# Point and Spatial Precipitation Frequency Review Comments and Responses

## Ohio River Basin and Surrounding States

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**Introduction**

The Hydrometeorological Design Studies Center (HDSC) conducted a peer review of the point and spatially interpolated precipitation frequency estimates for the Ohio River Basin and Surrounding States during the period August 15, 2003 to September 14, 2003. This document presents a consolidation of all the review comments with HDSC's response. We have used the original wording of the comments to make sure the meaning of the comment/question was not misconstrued and so that individual reviewers can identify their comments. HDSC requested comments from nearly 200 individuals and we received comments from 27, some of whom represented the feedback from their staff. There were 82 individual inquiry comments submitted. After parsing all of the comments, we found 53 unique comments that required a response; they are included in this document.

The most reported issue pertained to the "islands" or "bull's eyes" on the 100-year maps. The response to these comments is provided in 5.1.

Similar issues/comments were grouped together and are accompanied by a single response. The comments and their respective responses have been divided into seven categories:

1. **Point estimates – are they representative?**
2. **Point estimates – how do they compare to current (e.g. TP-40) design thresholds?**
3. **Cartographic comments**
4. **General questions and comments**
5. **Are estimates and patterns reasonable when compared to your local or regional knowledge?**
6. **Are stations located correctly on the map?**
7. **Confidence limits and confidence intervals**
8. **Potentially bad data**

## 1 Point estimates – are they representative?

1.1 I was able to reproduce the numbers you had for Gibson City and Clinton for the 100-year, 24-hour storm. However, when I looked at the data for Farmer City it was marginal (lots of missing data - always a bad sign). The other nearby site that was abnormally low was Downs. I could only find about 3 years of record in my files. Could you check on the quality and quantity of the records for both Farmer City and Downs?

**Response**: The daily data record for Farmer City, IL (11-2993) is 7/1948 – 12/2000, 53 years of data. 30% of that data are missing. Thus, the annual maximum series used in the analysis has 39 years of data. It is missing maxima for the years 1952-1961, 1993-1995 and 1999. All other years had sufficient data to extract an annual maximum. Farmer City also has co-located hourly data. 24-hour precipitation frequency estimates are derived from daily data for co-located stations. In general, the mean annual maximum of Farmer City is consistent with nearby stations.

Downs, IL (11-2417) is an hourly-only station. Its period of record runs from 7/1948 – 4/1987, 40 years of data. 2% of that data are missing. The annual maximum series is missing only 1987, meaning that there were sufficient data in the other 39 years. The mean annual maximum of Downs does seem low compared to nearby stations. We will investigate this station further.

1.2 For the PFDS data for the individual stations that have continuously recorded data (Toledo Airport WSO, Detroit Metro WSO, Ft. Wayne WSO), the rainfall depth vs. duration curves appear to have "discontinuities" in their smoothness at durations of 60 minutes and around 24 hours. These are especially pronounced for the more extreme storm frequencies (which one would expect), but it's also noticeable for even the 2-year frequency curve. This phenomenon also occurs at the other major "recording" gages I checked (Akron WPCS, Cleveland WSFO). I realize that there may have been no attempt to "smooth" the results, but I feel this raises some questions that should be either addressed, or explained in the final report.

**Response**: You are correct the data has not been "smoothed" and represents the PF (precipitation frequency) estimates output by our software as apposed to values extracted from a grid of spatially interpolated PF estimates. When the final grids are created, the "discontinuities" you noted will be mitigated through the spatial interpolation procedure. Although the actual PF estimates govern the spatial patterns, the spatial interpolation process will adjust (slightly) the final PF estimates into gradual temporal distributions.

1.3 Looking at Lockport IL, near Joliet, it seems to be significantly lower than surrounding sites and I only have about five years of daily data for that site. I'd say toss it, unless you have access to a lot more data than I can find from Td-3200.

**Response**: Lockport, IL (11-5136) is an hourly-only station with a data record of 7/1948-12/1974. Even though 30% of the data are missing, there were sufficient data to extract annual maximums for 26 years of data. Only the data in year 1974 did not yield an annual maximum based on our criteria. It is not discordant within its daily region (region 54 with 26 stations) or within its hourly region (region 20 with 23 stations). Given the inconsistency of this station with its surrounding stations, we will take a closer look at this station and assess the appropriateness of removing it from the analysis.

1.4 A comment very similar to the above regards sites shown on the mapping where there are two or more gages with high rainfall and a gage or gages in between with lower frequency rainfall as proposed by NWS. For areas where the topography remains the same, it appears that the probabilities of an area receiving the larger frequency rainfall at the sites of proposed lower frequency rainfall would be the same as the higher rainfall stations. One typical example of many is shown at the Columbus and Crothersville rainfall stations in Indiana where the 24 hour 1% chance rainfall are given as 7.8 and 8.1 inches. A Seymour gage located between these two gages shows frequency rainfall of 6.9 inches with the map isohyets adjusted for these rainfall depths. There is absolutely no difference in the topography of these sites that could cause reduced rainfall at the Seymour site. It would appear that the Seymour location could expect a 1% chance rainfall depth of 7.8 to 8.1 inches as the Columbus and Crothersville sites would.

**Response**: A check of these stations, which all reside in the same L-moment region and have essentially the

same 24-hour mean of 3", suggest the data is accurate. The question then becomes, are the PF estimates at Seymore or Columbus and Crothersville more representative of this area? Perhaps the most accurate answer is a blend of all, which can be accomplished by integrating some kind of filtering (smoothing) of the final PF estimate grids. We are investigating the integration of some kind of filtering (smoothing) of the final PF estimate grids to mitigate the "high/low centers." (See also response to 5.1 for more details)

1.5 Some concerns I have with the station data in general and/or results of the point frequency information being represented on the mapped spatial analysis can best be addressed by looking at the precipitation frequency information shown for the station Stickney W. Side Treat (11-8278). This station is one that provides hourly data.

The 100 year, 60 minute analysis I read from the table provided for Stickney that the point value is 3.55 but the mapped analysis only depicts a level of 3.31-3.50. Why wasn't and small center representing the precipitation level of 3.51-3.70 indicated? Additionally, along the same lines, for the 100 year, 24 hours a value of 6.7 is plotted on the map but from what I can see is not at all analyzed for with some enclosed (deficit) or the same for the station immediately to the south (Chicago Roseland Pump) that indicates a value of 8.2 (maximum). If these highs and lows are not drawn for, than why draw for all the other station centers that exhibit highs/lows? From what you show for Stickney and Chicago Roseland Pump, the results only supports my earlier concern that additional smoothing should be taken into account to help eliminate or at least tone down the effect of all the high/low centers your currently indicate on the draft map analysis.

**Response**: In areas with a high density of stations, the resolution of the grids (30-seconds) can not depict all of the existing variability - particularly if more than one station resides in the same grid cell. In these cases, the spatial interpolation procedure is forced into smoothing the PF estimates. In areas with few stations, the spatial interpolation is not constrained by nearby stations and therefore develops an appropriate radius of influence around stations. We are investigating the integration of some kind of filtering (smoothing) of the final PF estimate grids to mitigate the "high/low centers." (See also response to 5.1 for more details)

1.6 I spent the majority of my time examining the station values listed for 100-year, 24-hours. In general, the station values computed appear to be reasonable. However, I did note that for Chicago-Midway (11-1577), that for return periods of 500 & 1000 years, the 24 hr values were greater than that indicated for 48 hours. Suggest that you review the station point tables for all locations to make sure that this doesn't occur.

**Response**: This was the result of a software bug that has now been fixed. Thank you for spotting it.

**2 Point estimates – how do they compare to current (e.g. TP-40) design thresholds?**

2.1 I did note that in the immediate Chicago area that site-specific station 2 year precipitation seemed pretty representative to what one might read using T.P. 40 information. However, at 100 year, the change indicated seems to be much larger, especially looking at the 100 year, 1 hour amounts, where the change is some 30 to 40 percent greater than what was determined for T.P. 40. I noticed that this didn't seem to present as much of a problem to me for a number of stations I looked at in West Virginia.

**Response**: We recognize the difference between the draft NOAA Atlas 14 results and those published in TP-40. For a number of reasons we expect differences, but most importantly we strongly believe the new estimates are more accurate than TP-40. Certainly the statistical estimation procedure (regional L-moments) and spatial interpolation schemes are much better than was available back in the 1960s for TP-40 and we also have additional data to work with.

2.2 The spatial pattern of rainfall in the HDSC Study is consistent with the spatial pattern in TP 40 (Southeastern Wisconsin Regional Planning Commission in conjunction with Camp Dresser & McKee, Inc. and the University of Wisconsin-Madison Department of Civil and Environmental Engineering published SEWRPC Technical Report No. 40, Rainfall Frequency in the Southeastern Wisconsin Region, April 2000). Do you plan to publish isohyetal maps in hard copy or just show the isohyetal maps on your web site? When will the spatial interpolation procedures be available for review? Under the study documented in TR No. 40, the 2-year 24-hour rainfall depth based on an annual series was determined to be 2.26 inches and the 100-year 24-

hour depth was determined to be 5.88 inches. Those depths compare well with the Ohio Basin Study depths for gauges within the Southeastern Wisconsin Region. The two-year depths for the individual Ohio Basin study gauges within the SE Wisconsin Region are within -4 to +16 % of the SEWRPC TR No. 40 depth, with most gauges being within +1 to +11% of the TR 40 depth. The 100-year depths for the individual gauges are within -16 to +12 % of the SEWRPC TR No. 40 depth, with most gauges being within -11 to +11% of the TR 40 depth.

**Response**: We will provide isohyetal maps that can be downloaded from our web site and printed. We do not plan to print and sell hard copies ourselves. The spatial interpolation procedure, which is based on the approach used to create the new National Climatic Data Center Climate Atlas maps, will be described in the final study documentation. We are pleased that the draft NOAA Atlas 14 precipitation frequency estimates compare favorably with those published in TR No. 40.

2.3 A marked low precipitation area in southern West Virginia and northeastern Tennessee (100yr 24hr) is shown on the study area maps. This area does not show up in TP40, which may have been wrong. The area seems fairly homogeneous. However, the results are much lower than TP40. A discussion explaining why this may or may not be accurate is requested.

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The range seems large with isohyetal amounts from 4.5 inches around the Tri-Cities area in northeast Tennessee to 13.5 inches around the Lake Toxaway, North Carolina area. The TP40 atlas ranges from 6 to 11+ inches in similar areas. A verification of those numbers would be recommended.

**Response**: There are an adequate number of stations in each of these areas to support the lower precipitation frequency estimates. Our high-resolution spatial interpolation procedure is capturing the rain-shadow effect of the Appalachian Mountains. This level of detail was not possible when TP-40 was developed.

2.4 How do all these return period's affect the matching with New England in either TP-40 or Cornell's "Atlas of Extreme Precipitation Events'?

**Response**: We have not tried to match previous studies in developing the new updates. If we receive funding to update NWS estimates in the New England area we would expect a pretty good match at the edges because we have deliberately made our calculations well beyond the State lines to ensure continuity.

I note some changes in the new values relative to TP40 over NC, where I focused my review since I'm quite familiar with that state. For instance, the 2-year return values for 24 hour durations are quite similar to TP40, but differences become quite evident at the 100-year return interval. For example, at Neuse 2 NE near Raleigh, the 2-yr/24hr value is now 3.20 inches, while the TP40 value was 3.60 inches. The 100yr/24hr value at Neuse is now 7.49 inches, which also is less than the TP40 map value of around 8 inches. On the coast, the Wilmington WSO Airport 2yr/24hr value is now 4.38 inches, while TP40 showed around 4.5 inches—very little change. However, at 100yr/24hr, Wilmington is now 13.30 inches, which is much larger than the old TP40 value of around 10.0 inches—3.3 inches, or 33% more. This is substantial. A similar increase is observed at Southport, immediately south of Wilmington and also on the coast, which has a new 100yr/24hr value of 13.75 inches compared to approximately 10.5 inches in TP40. In the wettest part of the mountains at Highlands (3800 feet elevation) the new 2yr/24hr value is now 5.02 inches, which is almost exactly the same (5 inches) as in TP40. The 100yr/24hr value at Highlands is now 11.20 inches, which is just slightly larger than the 10.8 inches that is roughly determined from the TP40 map.

In short, inland areas show relatively small changes, if any, from TP40, although the Piedmont location selected showed new values were slightly less than the older ones. In contrast, the coastal locations saw substantial upward change in the longer return interval values (100 years or so), but no change at shorter return intervals. Thus, as the return interval increases the coastal values increase and the gradient from coast to Piedmont and mountains also increases in the new calculations, relative to TP40.

This would seem to be appropriate just from these quick comparisons, and based on personal experience and

knowledge in the area. The coastal increases are no doubt due to a greater frequency of tropical storms, and very heavy rain from some extreme storms and hurricanes in recent years. Are these recent storms and years included in these analyses (such as Hurricane Floyd in 1999)? If so, then this certainly makes sense.

**Response**: Our database includes data through and including December 2000, so yes, the recent storms you referred to are included.

2.5 As you get to the middle and southern parts of the Pittsburgh District, the new rainfall amounts were almost one inch less than the old values for the 24hr-100yr. This occurred from Morgantown, WV to the Tygart River basin. In Pittsburgh, the 24-hour 100yr rainfall decreased by almost one half inch. These values need to be double checked. It is suggested that NWS take a good hard look at the rainfall data, including Pittsburgh and south of Pittsburgh, to make sure it is not skewed by extremely low rainfall periods (droughts) which would tend to reduce the rainfall frequency values.

**Response**: After double checking the precipitation frequency estimates at Pittsburgh and the vicinity, nothing unusual or suspicious was found. We have not tried to "match" the result of previous studies; rather we have taken advantage of vastly more data, and improved statistical and spatial interpolation techniques to derive new estimates. We have noticed that the deviations from TP40 are most pronounced in areas of significant terrain. We are not surprised at this result because it is in these areas in particular that the new techniques combined with increased data density are most likely to show differences.

2.6 Based upon a recent telephone conversation with NWS, it is recognized that the large rainfall in central Indiana this (September 1, 2003) Labor Day weekend that caused flooding of many streams will not be included in the study at this time due to time constraints. This rainfall varied from about 7 to 10 inches in a 24 hour time period with Indianapolis receiving about 7.3 inches at the NWS gage for this 24 hour duration. We request that frequency rainfall data for central Indiana be revised at a later date and be included as an addendum to this study when time permits. As now shown, the 1% chance rainfall is about 5.7 to 5.9 inches for the Indianapolis area

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Kokomo (in north-central Indiana) reportedly received 9 to 11 inches of rain in places during a 24-hour period during the July 4th weekend of 2003. The draft study gave 9.32" for the 1000-year 24-hour estimate (no 90% Confidence Limits). For the 7-day period of July 5-11, the official total was 11.01". The draft study gave 11.27" for the 1000-year 7-day estimate (the 90% Confidence Limits were 11.96" and 10.41") and 10.49" for the 500-year 24-hour estimate (90% Confidence Limits of 11.14" and 9.73").

Indianapolis Airport (central Indiana) officially received 7.20" during a 24-hour period that included most of September 1, 2003 (Labor Day). The draft study gave 7.65" for the 1000-year 24-hour estimate (90% Confidence Limits of 8.10" and 6.92"), and 7.11" for the 500-year 24-hour estimate (90% Confidence Limits of 7.51" and 6.48").

Can you evaluate whether these large events would alter (1) the statistical distribution/curve-fitting, and (2) draft precipitation estimates to a significant extent?

**Response**: The July 2003 rainfall event and September 1, 2003 rainfall event in the Indianapolis, IN area were significant events. However, we face the moving train problem and have fixed December 2000 as the end of the period of record to be included in this study. As we increase the period of record, the influence of extreme events is reduced. The statistical technique we are using is also more robust than previous techniques. The range of the confidence intervals we are providing provides some indication of the degree of estimate variability. While 2003 events are not included in this study, a quick analysis of results after adding those events to the annual maximum series for Kokomo, IN (12-4662) and Indianapolis Airport (12-4259) did not change the best-fitting distribution for the affected regions (daily regions 52 and 45, respectively). The 1000-year precipitation frequency estimates for the 24-hour and 7-day durations changed by 3% or less. We also agree that if funding is provided we should update the estimates more frequently than they have been in the past. Such an update would not only include just the extreme events, but all the events that have occurred since the last update to ensure the statistics are not biased. We would hope updates are made about every 10 years in future.

2.7 My main concern is that we are now going to use rainfall frequency values which are less than the old TP-40 in our designs. This is OK if it is based on the new rainfall data and there are no errors in the data. The original TP-40 was published in 1960 and we now have more rainfall data (about 40 years) to use in the frequency analysis.

**Response**: We strongly believe the new estimates are more accurate than TP-40. The statistical procedure (Regional L-moments) and spatial interpolation schemes are much better than those available back in the 1960s for TP-40 and as you mention we have additional data to work with.

2.8 When we receive a request for rainfall frequency, I typically refer to Bulletin 71 from the Midwestern Climate Center (Rainfall Frequency Atlas of the Midwest). Between Bulletin 71 and the current precip frequency review, there seems to be pretty significant differences. As a general rule - the 100 year events for both hourly and daily rainfall is lower than that of the MCC study.

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The draft precipitation frequency estimates for the 100-year 24-hour storms for selected stations in northern, central, and southern Indiana fell mostly within the range estimated from TP-40 and Bulletin 71 by Huff and Angel. However, the draft estimate for LaPorte was substantially higher than the estimate from TP-40 and Bulletin 71.

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We printed out the station data for about 20 rainfall stations across the state and compared the 100-year 24-hour rainfall from the rainfall stations to spatial patterns on the two maps provided on the HSDC web site: the 100-year 24-hour rainfall isohyetal map and the map showing the percent difference with TP 40. In extreme western Maryland (e.g., Garrett County), there is significant variation from station to station and most stations show 100-year 24-hour rainfalls in excess of 6.0 inches. This is greater than TP 40 since that report shows less than 6.0 inches in Garrett County for the 100-year 24-hour rainfall. The percent difference map shows percentages of 0 to –10 percent but several stations that we examined indicated that HDSC values were increased over TP 40. It appears that the HDSC values are less than TP 40 only in Allegany and Washington Counties.

**Response**: 64.1% by area of the Ohio River Basin & Surrounding States region is within +/- 10% of TP-40 (for 100-year 24-hour), which is remarkable considering all of technological improvements and the vastly increased amount of data to work with. This gives us confidence we are in fact homing in on the "real" point probabilities.

## 3 Cartographic comments

3.1 The spatial maps also look reasonable, although a bit hard to read on the computer or printed out on 8.5 x 11 inch paper. I would like to note two things with the presentation of the data.

- On the "Draft Mean Annual Maximum 60-Minute Precipitation" legend some color blocks have ranges like 0.9-0.9 and others have single values like 1.3 assigned. This is confusing.
- I am somewhat color blind and found the colors hard to distinguish on the maps. Also when I printed the maps the colors on the maps were slightly different that the corresponding color in the blocks in the legend for the same range. I verified this with another person with normal color vision.

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Although I must admit town labels were a bit small, and color contours were a bit tough to distinguish one from another.

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The numbers were too small to read on some of the maps.

**Response**: We will fix the range and font size issues for the final maps. The color issues you raise are ones we recognize and have had problems resolving with the mapping software we have. We plan to fix at least the colors in the legend block in time for the final maps.

3.2 The USACE Nashville District states that it is always not apparent that the lines drawn on the maps are isolines. For example, looking at the draft mean annual maximum 24 hour precipitation, the isolines are not consistent when you start looking at the individual gage station values.

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It takes a long time to load the map, and the process will restart if panning around. We ended up selecting a relatively small area to save time. It appears that in a number of cases isolines had to be adjusted considerably to take site estimates (?) into account; an effect we noticed at Brazil, Spencer, Bloomington, Nashville, Crothersville and Lockport Lock.

What is slightly more disconcerting though is that while the value at the gauge reads '8.1' (for Crothersville) the value at the isoline reads '80'. According to the legend isolines are annotated in 10th of inches, but the gauge values in inches, which appears inconsistent.

**Response**: The spatial interpolation process used to create the draft mean annual maximum 24-hour precipitation maps performs some minor smoothing, therefore there are cases where the labeled mean value (at an observing site) is slightly different than what is indicated by the nearest "isoline." The final maps will not display gauge values, thus eliminating the inconsistence you raise.

3.3 The USACE Nashville District states the need for consistency with regards to the legends on the maps. Every category in the legend should be a range of frequency precipitation values and the upper bound of one range should be equal to the lower bound of the next range (ie 1.1-1.2, 1.2-1.3, 1.3-1.4).

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Precipitation legend: In viewing the entire ORB region (100 year, 24 hour) I was at first taken back by the seemingly detail provided in some states compared to others until I noticed that the precipitation scale provided used different increments of precipitation for each shaded division depending on the general total magnitude of precipitation. Would have preferred that the interval shown would remain constant. Use quarter, half, or full inch so that a better relationship of precipitation frequency values from one state to the other could have been easily made.

**Response**: We have deliberately chosen not to do this because it would produce over-crowding of contours in high-gradient areas. We are using a sliding scale so that the density of contour lines is consistent across each map. If more detail is needed than provided by the existing contours, users will be able to download the underlying grids from our web site and import them into a Geographic Information System (GIS) for finer contouring.

3.4 Additionally, showing the last interval in white (14.01-15.00) leaves one to think that a lot of precipitation is falling over reservoir, estuaries, lakes and ocean surfaces.

**Response**: To avoid this impression, the final maps will contain contour lines over water bodies.

## 4 General questions and comments

4.1 On another matter, looking at the DDF curves we noticed that the curves for the 6 and the 12 hour duration will cross, although admittedly for very high return periods. Did this problem occur for shorter return

frequencies as well (say 50 or 100 years) and if yes, how did you deal with it? (We are interested in this for our own work.)

**Response**: The precipitation frequency calculation is performed separately for each duration. It is natural, as you have pointed out, for errors in the estimating process to produce such internal inconsistencies. We have developed procedures for identifying and eliminating these inconsistencies. The procedures will be described in our final documentation.

4.2 Seasonality did not work for this particular site, although we have seen it work before, but we assume this is not part of what you are reviewing at the moment.

**Response**: The reviewer is referring to the PFDS button which (in the final version) will provide access to information on the seasonal distribution of heavy precipitation. That button was not functional during the peer review.

4.3 Confidence limits are given for one significance level only (90%), we would have wished for more flexibility here as well. These tables cannot be exported as a text version. This would be useful if one wanted to add the confidence limits to a graph showing the IDF curve for a certain duration.

**Response**: Adding an export option to the confidence limit data is something we will consider.

4.4 Another point where there could be a bit more flexibility is for 'non-standard' estimates, e.g. estimates for the say 3 day duration with a return frequency of 20 years will have to be derived by users 'manually'. We assume there will be well defined procedures, to ensure estimates are derived in a unique way?

**Response**: We have added additional grid lines (both in the duration and frequency dimensions) to the output graphs to accommodate interpolation from the graphs.

4.5 We were able to export the data to a text file, which turned out to be a comma-separated file with a header (containing station details) and a date stamp at the end. We would have liked to find the gauge name and number in the header. We do understand that, since these tables will soon be available at any given location, this might be the more universal solution, but users might want to add there own names?

**Response**: We have already modified the PFDS to include the station name and ID in the text table for observing locations.

4.6 Is there documentation on your web site of how you chose the frequency distribution, the homogeneity tests and other aspects of the analysis? In other words, a report that describes the analysis techniques.

**Response**: That information will be provided as part of the final documentation and will be available on our web site.

4.7 The web tools are great but not enough to get the overall picture of the data quality. It would nice to see more info in this regard. Graphs showing year-by-year availability for each site would be nice, for example.

**Response**: We have provided the confidence intervals because they provide a fair estimate of the quality of the estimates, better than merely the period of record. As part of the final documentation, we will post the time series that were derived and used in the statistical calculations.

4.8 One thing that has bothered me, probably the most, about the Ohio River study is the issue of climate change and its ramifications on rainfall frequency estimates - especially at the longer return periods. Picking on my favorite station, Aurora IL, the new study has the 100-year, 24-hour value at 8.07" and the 1000-year, 24-hour value at 14.71". However, Aurora has seen a remarkable increase in precipitation over time.

First of all, my estimates based on records from 1887-2003 and L-moments and GEV for the single site:

100-year, 24-hour value of 10.26"
1000-year, 24-hour value of 22.77"

If you used the 1948-2003 record, you get:
100-year, 24-hour value of 14.81"
1000-year, 24-hour value of 38.73"

If you used the 1887-1948 record, you get:
100-year, 24-hour value of 5.05"
1000-year, 24-hour value of 5.63"

As you can see, this gives you huge differences depending on what part of the record you use when climate change is present. This has several ramifications. First of all, you have to be careful about mixing sites with different periods of record. Second, the confidence intervals in the tables do not reflect the real uncertainty in the data and in the climate. Finally, it means the 1000-year estimates are probably worthless. In addition, the RF study seems to be going against the grain by ignoring the body of research on historical changes in precipitation and possible future changes in precipitation, both of which argue against putting out an estimate of the 1000-year event.

**Response**: Our trend analysis utilized data through 1998. The Chicago area, including the Aurora (11-0338), falls within a narrow east-west band across the entire study area of statistically significant positive upward trend. (Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.) The spatial distribution of trends and shifts that emerged and the lack of reliable forecasts of climate with sufficient spatial and temporal resolution forced us to conclude that we could do no better than to assume that the entire period of record was valid for use in this study. We agree that the semantics of return period are confusing and note that a 1,000 year return period does not mean that we expect the climate to be invariant for the next 1,000 years. We hope the confidence intervals supplied with the estimates will give users a better feel for the value of those estimates.

4.9 Did I miss it or you did not have the method of your analysis on the page somewhere?

**Response**: You're right, the methodology was not provided on the review web pages. In general we have followed the methodology described in Hosking, J. R. M., and Wallis, J. R. (1997) Regional frequency analysis, an approach based on L-moments. Cambridge University Press, Cambridge. A more complete description of the methodology will be provided as part of the final documentation.

4.10 Will values for less than 24 hour duration be available for stations without hourly data? I see that they presently are not available.

**Response**: Yes, values for less than the 24 hour duration will be available for stations without hourly data. In fact, the final product will include estimates for durations from 5 minutes through 60 days, at a spatial resolution of 30 arc-seconds, across the entire domain. Such values were recently published for the semiarid southwest and are available on our web site.

4.11 I'm also wondering how the maps based on hourly data are melded into the maps based on daily data? It seems like you could have real continuity problems as you move from < 24 hours to >= 24 hours. Personally, I don't like the hourly data for reasons stated earlier (shorter record, fewer sites, more missing data) so I give more credit to the patterns found in the maps based on the daily data.

**Response**: We certainly recognize this challenge. The procedures we are using to resolve this issue will be discussed as part of the final documentation.

4.12 The generalized PMP (HMR-51) maps are stippled in the Appalachian Mountains extending from Georgia to Maine. These stippling areas define generalized PMP estimates that might be deficient because detailed terrain effects have not been evaluated. Do the new point rainfall frequency maps consider the terrain effects?

The NWS Hydrometeorological Branch has been involved in detailed generalized studies covering the stippled regions. This has been ongoing for a number of years. This information needs to be included in the results of the study.

**Response**: The updated precipitation frequency estimates are updates to precipitation frequency estimates only and not to probable maximum precipitation estimates or HMR-51. In updating the precipitation frequency estimates we considered terrain effects when developing the homogeneous regions used in the statistical approach and when spatially interpolating the estimates derived at observing locations. The procedures we are using will be discussed in the final documentation.

4.13 The PFDS is very well put together and is easy to follow the maps and the graphics. However, It does appear to run very slow and wonders if this will be true for all users.

**Response**: The PFDS is actually significantly faster than some of our earlier iterations. The speed at which the state-specific pages load is based on Internet traffic and your computer speed. The speed of formation of the output page is related to the PFDS software and hardware. We are keeping an eye on PFDS performance and hope to ensure it is reasonable, particularly as the site becomes more popular.

4.14 The rainfall from this study will be used in hydrologic modeling for the determination of flows for drainage basins of all sizes some of which could be quite large. For these drainage basins, based upon the proposed mapping, rainfall depths could vary greatly within a particular study area. Decisions will need to be made on how to include this rainfall in the modeling. Should the rainfall be weighted along the basin, or maximum precipitation only be included? A general consensus should be reached on this topic with input from NWS included.

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A method needs to be found for using point rainfall to generate the proper runoff that accounts for duration and season to develop good hypothetical hydrographs for study purposes. The current practice of eliminating rainfall and stream gages continues to make the calibration process very difficult.

**Response**: While these are important issues in hydrologic modeling, it is not within the scope of this project to make recommendations on methods of hydrologic modeling beyond the interpretation of the results themselves. The NWS is currently examining the areal reduction factor curves published in TP-40 and expects to publish the results in the near future. However, the interpretation of the curves is not likely to change from that published in TP-40. A more detailed discussion of this interpretation is included in NOAA Atlas 2 and this discussion is likely to make its way into the discussion to be published with the results of this study.

4.15 It was noticed in the point estimates (PFDS) presentations that an area computation feature will be added. Nice feature. This page should really emphasize that these are "point" values.

**Response**: The output page currently reads “Site-specific Estimates,” but based on your comment we may instead say “Site-specific Point Estimates” or simply “Point Estimates.”

4.16 Northeast of the St. Louis area are shown two stations in Illinois (Carlinville:11-1280 & Carlinville 2: 11-1248) that have the same precipitation frequency vales given in the point estimate PF tables. Was the data forced to present similar results? Even though the stations are very close to each other, I wouldn't have expected exactly the same results.

**Response**: Carlinville, IL (11-1280) is a daily-only station, meaning that only estimates for 24-hour and longer were derived from this data. Carlinville 2, IL (11-1248) is an hourly-only station, meaning that only estimates for 48-hour and shorter were derived from this data. The PFDS has grid cells of, roughly, 3-miles by 3-miles and so apparently put both of these stations in the same grid cell. This caused them to have exactly the same data. The final deliverable grids will have a resolution of 30-seconds, roughly a mile. The 3-mile by 3-mile grid cell was only used for the purposes of the point estimate review. However, the close

proximity suggests that these two stations could be joined as a co-located pair of an hourly and daily station. We will investigate this possibility. Thank you for pointing this out to us.

4.17 Looking at the point estimate upper and lower bounds data, many of the stations have a -9.99 indicated for all return periods for 60 minutes. Not sure why this should happen.

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We checked the 24 hr/ 100 year estimate at Crothersville (8.1 inches) and noticed that for the 60 minute duration no upper/ lower limit for the confidence interval was given (-9.99), although there must have been data available to estimate the precipitation frequency?

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The Stickney W. Side Treat, IL (11-8278) station exhibits -9.99's indicated for all return periods for 60 minutes. Not sure why this should happen.

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I found that the confidence limit precipitation values for Wilmington NC WSO were missing for the 60 minute column, but were available for all other durations.

**Response**: A software glitch prevented some of the 60-minute upper and lower PF estimates from appearing. This will be resolved before the final estimates are released.

4.18 I was curious regarding the time of records of some stations used. In the documentation, I couldn't find an explanation regarding 'only data since 1950 was used'. I'm curious if stations which closed more than 20 years ago were used along with stations that have only been open for the past 20 years(?). It would be helpful to include this information in the final report that we would eventually use. It would also be great to have more detail on the statistical analysis (and perhaps an example with comparisons with other methods).

**Response**: The time series we derived and used will be posted on our web site as part of the final documentation. We are utilizing all available digitized data, including data collected in the late 1800's. A station is eligible to be used in our computations if it has 30 years of usable daily data or 20 years of useable hourly data, regardless of when the data was collected. A complete station list, which will include begin and end dates, will be provided. The methodology we used will be described in the final documentation. (Also see response to 4.7)

4.19 Edgerton, OH - only has 28 years of record. I was thinking the minimum period of record for use with the 24 hour rainfall was 30 years.

**Response**: Edgerton, OH (33-2512) is actually an hourly station that has been used in the 24-hour analysis. The criterion for hourly stations is that they must have at least 20 years of data. With 28 years of data, Edgerton meets this criterion.

4.20 We are interested in rainfall hyetographs that are needed for watershed modeling. We are aware of the temporal distributions for the Ohio River Basin that are documented in a paper proposed for the 2004 Transportation Research Board (TRB) Conference in Washington, DC. This paper includes graphs that show the 10th to the 90th percentile distribution for storms that occurred primarily in 1st, 2nd, 3rd, and 4th quartile of the total storm event. Is that the form that National Weather Service (NWS) plans to publish the results or will NWS make more detailed recommendations as to which distribution to use for preparing rainfall hyetographs?

**Response**: Temporal distributions of heavy rainfall in the Ohio River basin and surrounding states project will be presented in the form submitted to the 2004 TRB Conference. The methodology largely follows that of the Illinois State Water Survey (Huff, 1990) except for a significant difference in the definition of

duration. The temporal distributions will be expressed in probabilistic terms as cumulative percentages of precipitation and duration at various percentiles. The data will also be subdivided into quartiles based on when in the distribution the most precipitation occurred in order to provide more specific information on the varying distributions that were observed. It is not within the scope of this project to make recommendations on how to use these estimates of temporal distribution beyond the interpretation of the results themselves. These temporal distributions will not describe a single hyetograph. Rather we expect that modelers will be able to use the information to prepare an ensemble of possible scenarios from which they can extract most likely estimates.

Huff, F. A., 1990: time Distributions of Heavy Rainstorms in Illinois. Illinois State Water Survey, Champaign, 173, 17pp.

4.21 As described in your quarterly progress reports, new research is underway to develop depth area reduction factors for the Ohio River Basin. We believe this research work is important to either update or validate the depth area reduction factors in TP 40. When will this work be completed and will NWS request another review at that time?

**Response**: The NWS hopes to complete its Areal Reduction Factor (ARF) analysis for the United States by the end of calendar year 2003. Tests will be performed in order to determine if a single set of ARF curves for the entire country is valid or if a set of regional curves may need to be developed. We will carefully review the results in order to determine what additional work, if any, needs to be done.

4.22 It would be informative to show the frequency distribution used [in Maryland], such as the Generalized Extreme Value (GEV), and the length of record under the table showing the precipitation frequency estimates. The length of record would provide some justification for the variation in upper and lower 90% bounds among various stations.

**Response**: Information such as the frequency distributions used and the length of record will be included in the final documentation. The specific distribution can be different depending on both duration and location. Maryland stations are included in 7 of the different regions used in our regional analysis of the Ohio River Basin and Surrounding States. The following table provides current draft distributions being used over Maryland summarized in general geographic areas. These distributions may change prior to publication. Please note that as a result of the spatial interpolation and internal consistency adjustments within and among estimates at different frequencies and durations, the final estimates are not necessarily directly derivable from a distribution equation.

| Area | daily (24hr-60d) | hourly (60min-48hr) |
|---|---|---|
| Eastern MD | GEV | GEV |
| Northeast MD | GEV | GEV |
| Central MD | GEV | GEV |
| Western MD | GLO | GEV |

where : GEV is Generalized Extreme Value, GLO is Generalized Logistic

4.23 Once the spatial interpolation procedures are available, does NWS plan for a subsequent review?

**Response**: No. The spatial interpolation procedure, which is based on the approached used for derivation of the new NCDC Climate Atlas maps, has already undergone an internal review. (See 12th Progress Report for more details on the Cascade Residual Add-Back (CRAB) grid derivation procedure at http://www.nws.noaa.gov/oh/hdsc/current-projects/ORBPR12.pdf)

**5 Are estimates and patterns reasonable when compared to your local or regional knowledge?**

5.1 As I have stated earlier, the mapped depiction of the many small high and low precipitation is not warranted in my opinion, especially for longer return periods and in consideration that the results are to be used for water control structure design in most cases. I strongly support the elimination of all single station/point high and low centers as well as a general smoothing of other intermediate isolines. The current draft analysis

portrays an accuracy that I don't believe is really obtainable. would be interested in seeing a mapped analysis of 100 year, 24 hour precipitation for the state of Illinois that deleted the most recent 10 - 20 years of data. Would the same centers show up at the same locations or would there be dramatic shifts?

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Huntsville at 4.4 inches seems relatively high with 'bull's-eye' contouring surrounding the Huntsville station. A verification of those numbers would be recommended.

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On the spatial review we had picked one map only – Indiana, 100 year 24 hour precipitation.
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The lack of temporal consistency shows up as conspicuous bull's-eyes all over the maps.

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There are quite a few bulls eyes on the 100 year 60 minute and 24 hour data maps for Northwest Indiana and Western Michigan.

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Looking at the map for the 100-year, 60-minute, it really brings back the memories and frustration we had with the hourly data. The three main things against the hourly record are the shorter period of record, the much poorer quality of the data, and its sparseness. Looking at just IL, I can see bulls-eyes at Moline, Rockford, and Farmer City. The one at Belleville may very well be real and reflect the urban influence of St Louis.

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Regarding the 100-year 24-hour precipitation map for Ohio, I question the inclusion of rainfall contours forming small "islands" around certain rain gages (e.g. Fremont water works, Vickery, Galion water works). I realize that these contours may have been "automatically" computer-generated, but the final products (I believe) should be "smoothed" using some judgment. In contrast, the Toledo Express WSO gage, which indicates a value of 4.6" of rain, does not receive a contour "island". I am unsure I disagree about that, however; I have personally experienced at least one extreme storm of over 6" in a few hours in West Toledo, while the Airport gage reported 0.25" for that day. There is a commonly held belief in the Toledo area that storms tend to track north or south of Toledo, perhaps due to some effect of Lake Erie, but I have no hard data to back up that contention.

---

I have not had time to examine the gridded coverages, but I've heard others mention they were concerned about the "bull's-eyes" they see, especially noticeable for shorter durations (say, 60 min. or so). I would guess this is because there are fewer numbers of short interval reporting stations? If so, perhaps some way could be developed to insure short duration maps have the same essential smoothness as, say, 24 hour or 7 day maps. Over most of the flatter Midwest, I can't think why there should be any proclivity toward greater unevenness in the look of the map as one goes toward shorter durations, but perhaps I'm not thinking of all possible reasons.

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I am assuming that this is gage only data. I would like to see radar estimates included in these plots. While the radar estimates would not be useful from a point data sense, it would help in painting the generalities associated with each incremental amount, which leads me to my next comment. I am troubled by the

blotchiness of the maps. Having a small circle representing higher or lower amounts within broad region of a certain incremental amount does not appear representative, unless there is an orographic effect. Can these areas be smoothed?

---

Huntington District voices a similar concern as previous comments in that the new maps have a number of defined areas with rainfall amounts that seem to disrupt the isohyetal patterns. Evidently, the historical record supports having these isolated rainfall amount changes that could increase or decrease the hydrologic/hydraulic requirements on small localized projects in the same general area.

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Would like to see more continuous isolines without the maps "so broken up".

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The maps are consistent except for some "bulls eye" spots in Johnstown, Pa, Bradford, Pa, and Confluence, Pa that need to be looked into.

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I have serious concerns about "bulls eyes" in the maps. The peak at Farmer City, IL 100-yr 60-min precipitation does not make sense. This tells me that 30 miles in all directions this event would produce 1 inch less rainfall. There is nothing in the terrain to explain why such a radical aerial change in climate. I thought the initial concerns of the NWS about the Illinois Water Survey reports were the closed circles (bulls eyes), which NWS said should not occur in that area. This feature is occurring in many other areas of homogeneous terrain. In east central Ohio, the difference between Dillon Dam and Mohawk Dam is dramatic. I know of no features including terrain that can cause such a rapid change in precipitation over small distances. It appears that there is a basic problem with regionalizing the statistics.

---

The maps provided us show large pockets, or bulls eyes, of large frequency rainfall at many rainfall gages surrounded by areas of lower rainfall where there are no gages. For areas where the topography is relatively constant and the same climatological results would be expected, it would make more sense to show the higher frequency rainfall as continuous. For instance the 24 hour 1% chance (100-year) rainfall maps for the Rockville and Greencastle gages in Indiana show 7.3 and 7.6 inches of rainfall. However, the areas between these two gages where there are no additional gages show rainfall depths of 6.5 to 7.0 inches. It appears the rainfall within this reach should be in the 7.3 to 7.6 inch range. Many other examples with this type feature exist within the Louisville District boundaries.

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Bottom line...our TP-40 and Hydro-35 data needs updated and probably increased. With the 60 minute - 100 year frequency data that has been included from this current analysis, there are too many increments. In the June 1977 Hydro-35, the state of Arkansas has a 3.5 inch increment in the north and a 3.75 inch increment across the center. There is a 4 inch amount just over into north La. In the map that was included in this round, there is everything from 2.75 to 4 inches. Only a small portion of the map, mainly Little Rock Adams Field airport, has a 4 inch value. That is probably one event, a hell of a storm that happened a couple of years ago. These are not rare and there are numerous events such as these that occur over the state, just not over our buckets. Instead of relying on data with a point only assumption, I believe that weight should be given to applying these extreme events at one location over a broader area, not just a small circle around the site.

---

I concentrated mainly on reviewing 100 year, 24 hour analysis for the states of Illinois & West Virginia. Looking at the analysis provided I do question the reality of the numerous small, single station based, high and low centers that show up. For example, in central Illinois northwest of the St. Louis area, I would not draw for the three detached centers analyzed around the towns of Hillsboro 2 SSW, Pana, and Taylorville. Likewise, some 50 miles south of Hillsboro 2 SSW, one comes upon the stations Carlyle Reservoir and Centralia 2 SW both providing a 100 year, 24 hour value of 7.2 inches. I see no reason that Centralia 2 SW has a small encompassing isoline of 7.0 drawn around it whereas Carlyle Reservoir does not. I strongly believe the 7.0 isoline should be deleted surrounding Centralia 2 SW. There are many of these single station analyses (both high/low centers) that I believe should be eliminated. Additionally, I noticed not in Illinois but in West Virginia and other states that there are a number of very small centers that are depicted, not encompassing a station location, that are drawn. I think the largest/smallest encompassing isohyet should be deleted. Examples are the 4.4 enclosed isolines drawn just NW and SW of Athens Concord College in West Virginia or the 6.5 enclosed isohyet located just north of Willisburg 4 N in north central Kentucky for the 100 year, 24 hour mapped analysis. I see some support if topography is involved but if orographic effects are minimal, than I would not indicate such isolated centers.

---

We compared the new contoured analyses for the Ohio Basin Rainfall Frequency Study for southern Wisconsin against the graphs from Huff and Angel (1992) from the Midwestern Regional Climate Center. Some bull's-eyes appear in the newer charts across Southern Wisconsin. While the origins of these bull's-eyes may be due as she said to the peculiarities of the individual stations and their spacing, some of the problem may also be associated with southern Wisconsin being close to the edge of the analyses. If the analyses were centered over the Upper Mississippi Valley and western Great Lakes, then these would be more of an issue.

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Although MDOT's (Michigan Dept. of Transportation) regional approach may have tended to average the estimates too much, I believe that it did a better job of accounting for sampling variability at the gage locations than your methodology. Given the lack of orographic effects in lower Michigan, the "bulls-eyes" (such as Kent City for 60-min and 24-hr and Burnside for 24-hr) do not seem realistic. I believe these could be traced back to one extreme event that has an equally likely chance of occurring at other nearby locations.

---

We question the spatial variability of the precipitation depths over relatively small geographic areas as shown on the Ohio Basin study maps. We believe it is unlikely that the "islands" of relatively higher or lower depths represent true variations in spatial precipitation frequency depths. We do not think that there is a valid climatological reason for such variation.

**Response**: We are in the process of evaluating several methods to mitigate the "bull's eyes." Simply filtering (smoothing) the precipitation frequency grids will be a last resort solution since it will disrupt spatial detail where it is appropriate (e.g. in complex terrain).

5.2 Just as bad, if not worse, is the lack of spatial detail in the 60-minute map. The features in southern Illinois and northeast Illinois (around Chicago) have pretty much disappeared. That doesn't seem right since the same processes that drive the 24-hour pattern will probably drive the 60-minute pattern. BTW, the spot checks I made with our Bulletin 70 and my own calculations using different distributions and fitting techniques produces values that are comparable with what I see on the 100-yr, 24-hour map (given the level of uncertainty).

**Response**: The spatial patterns in/around Illinois have been among the most challenging of this project. Based on results for the entire Ohio project area, we made the conscious decision to regionalize the 24-hour duration and apply those regions to the longer durations and to regionalize the 60-minute duration for the

shorter durations. We will carefully examine the results in/around Chicago, based on your comments. We regard corresponding with you during our investigation critical to obtaining the best results possible.

5.3 Western Kentucky, around Dyer, same story - area of relatively high values at 24-hours and a local minima at the 60-minute scale looks suspicious. Same for western Ohio around Greenville and northeast Ohio, along Erie.

**Response**: Dyer, KY has 49 years of usable hourly data which is enough to make stable estimates of 100-year depths. Its 60-minute mean annual maximum value is 3.13", relatively low as compared to the surrounding stations. Greenville, OH has 47 years of usable hourly data, which is enough to make stable estimates of 100-year depths. The mean values look reasonable compared with nearby sites. We will look at these stations again. We believe the pattern around the Great Lakes, including along Lake Erie in northeast Ohio, is indicative of a real lake influence on short-duration precipitation.

5.4 Southwest of Indianapolis, there is an area of relatively high values in the 24-hour map and relatively low values in the 60-minute map. I think we can safely assume that many of the physical processes operating on the 60-minute rainfall are operating on the 24-hour rainfall. So I wonder when the pattern reverses between the two sets of maps. This looks suspicious.

**Response**: The relatively low 60-minute precipitation frequency estimates in this area are the result of Eminence, IN and Martinsville, IN, both of which we will investigate further.

5.5 Attached [to right] is a map of mean annual precipitation in Cook County, Illinois, based on a 25-gage network operating since 1990. In the southern portion of Cook County is a relative high, w.r.t. precipitation. I'd bet that you would find a similar pattern in Cook County on the 24-hour, 100-year map if you had a station(s) in that part of Cook County. It would tie in with the pattern extending from Rockford to Peotone. Are there ways to incorporate "auxiliary" information when defining the spatial patterns?

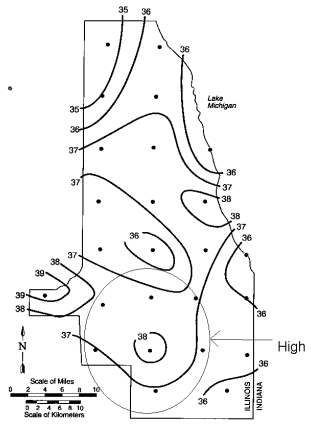

Figure 7. Thirteen-year average precipitation pattern (inches), Water Years 1990-2002.

23

**Response**: A "pseudo" station could be added to increase the mean annual maximum estimates in this area. A change in the mean annual maximum pattern will influence the 100-year map/grid. We will be in touch to discuss any possibilities.

5.6 Regarding the 100-year 60-minute map: In west-central Indiana, the 3.3" isohyet is closed at Waveland and Brazil. It appears all of the areas between the towns should be at least 3.3", and perhaps 3.5" in some areas.

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Regarding the 100-year 60-minute map: In south-central Indiana, the 3.3" isohyet is closed around Nashville and Columbus. It appears that the 3.3" isohyet should be redrawn to include at least all of the areas between both towns.

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Regarding the 100-year 60-minute map: In southwestern Indiana, the 3.5" isohyet is closed at Princeton and Spurgeon. It appears that the 3.5" isohyet should be redrawn to include more areas between Princeton and Spurgeon, and between Spurgeon and Jasper.

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Regarding the 100-year 24-hour map: In west-central Indiana, the 7.0" isohyet is closed at Rockville/Waveland, Greencastle and Brazil. It appears all of the areas enclosed by these towns should be at 7.0", and perhaps combined with the areas of Bowling Green, Bloomington, and possibly Nashville.

---

Regarding the 100-year 24-hour map: In southwestern Indiana, the 7.5" isohyet is closed at Princeton, Petersburg and Spurgeon, but not drawn at Jasper and Huntingburg (just to the east). It appears all of the areas enclosed by the 5 towns should be at 7.5".

**Response**: The method(s) we plan to implement to smooth the spatial patterns in topographically and climatologically similar regions will likely mitigate these. (See response to 5.1.) Once we have implemented a smoothing process, we will evaluate each of these areas.

## 6 Are stations located correctly on the map?

6.1 I would like to have three CORRECTIONS made:

| CURRENT NAME | CORRECT NAME |
|---|---|
| Chattanooga WSO AP | Lovell Field |
| Knoxville WSO AP | McGhee Tyson AP |
| Bristol WSO AP | Tri-Cities AP |

These corrected names are as they appear in NCDC climatic reports. WSO's are no longer located in those locations.

**Response**: Thank you. We will make these corrections.

6.2 I did notice on some of the maps that I pulled up that certain stations are not listed. For example, on the Illinois 100 year, 24 hour map the station Belleview SIU Research is not labeled however the dot indicating its location is printed. Hopefully this is just a printer (scale) error. Same goes for Harrisburg Disposal PL not indicated on the Mean Annual Maximum 24 hour map in southern Illinois.

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On the 100 year, 60 minute and 24 hour maps the station label is not shown. I do see a dot on each of these maps that represents the location of this station; however, only the 24 hour map shows the computed 100 year, durational value of 6.7 which is representative of the 6.74 indicated in the appropriate table for this station. Why isn't the 60 minute value shown for 100 years for this station on the 100 year, 60 minute map?

**Response**: In areas with a high density of stations, the mapping software cannot fit in all of the station labels. This does not mean that its PF estimate was not used in the interpolation. The station “dots” are always shown.

6.3 The town of Parkton is situated East of I-83. Please check to see if the Parkton Precipitation Station is West of I-83 as your map shows. We were surprised that there were no hourly stations in the larger metropolitan areas like Frederick and Salisbury.

**Response**: The “PARKTON 2 SW” station is 2 miles southwest of Parkton, and thus placing it west of I-83. A Frederick station exists, but it only has data back to 1996. The hourly gauge data we have for SALISBURY FAA ARPT (18-8005) has less than 20 years of data (1948-1951) and was therefore not used.

## 7 Confidence limits and confidence intervals?

7.1 There is a little confusion as to the terminology confidence limits and intervals. You are defining, I think, upper and lower one-sided confidence limits that yield one-sided confidence intervals. The upper bound is the 5-percent confidence limit (5 percent chance of being exceeded) and the lower bound is the 95-confidence limit (95 percent chance of being exceeded). As you state you are defining a 90-percent confidence interval but the lower and upper bounds are 95- and 5-percent confidence limits. As stated in

Bulletin 17B (page 9-2), "Thus, the union of two one-sided 95-percent confidence intervals is a two-sided 90-percent interval." This is no big deal but we though it was at least worthy of mention.

The upper and lower bounds are not symmetric with respect to the estimated value which was no surprise. However the negative departure (lower bound) is greater than the positive departure (upper bound). Given that rainfall is bounded by zero on the lower end, one would think the positive departure would be larger. This is certainly true for uncertainty bounds on streamflow.

Also the 90-percent confidence interval is usually small with values on the order of +/- 10 to 15 percent. Since this represents about 1.64 standard errors, one would expect this value to be larger.

**Response**: To compute the confidence limits we are using a Monte Carlo simulation technique described in Hosking and Wallis with 1,000 trials. This technique makes no assumption about the shape of the distribution of errors. The limits we are providing are defined as follows:

LL95% = < P < = UL5%

Where P stands for the estimated precipitation quantile and LL and UL are the lower and upper bounds or limits respectively. We refer to the range between LL and UL as the confidence interval. In this case, the "true" estimate has a 5% chance of lying below the lower limit, and a 5% chance of lying above the upper limit. It has a 90% chance of lying between the lower and upper limits. We are referring to the interval between the lower and upper limits as the confidence interval, and in this case, the 90% confidence interval.

The regional approach significantly reduces errors associated with estimates. The tight error bounds we see illustrate that effect. Sample calculations provided by Hosking and Wallis show variation in the relative magnitudes of departures of lower and upper bounds from the mean, even at single sites.

## 8 Bad data

8.1 Several research papers have been published regarding the possibility of a precipitation anomaly at the LaPorte gage in northern Indiana. However, I am unable to determine if the perceived broader range in the 90% confidence limits is statistically significant and the degree of correlation of the recorded data with the statistical distribution compared to the results for other nearby stations.

**Response**: To keep us fully-informed, please provide us with references to the research papers regarding the precipitation anomaly observed at La Porte. In response to your comment, La Porte, IN (12-4837) is a co-located daily and hourly station in our analysis. The 24-hour analysis and 60-minute analysis do not indicate that it is discordant with its surrounding stations based on annual maximum precipitation, nor did it cause regional heterogeneity.

We did analyze all daily annual maximum series with at least 50 years of 24-hour data for trends in mean. La Porte has 53 years and our analysis did not show a trend in mean annual maximum precipitation. Other trends in yearly precipitation do not always translate into trends in annual maximum precipitation. We are currently conducting an analysis of cross-correlation between stations. Preliminary results suggest that La Porte is not cross-correlated with nearby stations but that does not necessarily imply it is anomalous. Our confidence limits are computed using 1,000 Monte Carlo simulations with the same statistical characteristics as the station. The 100-year 24-hour confidence intervals for La Porte are 6.70"-8.89", a range of 2.19". These are broader than immediate surrounding stations, which have ranges of 0.96-1.98". However, they seem consistent for the region.

8.2 I did some checking on Farmer City, Illinois, looking at the old NWS and WB forms on the site. In a 1962 sketch, they have the recording rain gage about 20 feet to the north of an unidentified building. I remember Floyd Huff telling the story of a gage that was higher than surrounding sites and was getting extra water from the roof of the barn sitting right next to it. Now I'm wondering if it wasn't Farmer City.

**Response**: Without concrete evidence, it is difficult for us to objectively remove a station from the analysis.

Farmer City, IL passed our tests for discordancy and heterogeneity within its region; however, we will investigate the data further and take appropriate action. In addition, please see response to 5.1.