Contra Costa County
Flood Control
& Water Conservation District

Rainfall Intensity-Duration-Frequency (IDF) Curves

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Document Version Notes

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Rainfall Intensity-Duration-Frequency (IDF) Curves

Draft

Basic Method

The Precipitation Duration-Frequency-Depth (DFD)[1] curves can be used to derive rainfall intensities for the Rational Method. The rainfall intensity can be determined using the following steps:

1. Determine the Mean Seasonal Precipitation from the District isohyet map. (Dwg. No. B-166).
2. Choose the design storm frequency and use the appropriate DFD chart.
3. Choose a time of concentration on the time axis (T in minutes).
4. Choose a curve that corresponds to the MSP for the site (interpolate if needed).
5. Find the corresponding precipitation depth (P in inches) on the vertical axis.
6. Calculate the rainfall intensity with the following equation including a conversion to intensity in inches per hour:

Rainfall Intensity (in/hr) = P ÷ T (min)*60min

Creating IDF Curves

For small calculation efforts, the above method is adequate. For many engineering efforts in land development, engineers use computer programs to design extensive drainage systems. These models require Intensity-Duration-Frequency (IDF) curves. The District receives numerous requests for IDF curves each year. In the past we have directed engineers to the above process.

You can follow the above procedure for several times of concentration to develop an IDF curve. A method presented below "simplifies" the process for calculations for times of concentration (TOC) less or equal to 60 minutes. Once this method is coded into a spreadsheet, the creation of other IDF curves would be automated and less time consuming.

The DFD curves are almost linear between 5 and 60 minutes on the log-log plots of the DFD curves. If we add a break at the 20 minute point, we get two line segments that closely match the curves.

[1]The DFD curves can be found at http://www.co.contra-costa.ca.us/index.aspx?NID=530.

Using these lines and some regression equations we can calculate an IDF curve as close as we could expect if we too them off the DFD curves by hand.

Creating IDF Curves

Basic log-log regression equations, similar to the linear regression equation, can be used to perform a linear interpolation of precipitation values. Below are some basic equations.

Linear regression equations:

$$y = a \cdot x + b$$

Where: a = slope
b = the y intercept
x = independent variable
y = dependant variable

For a linear regression on a log-log plot between Time1 (T_1) and Time2 (T_2) the following regression equation applies:

$$P = 10^{(a \cdot \log(T) + \log(b))}$$ and

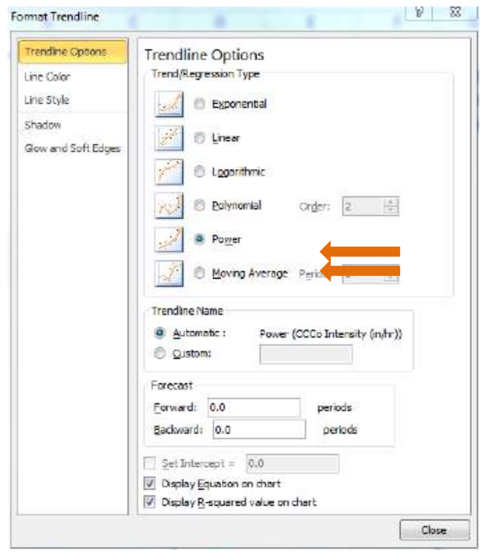
$$I = P \div T \cdot 60$$

Where: P = Precipitation (inches) for time T
I = Intensity (inches/hour) for time T
T = time (minutes)
a = slope on log plot = Delta log (D)/Delta log (T)
Where :
Delta log (T) = log (T2)-log (T1)
Delta log (D) = log (D2)-log (D1)
log (b) = intercept = log (y intercept) = log (D2)-log (T2) · a
also set:
Di = rainfall depth for Ti
i = time interval number

The depths can be found on the DFD curves using T_1 = 5min and T_2 = 20min. The values of "a" and "b" can be calculated using the above equations. A similar exercise can be done for T_1 = 20min and T_2 = 60min. Once this is done, the equation we will have two equations relating time to precipitation for the specific MSP. Then, I = P/T*60 can be used to determine the rainfall intensity "I" for any time of concentration "T" between 5 and 60 minutes. If the equations are established in a spreadsheet, then a full range of intensities can be calculated for a given project location, and an IDF curve can created between 5 and

60 minutes. Again, once this method is coded into a spreadsheet, creating other IDF curves can automated.

Power equation



The use of the log-log regression equations creates a smooth IDF curve that can be created and plotted in Excel. Excel has a plotting feature that allows you add a trend line to any data with the trend line option of using the power regression type as well as displaying the equation and R-squared value on the chart.

Some storm drain design programs allow the user to input parameters for an equation and have the program calculate the intensity values internally. The power regression equation (power equation) is one of these methods.

$$\mathbf{y = a \cdot x^{b}}$$

If the IDF points created using the log-log regression equations are plotted in Excel and a trend line is added using the Power option, the R-squared (R^2) value is, or very close to 1.0, meaning the curve is a “perfect” fit to the data. If this is so, then one equation can be used for the IDF curve. If the storm drain software uses a power equation, then the storm drain design software can be tailored for Contra Costa County and simplify the calculations.

To obtain the coefficients **a** and **b** for the Power equation, one can plot the IDF curve in Excel, add a trend line with the Power regression option and display the equation and the R^2 value. Optionally one can use regression functions in Excel. To do this, calculate the natural log (Ln) of the Time and Intensity values obtained in the above procedure. Then using the following Excel equations to determine the a and b coefficients

a = EXP(INTERCEPT(known_y's, known_x's))

b =SLOPE(known_y's, known_x's)

where: know_y’s and known_x’s are single column ranges in Excel. (e.g. D10:D65)

APPENDIX B contains an example of the use of these equations on the data in APPENDIX A .

Benefits of following this procedure

The benefits of following this procedure are:

1. With the equations developed for the site, any time of concentration may be used.
2. You only need to read three numbers for depth off of the DFD curves.
3. Using these equations, engineers should be able to create spreadsheets of their own to create the IDF curves they need.
4. Spreadsheets are compatible with most storm drain modeling programs used today which allow the user to copy and paste columns of numbers.
5. Some engineers have created spreadsheets for Rational Method calculations. The use of spreadsheets for creating IDF curves would be compatible with those personalized calculation tools.
6. The District has IDF curves that were published in 1975. To use them, engineers would need to read the values from the charts. Human error is introduced when reading several intensities for large projects.

Using the DFD curves has several advantages.

1. It allows the District to publish and maintain just one set of standard curves; the DFD curves.
2. Most engineering companies doing business in Contra Costa County already have DFD curves and they are available on-line.

The curves can be used for the Rational Method and also for the District's UH method.

APPENDIX A Intensity-Duration-Frequency Curve Example

Example for creating a Rainfall Intensity-Duration-Frequency (IDF) Curve Table

Step 1. Determine the Mean Seasonal Precipitation depth for the site using drawing B-166:

For this Example P = 12.5 inches/year

Step 2. Determine the 5, 20, and 60 minute storm depths for the 10 year storm for the 12.5 inch/year isohyet.

Time	5 min	20 min	60 min
Depth	0.199 in	0.383 in	0.643 in

Step 3. Calculate the values of "a" and "log(b)"

Equations:
$\log(\text{Precipitation}) = \log(P) = \log(\text{Time}) \cdot a + \log(b)$
$\text{Precipitation} = P = 10^{(\log(\text{Time}) \cdot a + \log(b))}$
$\text{Rainfall Intensity} = P/\text{Time} \cdot 60$ (in/hr)

Step 4. The equations for the precipitation depth curve for this example are:

For T = 5 to 20 minutes: $P = 10^{(0.478*\log(T) + (-1.033))}$ (See **Table A-1**)

For T = 20 to 60 minutes: $P = 10^{(0.468*\log(T) + (-1.020))}$ (See **Table A-2)**

Step 5. Create the resulting IDF curve table for these equations:

(See **Table A-3** and **Figure A-1**)

Table A-1 Example IDF calculations for 5 to 20 minutes

5 to 20 minutes: - Assumes that curves are linear on the log-log scale.			
Delta log (Time)		0.602	log(20)-log(5)
Delta log (Depth)		0.288	log(Depth@20)-log(Depth@5) log(0.388 in)-log(0.200 in)
Slope on log-log	a	0.478	Delta log(Depth)/Delta log(Time) 0.0288/0.602
Intercept on log-log	log(b)	-1.033	log(Depth@20)-log(20)*a log(0.388 in)-log(20)*0.479

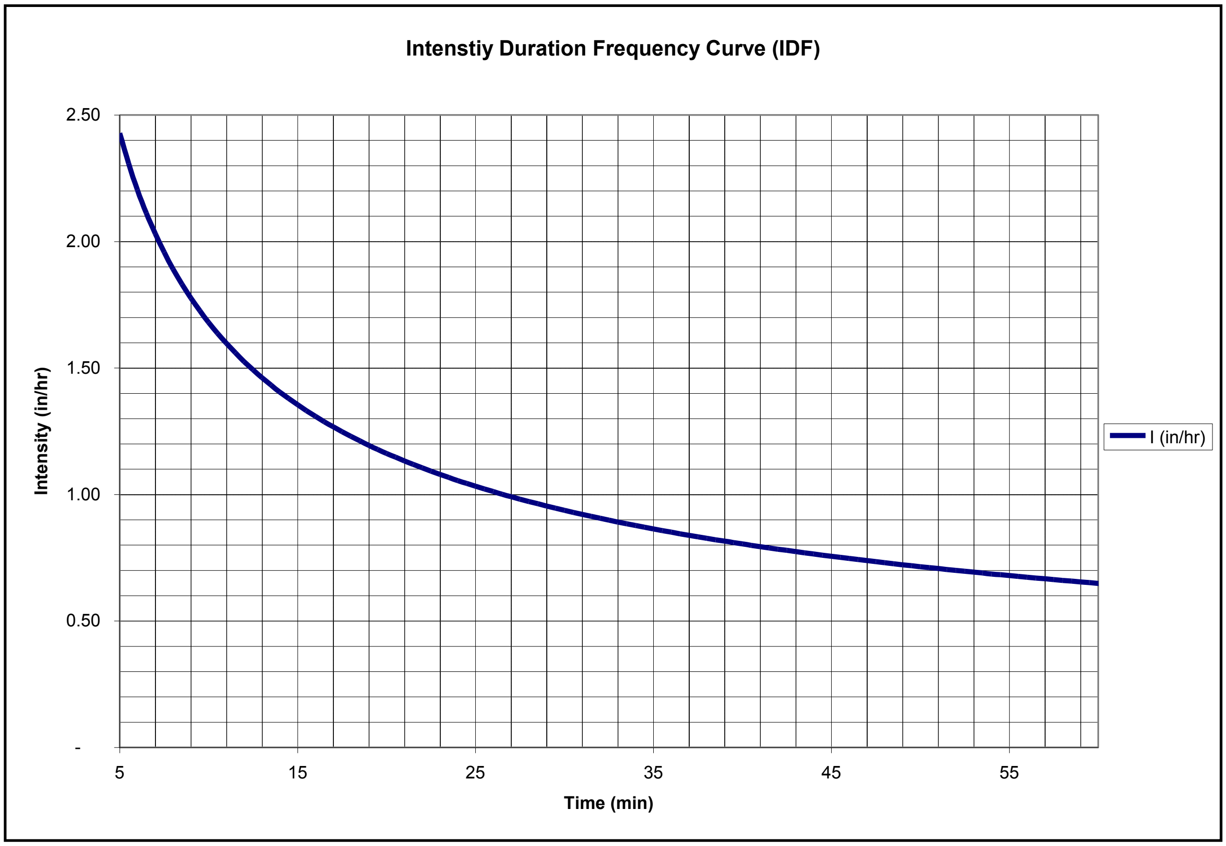
Table A-2 Example IDF calculations for 20 to 60 minutes

20 to 60 minutes: - Assumes that curves are linear on the log-log scale.			
Delta log (Time)		0.477	log(60)-log(20)
Delta log (Depth)		0.223	log(Depth@60)-log(Depth@20) log(0.649 in)-log(0.460 in)
Slope on log-log	a	0.468	Delta log(Depth)/Delta log(Time) 0.224 / 0.477
Intercept on log-log	log(b)	-1.020	log(Depth@60)-log(60)*a log(0.649 in)-log(60)*0.469

Table A-3 Example Intensity-Duration-Frequency (IDF) Curve Table

Time(min)	P(in)	I (in/hr)	Time(min)	P(in)	I (in/hr)	Time(min)	P(in)	I (in/hr)
5.0	0.20	2.39	30.0	0.46	0.93	55.0	0.62	0.67
5.5	0.21	2.27	30.5	0.47	0.92	55.5	0.62	0.67
6.0	0.22	2.17	31.0	0.47	0.91	56.0	0.62	0.67
6.5	0.23	2.08	31.5	0.47	0.90	56.5	0.62	0.66
7.0	0.23	2.00	32.0	0.48	0.90	57.0	0.63	0.66
7.5	0.24	1.93	32.5	0.48	0.89	57.5	0.63	0.66
8.0	0.25	1.86	33.0	0.48	0.88	58.0	0.63	0.65
8.5	0.26	1.80	33.5	0.49	0.87	58.5	0.63	0.65
9.0	0.26	1.75	34.0	0.49	0.87	59.0	0.64	0.65
9.5	0.27	1.70	34.5	0.49	0.86	59.5	0.64	0.65
10.0	0.28	1.66	35.0	0.50	0.85	60.0	0.64	0.64
10.5	0.28	1.61	35.5	0.50	0.85	EQUATIONS ARE NOT GOOD ABOVE 60 MINUTES		
11.0	0.29	1.57	36.0	0.50	0.84			
11.5	0.29	1.54	36.5	0.51	0.84			
12.0	0.30	1.50	37.0	0.51	0.83			
12.5	0.31	1.47	37.5	0.51	0.82			
13.0	0.31	1.44	38.0	0.52	0.82			
13.5	0.32	1.41	38.5	0.52	0.81			
14.0	0.32	1.39	39.0	0.52	0.81			
14.5	0.33	1.36	39.5	0.53	0.80			
15.0	0.33	1.34	40.0	0.53	0.80			
15.5	0.34	1.31	40.5	0.53	0.79			
16.0	0.34	1.29	41.0	0.54	0.79			
16.5	0.35	1.27	41.5	0.54	0.78			
17.0	0.35	1.25	42.0	0.54	0.78			
17.5	0.36	1.23	42.5	0.55	0.77			
18.0	0.36	1.21	43.0	0.55	0.77			
18.5	0.37	1.20	43.5	0.55	0.76			
19.0	0.37	1.18	44.0	0.55	0.76			
19.5	0.38	1.16	44.5	0.56	0.75			
20.0	0.38	1.15	45.0	0.56	0.75			
20.5	0.39	1.13	45.5	0.56	0.74			
21.0	0.39	1.12	46.0	0.57	0.74			
21.5	0.40	1.10	46.5	0.57	0.74			
22.0	0.40	1.09	47.0	0.57	0.73			
22.5	0.40	1.08	47.5	0.58	0.73			
23.0	0.41	1.07	48.0	0.58	0.72			
23.5	0.41	1.05	48.5	0.58	0.72			
24.0	0.42	1.04	49.0	0.58	0.71			
24.5	0.42	1.03	49.5	0.59	0.71			
25.0	0.42	1.02	50.0	0.59	0.71			
25.5	0.43	1.01	50.5	0.59	0.70			
26.0	0.43	1.00	51.0	0.60	0.70			
26.5	0.44	0.99	51.5	0.60	0.70			
27.0	0.44	0.98	52.0	0.60	0.69			
27.5	0.44	0.97	52.5	0.60	0.69			
28.0	0.45	0.96	53.0	0.61	0.69			
28.5	0.45	0.95	53.5	0.61	0.68			
29.0	0.46	0.94	54.0	0.61	0.68			
29.5	0.46	0.93	54.5	0.61	0.68			
Note: The value of P and I were calculated using values of “a” and “log(b)” that were not rounded off.								

Figure A-1 Example IDF Curve



APPENDIX B Power Function Example

Calculated Power Equation Coefficients

For Log-Normal data		For:	$y = a \cdot x^b$
Intercept	1.72026	a =	5.585993559
Slope	-0.52824	b =	-0.5282385

Time	CCCo IDF Curve for MSP =12.5 in/yr	Ln(Time)	Ln(precip)
(min)	(in/hr)	-	-
0	0.00	-	-
5.0	2.39	1.609437912	0.870456196
5.5	2.27	1.704748092	0.820070055
6.0	2.17	1.791759469	0.774071113
6.5	2.08	1.871802177	0.731756188
7.0	2.00	1.945910149	0.692578687
7.5	1.93	2.014903021	0.656105306
8.0	1.86	2.079441542	0.621986736
8.5	1.80	2.140066163	0.589937267
9.0	1.75	2.197224577	0.559720223
9.5	1.70	2.251291799	0.531137352
10.0	1.66	2.302585093	0.504020929
10.5	1.61	2.351375257	0.478227797
11.0	1.57	2.397895273	0.453634789
11.5	1.54	2.442347035	0.430135172
12.0	1.50	2.48490665	0.407635847
12.5	1.47	2.525728644	0.386055122
13.0	1.44	2.564949357	0.365320922
13.5	1.41	2.602689685	0.345369334
14.0	1.39	2.63905733	0.326143421
14.5	1.36	2.674148649	0.307592242
15.0	1.34	2.708050201	0.28967004
15.5	1.31	2.740840024	0.272335557
16.0	1.29	2.772588722	0.25555147
16.5	1.27	2.803360381	0.239283899
17.0	1.25	2.833213344	0.223502001

17.5	1.23	2.862200881	0.208177613
18.0	1.21	2.890371758	0.193284957
18.5	1.20	2.917770732	0.17880037
19.0	1.18	2.944438979	0.164702086
19.5	1.16	2.970414466	0.150970032
20.0	1.15	2.995732274	0.137585663
20.5	1.13	3.020424886	0.124550057
21.0	1.12	3.044522438	0.111828594
21.5	1.10	3.068052935	0.099406486
22.0	1.09	3.091042453	0.08726997
22.5	1.08	3.113515309	0.075406208
23.0	1.07	3.135494216	0.063803209
23.5	1.05	3.157000421	0.052449757
24.0	1.04	3.17805383	0.041335342
24.5	1.03	3.198673118	0.030450107
25.0	1.02	3.218875825	0.019784791
25.5	1.01	3.238678452	0.009330683
26.0	1.00	3.258096538	-0.00092042
26.5	0.99	3.277144733	-0.010976252
27.0	0.98	3.295836866	-0.020844113
27.5	0.97	3.314186005	-0.030530902
28.0	0.96	3.33220451	-0.040043145
28.5	0.95	3.349904087	-0.049387021
29.0	0.94	3.36729583	-0.058568386
29.5	0.93	3.384390263	-0.067592797
30.0	0.93	3.401197382	-0.07646553
30.5	0.92	3.417726684	-0.0851916
31.0	0.91	3.433987204	-0.093775776
31.5	0.90	3.449987546	-0.1022226
32.0	0.90	3.465735903	-0.110536397
32.5	0.89	3.481240089	-0.118721292
33.0	0.88	3.496507561	-0.126781223
33.5	0.87	3.511545439	-0.134719947
34.0	0.87	3.526360525	-0.142541056
34.5	0.86	3.540959324	-0.150247984
35.0	0.85	3.555348061	-0.157844017
35.5	0.85	3.569532696	-0.165332302
36.0	0.84	3.583518938	-0.172715851
36.5	0.84	3.597312261	-0.179997556
37.0	0.83	3.610917913	-0.187180186
37.5	0.82	3.624340933	-0.194266403

38.0	0.82	3.63758616	-0.201258759
38.5	0.81	3.650658241	-0.20815971
39.0	0.81	3.663561646	-0.214971613
39.5	0.80	3.676300672	-0.221696739
40.0	0.80	3.688879454	-0.228337269
40.5	0.79	3.701301974	-0.234895306
41.0	0.79	3.713572067	-0.241372874
41.5	0.78	3.725693427	-0.247771925
42.0	0.78	3.737669618	-0.254094338
42.5	0.77	3.749504076	-0.260341928
43.0	0.77	3.761200116	-0.266516445
43.5	0.76	3.772760938	-0.272619579
44.0	0.76	3.784189634	-0.278652961
44.5	0.75	3.795489189	-0.284618168
45.0	0.75	3.80666249	-0.290516724
45.5	0.74	3.817712326	-0.2963501
46.0	0.74	3.828641396	-0.302119723
46.5	0.74	3.839452313	-0.307826969
47.0	0.73	3.850147602	-0.313473175
47.5	0.73	3.860729711	-0.319059632
48.0	0.72	3.871201011	-0.32458759
48.5	0.72	3.881563798	-0.330058263
49.0	0.71	3.891820298	-0.335472825
49.5	0.71	3.90197267	-0.340832416
50.0	0.71	3.912023005	-0.346138141
50.5	0.70	3.921973336	-0.351391072
51.0	0.70	3.931825633	-0.356592249
51.5	0.70	3.941581808	-0.361742682
52.0	0.69	3.951243719	-0.366843352
52.5	0.69	3.96081317	-0.37189521
53.0	0.69	3.970291914	-0.376899183
53.5	0.68	3.979681654	-0.38185617
54.0	0.68	3.988984047	-0.386767045
54.5	0.68	3.998200702	-0.391632657
55.0	0.67	4.007333185	-0.396453834
55.5	0.67	4.016383021	-0.40123138
56.0	0.67	4.025351691	-0.405966077
56.5	0.66	4.034240638	-0.410658687
57.0	0.66	4.043051268	-0.415309952
57.5	0.66	4.051784948	-0.419920595
58.0	0.65	4.060443011	-0.424491318

58.5	0.65	4.069026754	-0.429022807
59.0	0.65	4.077537444	-0.433515729
59.5	0.65	4.085976313	-0.437970736
60.0	0.64	4.094344562	-0.442388462

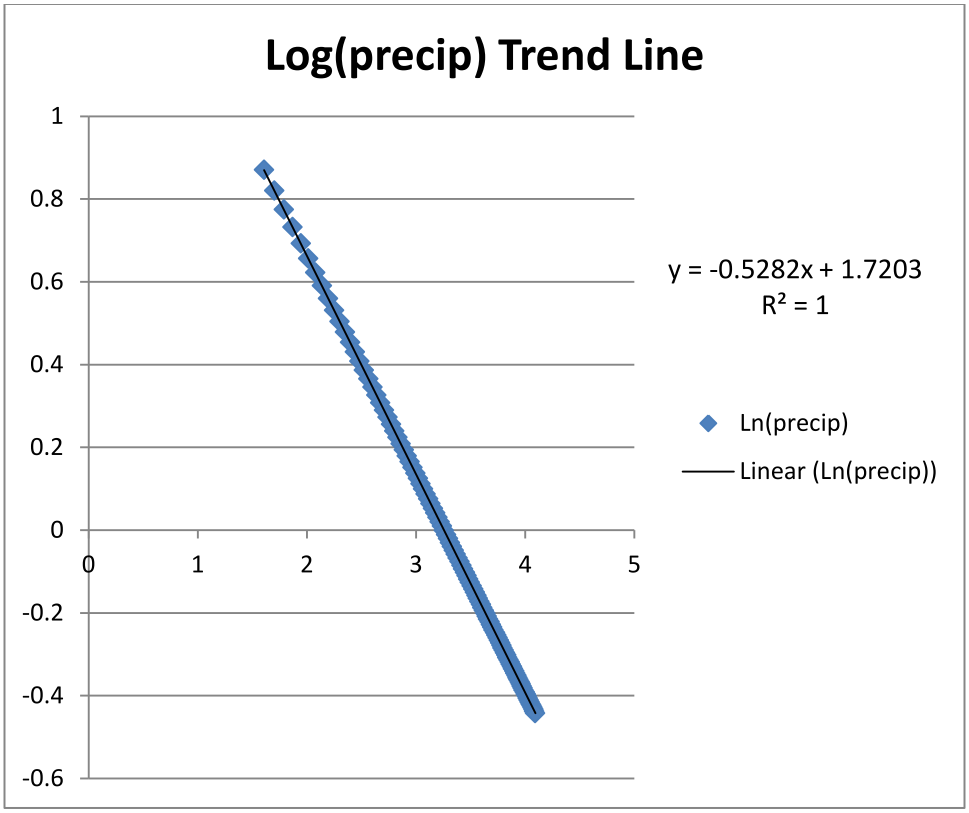


Figure B-1 Areal Rainfall Reduction Factor Standard