SEMIARID PRECIPITATION FREQUENCY PROJECT

Update of *Technical Paper No. 49* and *NOAA Atlas 2*

Twenty-seventh Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service has updated its precipitation frequency estimates for the Semiarid Southwestern United States. Updated precipitation frequency estimates contained in NOAA Atlas 14 Volume 1 “Precipitation Frequency Atlas of the United States” replace those found in *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964), *NOAA Atlas 2* “Precipitation-Frequency Atlas of the Western United States” (Miller et al 1973), “Short Duration Rainfall Frequency Relations for California” (Frederick and Miller, 1979) and “Short Duration Rainfall Relations for the Western United States” (Arkell and Richards, 1986) for the Semiarid region. The project included data collection and quality control, dataset formatting, regional frequency analyses, frequency distribution selection and fitting techniques, and spatial interpolation with reports and other documentation to follow.

The project determined annual all-season precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. For the project, HDSC reviewed and processed all available rainfall data for the Semiarid project area and used accepted statistical methods. In particular, the Semiarid Project was the pilot project in which decisions regarding the methods and format were made that affect subsequent projects. The project results are published as Volumes of *NOAA Atlas 14* on the internet (http://hdsc.nws.noaa.gov/hdsc/pfds/) with the additional ability to download digital files.

The Semiarid Project includes estimates for 4 states completely, Arizona, Nevada, New Mexico, and Utah, and southeastern California. Additional data from 7 bordering states and Mexico (Figure 1) were included for continuity across state borders. The core and border areas and regional groups used for long duration (24-hour through 60-day) analyses are shown in Figure 1. Regional groups used for short duration (60-minute through 12-hour) analyses are shown in Figure 2.

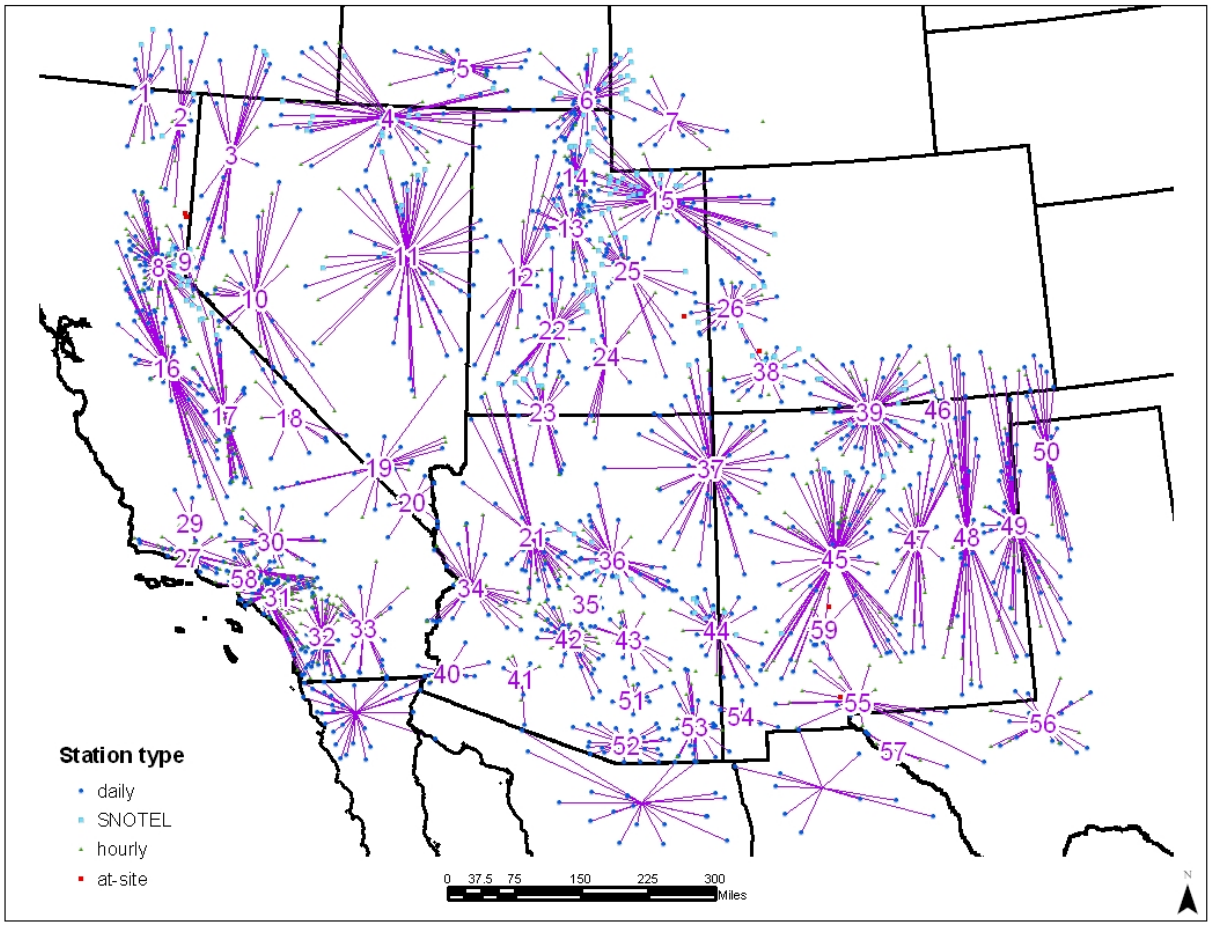

Figure 1. Semiarid Precipitation Frequency project area and 59 regional groups for 24-hour and longer duration values.

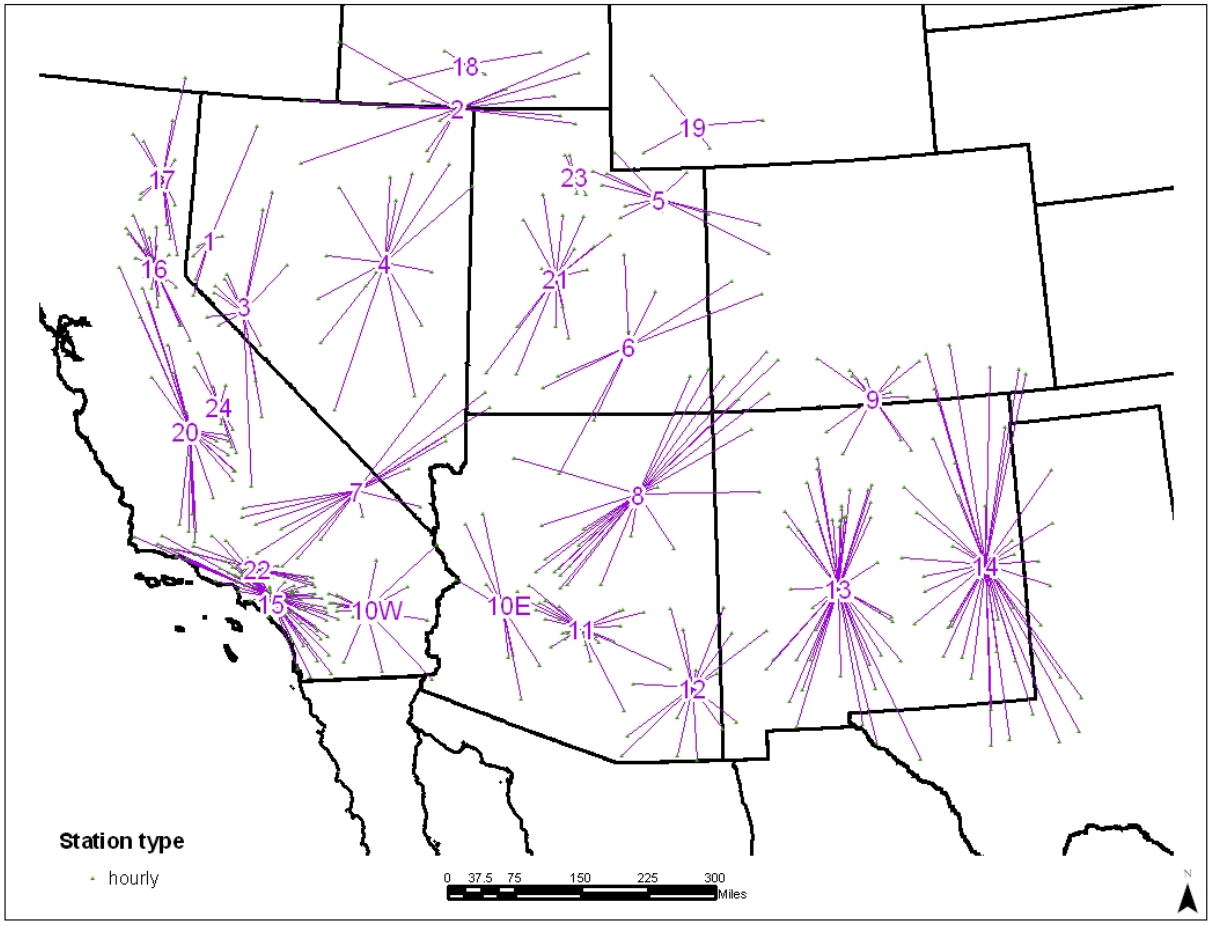

Figure 2. Semiarid Precipitation Frequency 25 regional groups for 12-hour and shorter duration values.

2. Highlights

NWS published the updated NOAA Atlas 14 Volume 1 Version 3 precipitation frequency estimates for the Semiarid Southwestern United States on January 8, 2004. They are available via the Precipitation Frequency Data Server at http://hdsc.nws.noaa.gov/hdsc/pfds/.

Data corrections were made resulting from the annual maxima consistency adjustment. Additional information is provided in Section 3.1, Data Quality Control.

L-moments and confidence limits were run on updated data for all durations and return frequencies. Minor discrepancies involving individual stations were found and corrected during this re-run. Additional information is provided in Section 3.2, L-moment Analysis.

The recent data corrections and updates have produced better, more reliable final precipitation frequency estimates in Version 3. Differences between Version 2 and Version 3 results were thoroughly verified and documented. Also, final Version 3 results will be presented as partial duration series (PDS) results, rather than annual maxima series (AMS) results. Additional information is provided in Section 3.3, Version 3 Results.

Conversion factors from annual maximum series (AMS) results to partial duration series (PDS) results were calculated and applied for publication of Version 3. The ratios are consistent with NOAA Atlas 2 and theoretical computations. Additional information is provided in Section 3.4, Partial Duration Series.

A procedure for adjusting mean PRISM grids was developed, tested and applied to Semiarid grids for all durations. Differences between Version 2 and Version 3 mean grids were carefully evaluated. The Cascade, Residual Add-back (CRAB) derivation procedure was modified to accommodate the conversion from AMS-based results to PDS-based results. Additional information is provided in Section 3.5, Software Updates/Spatial Interpolation.

The Precipitation Frequency Data Server (PFDS) underwent several modifications. In particular, the results provided by the PFDS are now in terms of partial duration series as the default, rather than annual maximum series. Additional information is provided in Section 3.6, Precipitation Frequency Data Server.

Study areas to be used and tested in the areal reduction factor (ARF) development have been selected and are being quality controlled. Software development to process the data and ultimately generate the ARF curves is 90% completed. Additional information is provided in Section 3.4, Areal Reduction Factors.

3. Progress in this Reporting Period

3.1 Data Quality Control

Data corrections were completed based on the annual maxima consistency check conducted last quarter. In this check we compared the largest annual maximum events at each station for consecutive durations. Stations where the shorter duration had a higher maximum than the longer duration were flagged and inspected. A 10% difference in annual maxima was used to flag stations, since the more extreme cases are more likely to influence the precipitation frequency estimates. Each of the 16 cases that were more than 10% different were corrected for data quality issues. Lists 1 and 2 include the regions and stations whose 24-hour data were corrected during this check. Other minor corrections that are not listed were made to station data and impact only longer duration (>24-hour) annual maxima.

Subsequently, if the difference between annual maxima of consecutive durations was small (<10%), the longer duration annual maximum was set equal to the shorter duration for that year in the *annual maxima consistency adjustment*. This occurred most often at the 48-hour and 4-day durations because conversion factors for different sampling periods (e.g., 1-day to 24-hour; 2-day to 48-hour) are applied to the associated shorter durations. This was widespread throughout the entire project area.

Other changes made during this quarter to the 24-hour dataset are also listed in Lists 1 and 2 and described in Section 3.2 L-moment Analysis.

3.2 L-moment Analysis

L-moments and confidence limits were re-run on updated data for all durations and return frequencies. Minor discrepancies involving individual stations were found and corrected during this re-run to create Version 3 results.

As mentioned in the 26th Semiarid Progress Report, daily stations 02-5922 and 02-6563 were deleted from daily regions 52 and 54, respectively, because they were found to have data identical to 2 other stations. Daily station 42-6938 in daily region 6 and hourly station 04-4412 in daily region 32 were removed from the analysis because, upon close scrutiny, they were found to have unreliable data.

List 1: Corrections to the 24-hour dataset for the release of Version 3.

1. Region 6 - daily station 42-6938 was deleted; bad value corrected at hourly 42-6938
2. Region 10 - data corrections at station 26-2780
3. Region 13 - data corrections at station 42-5402
4. Region 16 - data corrections at station 04-0442
5. Region 25 - station 42-0336 was added to multi-day analysis
6. Region 31 - data at hourly station 04-2805 were corrected to properly include post-1960 Riverside data
7. Region 32 - hourly station 04-4412 was deleted; data at hourly stations 04-7813 and 04-4181 were corrected to properly include post-1960 Riverside data
8. Region 37 - data corrections at stations 29-8919 and 42-5805
9. Region 45 - various station changes were properly incorporated into Version 3
10. Region 50 - data corrections at station 05-7862
11. Region 52 - deleted daily station 02-5922 that had duplicate data
12. Region 54 - deleted daily station 02-6563 that had duplicate data
13. Region 59 - hourly stations 29-7423 and 29-8387 were incorporated into analysis
14. A5 - deleted 42-0336 that had been moved to region25

List 2: Corrections to the hourly dataset for the release of Version 3.

1. Region 2 - data correction at hourly station 42-6938
2. Region 11 - data at hourly station 02-6481 was properly adjusted for co-location with its daily counterpart in daily region42
3. Region 15 - data at hourly stations 04-2805, 04-7813, and 04-4181 were corrected to properly include Riverside data (see daily regions 31 and 32)

After the re-run, differences between Version 2 and Version 3 were found at 3 hourly stations in Riverside County California (04-2805 Elsinore, 04-7813 San Jacinto, and 04-4181 Hurkey Creek). Modified data series had been erroneously over-written with old data that did not include accumulations of 15-minute data previously sent from Riverside County Flood Control District to extend the data record at these stations. During the resulting update of the station data, the existing hourly NCDC data was replaced with the accumulated Riverside data for each station's post-1960 time period since previous correspondence with Riverside County stated that data at these stations were serially complete for approximately the last 40 years; records prior to that period were based on selected storms. Thus, only data after 1960 was replaced at this time. These changes impacted daily regions 31 and 32 and hourly region 15. The 100-year quantiles of all daily and hourly durations in these regions changed less than 1.5% from Version 2 to Version 3. The corrected stations changed up to ~8%.

In another correction, Version 3 results for co-located station 02-6481, Phoenix WSO AP, AZ, were properly adjusted. This station has separate hourly and daily datasets

(daily region 42, hourly region 11). In Version 2, the co-located adjustment for this station had not been properly applied due to an error/typo that resulted in the 1-day to 24-hour conversion factor not being used in the adjustment when running the software. Once the co-located adjustment was properly applied, the 60-minute mean at this station increased 15% (from 0.60" to 0.69"). This particular error did not occur in Version 3 because an automated script is now in place to run the co-located adjustment software.

Finally, some station regionalization changes in daily region 45 and at-site 5, Moab Radio Station, UT (A5), had not been properly incorporated into the Version 2 results. With Version 3, these errors were found and corrected. Hourly station 29-8011 was added back into the analysis; hourly stations 29-7423 and 29-8387 were deleted because they had been found to have unreliable data; daily stations 29-0983, 29-7423, and 29-8387 were deleted because they had previously been moved to region 59; and daily station 42-0336 was deleted because it had previously been moved to region 25.

3.3 Version 3 Results

On January 8, 2004, HDSC updated the Semiarid Southwest precipitation frequency (PF) estimates, known as NOAA Atlas 14 Volume 1, to incorporate dataset corrections. The previous version, Version 2, is superceded by Version 3. We believe Version 3 is more accurate than Version 2 and we do not anticipate updating the Semiarid Southwest again in the foreseeable future.

Dataset corrections were made in order to provide the best possible estimates and to remedy some discrepancies. The updates are described in Section 3.1 Data Quality Control and Section 3.2 L-moment Analysis. Most changes were data corrections and reassessments of specific stations. Some questionable stations were deleted upon closer inspection because they had unreliable data. Other stations/data that had been erroneously omitted were included. Most of these changes were relatively isolated to a particular station and resulted in a slight (usually less than 3%) change in the final quantiles for a given region.

Although Version 3 and Version 2 are essentially the same across most of the domain, the 48-hour and 4-day durations increased across the entire study area as a result of the application of the *annual maxima consistency adjustment* (see Section 3.1 Data Quality Control). There were 7 cases, other than those found in Lists 1 and 2, where the Version 3 mean for a given duration was more than 8% greater than the Version 2 mean. These were investigated (see Table 1). All increases were found to be the result of the annual maxima consistency adjustment. For the most part during the update, mean values increased, but not always.

Table 1: Cases where Version 3 mean > Version 2 mean by more than 8%.

Region	Duration	Station	% Difference
3	7-day	26-7873	+8%
10	30-day	26-5931	+10%
33	4-day	04-4259	+9%
33	7-day	04-2111	+9%
34	48-hour	04-0924	+11%
40	48-hour	02-8396	+9%
40	48-hour	02-2434	+9%
40	4-day	04-2434	+10%

Given the recent updates to the Semiarid dataset, the areas with more than 2% change in precipitation frequency estimate include:

1. The 5-minute through 60-day PF estimates PF estimates in the Moab, Utah vicinity decreased.
2. The 5-minute through 12-hour PF estimates PF estimates in the immediate Phoenix, Arizona vicinity increased.
3. The 5-minute through 60-day PF estimates PF estimates in the mountains of Socorro County New Mexico increased.
4. The 24-hour through 60-day PF estimates in southeastern Graham County and northeastern Cochise County Arizona decreased.
5. The 48-hour PF estimates in the Plymouth, Utah vicinity have increased.
6. The 5-minute through 12-hour PF estimates in southwestern Inyo County California decreased substantially.
7. The 5-minute through 12-hour PF estimates in northeastern Los Angles County and eastern San Bernardino County California decreased.
8. The 5-minute through 12-hour PF estimates in other isolated areas, particularly at higher elevations of Nevada and Utah, decreased slightly.

These differences can be evaluated spatially at the following links to difference maps. The red/orange coloring indicates areas where the estimates have decreased and the blues/greens where the estimates have increased.

- 60-minute - ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sa/sa_v2_vs_v3_60m.pdf
- 24-hour - ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sa/sa_v2_vs_v3_24h.pdf
- 48-hour - ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sa/sa_v2_vs_v3_48h.pdf

The Version 3 estimates are now available via the Precipitation Frequency Data Server (PFDS) at http://hdsc.nws.noaa.gov/hdsc/pfds/.

Another important change from Version 2, is the fact that Version 3 includes precipitation frequency estimates from partial duration (PDS) series as well as annual maximum series (AMS). Just as in NOAA Atlas 2, the NOAA Atlas 14 grids and maps were converted – using a domain wide conversion factor – from an AMS-based

estimate to a PDS-based estimate. Although the downloadable grids and maps (posted in January 2004) will reflect PDS-based PF estimates, PFDS users can extract PF estimates for either type of series. The PDS based estimates are greater than the AMS-based estimates (at all durations) by 11.3% at the 2-year return period, reducing to 0.4% at return periods of 50-years and greater. This difference is consistent with generally accepted values.

3.4 Partial Duration Series

Precipitation frequency results were calculated using annual maximum series (AMS) data. Conversion factors from AMS to partial duration series (PDS) results have been calculated and applied to the results. The ratios (see Table 2) are consistent with NOAA Atlas 2 and theoretical computations.

To derive the AMS to PDS ratios, it was decided to use regional data only (no at-sites) and to use the best-fitting distributions for each individual region for the PDS computations. Generalized Pareto was the best-fitting distribution for the PDS data in all but 9 regions. For regions 9, 24, 29, 33, 35, 50, 55, 56, and 59, Generalized Normal was the best-fitting distribution. An asymptote of 1.004, the 50-year value, is applied to the 100-year and longer return intervals to generate a smooth consistent curve.

Table 2: AMS to PDS ratio for Semiarid data.

2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	1000yr
1.113	1.029	1.013	1.006	1.004	1.004	1.004	1.004	1.004

3.5 Software Updates/Spatial Interpolation

Due to slight changes in the mean values (see Sections 3.1, 3.2 and 3.3), we developed a process to adjust the PRISM mean annual maxima grids since it is not always cost effective to have the Spatial Climate Analysis Service at Oregon State University re-run the grids with our updated data.

The procedure starts with the calculation of an adjustment factor: new mean divided by old mean at each station. Here the old mean is the mean that was used in creating the original PRISM mean grid. Both means are from the database and not interpolated from the PRISM mean grid. These point adjustment factors are then spatially distributed using an inverse-distance-weighting (IDW) algorithm. The resulting grid is then filtered to remove extraneous noise in the adjustment grid. The filtered adjustment grid is then multiplied by the original mean annual maxima grid to produce an adjusted PRISM mean annual maxima grid. This procedure was applied to the Version 2 mean grids to create Version 3 mean grids.

This simple approach allows fine-tuning of the PRISM mean annual maxima grid cell values, but it is not robust enough to accommodate new data points (i.e., stations not

used in the original PRISM gridding), omissions of stations, or any major changes in the mean values. During the procedure, the software produces percent difference grids that we then use to evaluate differences between the new mean grids and the old. The 60-minute through 24-hour grids indicated specific areas of changes. The 48-hour and 4-day grids showed a general change (slight increase) across the domain. The >4-day grids were generally unchanged.

After the application of the PRISM mean annual maxima grid adjustment to all durations, the Cascade, Residual Add-back (CRAB) derivation procedure was used to create the entire suite of Semiarid Version 3 precipitation frequency grids. Careful evaluation of the resulting grids, including exhaustive comparison with Version 2 grids, indicated little change at 24-hour and at the longer durations (>7day). Pockets of change occurred at 5-minute through 12-hour, while more widespread, but slight, change occurred at 48-hour and 4-day (see Section 3.3 Version 3 Results for more details).

In addition, the CRAB software was modified to create PDS-based grids, rather than the previous AMS-based.

Finally, the software used to create vector (contour) shapefiles from the precipitation frequency grids was made more robust by incorporating logic to determine the best contour interval for the given grid. The software forces the number of contour intervals to be less than or equal to 30 and greater than 10. The contour intervals are forced to fall at convenient break points, yet provide as much spatial detail as possible. The shapefiles are posted on the Precipitation Frequency Data Server (PFDS).

3.6 Precipitation Frequency Data Server (PFDS)

The Precipitation Frequency Data Server (PFDS) underwent several modifications. In particular, the results provided by the PFDS are now in terms of partial duration series, rather than annual maximum series, as the default. Results based on either series can be selected as a criterion from the state-specific web-pages of the PFDS.

A mask is now applied to the final results on the PFDS so that only the core area will be available for Version 3. Stations in the pull-down list are within the core area only. Previously, during the review period, stations in the border areas were also included. The state-specific input pages have also been simplified by eliminating the radio buttons. The PFDS interface now detects which input type (via a click on the map, a click on a station, the pull-down list, static location, or by area) without the user having to indicate it.

In addition, reference information pages have recently been added. And we have also resolved legend color issues on the maps that we will be providing. A new color ramp was built to mimic the transparency color on maps.

3.7 Areal Reduction Factors

Progress continues in the development of geographically-fixed Areal Reduction Factor (ARF) curves for area sizes of 10 to 400 square miles. We have successfully completed testing and evaluation of the software through Chapter 5 of TR-24 by looking at the statistical results for Chicago, IL data. We are now working on the remaining chapters.

We have completed quality control on the data for Chicago, IL; Walnut Gulch, AZ; Tifton, GA; North Danville, VT; and Hastings, NE. Quality control work is continuing on the remaining study areas. We have added Riverside, CA and Maricopa, AZ to the list of areas we are studying. It is anticipated that a total of 15 study areas throughout the United States will be used in the study. The set of ARF curves developed for each study area will be tested for differences to determine if a single set of ARF curves can be used for the entire U.S. as is the case today or whether separate curves for different regions of the country are more appropriate.

4. Issues

4.1 Upcoming Presentations

Interest in the new estimates is increasing. As a result, Geoff Bonnin, representing HDSC, will give a presentation entitled "Temporal Distributions of Heavy Rainfall Associated with Updated Precipitation Frequency Estimates" at the Transportation Research Board Conference in Washington DC on January 15, 2004.

Geoff Bonnin will present "Recent Updates to NOAA/NWS Rainfall Frequency Atlases" at the American Association of Geographers Annual Meeting in Philadelphia, PA on March 18, 2004 and at the Southeast Region meeting of the Association of State Dam Safety Officers in Norfolk, VA on April 19, 2004.

He will also present a paper, "Statistics of Recent Updates to NOAA/NWS Rainfall Frequency Atlases," at the World Water and Environmental Resources Congress 2004 to be held June 28-July 1, 2004 by the American Society of Civil Engineers.

5. Projected Schedule and Remaining Tasks

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Precipitation Frequency Maps [February 2004]
Final Report [February 2004]
Spatial Relations (Areal Reduction Factors) [April 2004]

5.1 Spatial Interpolation

In the next quarter, final cartographic maps (as Adobe PDF files) will be produced and published. Grids and GIS shapefiles are already available.

5.2 Documentation

Final documentation will be written during the next quarter and published using the Precipitation Frequency Data Server. The documentation will include the new temporal distributions.

5.3 Areal Reduction Factors (ARF)

Software for the ARF computations will be completed in the next quarter and the computations will be performed for 15 areas. The resulting curves will be tested for differences to determine if a single set of ARF curves is applicable to the entire U.S. or whether curves vary by region.

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