60-day	0.004 (0.003-0.005)	0.005 (0.004-0.005)	0.005 (0.005-0.006)	0.006 (0.005-0.007)	0.007 (0.006-0.009)	0.008 (0.006-0.010)	0.008 (0.006-0.011)	0.009 (0.007-0.012)	0.010 (0.007-0.014)	0.010 (0.007-0.015)

[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.

Please refer to NOAA Atlas 14 document for more information.

Estimates from the table in CSV format: All Submit

Figure 5-2. Output table of precipitation intensity estimates including 90% confidence intervals produced for a point near Red Feather Lakes using NOAA Atlas 14

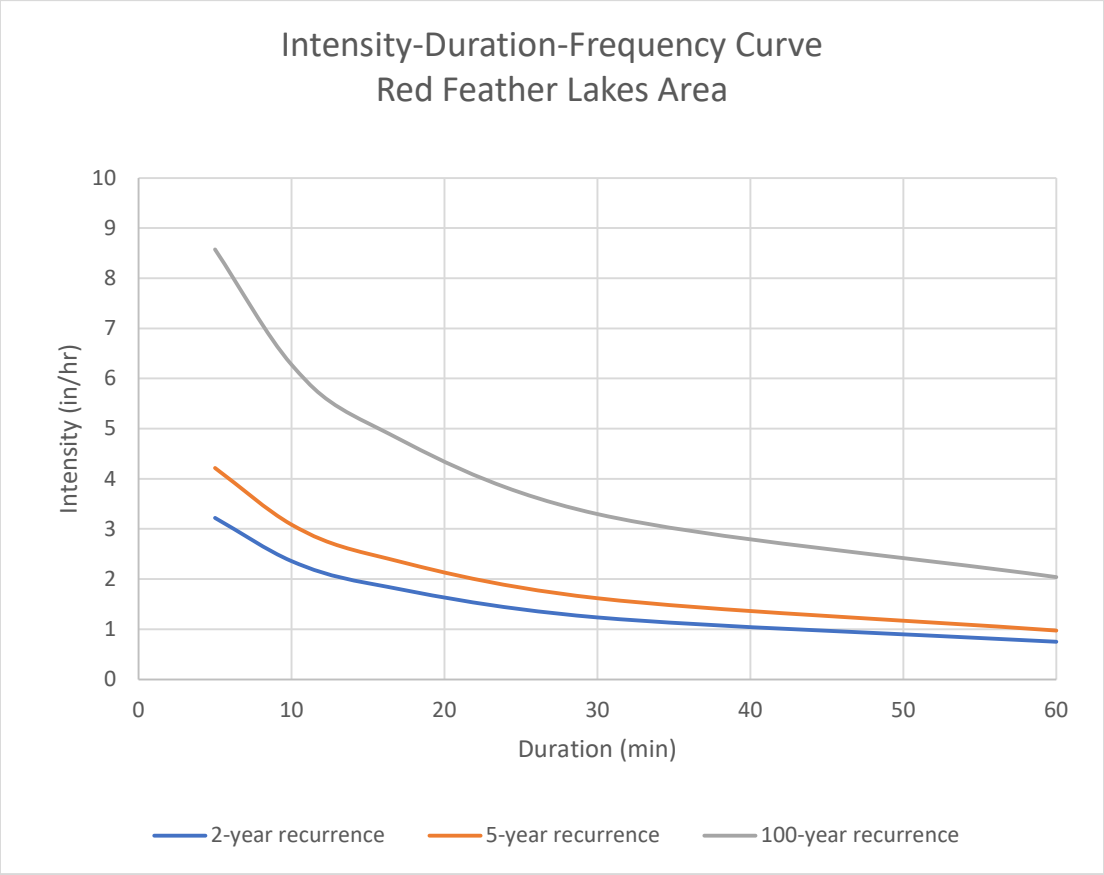

Figure 5-3. Intensity-duration-frequency curve generated from NOAA Atlas 14 data for a point outside Red Feather Lakes

5.6 Submittal Requirements

Drainage reports shall include the following information related to rainfall:

- Map showing NOAA Atlas 14 rainfall location,
- Summary table and/or figures of relevant precipitation values and return intervals, and
- Summary table and/or figures of design storms.

5.7 References

National Oceanic and Atmospheric Administration (NOAA), 2013. NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0.