EVALUATION OF THE EFFECTS OF THE NEW NRCS-NOAA ATLAS 14 RAINFALL REGIONS AND RAINFALL DISTRIBUTION CURVES

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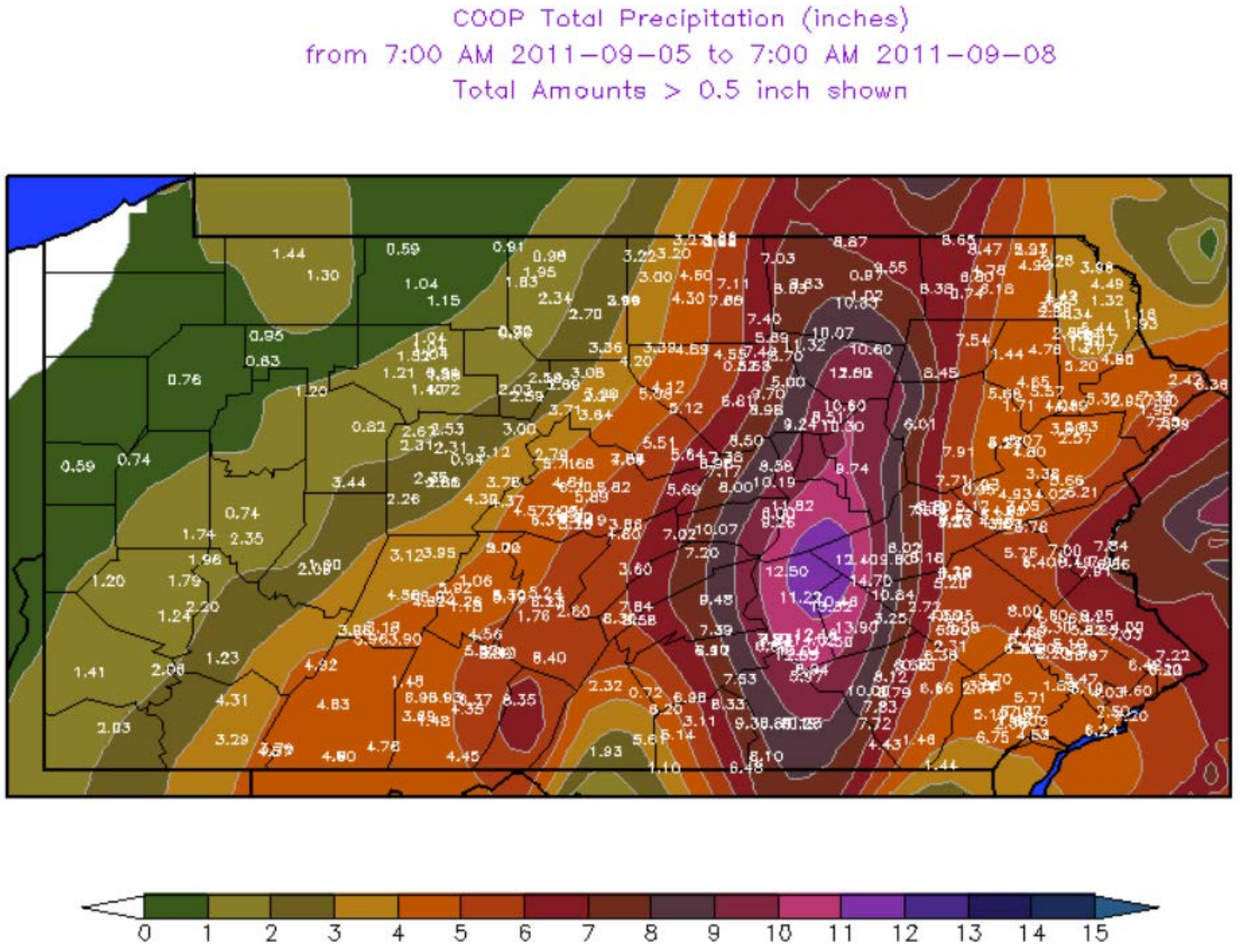
Newell Tereska & Mackay
ENGINEERING

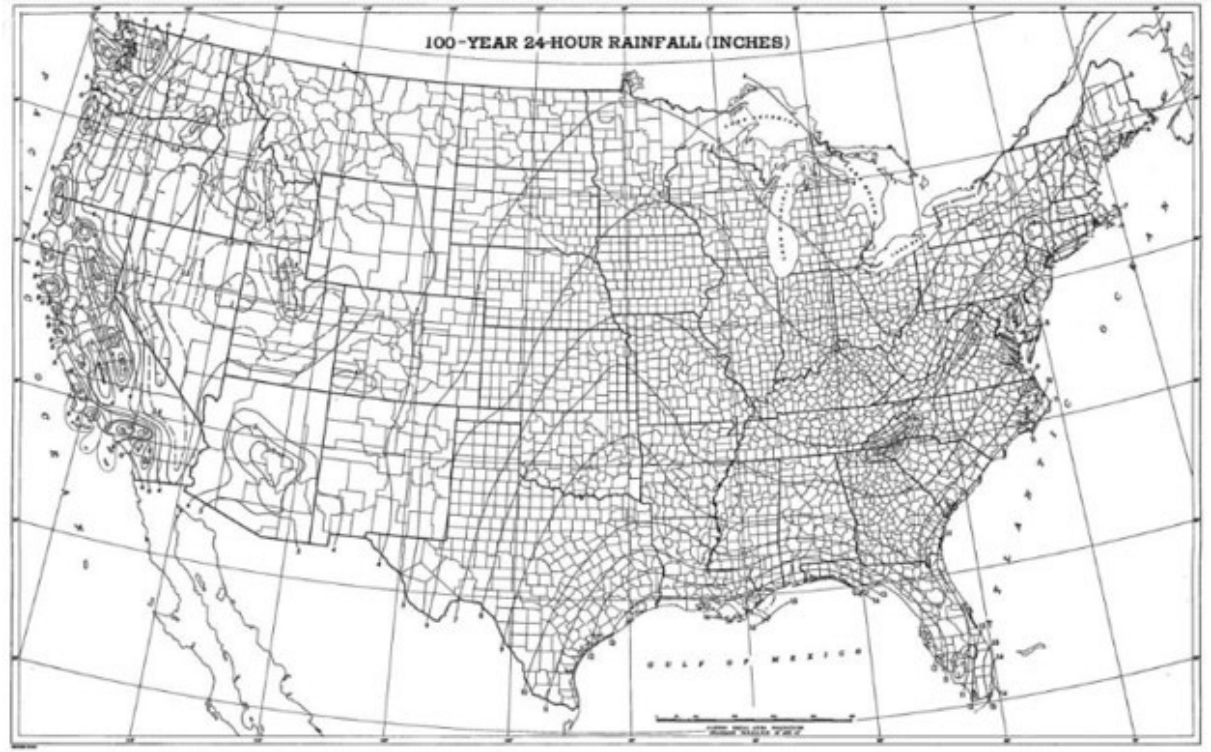
AGENDA

- NRCS (NWS) Rainfall History
- NOAA Atlas 14 Data
- PennDOT IDF Curves
- New NRCS NOAA Atlas 14 Regions and Distribution Curves
- Type II versus New Distribution Results and Impact on:
  - Channels & Culverts
  - Stormwater Control Measures
  - Bridges



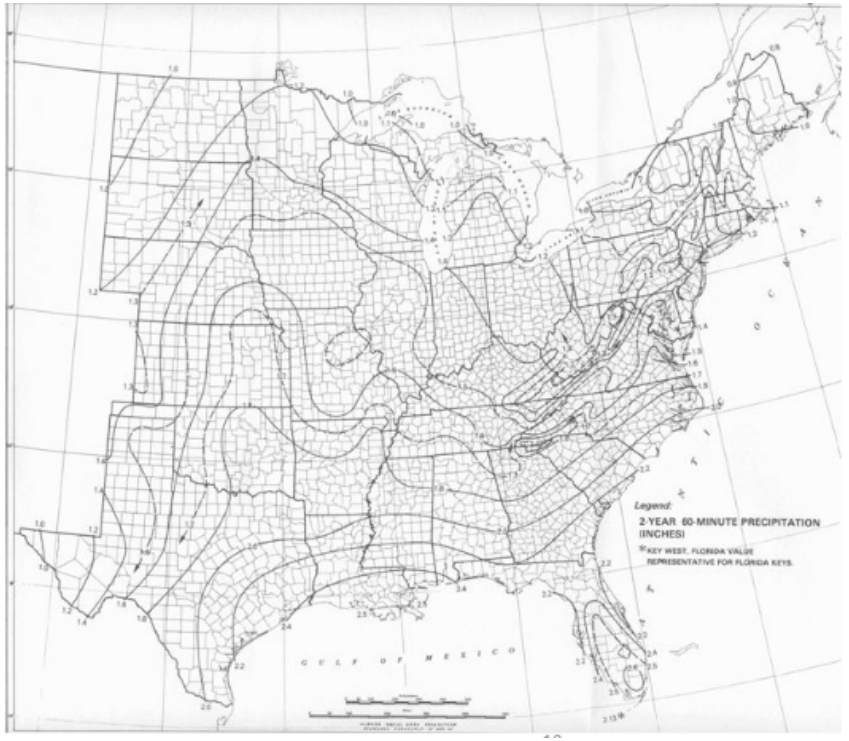
HISTORY

- U.S. Weather Bureau Technical Paper 40 (TP-40)
- Title: “Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years”
  - Initial publication 1961 (Hershfield, D.M.)
  - Data through year 1958
  - Rainfall durations 30 minutes to 24 hours
  - Rainfall Frequency 1-year to 100-year events
  - Universally used and widely accepted
  - Developed using much fewer rain stations than what exists today



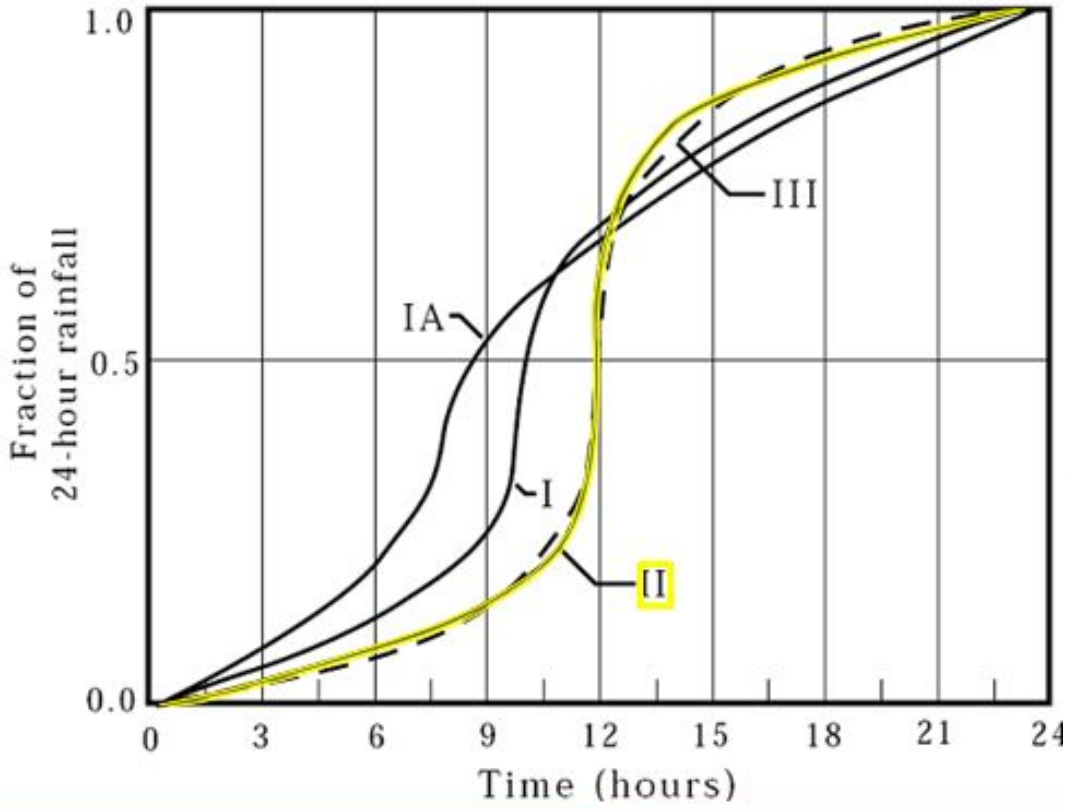
HISTORY

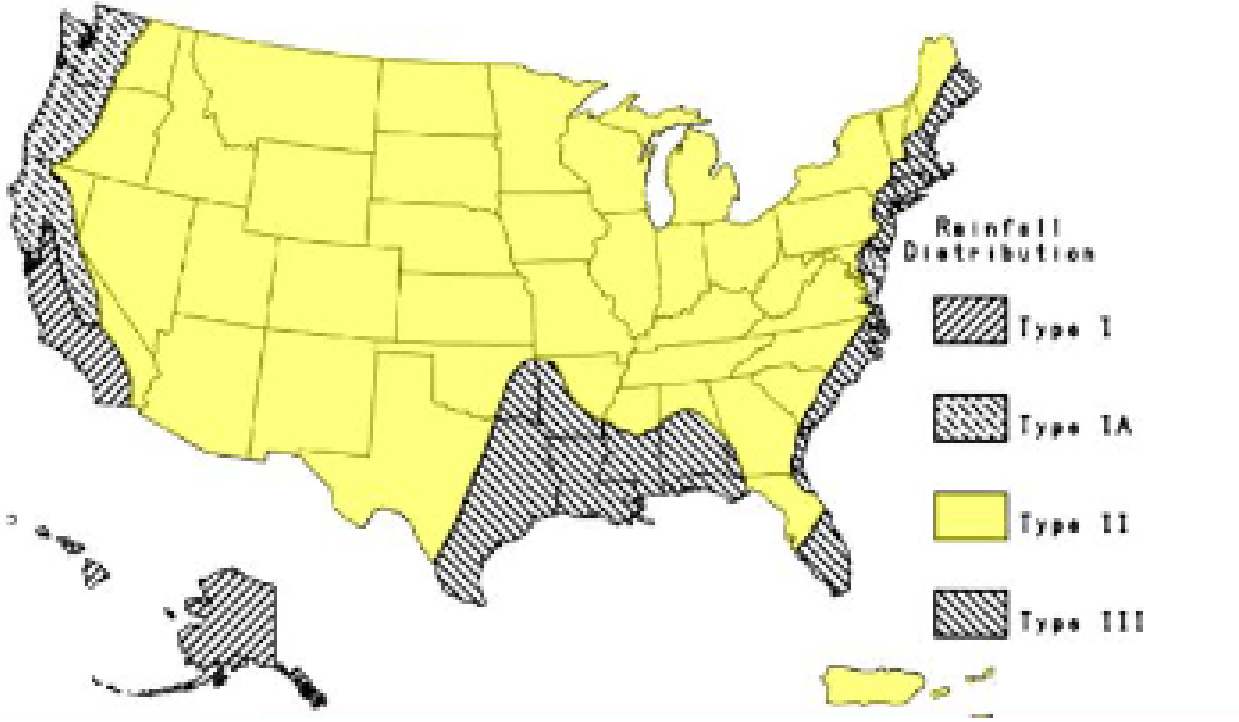
- NWS Hydro-35
- Five- to 60-minute precipitation frequency for the Eastern and Central United States
  - Initial publication 1977 (Frederick, R.H., V.A. Myers, E.P. Auciello)
  - Rainfall durations 5, 15, and 60 minutes
  - Rainfall Frequency 2- and 100-year events
  - Equations provided to provide 10- and 30-minute values
  - Universally used and widely accepted
  - Developed using much fewer rain stations than what exists today



SCS (NRCS) RAINFALL DISTRIBUTIONS DEVELOPED FROM NWS DATA

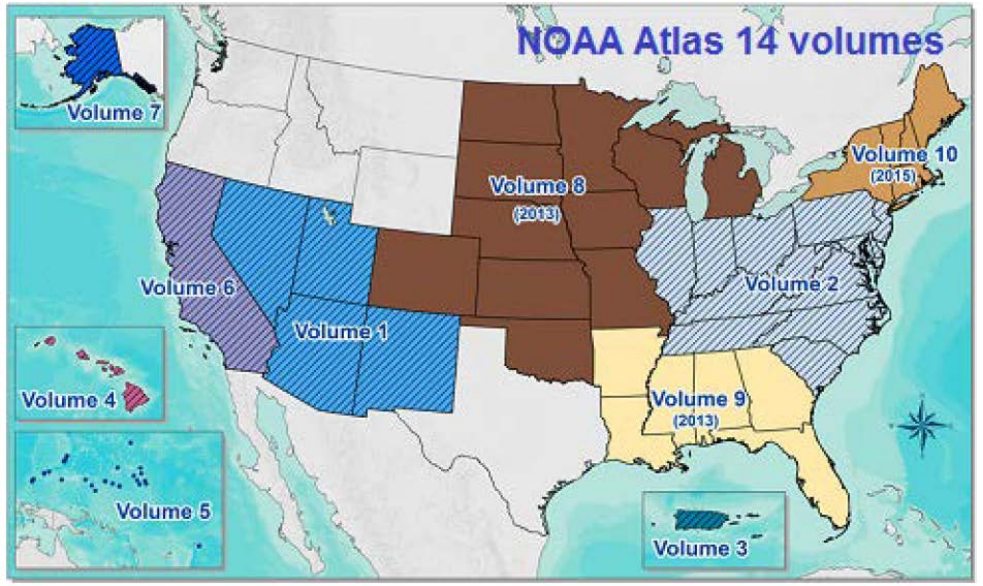
- Regions I, IA, II, and III
- One region for PA - Region II (Type II storm)





U.S. NOAA NWS ATLAS 14, VOL 2, VERSION 3

- Initial publication 2004, revised 2006
- Rainfall durations 5 minutes to 60 days
- Rainfall frequency 1-year to 1000-year events
- PDF publication and web application

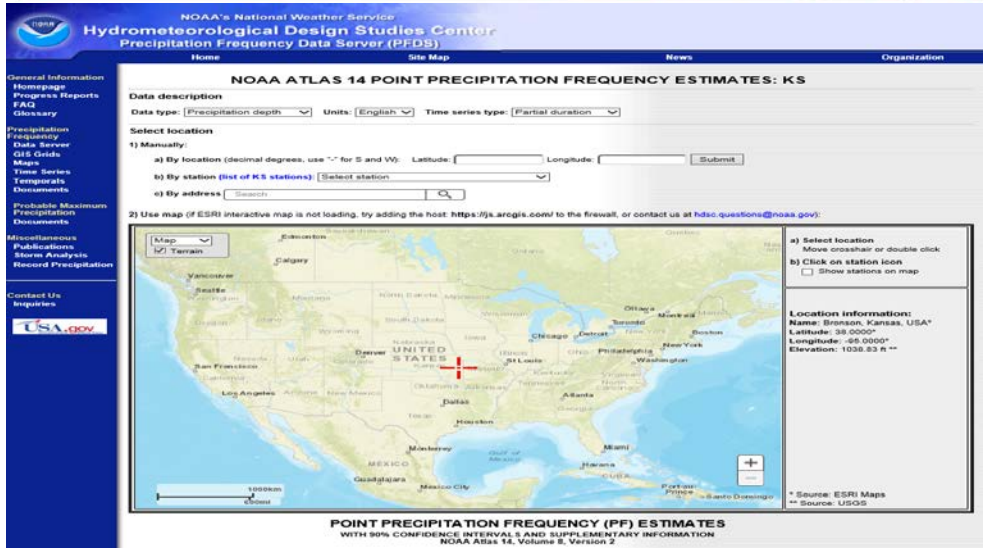


NOAA Atlas 14

Precipitation-Frequency Atlas of the United States

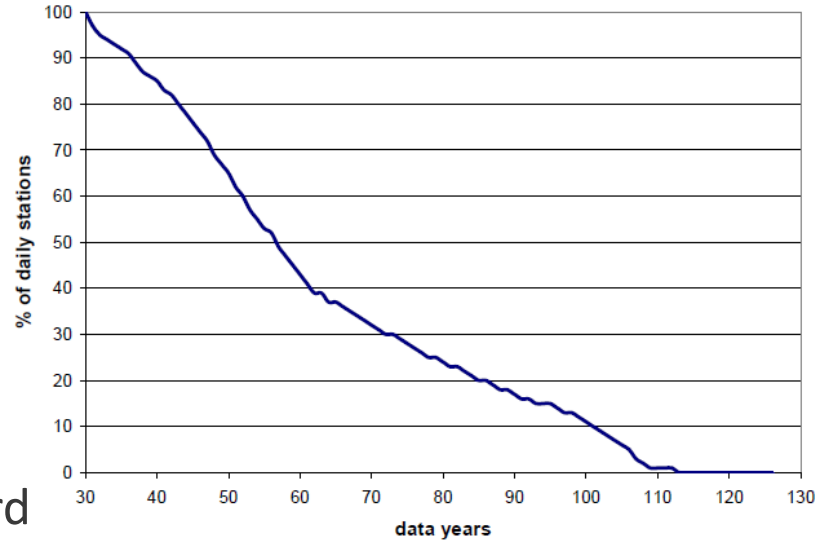
Volume 2 Version 3.0: Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia

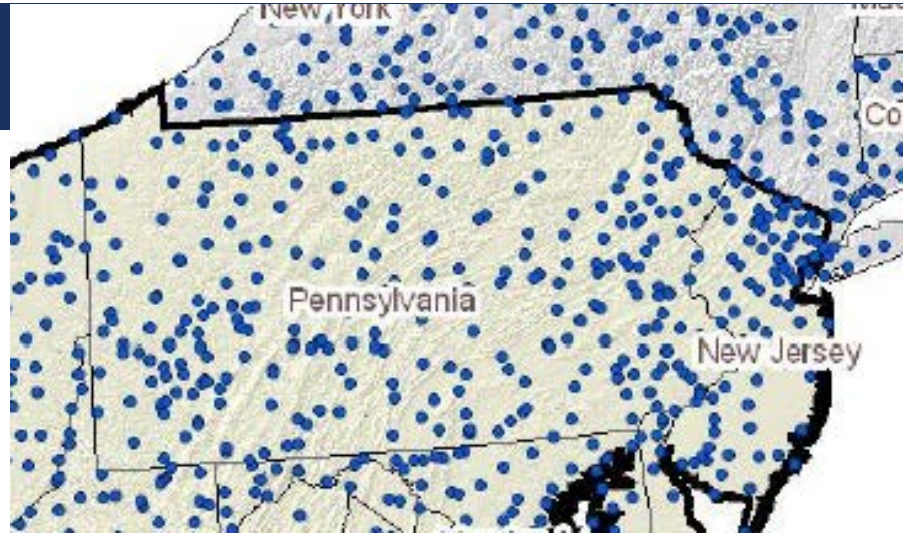
Geoffrey M. Bonnin, Deborah Martin, Bingzhang Lin, Tye Parzybok, Michael Yekta, David Riley



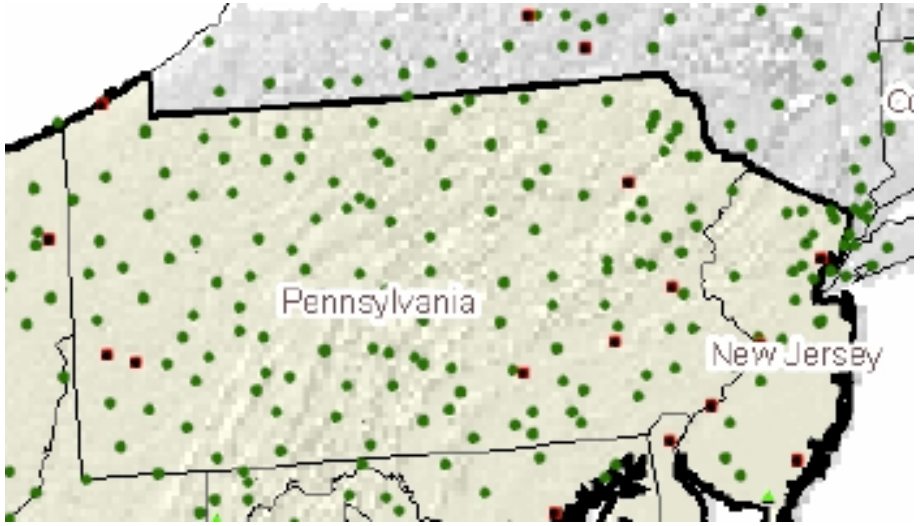
U.S. NOAA NWS ATLAS 14, VOL 2, VERSION 3

- For Pennsylvania:
  - Data through year 2000
  - 278 daily gages
  - 139 hourly gages
  - 8 N minute gages (most likely 15 min.)
  - Plus surrounding states
  - 30 to 126 years of record
  - GIS ArcInfo grid processing





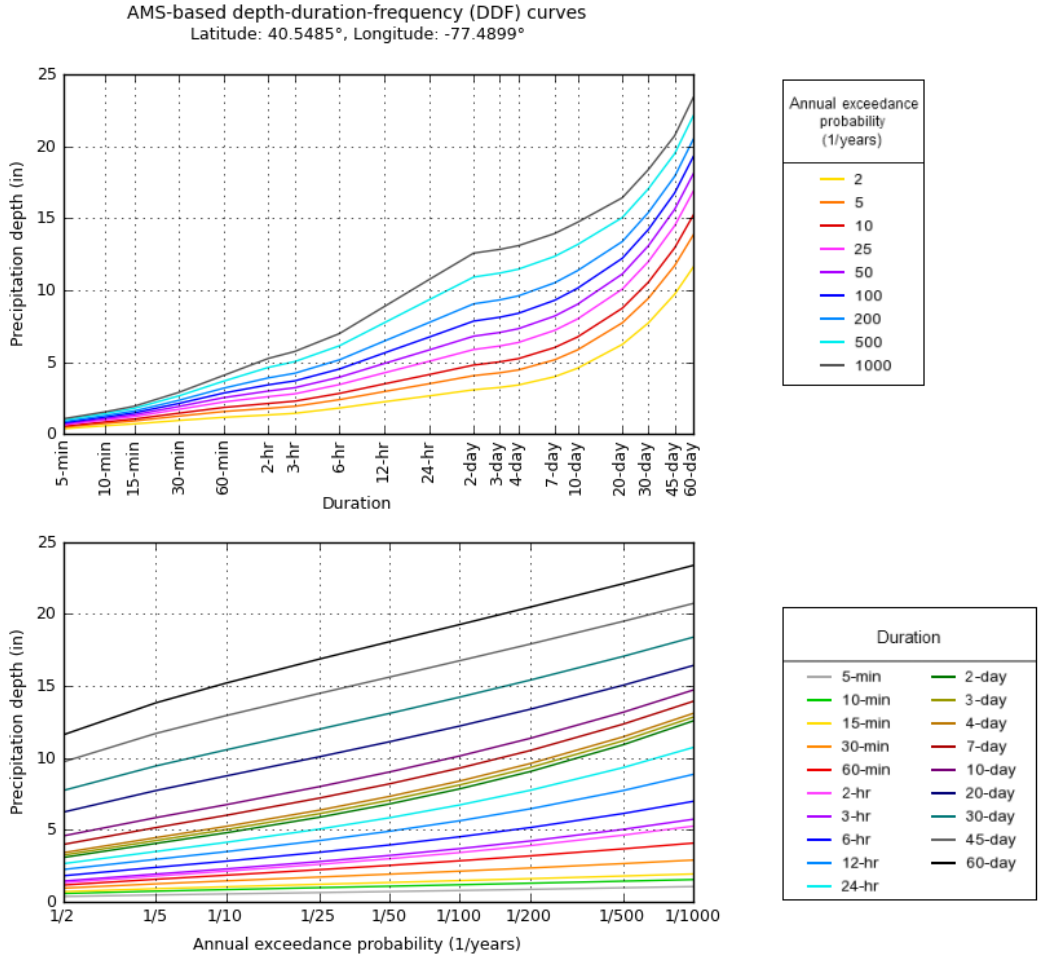
Daily Stations



Hourly & N Minute Stations

U.S. NOAA NWS ATLAS 14, VOL 2, VERSION 3

- Tabular, graphical, and GIS grid cell data available



PF tabular | PF graphical | Supplementary information | Print page

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

Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
5-min	0.370 (0.328-0.419)	0.477 (0.421-0.538)	0.549 (0.484-0.619)	0.642 (0.564-0.724)	0.714 (0.623-0.803)	0.786 (0.684-0.884)	0.864 (0.746-0.969)	0.975 (0.831-1.09)	1.06 (0.898-1.19)
10-min	0.579 (0.513-0.656)	0.741 (0.655-0.838)	0.848 (0.748-0.958)	0.984 (0.865-1.11)	1.08 (0.946-1.22)	1.19 (1.03-1.33)	1.29 (1.12-1.45)	1.43 (1.22-1.61)	1.55 (1.31-1.73)
15-min	0.708 (0.627-0.802)	0.911 (0.805-1.03)	1.04 (0.921-1.18)	1.22 (1.07-1.37)	1.34 (1.17-1.51)	1.47 (1.28-1.66)	1.61 (1.39-1.80)	1.79 (1.53-2.00)	1.93 (1.64-2.17)
30-min	0.949 (0.841-1.08)	1.25 (1.11-1.41)	1.45 (1.28-1.64)	1.72 (1.51-1.94)	1.92 (1.68-2.16)	2.13 (1.85-2.39)	2.35 (2.03-2.63)	2.66 (2.27-2.97)	2.90 (2.46-3.25)

Duration	1/10	1/25	1/50
6-hr	**2.82** (2.52-3.18)	**3.44** (3.05-3.85)	**3.95** (3.47-4.41)
12-hr	**3.48** (3.11-3.87)	**4.25** (3.77-4.71)	**4.90** (4.31-5.42)
24-hr	**4.13** (3.80-4.49)	**5.05** (4.61-5.47)	**5.84** (5.30-6.31)

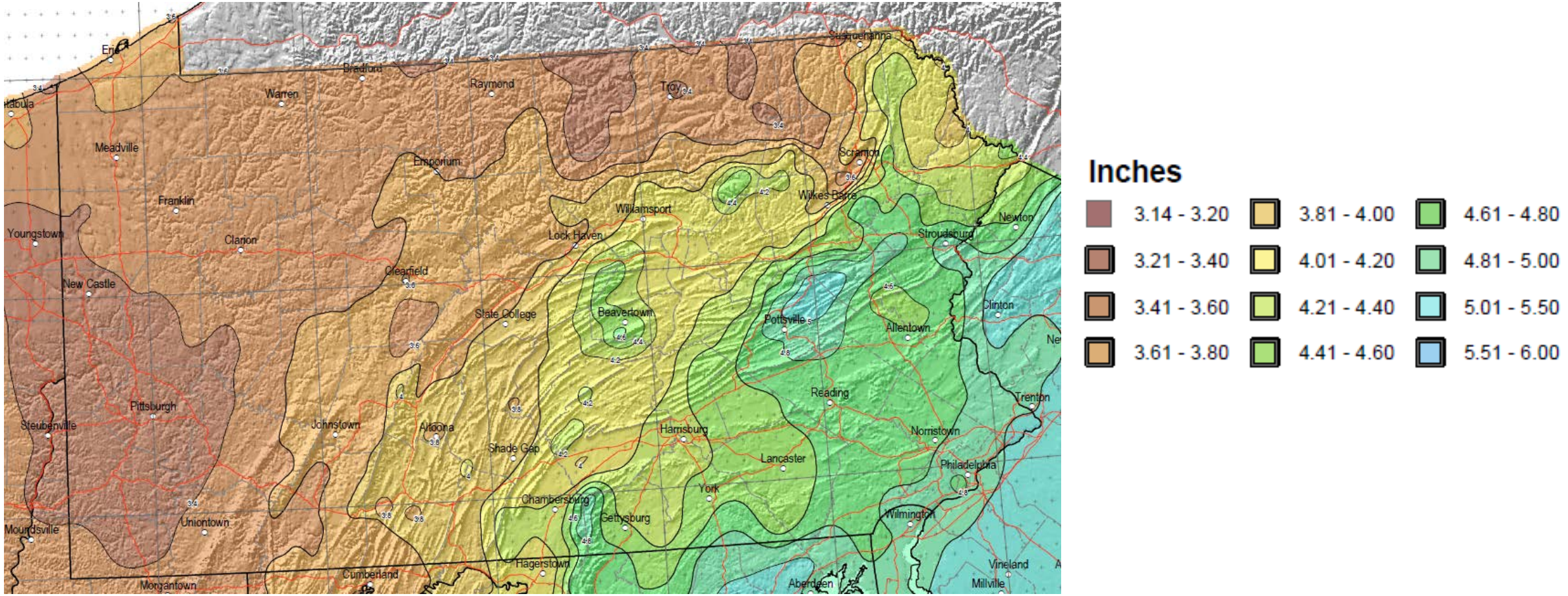
Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
7-day	3.98 (3.71-4.31)	5.16 (4.80-5.57)	6.01 (5.58-6.48)	7.20 (6.65-7.77)	8.20 (7.52-8.82)	9.29 (8.48-9.99)	10.5 (9.52-11.3)	12.3 (11.0-13.3)	13.9 (12.3-15.0)
10-day	4.58 (4.29-4.92)	5.85 (5.47-6.28)	6.75 (6.30-7.24)	8.00 (7.43-8.57)	9.02 (8.34-9.65)	10.1 (9.31-10.8)	11.4 (10.4-12.2)	13.2 (11.9-14.1)	14.7 (13.2-15.8)
20-day	6.23 (5.86-6.63)	7.73 (7.26-8.22)	8.75 (8.21-9.29)	10.1 (9.43-10.7)	11.1 (10.4-11.8)	12.2 (11.4-12.9)	13.4 (12.4-14.2)	15.0 (13.8-16.0)	16.4 (15.0-17.5)
30-day	7.73 (7.32-8.19)	9.44 (8.93-10.00)	10.6 (9.98-11.2)	12.0 (11.3-12.7)	13.1 (12.3-13.8)	14.2 (13.3-15.1)	15.4 (14.4-16.3)	17.1 (15.8-18.1)	18.4 (17.0-19.5)
45-day	9.72 (9.23-10.2)	11.7 (11.1-12.3)	12.9 (12.3-13.6)	14.5 (13.7-15.3)	15.6 (14.8-16.5)	16.8 (15.8-17.7)	17.9 (16.8-18.9)	19.5 (18.2-20.6)	20.7 (19.3-22.0)
60-day	11.6 (11.0-12.2)	13.8 (13.2-14.5)	15.2 (14.5-16.0)	16.9 (16.0-17.7)	18.1 (17.1-19.0)	19.3 (18.3-20.2)	20.5 (19.3-21.5)	22.1 (20.8-23.2)	23.4 (21.9-24.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of annual maxima series (AMS).
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 annual exceedance probability) 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: Precipitation frequency estimates | Submit

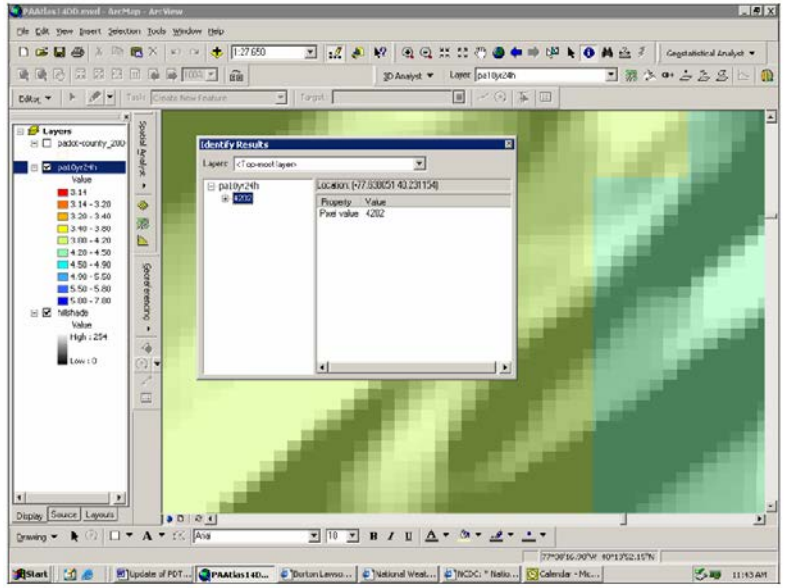
U.S. NOAA NWS ATLAS 14, VOL 2, VERSION 3

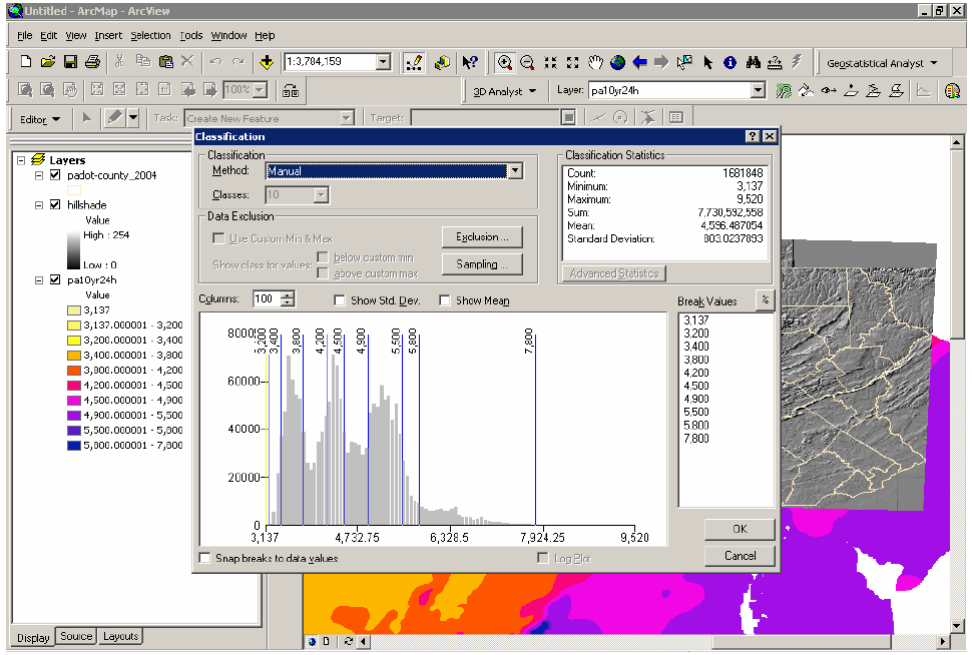
- ArcInfo Grid Cell data available
- 10-year, 24-hour event shown

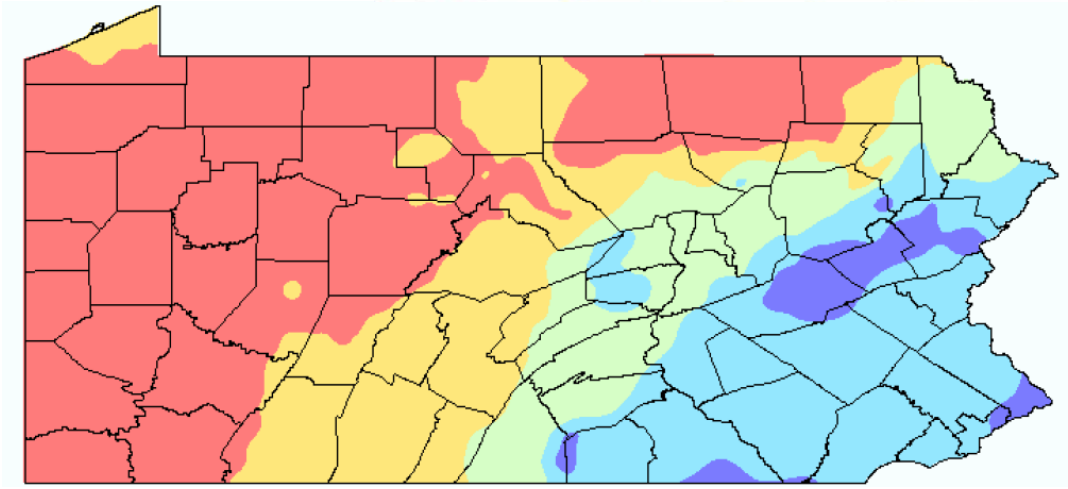


PENNDOT INTENSITY-DURATION-FREQUENCY (PDT-IDF) CURVES & DATA

- PennDOT Pub. 584, Appendix 7A (2009)
- Developed from NOAA Atlas 14 grid cell data
- All frequencies and durations downloaded
- Data classified to determine patterns







PENNDOT INTENSITY-DURATION-FREQUENCY (PDT-IDF) CURVES & DATA

- Data classified to also determine Rainfall Regions
- 6 distinct maps based on duration rainfall patterns
- 5 distinct regions determined
- IDF curves determined for each region

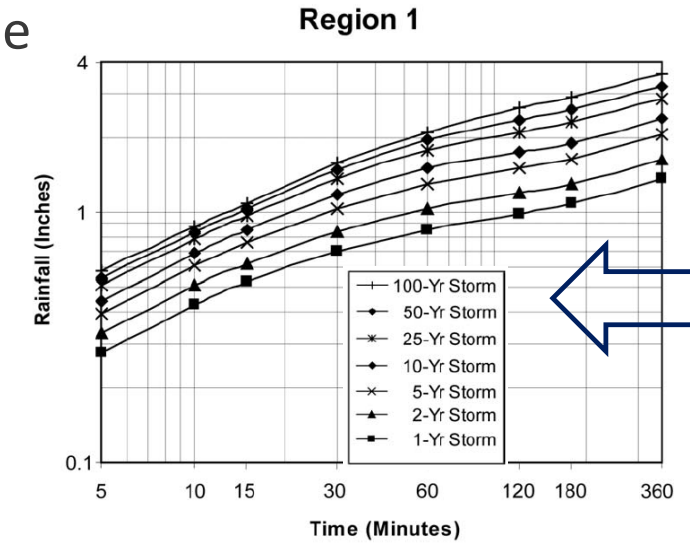
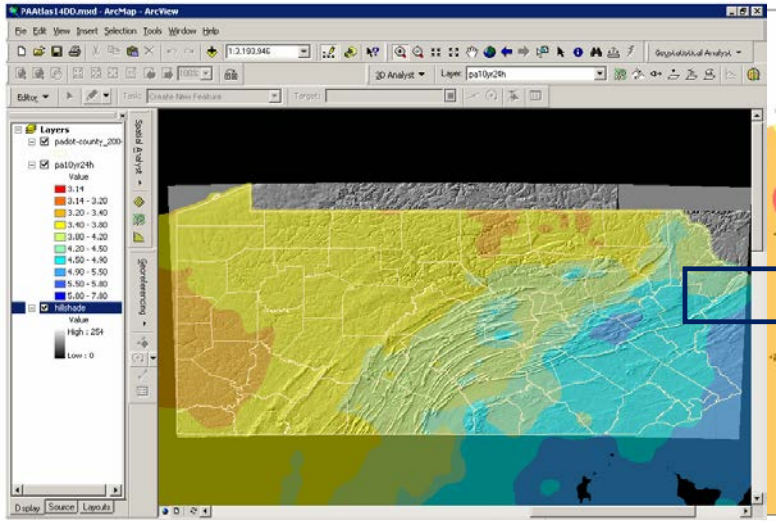
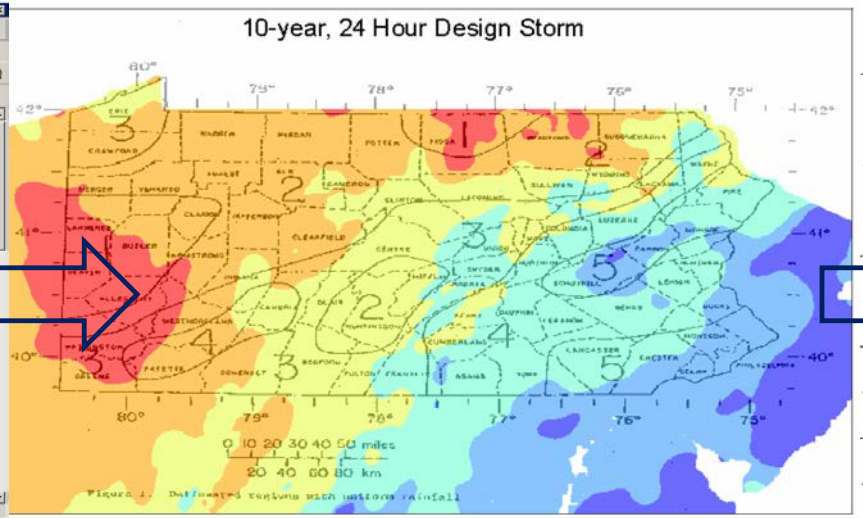
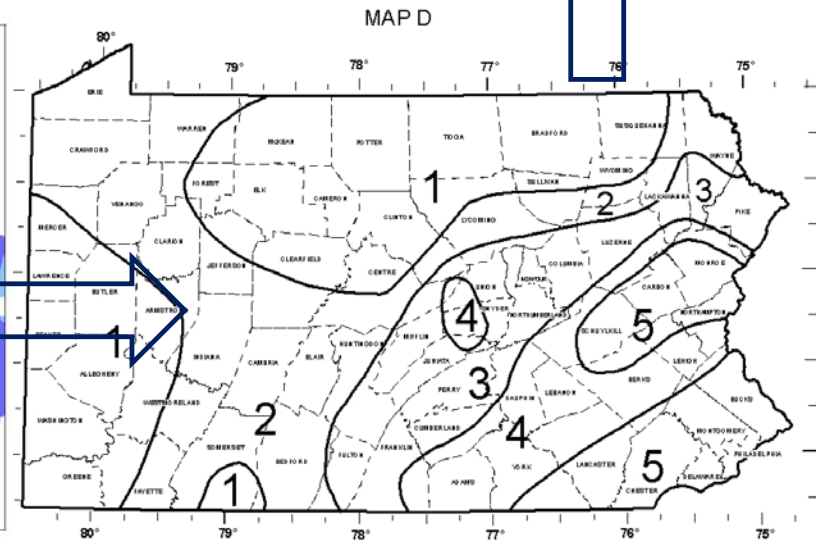


Table 7A.1 Appropriate Rainfall Region Map for each Storm Duration and Frequency

	Frequency							
Duration	1 year	2 year	5 year	10 year	25 year	50 year	100 year	500 year
5 min	C	C	C	C	B	B	B	-
10 min	C	C	C	C	C	C	C	-
15 min	A	A	A	A	C	C	C	-
30 min	A	A	A	A	A	C	C	-
60 min	A	A	A	A	A	C	C	-
2 hr	E	E	E	E	E	E	E	-
3 hr	E	E	E	E	E	E	E	-
6 hr	D	D	D	D	D	D	D	-
12 hr	F	F	F	F	F	F	F	-
24 hr	F	F	F	F	F	F	F	F

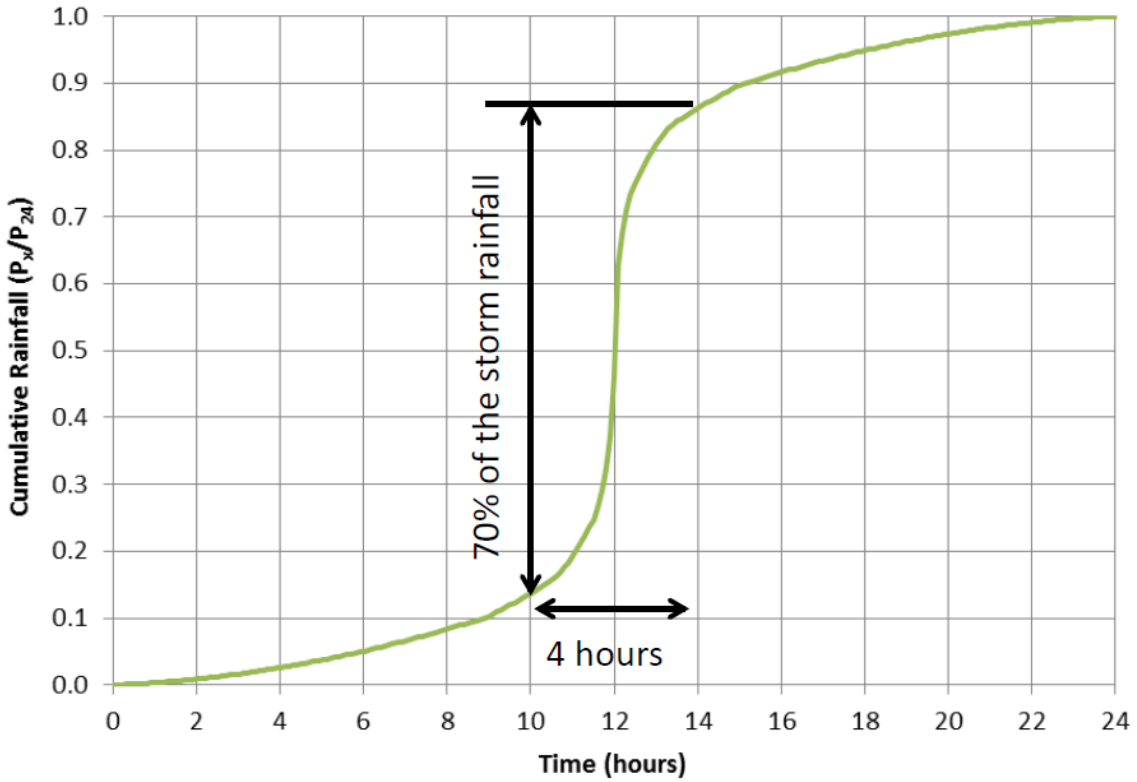






SYNTHETIC RAINFALL DISTRIBUTION DEFINED

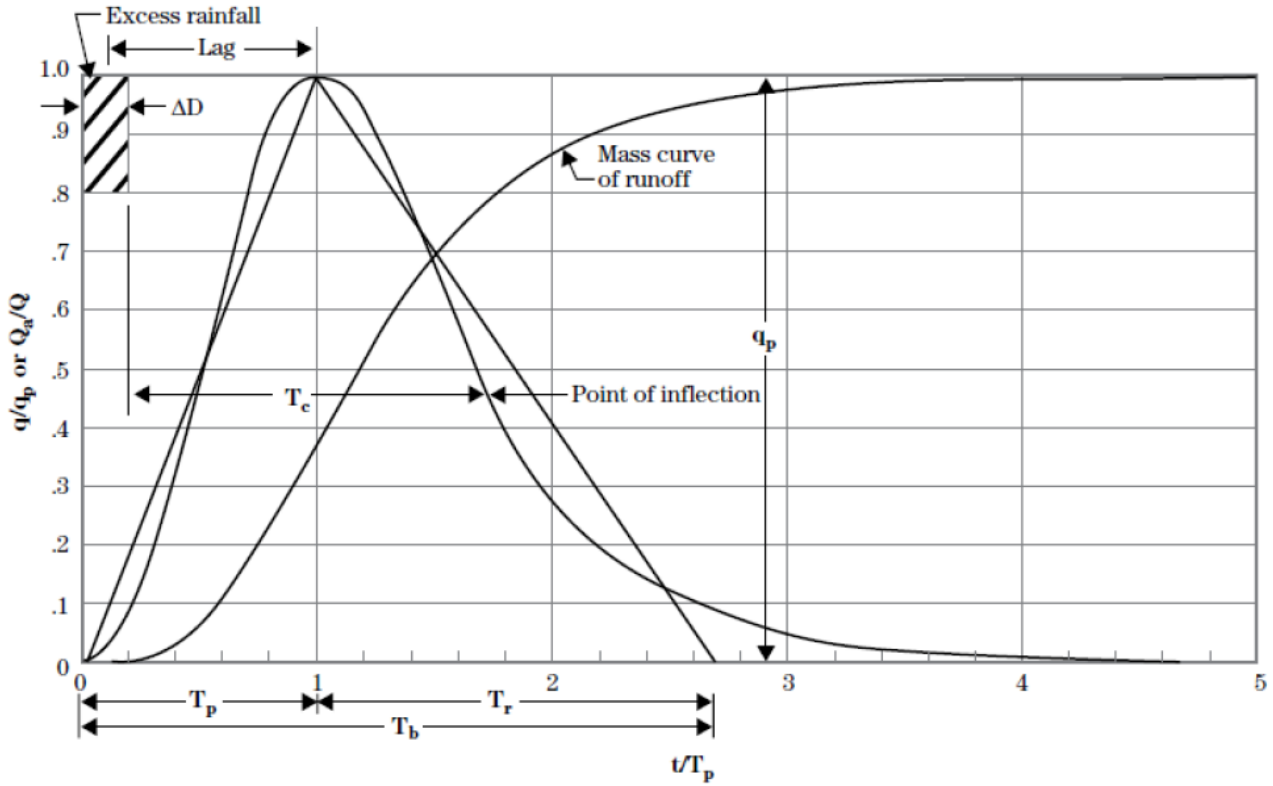
- Synthetic Rainfall Distribution
  - Synthetic arrangements of a total rainfall amount over time such that it includes maximum rainfall duration intensities for selected design frequency that is critical for producing peak runoff.



WHY RAINFALL DISTRIBUTIONS????

- Required to determine hydrographs, storm event peaks for storm system and infrastructure sizing
- Used by models (HEC-1, HEC-HMS, SWMM, TR-55, TR-20, EFH-2, HydroCAD, PondPack, etc.)

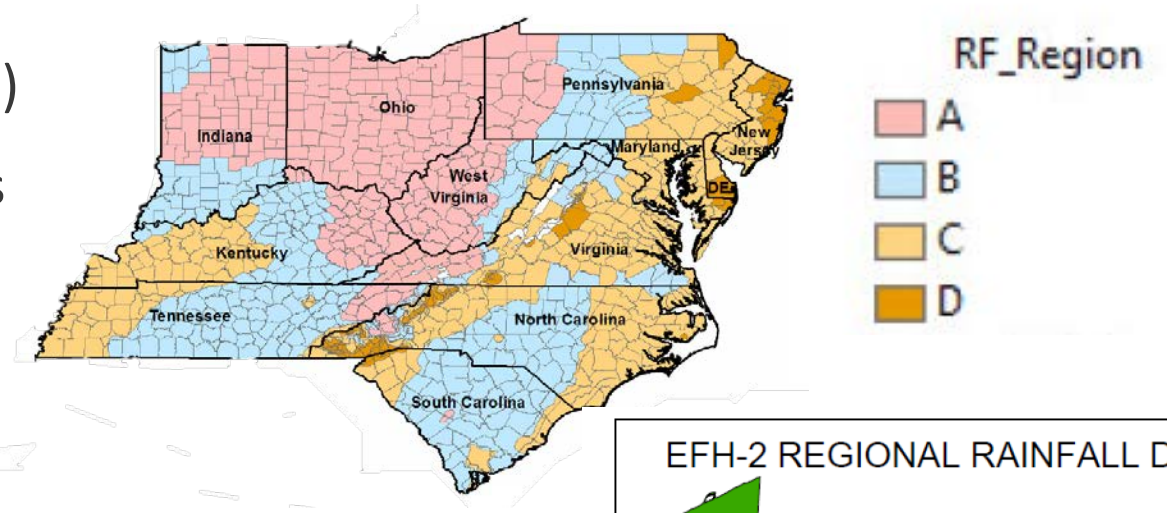
Figure 16A–1 Dimensionless curvilinear unit hydrograph and equivalent triangular hydrograph

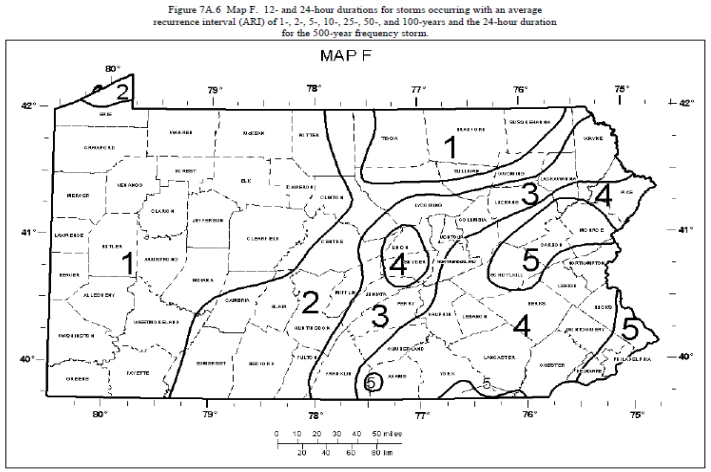


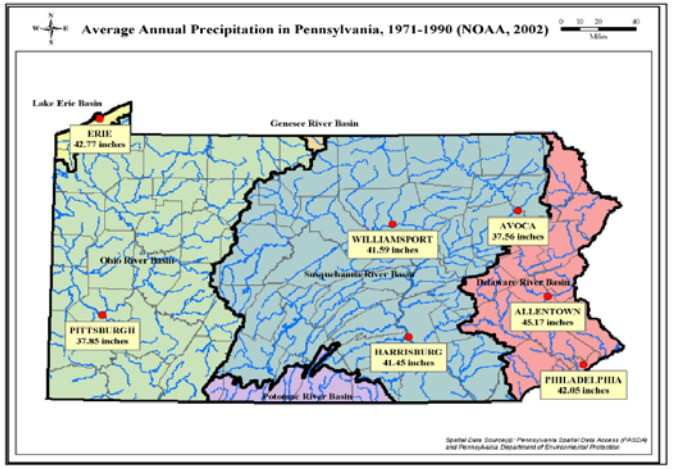
Tr = time from the peak to the end of the triangular hydrograph
Tp = time from the beginning of the triangular hydrograph to its peak
Tc = time of concentration
qp = peak discharge

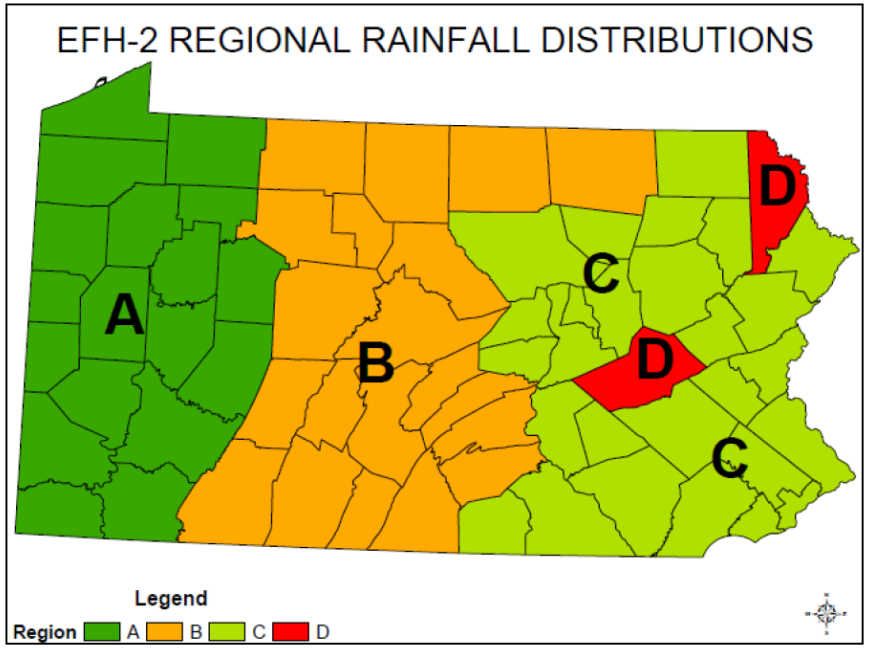
NRCS NOAA RAINFALL REGIONS & DISTRIBUTIONS FOR PA

- Four Rainfall Regions, and therefore, distributions (A,B,C,D)
- Roughly mimics PDT-IDF regions and major river basins (orographics, topography, and regions)
- Based on Counties



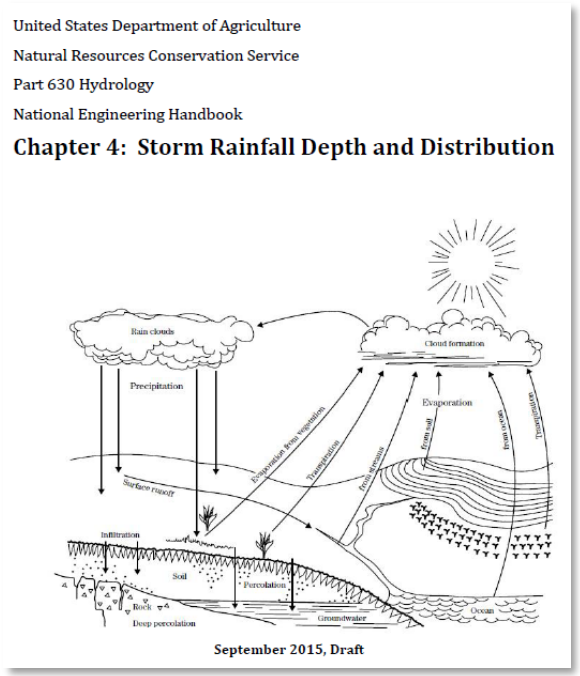




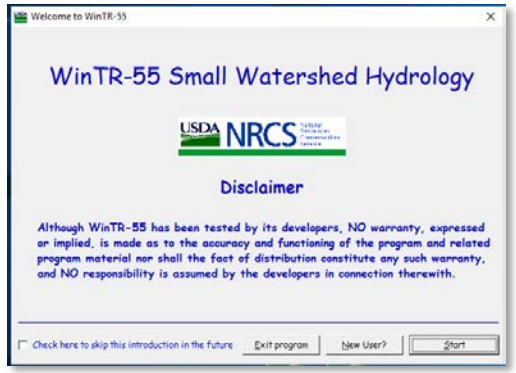


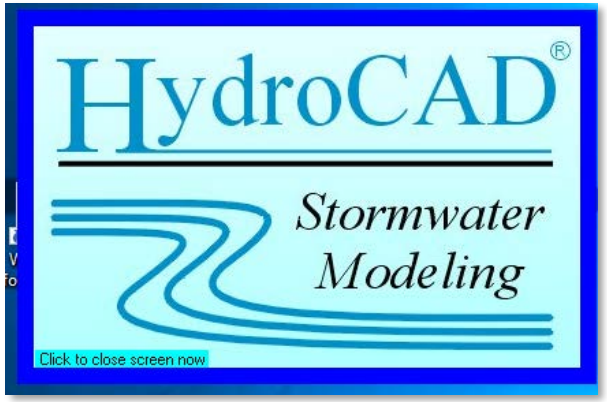
NRCS NOAA RAINFALL DISTRIBUTIONS – REFERENCES AND MODELS

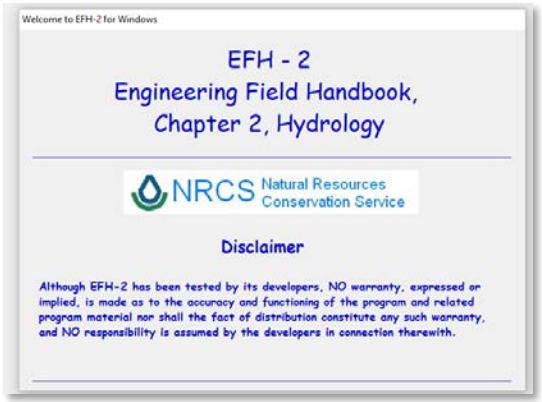
- NEH-4 (2015)
- EFH-2, PA Notice 34 Supplement
- Subsequent publication for the mid Atlantic region (Undated)
- Can be imported into EFH-2, Win TR-55
- Incorporated into HydroCAD


United States Department of Agriculture
Natural Resources Conservation Service
Part 630 Hydrology
National Engineering Handbook
Chapter 4: Storm Rainfall Depth and Distribution

September 2015, Draft







DESIGN RAINFALL DISTRIBUTIONS BASED ON NOAA ATLAS 14 RAINFALL DEPTHS AND DURATIONS

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Abstract
For hydrologic design purposes, the Natural Resources Conservation Service (NRCS) has historically used rainfall distributions derived from rainfall-frequency data. The rainfall distribution represents the cumulative rainfall from the beginning to the end of the design storm. The rainfall distribution is non-dimensional, and begins at a value of zero and ends at a value of 1.0. The Type I, Type IA, Type II, and Type III rainfall distributions are in general use throughout the United States. NRCS hydrologic models including Engineering Field Handbook Chapter 2 EFH-2, USDA (2014), WinTR-55 Small Watershed Hydrology, USDA (2010) and WinTR-20 Project Formulation Hydrology, USDA (2010) make use of these rainfall distributions.
The Type I, Type II, and Type III rainfall distributions were developed from rainfall-frequency data contained in the United States (US) Department of Commerce publications US Weather Bureau Technical Paper 40 (1961) and National Weather Service (NWS) Hydro-35 (1977). USDA NRCS Technical Paper 149 (1973) describes the way in which the Type I and Type II distributions were developed and shows plots of rainfall versus duration at several locations. These legacy rainfall distributions are being replaced with rainfall distributions developed from data contained in the NWS National Oceanic and Atmospheric Administration (NOAA) Atlas 14. Volumes 1 (2006) through 9 (2013) have been released and cover 37 states, Puerto Rico, US Virgin Islands, and selected Pacific Islands.

RAINFALL DISTRIBUTIONS - TABULAR

- NRCS rainfall Distribution was run for several actual model scenarios with varying input parameters
  - Rainfall distribution was obtained from Win TR-55
  - 6-minute (0.1 hour) cumulative time increment

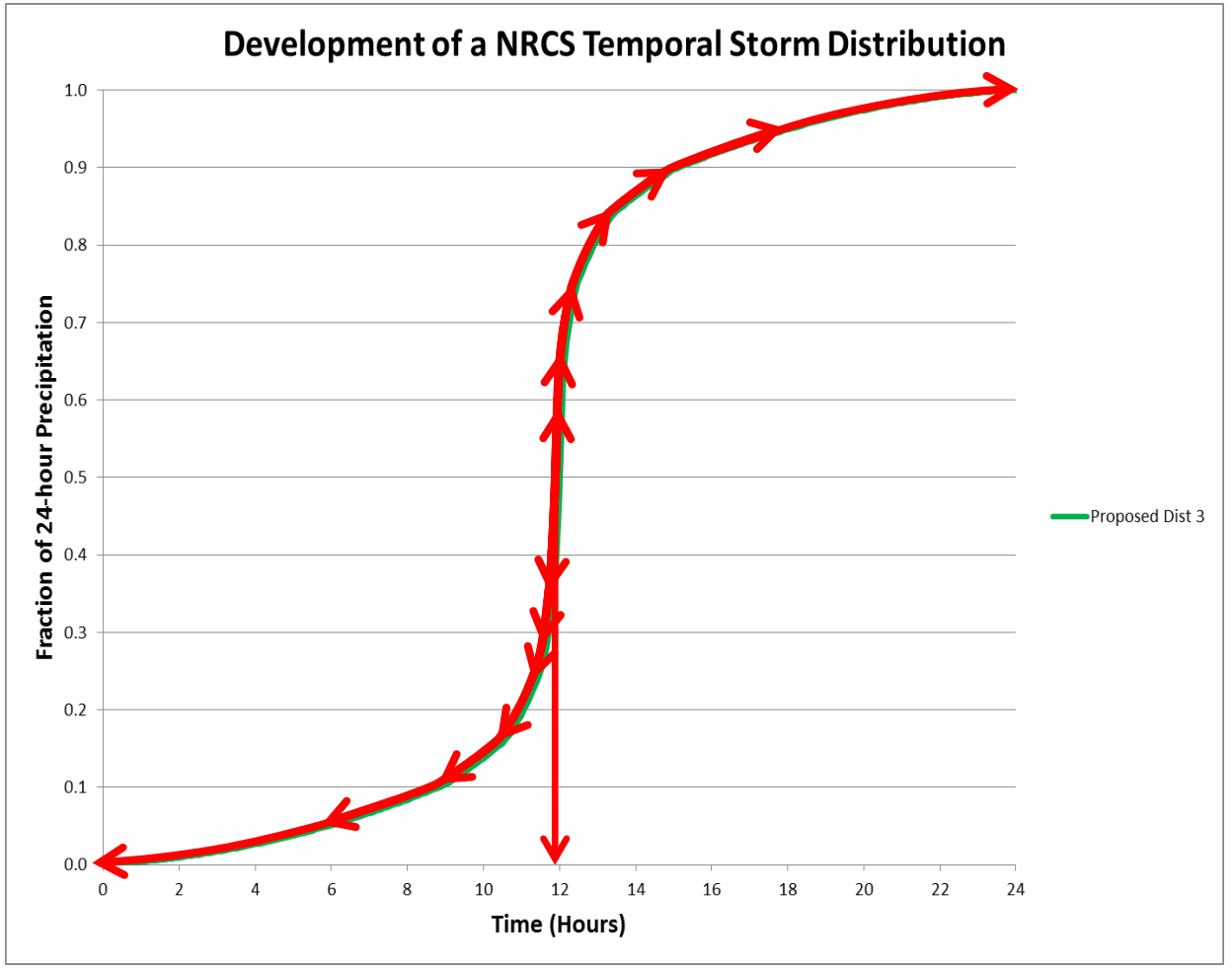
NOAA_B	0.1			
0.0	0.00101	0.00182	0.00265	0.00348
0.00433	0.00518	0.00605	0.00692	0.00780
0.00870	0.00960	0.01051	0.01144	0.01237
0.01331	0.01426	0.01522	0.01619	0.01718
0.01817	0.01917	0.02018	0.02120	0.02223
0.02327	0.02432	0.02538	0.02644	0.02752
0.02861	0.02971	0.03082	0.03193	0.03306
0.03420	0.03534	0.03650	0.03767	0.03884
0.04003	0.04122	0.04243	0.04364	0.04487
0.04610	0.04735	0.04860	0.04986	0.05114
0.05242	0.05371	0.05501	0.05633	0.05765
0.05898	0.06032	0.06167	0.06303	0.06440
0.06578	0.06720	0.06866	0.07016	0.07169
0.07327	0.07488	0.07653	0.07822	0.07996

Etc.

```
IDHEC-1 Analysis using WMS
IDUNT to Buffalo Run
IDBBS 09-02-2015
*DIAGRAM
IT   1 01JAN94     0   2000
IO   4
JR  PREC    1.0  1.196  1.686  2.005  2.279  2.569  3.304
KK   1B
KO   0     0    0.0     0    22
BA0.2369
PB  2.04
IN    6 01JAN94     0
* typeA-24hour
PC   0.0 0.00078 0.00141 0.00205  0.0027 0.00336 0.00403 0.00471 0.00539 0.00609
PC0.0068 0.00751 0.00823 0.00897 0.00971 0.01046 0.01122 0.01199 0.01277 0.01356
PC0.0144 0.01516 0.01598  0.0168 0.01764 0.01848 0.01933 0.02019 0.02106 0.02194
PC0.0228 0.02373 0.02464 0.02556 0.02648 0.02742 0.02836 0.02932 0.03028 0.03125
PC0.0322 0.03322 0.03422 0.03523 0.03625 0.03727 0.03831 0.03936 0.04041 0.04147
PC0.0426 0.04363 0.04472 0.04582 0.04693 0.04805 0.04918 0.05032 0.05146 0.05262
PC0.0538 0.05498 0.05622  0.0575 0.05881 0.06016 0.06154 0.06297 0.06442 0.06592
PC0.0675 0.06902 0.07063 0.07227 0.07395 0.07567 0.07742 0.07921 0.08104  0.0829
PC0.0848 0.08674 0.08871 0.09072 0.09277 0.09485 0.09697 0.09913 0.10132 0.10355
PC0.1058 0.10824 0.11081 0.11354 0.11643 0.11946 0.12265 0.12599 0.12949 0.13314
PC0.1370  0.1409 0.14502 0.14928  0.1537 0.15827 0.16348 0.16932  0.1758 0.18291
PC0.1907 0.19971 0.21009 0.22179 0.23481   0.249 0.27176 0.29572 0.32954  0.3782
PC0.4666  0.6218 0.67046 0.70428 0.72824   0.751 0.76519 0.77821 0.78991 0.80029
PC0.8094 0.81709  0.8242 0.83068 0.83652 0.84173  0.8463 0.85072 0.85498  0.8591
PC0.8631 0.86686 0.87051 0.87401 0.87735 0.88054 0.88357 0.88646 0.88919 0.89176
PC0.8942 0.89645 0.89868 0.90087 0.90303 0.90515 0.90723 0.90928 0.91129 0.91326
PC0.9152  0.9171 0.91896 0.92079 0.92258 0.92433 0.92605 0.92773 0.92937 0.93098
PC0.9326 0.93408 0.93558 0.93703 0.93846 0.93984 0.94119  0.9425 0.94378 0.94502
PC0.9462 0.94738 0.94854 0.94968 0.95082 0.95195 0.95307 0.95418 0.95528 0.95637
PC0.9575 0.95853 0.95959 0.96064 0.96169 0.96273 0.96375 0.96477 0.96578 0.96678
PC0.9678 0.96875 0.96972 0.97068 0.97164 0.97258 0.97352 0.97444 0.97536 0.97627
PC0.9772 0.97806 0.97894 0.97981 0.98067 0.98152 0.98236  0.9832 0.98402 0.98484
PC0.9857 0.98644 0.98723 0.98801 0.98878 0.98954 0.99029 0.99103 0.99177 0.99249
PC0.9932 0.99391 0.99461 0.99529 0.99597 0.99664  0.9973 0.99795 0.99859 0.99922
```

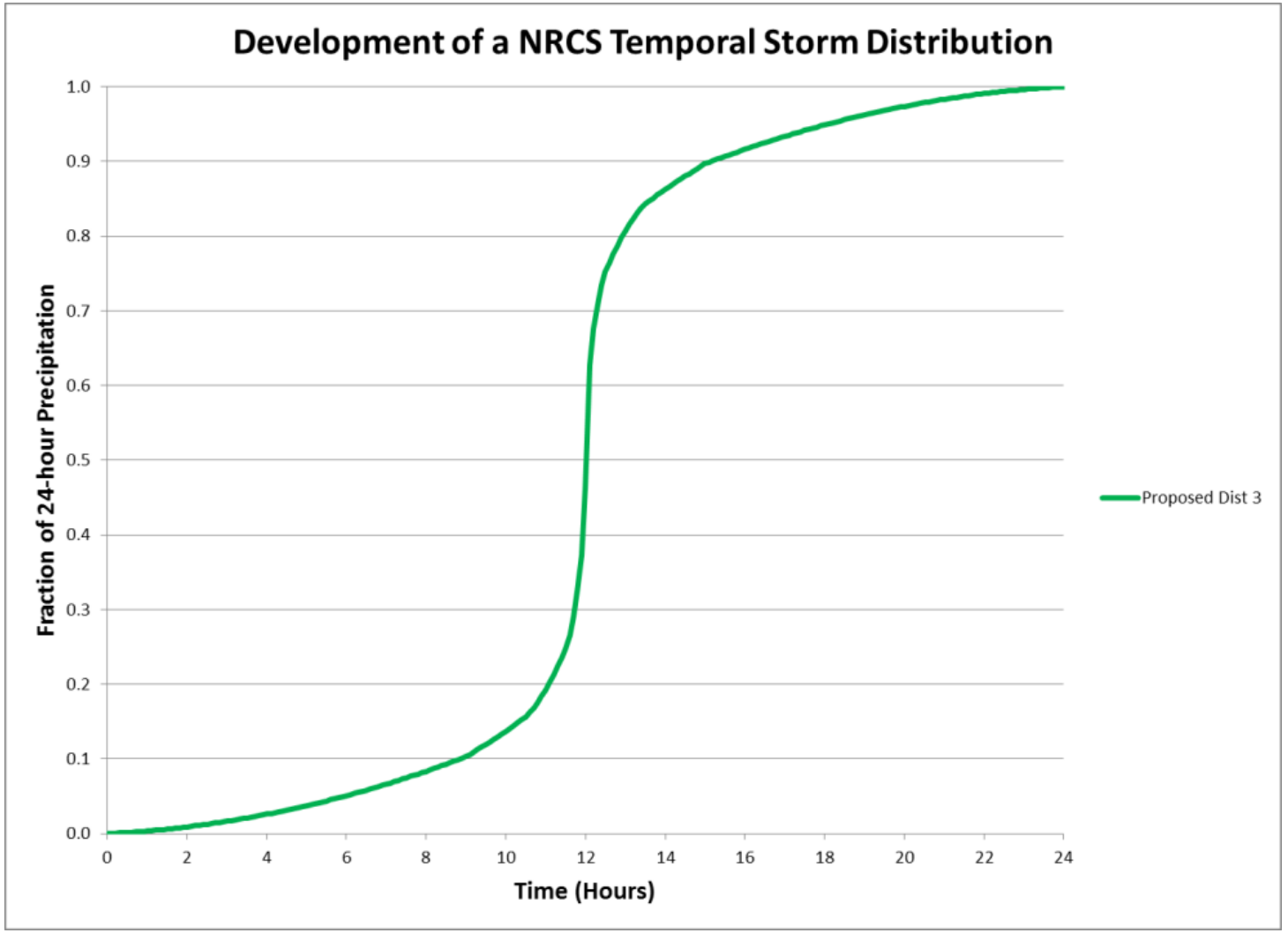
NRCS TEMPORAL DISTRIBUTIONS

- Usually 24 hours in duration – applicable to watersheds with Tc ≤ 24 hours
- Developed by “nesting” precipitation depths for all durations (5 min. through 24 hrs.)
- Most intense (5 min.) is centered at 12 hrs.
- Intended to be conservative for design purposes
- Not intended to duplicate actual storm distributions



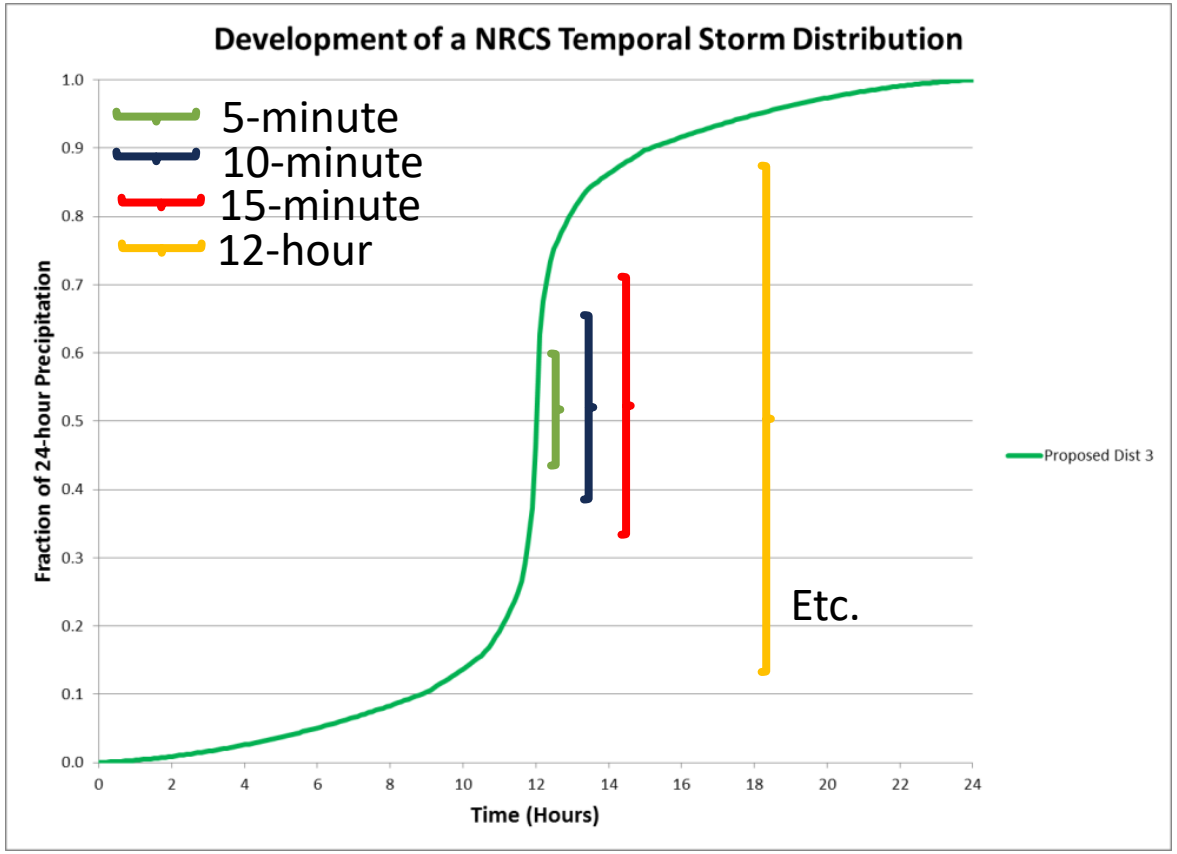
S CURVE IS APPLICABLE TO ANY STORM DURATION

- The storm duration producing the largest peak discharge is generally approximately equal to the time of concentration of the watershed to the design point (NRCS NEH Ch. 4)
- Thus, the NRCS 24-hour Temporal Distribution is applicable to any watershed with a Tc less than 24 hours



STORM DURATION CALCULATIONS

- Rainfall distributions based on “nesting” the highest intensity short durations within the lower intensity storm durations
- For example, maximum 5-minute rainfall is placed within the maximum 10-minute rainfall, which is within the maximum 15-minute rainfall, up to a 24-hour rainfall
- Peak runoff occurs when storm duration = Tc of the DA
- Therefore, the S curve actually accurately represents the shorter duration events, and smaller drainage areas, even though it is known as a 24-hour storm



RAINFALL DISTRIBUTION - DURATIONS

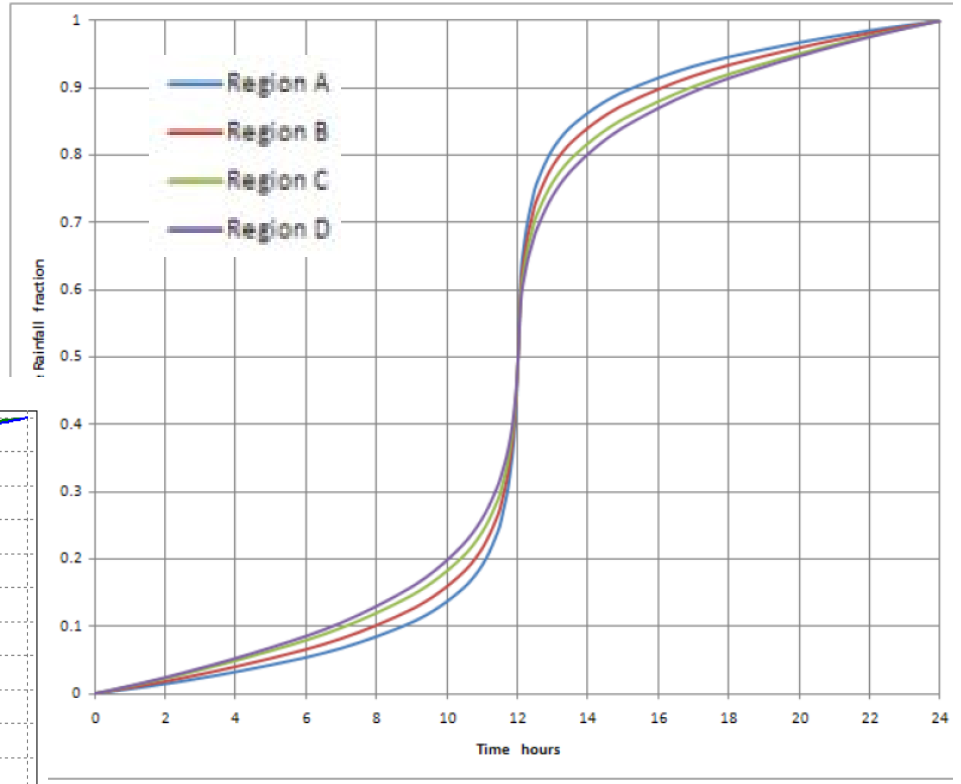
- Sample calculation – 10-year, 1-hour event
- 0.751 – 0.249 = 0.502
  - i.e. 50.2 % of total rainfall falls in most intense hour
- If 10-year, 24-hour rainfall = 4.2 inches, then
  - 0.502 * 4.2 = 2.1 inches in 60 minutes
- NOAA Atlas 14 10-year, 1-hour rainfall = 2.1 inches
- Therefore, 1-hour rain event represented in the S curve

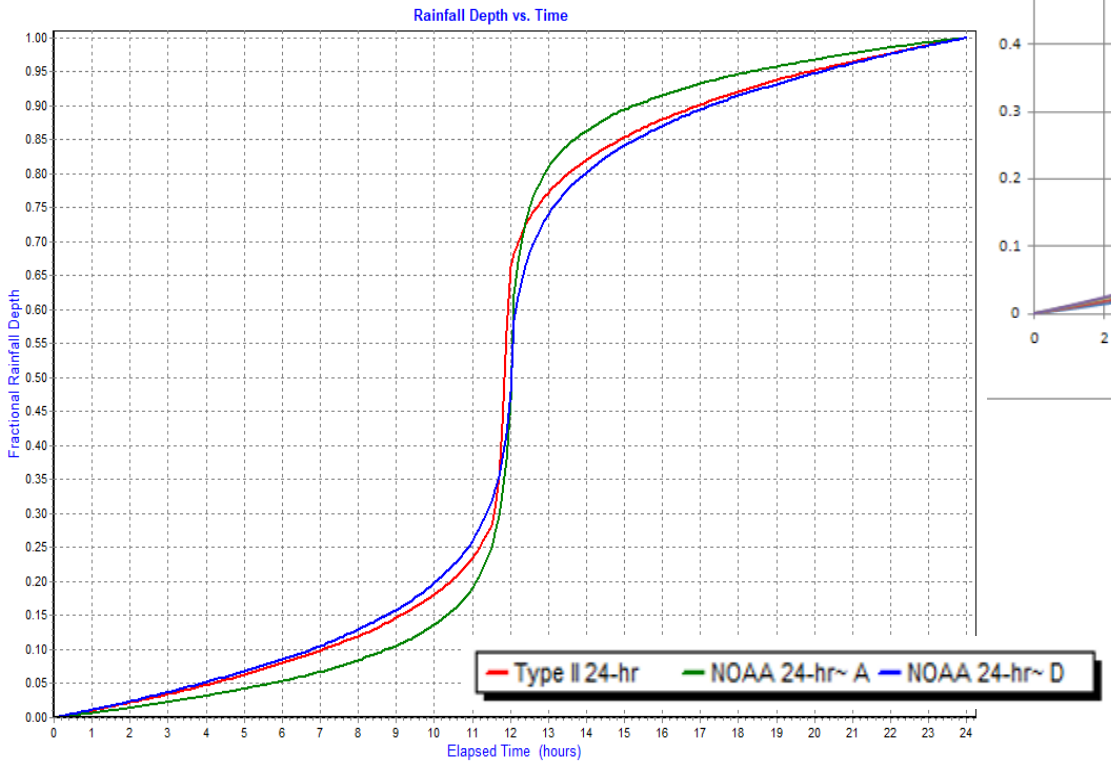
Center 1-hour Rainfall Distribution
Type A

Time	Type A
11.5	0.249
11.6	0.27176
11.7	0.29572
11.8	0.32954
11.9	0.3782
12	0.4666
12.1	0.6218
12.2	0.67046
12.3	0.70428
12.4	0.72824
12.5	0.751

RAINFALL DISTRIBUTION – S CURVE

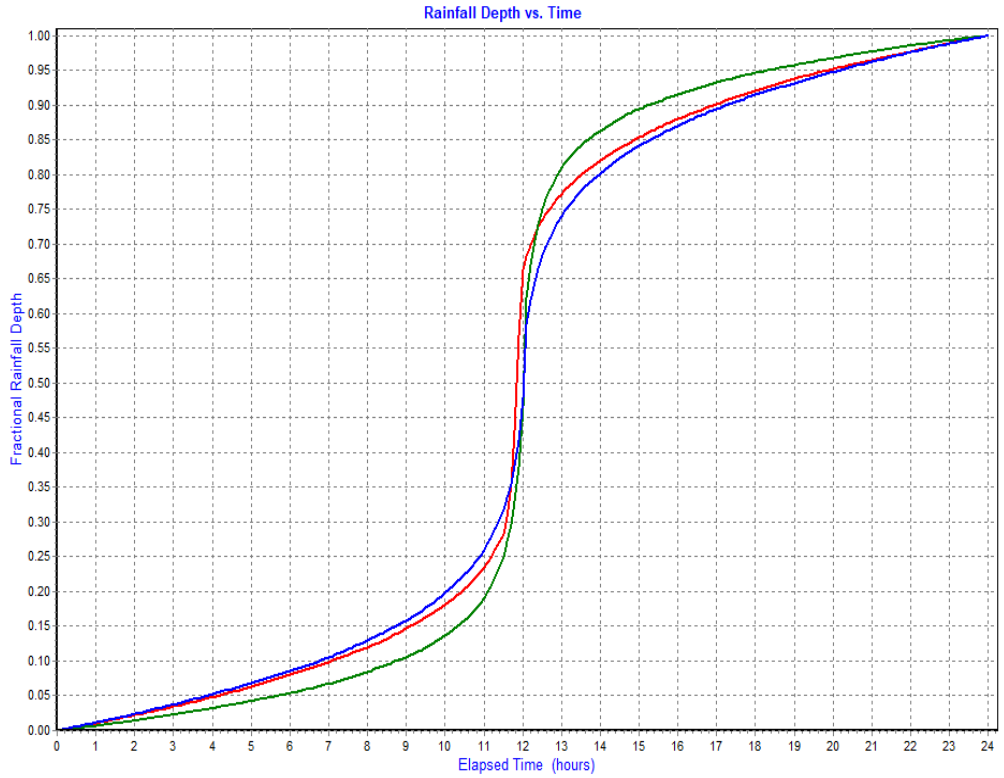
- Comparison of A, B, C, D Distributions: A is most intense (steepest curve), D least intense
- Comparison of Type II with A and D: A more intense than II, D less intense than II
- Implications: A should produce higher peaks than II, D lower peaks

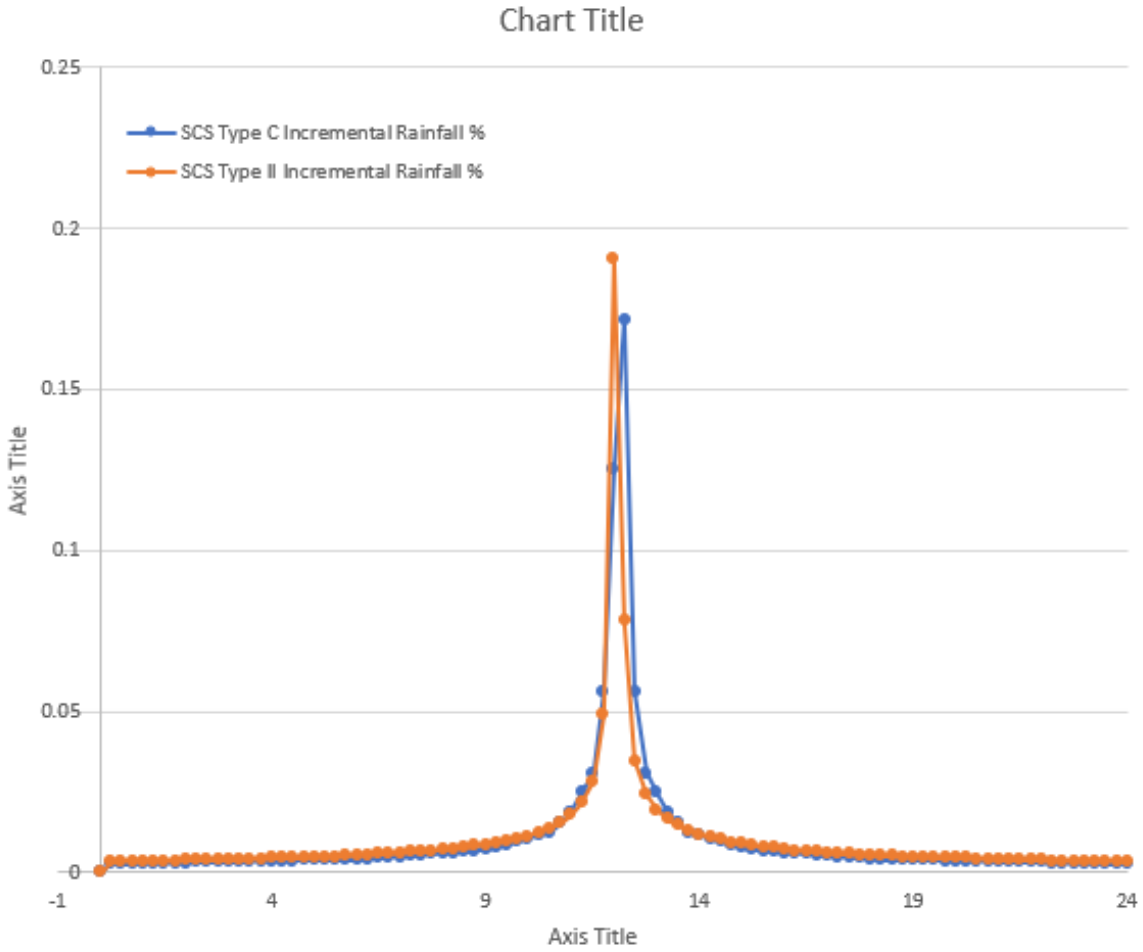




RAINFALL DISTRIBUTION – TIMING

- Notice: Type II peaks slightly before A, B, C, D





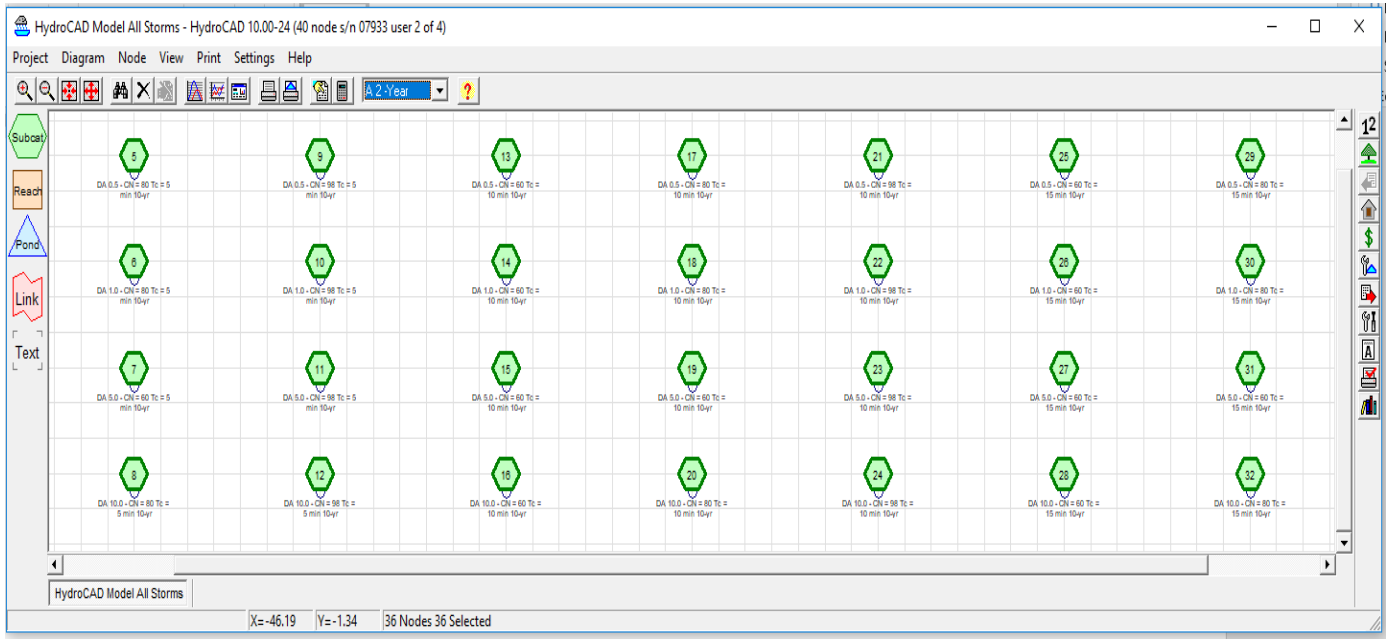
IMPLICATIONS ON PEAKS AND VOLUMES

- Culverts / channels
- SCMs, detention basins
- Bridges

Source: Penn State Univ.

CULVERTS / CHANNELS - HYDROCAD

- HydroCAD version 10.00-24 has new NRCS-NOAA distributions incorporated into the software
- HydroCAD model set up to model:
  - NRCS-NOAA PA rainfall distribution / regions Type II, A, B, C, D
  - Drainage area = 0.5, 1, 5, 10 Acres
  - T_c (minutes) = 5, 10, 15, 60
  - CN = 60, 80, 98
  - Storm frequency = 2-, 10-, 25-year



CULVERTS / CHANNELS – HYDROCAD ANALYSIS

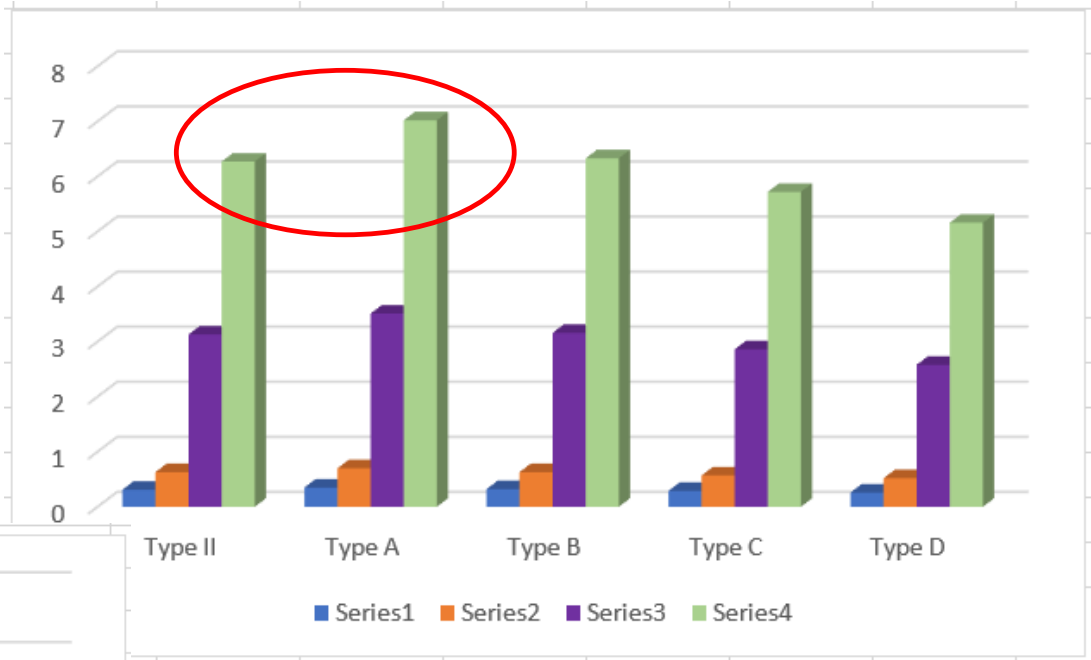
- 20 different combinations of scenarios modeled and results tabulated
- Notice: 15 minute event Type A is < Type II. 60 minute event Type A > type II event

P2 for Tc = 2.92					pg 2
25-year Event - - Peak Flow Values (cfs)					
Assumed 25-year, 24-hour Rainfall = 5.1"					
Tc = 15 minutes		CN = 98			
Drainage Areas (AC)	Type II	Type A	Type B	Type C	Type D
0.5	2.66	2.56	2.22	1.98	1.77
1	5.33	5.12	4.45	3.96	3.54
5	26.63	25.58	22.24	19.81	17.72
10	53.27	51.17	44.48	39.61	35.44
Tc = 60 minutes		CN = 60			
Drainage Areas (AC)	Type II	Type A	Type B	Type C	Type D
0.5	0.31	0.35	0.32	0.29	0.26
1	0.63	0.7	0.63	0.57	0.52
5	3.13	3.51	3.16	2.86	2.58
10	6.27	7.02	6.33	5.72	5.16

Pipe, Storm Sewer, Culvert Design Summary					
10-year Event - Peak Flow Values (cfs)					
Assumed 10-year, 24-hour Rainfall = 4.2"					
Tc = 15 minutes		CN = 98			
Drainage Areas (AC)	Type II	Type A	Type B	Type C	Type D
0.5	2.19	2.1	1.83	1.63	1.46
1	4.38	4.2	3.65	3.25	2.91
5	21.88	21.02	18.27	16.27	14.56
10	43.75	42.03	36.54	32.54	29.11
Tc = 60 minutes		CN = 60			
Drainage Areas (AC)	Type II	Type A	Type B	Type C	Type D
0.5	0.18	0.21	0.19	0.17	0.15
1	0.36	0.42	0.37	0.33	0.3
5	1.8	2.08	1.86	1.67	1.49
10	3.59	4.15	3.72	3.33	2.99

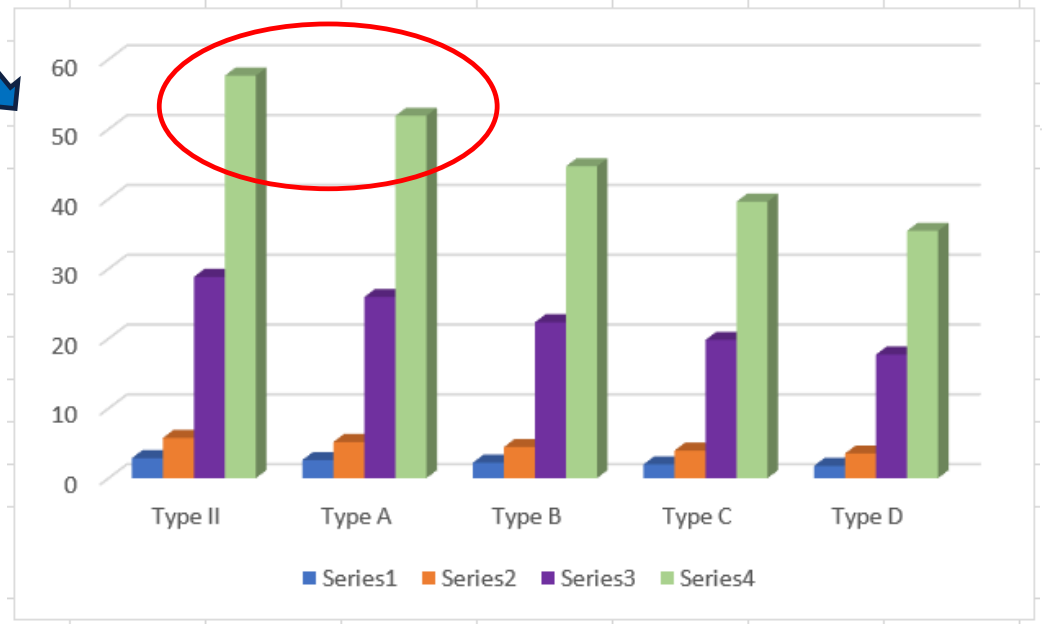
CULVERTS / CHANNELS – HYDROCAD RESULTS

- Generally, Type A peaks were greater than Type II peaks
- One exception: Tc < 15 minutes where Type A had lower peaks than Type II peaks



Tc = 60 min, CN = 60
DA's = 0.5, 1, 5, and 10 Acres

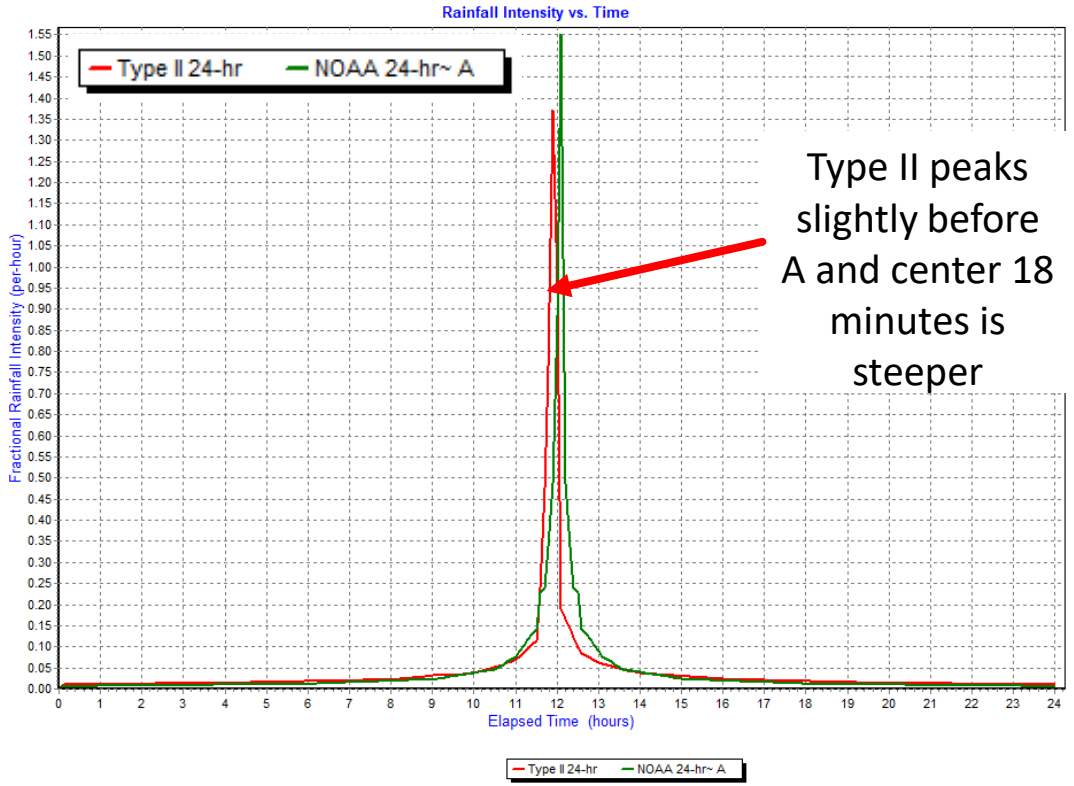
Tc = 5 min, CN = 98
DA's = 0.5, 1, 5, and 10 Acres



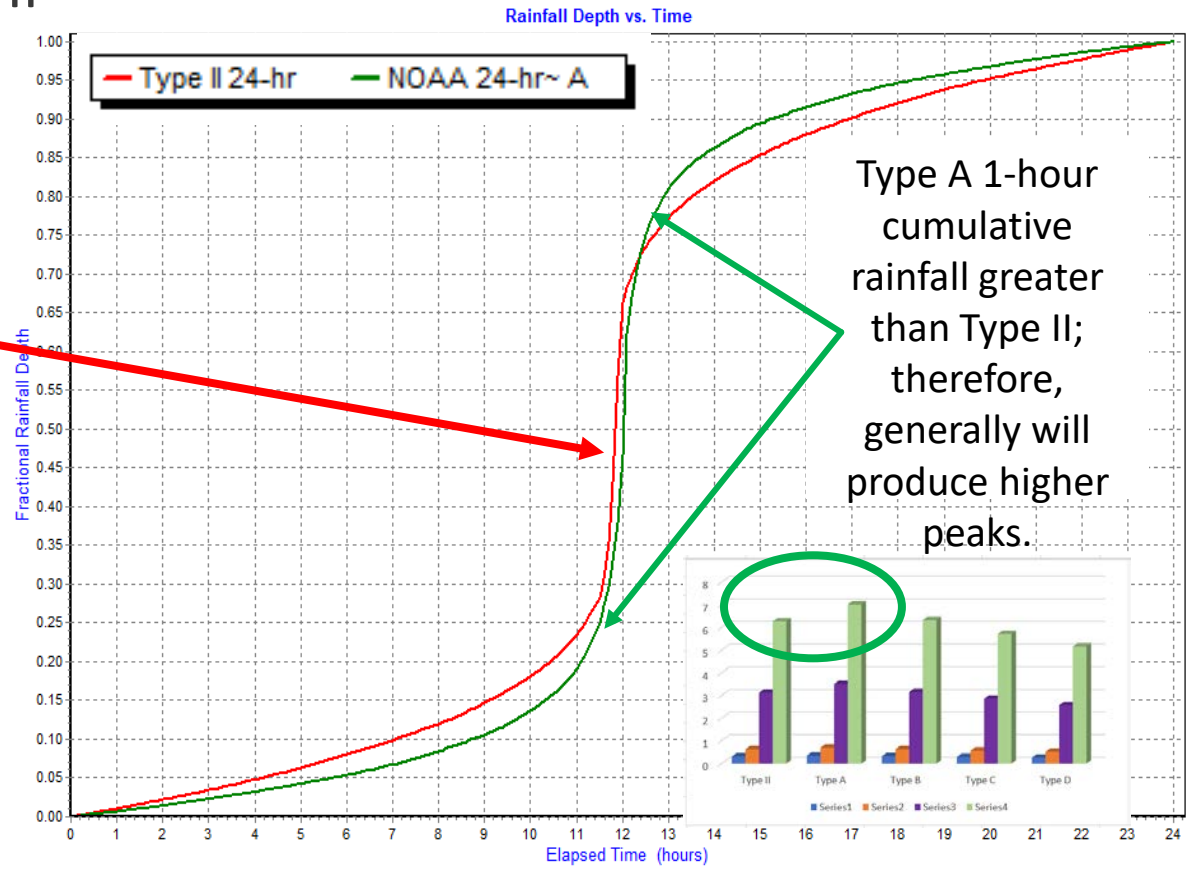
CULVERTS / CHANNELS – HYDROCAD RESULTS

- Explanation: The Type II curve is slightly steeper for the center 18 minutes; therefore, for short duration events, Type II will have a higher peaks than Type A

Tc = 5 min, CN = 98
DA's = 0.5, 1, 5, and 10 Acres



Type II peaks slightly before A and center 18 minutes is steeper

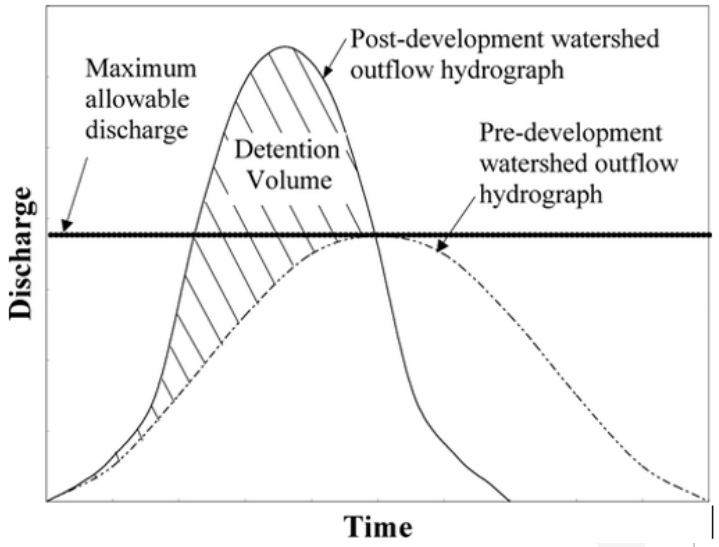


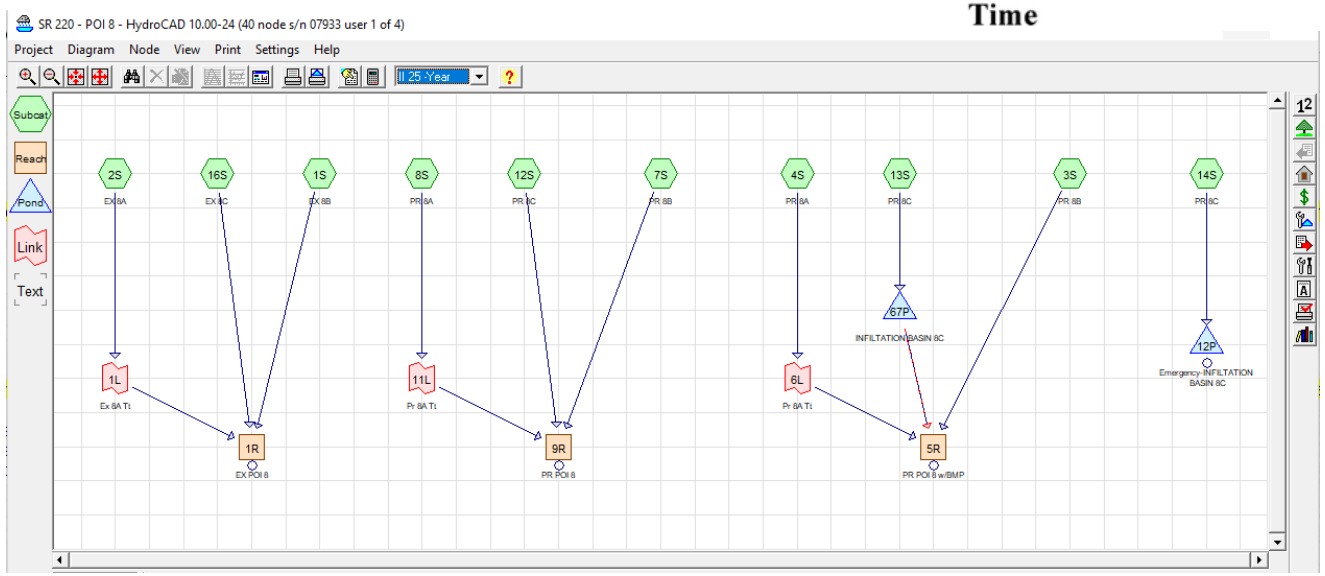
Type A 1-hour cumulative rainfall greater than Type II; therefore, generally will produce higher peaks.

HYDROCAD ANALYSIS FOR SMALL DA'S – SCM'S & DETENTION BASINS

HydroCAD version 10.00-24 has the new NRCS-NOAA rainfall distributions incorporated into the software. One model was set up to analyze the following scenarios:

- NRCS-NOAA PA rainfall distribution regions A, B, C, D
- Seven (7) actual SCM's
- Drainage area (acres) = 3 - 122
- T_c (minutes) = 5 - 28
- CN = varied
- Storm frequencies = 2-, 10-, & 25-yr
- Inflow and outflow hydrographs analyzed





RUNOFF VOLUME V. DETENTION BASIN VOLUME

- Since the runoff volume is simply a function of the rainfall total and the curve number (CN), the rainfall distribution does not affect the total runoff volume

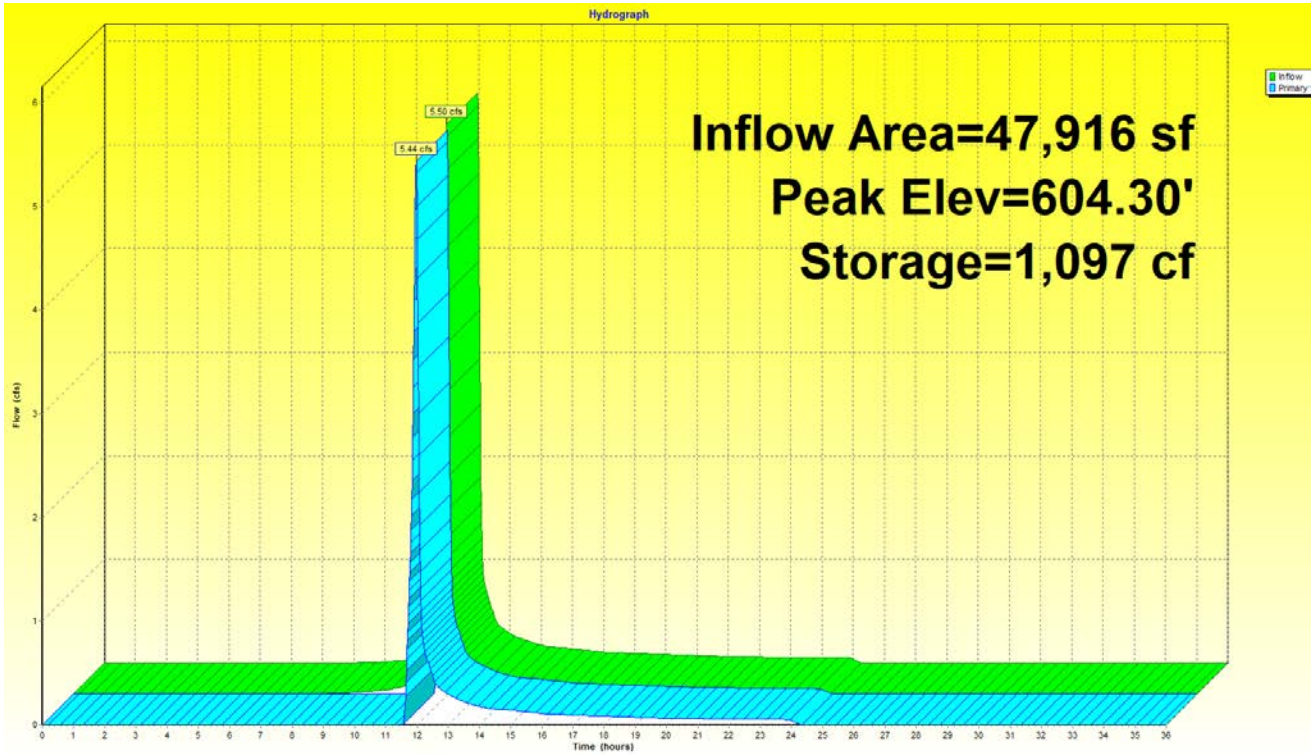
$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \qquad S = \frac{1000}{CN} - 10$$

- However, since the generated hydrographs, which are based on the distributions are different, the routed inflow/outflow/storage are slightly different

		2-year Event - Runoff Volume Values (CF)			
		Assumed 2-year, 24-hour Rainfall = 2.92"			
POI	Acres	CN	Existing	Type II	Type A	Type B
1	162.81	73	Existing	503083	503083	503083
7	14.36	60	Existing	15427	15427	15427
8	32.5	73	Existing	98976	98976	98976
10	131.6	67	Existing	274341	274341	274341
12	272.12	69	Existing	620371	620371	620371
21	64.88	78	Existing	254253	254253	254253
23	75.42	75	Existing	259929	259929	259929
POI			Proposed	Type II	Type A	Type B
1	162.87	73	Proposed	508528	508528	508528
7	14.36	60	Proposed	17452	17452	17452
8	32.5	73	Proposed	98976	98976	98976
10	132.23	67	Proposed	286862	286862	286862
12	272.11	69	Proposed	622584	622584	622584
21	67.54	78	Proposed	268640	268640	268640
23	75.84	75	Proposed	258535	258535	258535
POI			Proposed w/ BMP	Type II	Type A	Type B
1	162.87	73	Proposed w/ BMP	505519	505519	505519
7	14.36	60	Proposed w/ BMP	8500	8500	8500
8	32.5	73	Proposed w/ BMP	98509	98509	98509

DETENTION BASIN ANALYSIS - HYDROCAD

- In our analysis, since Tc's were short (< 18 minutes), Type II produced the same or slightly higher peaks than Type A. Types B, C, & D were all lower than Type II



Pond 67P: INFILTATION BASIN 8C - SR 220 - POI 8

Summary | Hydrograph | Discharge | Storage | Events | Sizing

Inflow Area = 47,916 sf, 0.00% Impervious, Inflow Depth = 2.71" for II 25 -Year event
Inflow = 5.50 cfs @ 11.96 hrs, Volume= 10,809 cf
Outflow = 5.46 cfs @ 11.97 hrs, Volume= 10,342 cf, Atten= 1%, Lag= 0.4 min
Primary = 5.46 cfs @ 11.97 hrs, Volume= 10,342 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 603.80' @ 11.97 hrs Surf.Area= 705 sf Storage= 675 cf

Plug-Flow detention time= 35.2 min calculated for 10,342 cf (96% of inflow)
Center-of-Mass det. time= 10.5 min (835.2 - 824.7)

Volume	Invert	Avail.Storage	Storage Description
#1	602.50'	2,374 cf	**Custom Stage Data (Prismatic)** Listed below

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
602.50	332	0	0
603.00	463	199	199
603.50	608	268	467
604.00	768	344	811
605.00	1,129	949	1,759
605.50	1,331	615	2,374

Device	Routing	Invert	Outlet Devices
#1	Primary	601.30'	**15.0" Round 15" RCP Crosspipe** L= 150.5' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 601.30' / 590.68' S= 0.0706 '/' Cc= 0.900 n= 0.012, Flow Area= 1.23 sf
#2	Device 1	603.50'	**39.7" x 20.5" Horiz. Primary - Standard Vault - Trash Rack** C= 0.600 Limited to weir flow at low heads
#3	Device 1	604.00'	**20.5" x 39.7" Horiz. Emergency - Standard Vault - Trash Rack** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=5.45 cfs @ 11.97 hrs HW=603.80' (Free Discharge)
↑**1=15" RCP Crosspipe** (Passes 5.45 cfs of 8.10 cfs potential flow)
↑**2=Primary - Standard Vault - Trash Rack** (Weir Controls 5.45 cfs @ 1.80 fps)
↑**3=Emergency - Standard Vault - Trash Rack** (Controls 0.00 cfs)

DETENTION BASIN ANALYSIS - HYDROCAD

- Due to a slight difference in shape of the S curve, Type A produced variable results:
  - Sometimes lower inflows, but higher outflows and storage than Type II
  - Sometimes less inflow, outflow, and storage
- Differences between Types II and A were insignificant. Types B, C, D slightly lower, but still not significant

SR 220 Detention Basin Comparison				
Assumed 2-year, 24-hour Rainfall=2.92"				
Assumed 10-year, 24-hour Rainfall=4.20"				
Assumed 25-year, 24-hour Rainfall=5.10"				
Drainage Area = 3.99 Ac				
Tc = 5 Minutes				
POI 1 - Pond 19P				
Design Storm	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (cubic-feet)
II 2 -Year	12.21	12.09	557.83	3,627
A 2 -Year	12.16	12.02	557.83	3,624
B 2 -Year	10.35	10.23	557.79	3,559
C 2 -Year	9.12	9.00	557.77	3,511
D 2 -Year	8.13	8.03	557.75	3,473
II 10 -Year	20.12	19.94	557.96	3,899
A 10 -Year	20.05	19.84	557.96	3,895
B 10 -Year	17.09	16.94	557.91	3,795
C 10 -Year	15.07	14.94	557.88	3,727
D 10 -Year	13.46	13.33	557.85	3,672
II 25 -Year	25.72	25.47	558.04	4,108
A 25 -Year	25.63	25.35	558.04	4,103
B 25 -Year	21.86	21.65	557.98	3,963
C 25 -Year	19.29	19.11	557.94	3,869
D 25 -Year	17.23	17.09	557.91	3,800

SR 220 Detention Basin Comparison				
Assumed 2-year, 24-hour Rainfall=2.92"				
Assumed 10-year, 24-hour Rainfall=4.20"				
Assumed 25-year, 24-hour Rainfall=5.10"				
Drainage Area = 3.05 Ac				
Tc = 5 Minutes				
POI 7 - Pond 17P				
Design Storm	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (cubic-feet)
II 2 -Year	4.49	0.00	637.57	8,952
A 2 -Year	4.45	0.00	637.57	8,952
B 2 -Year	3.75	0.00	637.57	8,952
C 2 -Year	3.28	0.00	637.57	8,952
D 2 -Year	2.9	0.00	637.57	8,952
II 10 -Year	9.5	0.45	638.05	11,126
A 10 -Year	9.46	0.90	638.07	11,263
B 10 -Year	8.02	0.69	638.06	11,203
C 10 -Year	7.04	0.52	638.05	11,154
D 10 -Year	6.26	0.44	638.05	11,119
II 25 -Year	13.38	2.89	638.16	11,748
A 25 -Year	13.34	3.73	638.19	11,912
B 25 -Year	11.32	2.96	638.17	11,763
C 25 -Year	9.96	2.33	638.14	11,628
D 25 -Year	8.86	1.87	638.12	11,530

BRIDGES - HEC-1 ANALYSIS

- Watershed models were run for the NRCS NOAA region for which they were located (green shaded area), plus the other three regions since Type II covered the entire state

	50-year Event															
Run	NOAA Region	County	District	Model	Method	Curve No.	PDT 24-hr Rainfall	PDOT Rainfall Region	Cumul-ative Drainage Area (SM)	Lag(s) (Hr)	Tc (min)	No. of DA's	Type II Flows	Type A Flows	Type B Flows	Type C Flows	Type D Flows
1D	A	Allegheny	11-0	HEC-1	NRCS CN	76.2	4.65	1	0.89	0.74	73.80	1	629	687	623	567	514
2D	A	Westmoreland	12-0	HEC-1	NRCS CN	77	4.65	1	0.24	0.37	37.31	1	278	287	255	230	207
3D	B	Mifflin	2-0	HEC-1	Snyder	65.41	5.27	2	20.30	n/a	n/a	4	2133	2307	2222	2132	2076
4D	B	Elk	2-0	HEC-1	NRCS CN	69.47	4.65	1	31.39	0.98-1.65	98-165	12	4052	4356	4214	4060	3973
5D	C	Berks	5-0	HEC-1	NRCS CN	74.34	6.53	4	0.37	0.62	61.57	1	491	527	475	431	389
6D	C	Luzerne	4-0	HEC-1	NRCS CN	72-74	6.21	3-4	9.30	0.95-1.35	95-135	4	3420	3734	3496	3272	3083
7D	D	Schuylkill	5-0	HEC-1	Snyder	53.01	7.16	5	18.77	n/a	n/a	4	1468	1689	1574	1462	1384

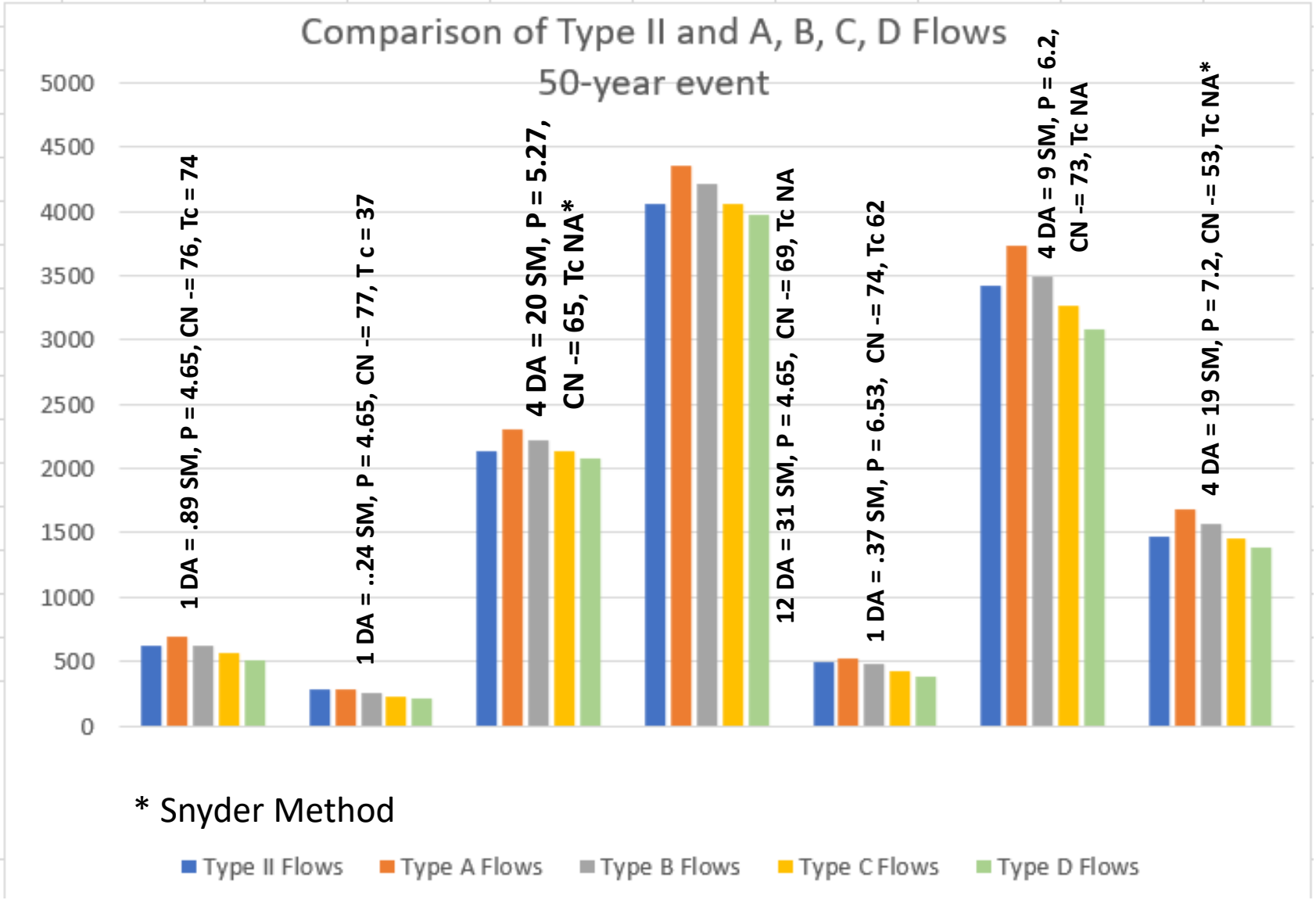
Figure 12. Modeling Results for the 50-year Event

	100-year Event															
Run	NOAA Region	County	District	Model	Method		Rainfall	PDOT Rainfall Region	Cumul-ative Drainage Area (SM)	Lag(s) (Hr)	Tc (min)	No. of DA's	Type II Flows	Type A Flows	Type B Flows	Type C Flows	Type D Flows
1D	A	Allegheny	11-0	HEC-1	NRCS CN	76.2	5.24	1	0.8947	0.74	73.80	1	769	838	760	691	627
2D	A	Westmoreland	12-0	HEC-1	NRCS CN	77	5.24	1	0.2369	0.37	37.31	1	338	349	310	279	251
3D	B	Mifflin	2-0	HEC-1	Snyder	65.41	6.03	2	20.3	n/a	n/a	4	2851	3048	2946	2842	2771
4D	B	Elk	2-0	HEC-1	NRCS CN	69.47	5.24	1	31.39	0.98-1.65	98-165	12	5119	5484	5312	5118	5005
5D	C	Berks	5-0	HEC-1	NRCS CN	74.34	7.63	4	0.3739	0.62	61.57	1	622	665	600	544	491
6D	C	Luzerne	4-0	HEC-1	NRCS CN	72-74	7.23	3-4	9.3	0.95-1.35	95-135	4	4368	4755	4455	4170	3930
7D	D	Schuylkill	5-0	HEC-1	Snyder	53.01	8.43	5	18.77	n/a	n/a	4	2176	2471	2315	2162	2053

Figure 13. Modeling Results for the 100-year Event

BRIDGES HEC-1 ANALYSIS – 50-YEAR EVENT

- Altered # of DA's, DA size, CN, Tc, Region, Rainfall, Method
- Type A 3 to 15% greater than Type II
- Type B -8 to 7% different than Type II
- Type C -17 to 0% less than Type II
- Type D -2 to -26% less than Type II
- Other analyses similar results



CONCLUSIONS

- Of the new distributions, Type A is the most intense, followed by B, C, and D
- Generally, the Type A distribution produced higher peaks and volumes than the Type II, B was very similar, and C and D produced lower peaks and volumes
- Once exception was for shorter duration events where the Type II produced higher peaks and volumes than A due to the center 18-minute distribution being steeper for the Type II
- Type D, which applies to only Wayne and Schuylkill Counties, is up to 26% lower than Type II
- Results were the same for the culvert / channel, SCM / detention basin, or the bridge analysis
- NRCS is developing software to import NOAA 14 text files with site-specific rainfall data for a project area

QUESTIONS??

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