White Paper for Rainfall Distribution for NOAA Atlas 14 Volume 2

By William Merkel
National Water Quality and Quantity Technology Development Team
NRCS, Beltsville, MD

Background

The National Weather Service recently released updated rainfall frequency data for 13 Mid-Atlantic and central states in NOAA Atlas 14 Volume 2, Ohio River Basin and Surrounding States (2004). These data update the rainfall-frequency data contained in Weather Bureau TP-40 (1961) and NWS Hydro-35 (1977). The web site where these data may be accessed is http://hdsc.nws.noaa.gov/.

No generalizations on the increase or decrease of rainfall magnitudes can be made. The difference between NOAA Atlas 14 and TP-40 is highly location dependent. Table 1 includes a comparative summary for several locations.

Location	Comparison of 24-hour rainfall magnitude
Indianapolis, IN	100-year equal, all others NOAA 14 lower
Nashville, TN	100-year NOAA 14 higher, all others NOAA 14 lower
Columbia, SC	2, 5, 10-year NOAA 14 lower, 25, 50, 100-year NOAA 14 higher
Charleston, WV	NOAA 14 lower
Annapolis, MD	2, 5, 10-year NOAA 14 lower, 25, 50, 100-year NOAA 14 higher
Mercer Co. NJ	2, 5, 10-year NOAA 14 lower, 25, 50, 100-year NOAA 14 higher

Table 1. Comparison of 24-hour rainfall from TP 40 to NOAA Atlas 14.

The difference in rainfall magnitude will cause only part of the difference in peak discharge when applying hydrologic models. The other key factor is the distribution of the design storm. The standard NRCS Type II rainfall distribution which is used for design and planning of NRCS water-related projects is based on TP-40 rainfall frequency maps. The NRCS Type III distribution is based on TP-40 and Hydro-35.

The Type I, Type II, and Type III distributions are currently applied to very large geographic regions, for instance, the Type II distribution covers most of the continental Unites States, Puerto Rico, and Virgin Islands (see map, figure 1).

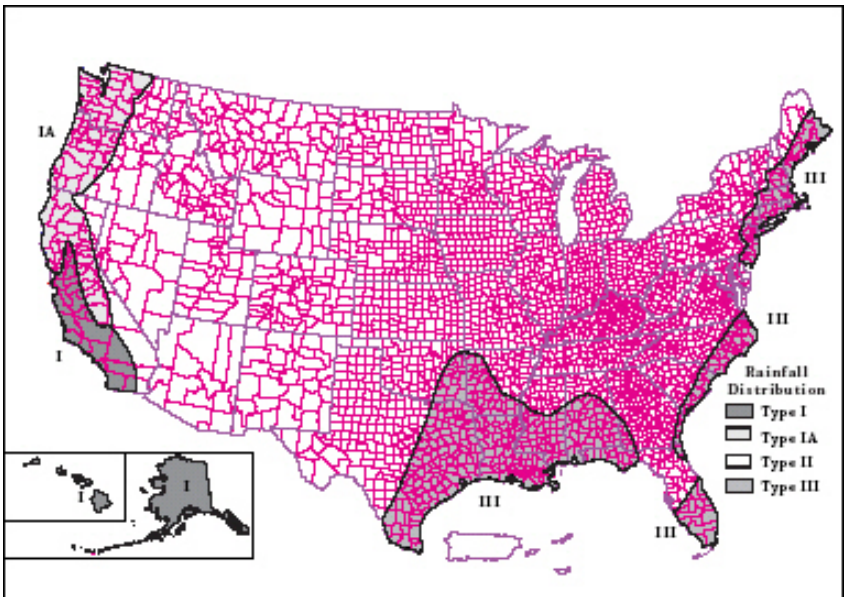

Figure 1. NRCS rainfall distributions, recommended areas of use (from SCS TR-55, 1986).

Within each region there is significant variability of rainfall magnitude and distribution. For example, developing a distribution based on TP-40 data at various locations will show differences in both magnitude and distribution. How much difference is acceptable to the user is the question. In SCS TP-149 (1973), there are several locations (Alabama, Puerto Rico, Nebraska, and Utah) where the rainfall versus duration is plotted and shows differences at a station over 0.5 inch from the Type II curve. From the locations plotted, reservations may be raised on how much variation there would be within the Type II region and if it is justified to use one distribution to represent such a large region. There is no available documentation that any error analysis was done. In other words, for the Type II and type III regions, what is the maximum range of errors (plus and minus) when compared to the adopted Type II or Type III distribution ? Columbus Ohio was randomly selected as a location to compare the site-specific rainfall distribution developed with data from TP-40 and Hydro-35 with the standard with the Type II distribution which has been used there in the past. The ratios imbedded in the standard Type II rainfall distribution are:

Duration	Ratio to 24 hour rainfall
5 minute	0.114
10 minute	0.201
15 minute	0.270
30 minute	0.380
1 hour	0.454
2 hour	0.538
3 hour	0.595
6 hour	0.707

12 hour	0.841
24 hour	1.00

Figure 2 is based on rainfall frequency data from TP-40 and Hydro-35 at Columbus, Ohio. The key factor involved is the ratio of the rainfall for the shorter duration to the 24-hour rainfall.

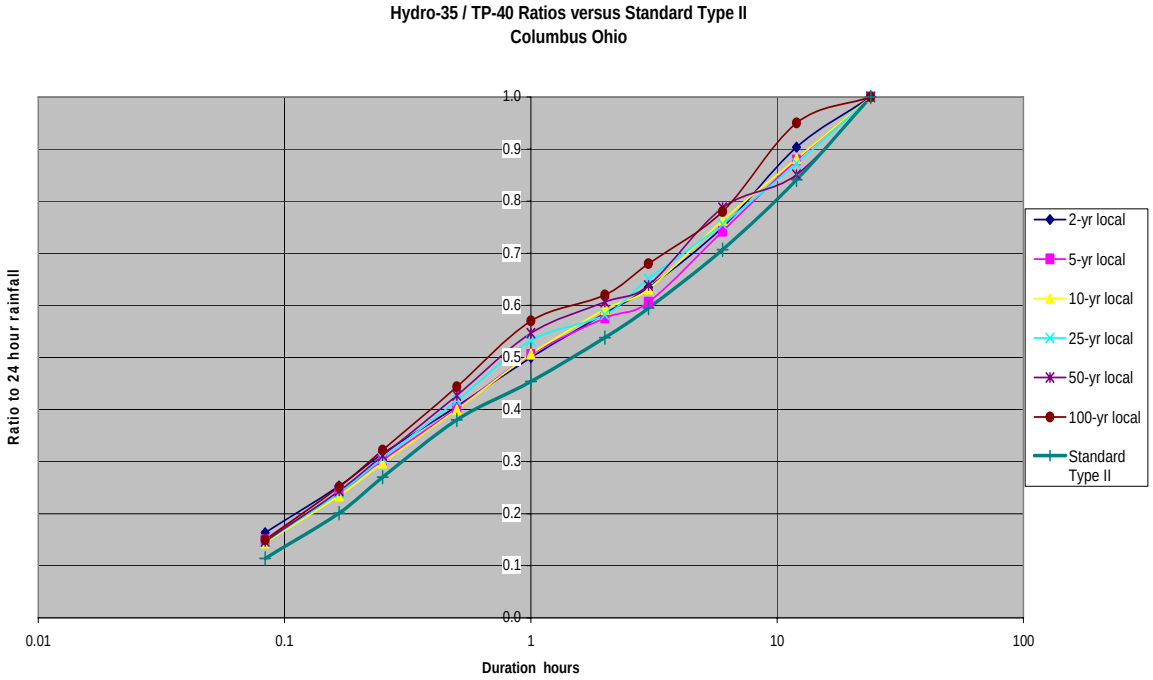

Figure 2. Comparison of a local rainfall distribution developed from rainfall frequency data from TP-40 and Hydro-35 at Columbus, Ohio with the standard Type II distribution.

Figure 2 shows that the ratio and thus the rainfall distribution vary by return period. Rainfall intensities for durations of 5 minutes to 2 hours are significantly higher than the Type II distribution (these are up to 30 percent higher). The 100-year ratio is significantly higher all the way up to 12 hours or 720 minutes.

Even though this would be an interesting study, we can only look in hindsight and say that for many years we have been living with (and accepting) potentially large errors in hydrologic estimates. Since almost all of the work NRCS does is in ungaged areas, it would seem that we should base our analyses on the best possible data. Rainfall data is generally perceived to be the most accurate of all the hydrologic data gathered.

Putting the past behind us, we can do a much better evaluation of rainfall distribution based on NOAA 14 data with current GIS technology and EXCEL spread sheets. The NOAA 14 rainfall data are available as GIS layers which opens up a vast array of possible applications in spatial analysis.

An attempt was made to see if the Type II and Type III would still be applicable with the new NOAA Atlas 14 data. Figure 3 was developed which considered ratios of all durations from 5 minutes to 12 hours which are imbedded in the 24-hour storm distributions derived from point-by-point GIS analysis and compared to the standard Type II and III distributions.

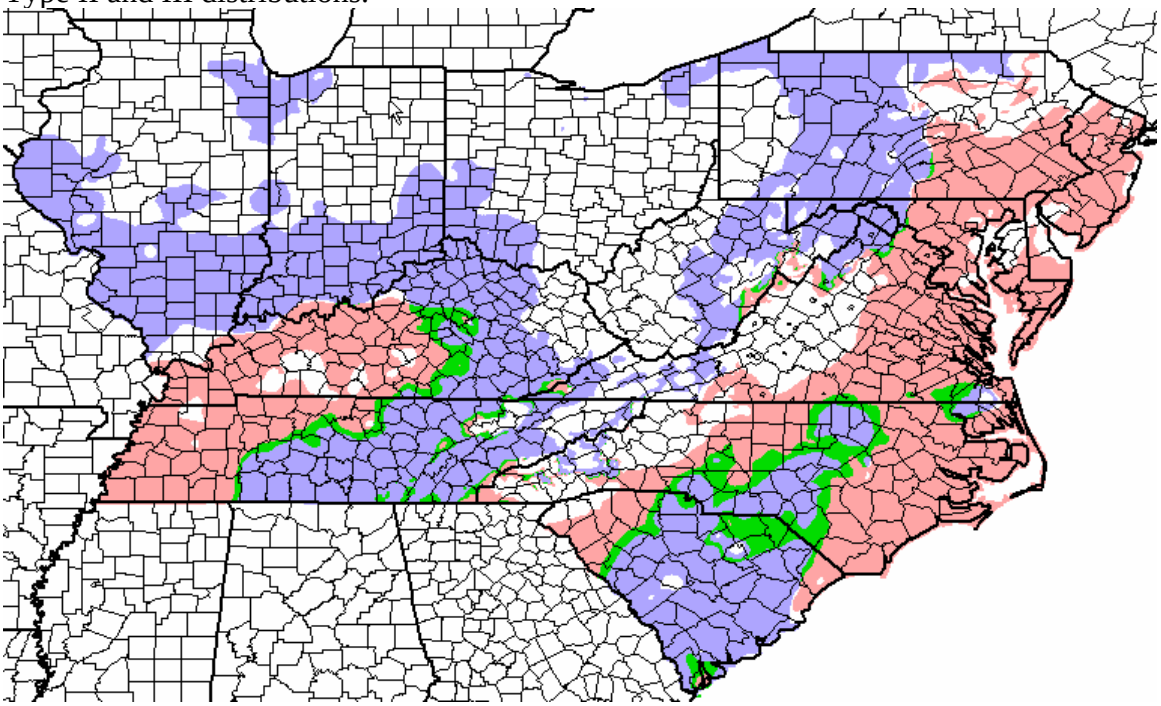

Figure 3. The standard NRC types II and III distributions compared to local distributions developed by point-by-point GIS analysis with NOAA Atlas 14 Volume 2 data. Pink indicates NRCS Type III within 5% and purple indicates NRCS Type II within 5%. Green indicates Either Type II or Type III could be applicable and white indicates neither type would apply.

The above figure shows results from the 25-year frequency. The pink color is where the Type III is reasonable within plus or minus 5% of the 24 hour rainfall (in other words, all ratios from 5 minutes to 12 hours were within 0.05 of the standard table ratio). The purple color is where the Type II is reasonable within plus or minus 5% of the 24 hour rainfall. The green is where either Type II or Type III would be applicable. The white area is where neither is reasonable. Notice the scattered areas of white (large blocks of Ohio, Indiana, Illinois, and West Virginia as well as numerous smaller areas throughout the 13 states) where a new distribution would need to be developed.

The whole purpose of a rainfall distribution is to insure that the maximum rainfall for all durations from 5 minutes to 24 hours are represented accurately. The peak discharge for a watershed is highly dependent on the rainfall during a duration equal to the watershed time of concentration. Nesting all durations into a single 24-hour distribution will allow one distribution to be used on all watersheds with a Tc less than 24 hours. Also, it allows for efficient interpolation of rainfall intensities for non-standard durations such as 45 minutes or 1.5 hours. Developing a generalized distribution for a geographic region of significant areal extent could involve errors of plus or minus 30 percent or more when

comparing the ratio of rainfall for a particular duration to the actual ratio at a location based on NOAA Atlas 14 data. Why allow this type of error when a distribution can be easily developed at any particular site ?

Using local NOAA Atlas 14 data to develop a local rainfall distribution

As mentioned earlier, maps with ratios of each shorter duration to the 24-hour duration were developed using GIS. These ratio maps are so variable that it does not appear feasible to develop rainfall distributions for significant regions. In the eastern, one or more locations were selected in each county to develop a site-specific distribution based on NOAA Atlas 14 data. For each selected location, the NOAA Atlas 14 data were retrieved as a text file. Maximized storm distributions were developed for each return period. WinTR-20 was run for each location to determine impacts on peak discharge of changing from the past rainfall and distribution to NOAA Atlas 14 data and its derived rainfall distribution. In the eastern states, TP-40 rainfalls with the appropriate distribution (Type II or Type III) were used.

The results using the data from the NOAA Atlas 14 Volume 2 were compared to those using TP-40 and the standard NRCS rainfall distributions. The generalized results for Maryland indicate peak discharges for western Maryland (Garrett, Allegany, and Washington counties) decrease when using NOAA 14 data. This decrease may be small or as much as 35% depending on return period and watershed size (as reflected by its time of concentration). For the rest of Maryland, the difference is between plus and minus 25 %. This difference varies by return period and size of the watershed (as reflected by its time of concentration).

Uses of NOAA 14 data in NRCS

There are two courses of action decided by NRCS.

1. At the most detailed level, in order to eliminate any error in rainfall distribution, the user can go to the NWS web site directly and download the site specific rainfall data. A computer program has been written which will take these data and develop site-specific rainfall tables for use in the WinTR-20 hydrologic model. In order to use this program, the user needs to go the NOAA Atlas 14 web site and download the rainfall frequency data for their site in a text file. Then upon opening WinTR-20, select **File** and **Import NOAA Atlas 14 Data**. This option will be included in the next release of WinTR-20. Each return period has its own distinct rainfall distribution. In this case there would be no regional rainfall distribution. Every site would be slightly different.

2. An approach for the eastern states which is more field-use friendly is the selection of a location in each county to represent its rainfall frequency data and derived rainfall tables. This data table will replace the current county rainfall table currently in WinTR-55 and Engineering Field Handbook Chapter 2 (EFH-2) which has only 24 hour rainfall values. The hydrologic models will be programmed to allow the user to select a state/county or division of county and then read the data and develop a distribution for each rainfall

frequency. This would make the rainfall distribution transparent to the user. In reality, each county would be a distribution region. Any error introduced in the rainfall distribution would be caused by variation within the county. If there is more variation within a county than is acceptable, the county will be divided into two or more parts.

Summary

Developing rainfall distributions from NOAA Atlas 14 data to replace the current Type II and Type III distributions are important to improve peak discharge estimates throughout the states covered by NOAA Atlas 14. There are two approaches considered which make the process more user-friendly to the field office yet allow flexibility for complex hydrologic studies and projects.