Appendix A.1. Temporal distributions of heavy precipitation associated with NOAA Atlas 14 Volume 1

1. Introduction

Temporal distributions of heavy precipitation are provided for use with precipitation frequency estimates from NOAA Atlas 14 Volume 1 for 6-, 12-, 24- and 96-hour durations covering the semiarid southwestern United States. The temporal distributions are expressed in probabilistic terms as cumulative percentages of precipitation and duration at various percentiles. The starting time of precipitation accumulation was defined in the same fashion as it was for precipitation frequency estimates for consistency.

   The project area was divided into two sub-regions based on the seasonality of observed heavy precipitation events. Figure A.1.1 shows the areal divisions for the temporal distribution regions.

   Temporal distributions for each duration are presented in Figures A.1.2 and A.1.3. The data were also subdivided into quartiles based on where in the distribution the most precipitation occurred in order to provide more specific information on the varying distributions that were observed. Figures A.1.4 through A.1.11 depict temporal distributions for each quartile for the four durations. Table A.1.1 lists the number and proportion of cases in each quartile for each duration and region.

2. Methodology. This project largely follows the methodology used by the Illinois State Water Survey (Huff, 1990) except in the definition of the precipitation accumulation. This project computed precipitation accumulations for specific (6-, 12-, 24- and 96-hour) time periods as opposed to single events or storms in order to be consistent with the way duration is defined in the associated precipitation frequency project. As a result, the accumulation cases may contain parts of, one, or more than one precipitation event. Accumulation computations were made moving from earlier to later in time resulting in an expected bias towards front loaded distributions when compared with distributions for single storm events.

   The General and Convective Precipitation Areas (Figure A.1.1) were established using factors set forth in previous work (Gifford *et al.*, 1967; NOAA, 1989), including the seasonality of maximum precipitation and event types. Maximum events in the General Precipitation Area were dominated by cool season precipitation while maximum events in the Convective Precipitation Area occurred in the warm season.

   For every precipitation observing station in the project area that recorded precipitation at least once an hour, the three largest precipitation accumulations were selected for each month in the entire period of record and for each of the four durations. A minimum threshold was applied to make sure only heavier precipitation cases were being captured. The precipitation with an Average Recurrence Interval (ARI) of 2 years at each observing station for each duration was used as the minimum threshold at that station.

   A minimum threshold of 25-year ARI was tested. It was found to produce results similar to using a 2-year ARI minimum threshold. The 25-year ARI threshold was rejected because it reduced the number of samples sufficiently to cause concern for the stability of the estimates.

   Each of the accumulations was converted into a ratio of the cumulative hourly precipitation to the total precipitation for that duration, and a ratio of the cumulative time to the total time. Thus, the last value of the summation ratios always had a value of 100%. Within the General Area, and separately within the Convective Precipitation Area, the data were combined, cumulative deciles of precipitation were computed at each time step, and then results were plotted to provide the graphs presented in Figures A.1.2 and A.1.3. The data were also separated into categories by the quartile in which the greatest percentage of the total precipitation occurred and the procedure was repeated for each quartile category to produce the graphs shown in Figures A.1.4 through A.1.11. A moving window weighted average smoothing technique was performed on each curve.

3. Interpreting the Results

Figures A.1.2 and A.1.3 present cumulative probability plots of temporal distributions for the 6-, 12-, 24- and 96-hour durations for the General and the Convective Precipitation Areas. Figures A.1.4 through A.1.11 present the same information but for categories based on the quartile of most precipitation. The x-axis is the cumulative percentage of the time period. The y-axis is the cumulative percentage of total precipitation.

The data on the graph represent the average of many events illustrating the cumulative probability of occurrence at 10% increments. For example, the 10% of cases in which precipitation is concentrated closest to the beginning of the time period will have distributions that fall above and to the left of the 10% curve. At the other end of the spectrum, only 10% of cases are likely to have a temporal distribution falling to the right and below the 90% curve. In these latter cases the bulk of the precipitation falls toward the end of the time period. The 50% curve represents the median temporal distribution on each graph.

First-quartile graphs consist of cases where the greatest percentage of the total precipitation fell during the first quarter of the time period. i.e., the first 1.5 hours of a 6-hour period, the first 3 hours of a 12-hour period, etc. The second, third and fourth quartile plots, similarly are for cases where the most precipitation fell in the second, third or fourth quarter of the time period.

The time distributions consistently show a greater spread, and therefore greater variation, between the 10% and 90% probabilities as the duration increases. Longer durations are more likely to have captured more than one event separated by drier periods; however, this has not been objectively tested as the cause of the greater variation at longer durations. The median of the distributions gradually becomes steeper at longer durations. The cases of the Convective Precipitation Area had steeper gradients than the cases of the General Precipitation Area for all durations and quartiles.

The following is an example of how to interpret the results using Figure A.1.8a and Table A.1.1. Of the 1,728 cases in the General Precipitation Area, 630 of them were first-quartile events:

- In 10% of these cases, 50% of the total rainfall (y-axis) fell in the first 1.8 hours of event time (7.5% on the x-axis). By the 12th hour (50% on the x-axis), all of the precipitation (100% on the y-axis) had fallen.
- A median case of this type will drop half of its total rain (50% on the y-axis) in 5.4 hours (22.5% on the x-axis).
- In 90 percent of these events, 50% of the total precipitation fell by 10.2 hours (42.5% on the x-axis).

4. Summary and General Findings

The results presented here can be used for determining temporal distributions of heavy precipitation at particular durations and amounts and at particular levels of probability. The results are designed for use with precipitation frequency estimates and may not be the same as the temporal distributions of single storms or single precipitation events. A majority of the cases analyzed were first-quartile cases regardless of precipitation area or duration (Table A.1.1). Fewer and fewer cases fell into each of the subsequent quartile categories with the fourth quartile containing the fewest number of cases. The time distributions show a greater spread between the percentiles with increasing duration. The median of the distributions becomes steeper with increasing duration. Overall, the Convective Precipitation Area distributions showed a steeper gradient and therefore depicted more initially intense precipitation than the General Precipitation Area distributions regardless of duration.

Table A.1.1. Numbers and proportion of cases in each quartile for each duration and temporal distribution region associated with NOAA Atlas 14 Volume 1.

Convective Precipitation Area					
	1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**Total number of cases**
6-hour	1679 (52%)	744 (23%)	509 (16%)	284 (9%)	3216
12-hour	1753 (51%)	769 (22%)	567 (17%)	354 (10%)	3443
24-hour	1751 (50%)	645 (19%)	571 (17%)	492 (14%)	3459
96-hour	1952 (63%)	707 (19%)	530 (14%)	527 (14%)	3716

General Precipitation Area					
	1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**Total number of cases**
6-hour	669 (36%)	471 (26%)	468 (25%)	243 (13%)	1851
12-hour	596 (33%)	465 (26%)	469 (26%)	277 (15%)	1807
24-hour	630 (36%)	442 (26%)	380 (22%)	276 (16%)	1728
96-hour	841 (46%)	376 (21%)	292 (16%)	320 (17%)	1829

Figure A.1.1. Regional division for temporal distributions associated with NOAA Atlas 14 Volume 1.
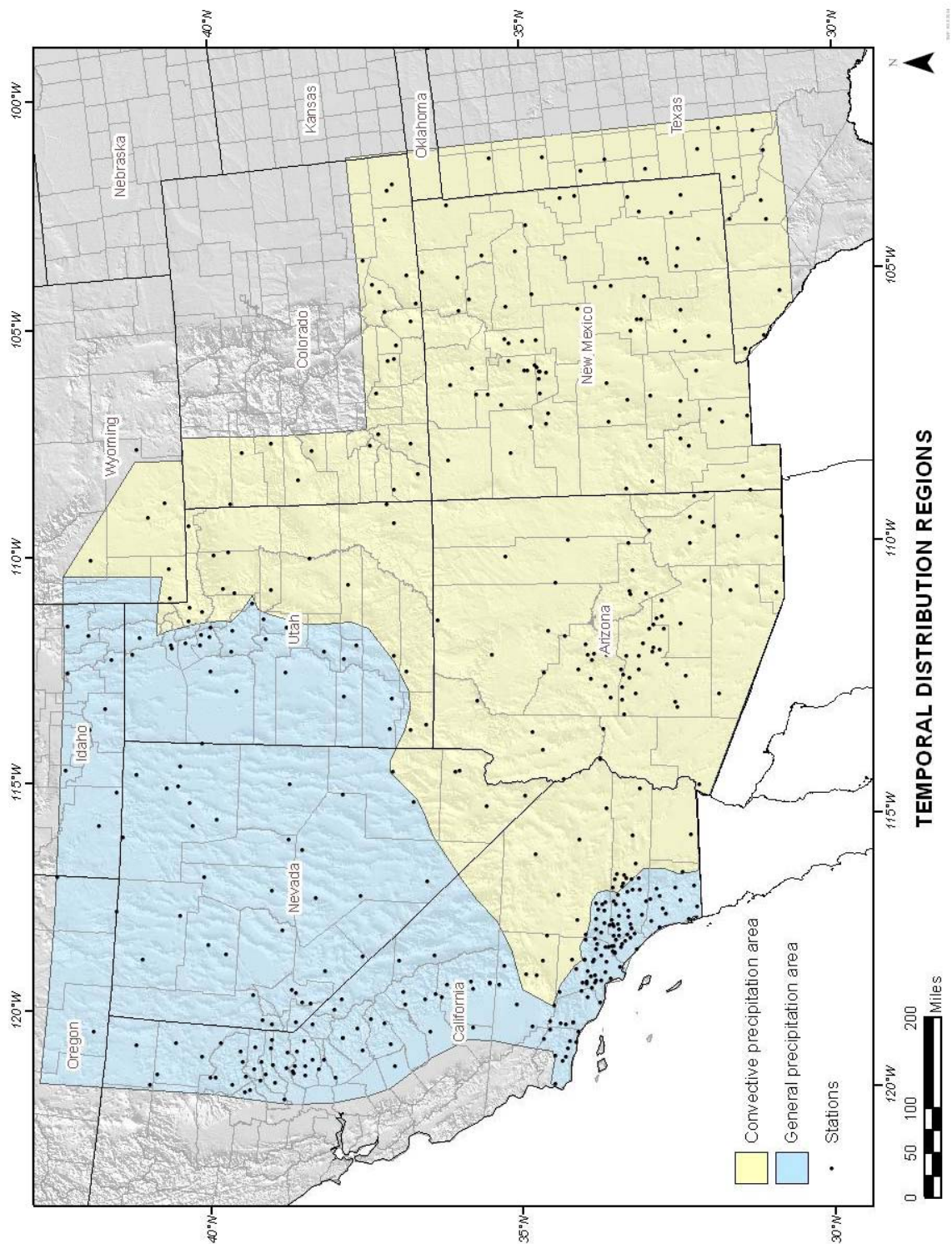
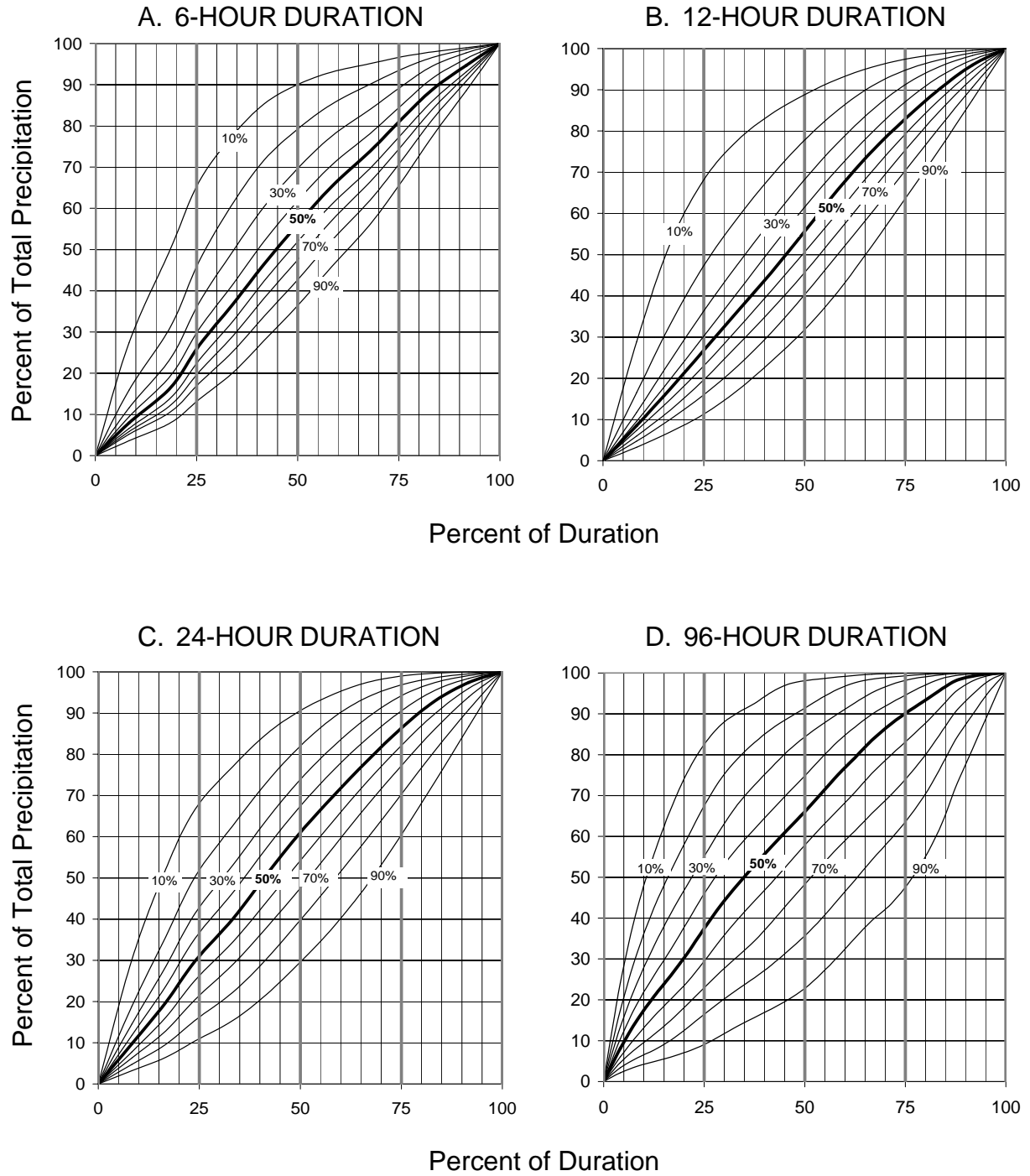**TEMPORAL DISTRIBUTION REGIONS**

Convective precipitation area
General precipitation area
Stations

FIGURE A.1.2
TEMPORAL DISTRIBUTION: ALL CASES
GENERAL PRECIPITATION AREA

A. 6-HOUR DURATION

B. 12-HOUR DURATION

Percent of Duration

C. 24-HOUR DURATION

D. 96-HOUR DURATION

Percent of Duration

Figure A.1.3
Temporal Distribution: All Cases
Convective Precipitation Area

A. 6-HOUR DURATION

B. 12-HOUR DURATION

C. 24-HOUR DURATION
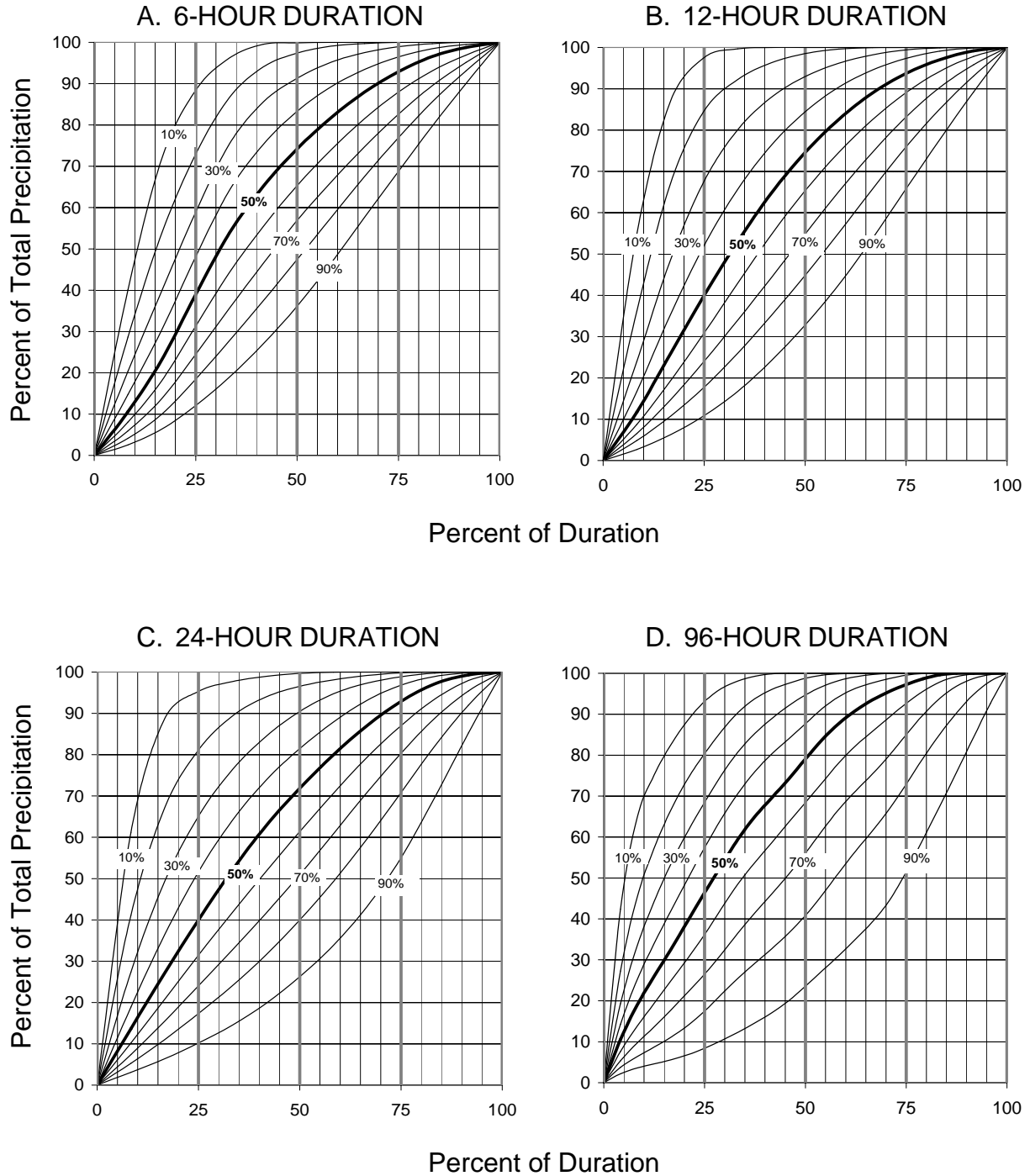
D. 96-HOUR DURATION

FIGURE A.1.4
TEMPORAL DISTRIBUTION: 6-HOUR DURATION
GENERAL PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
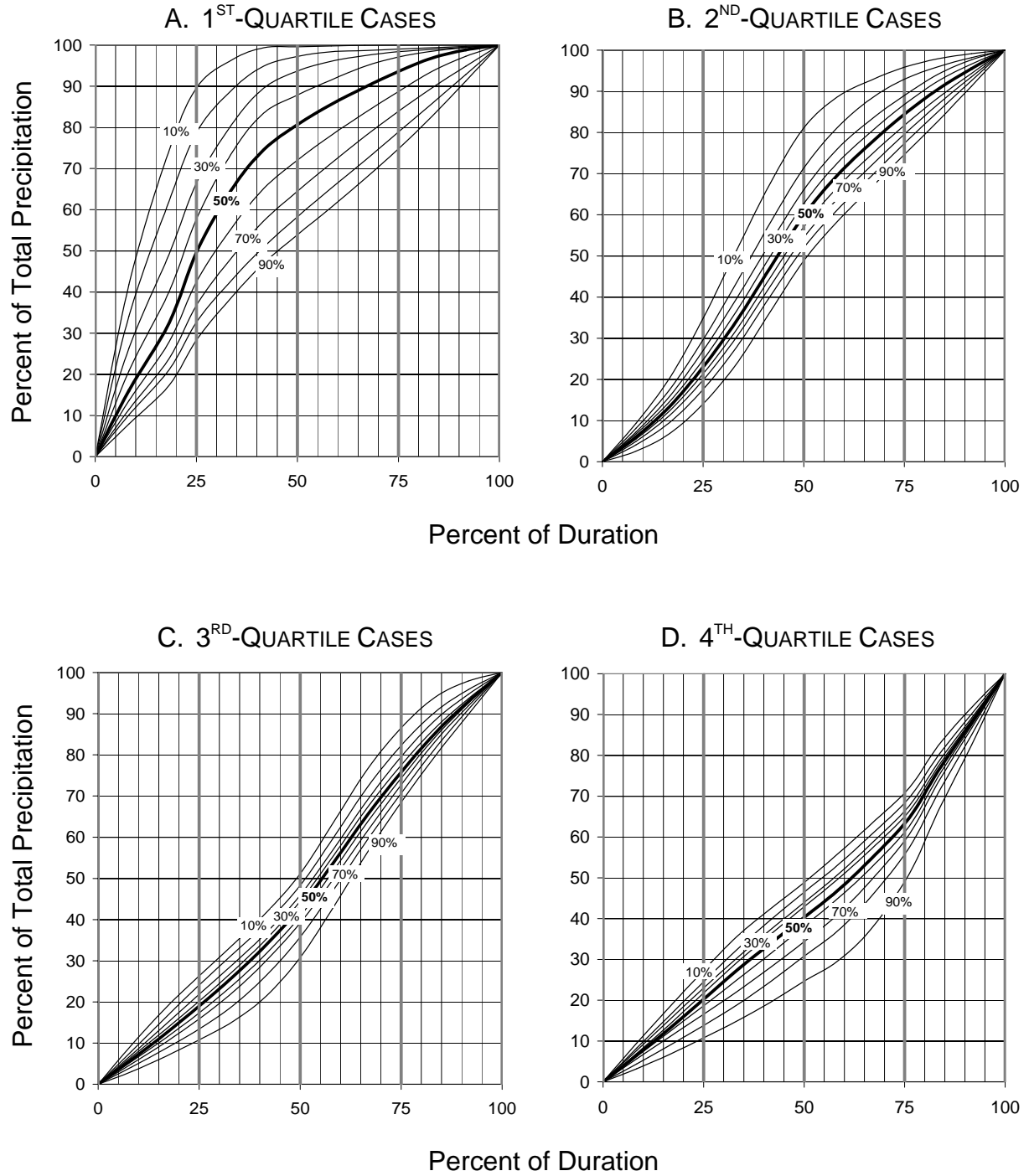
FIGURE A.1.5
TEMPORAL DISTRIBUTION: 6-HOUR DURATION
CONVECTIVE PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
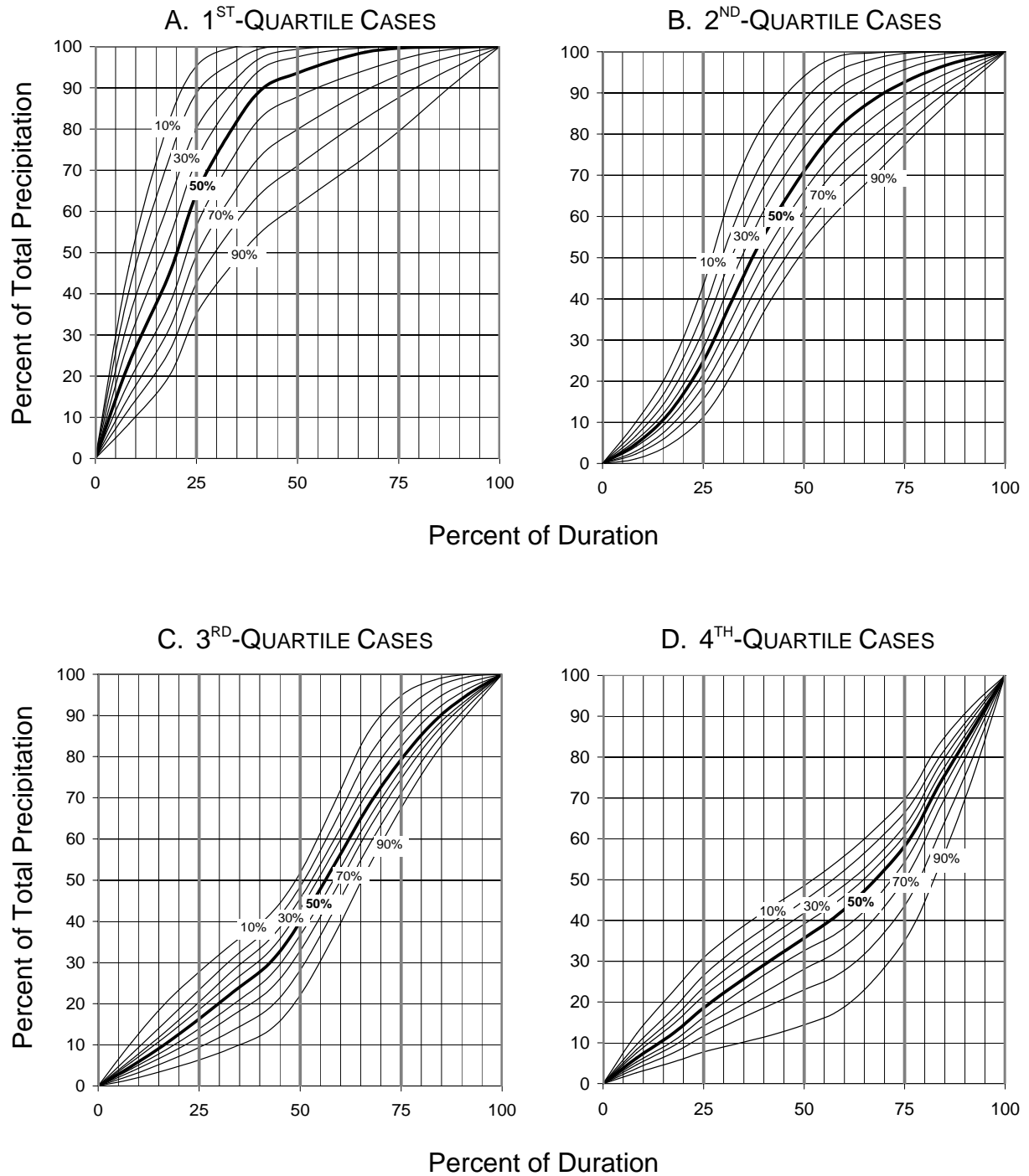
FIGURE A.1.6
TEMPORAL DISTRIBUTION: 12-HOUR DURATION
GENERAL PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
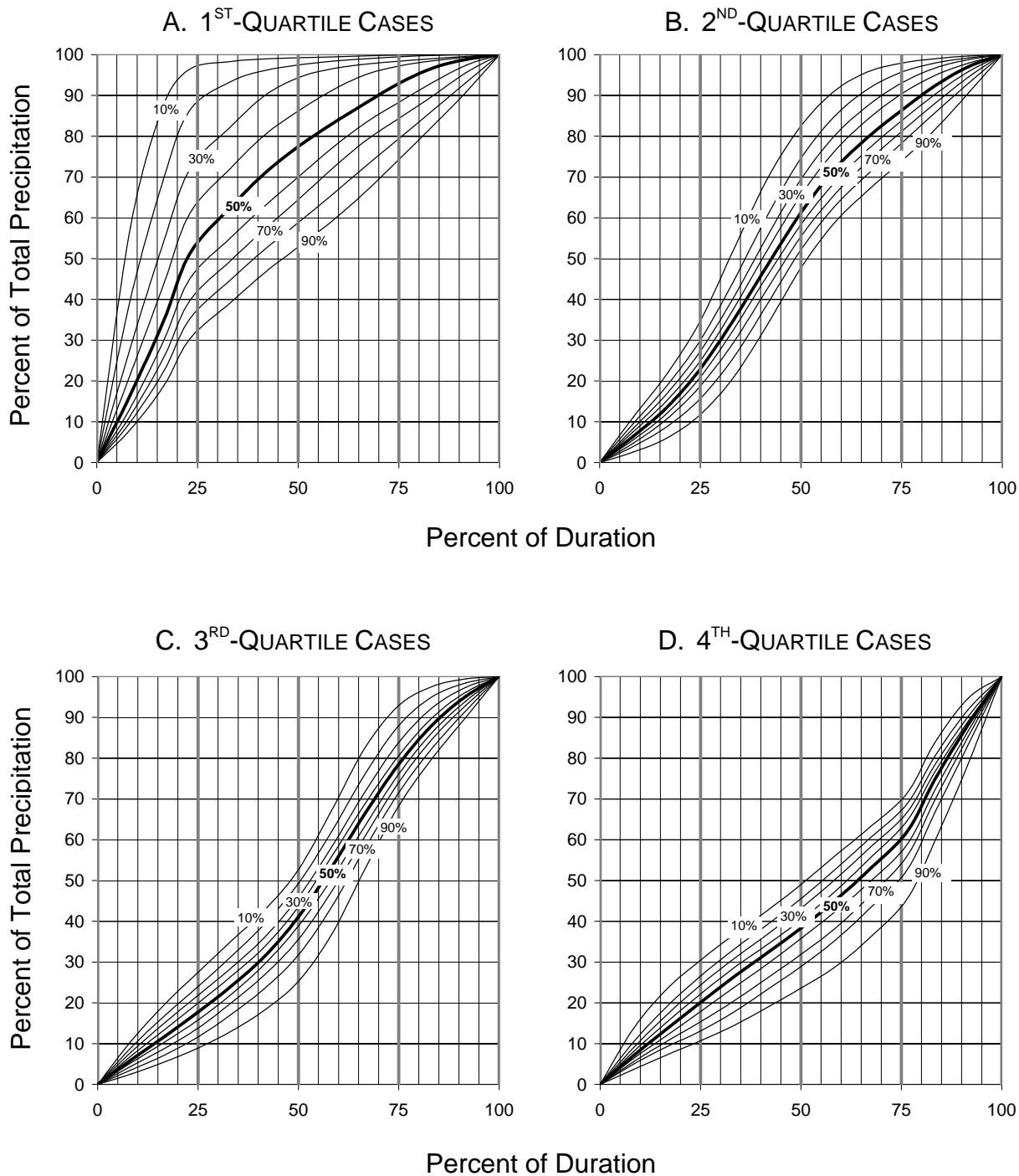
FIGURE A.1.7
TEMPORAL DISTRIBUTION: 12-HOUR DURATION
CONVECTIVE PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
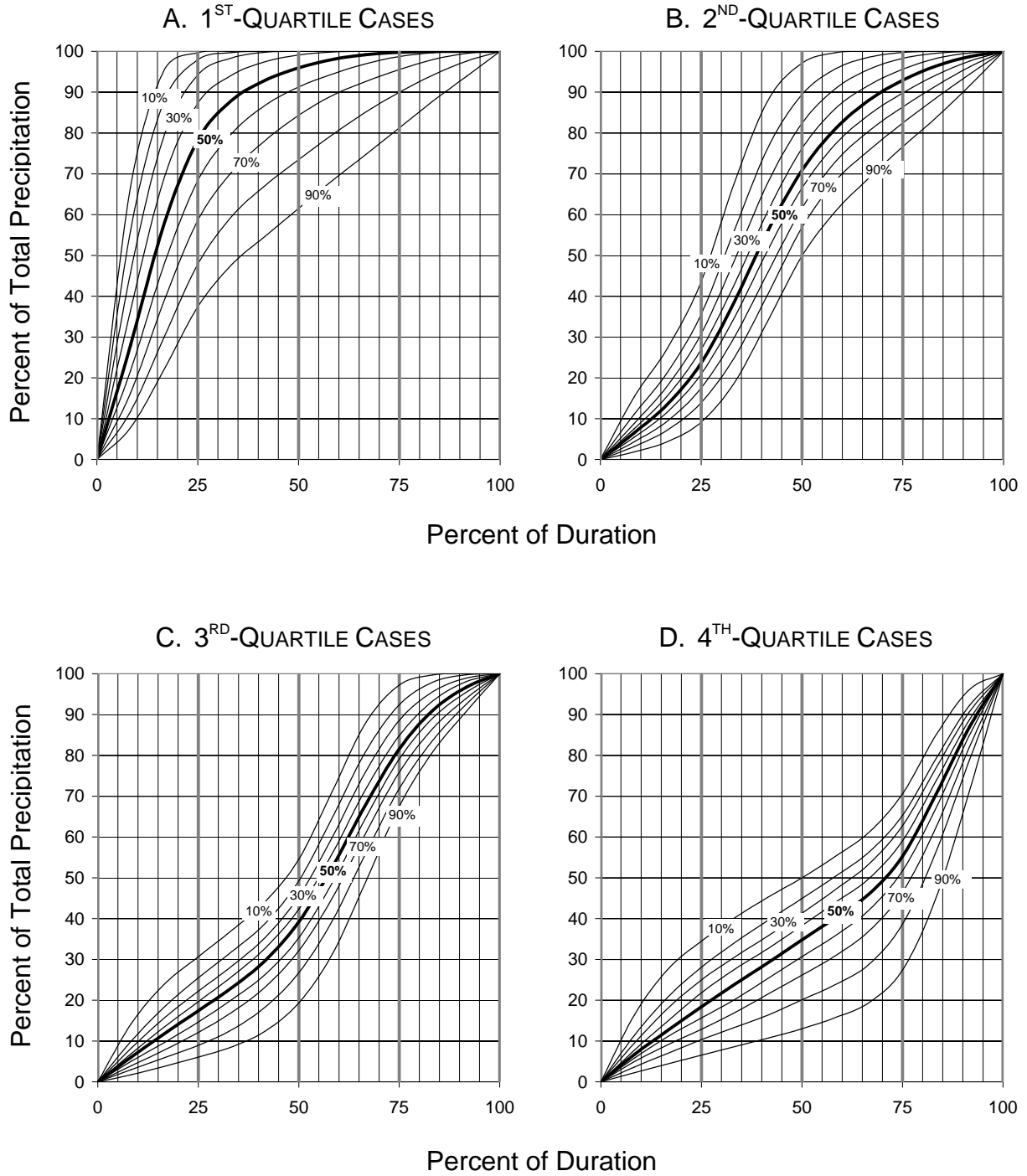
FIGURE A.1.8
TEMPORAL DISTRIBUTION: 24-HOUR DURATION
GENERAL PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
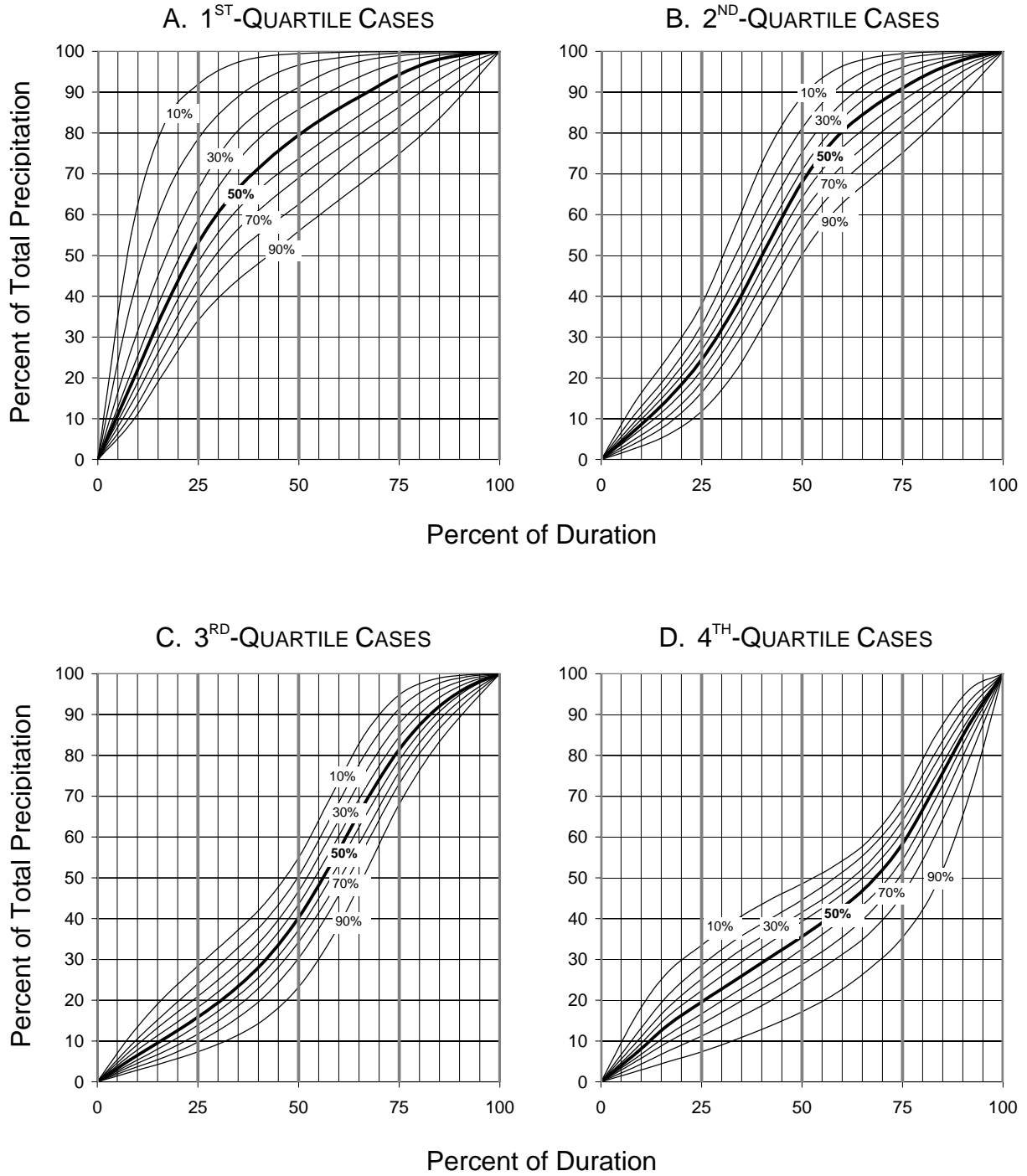
FIGURE A.1.9
TEMPORAL DISTRIBUTION: 24-HOUR DURATION
CONVECTIVE PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration
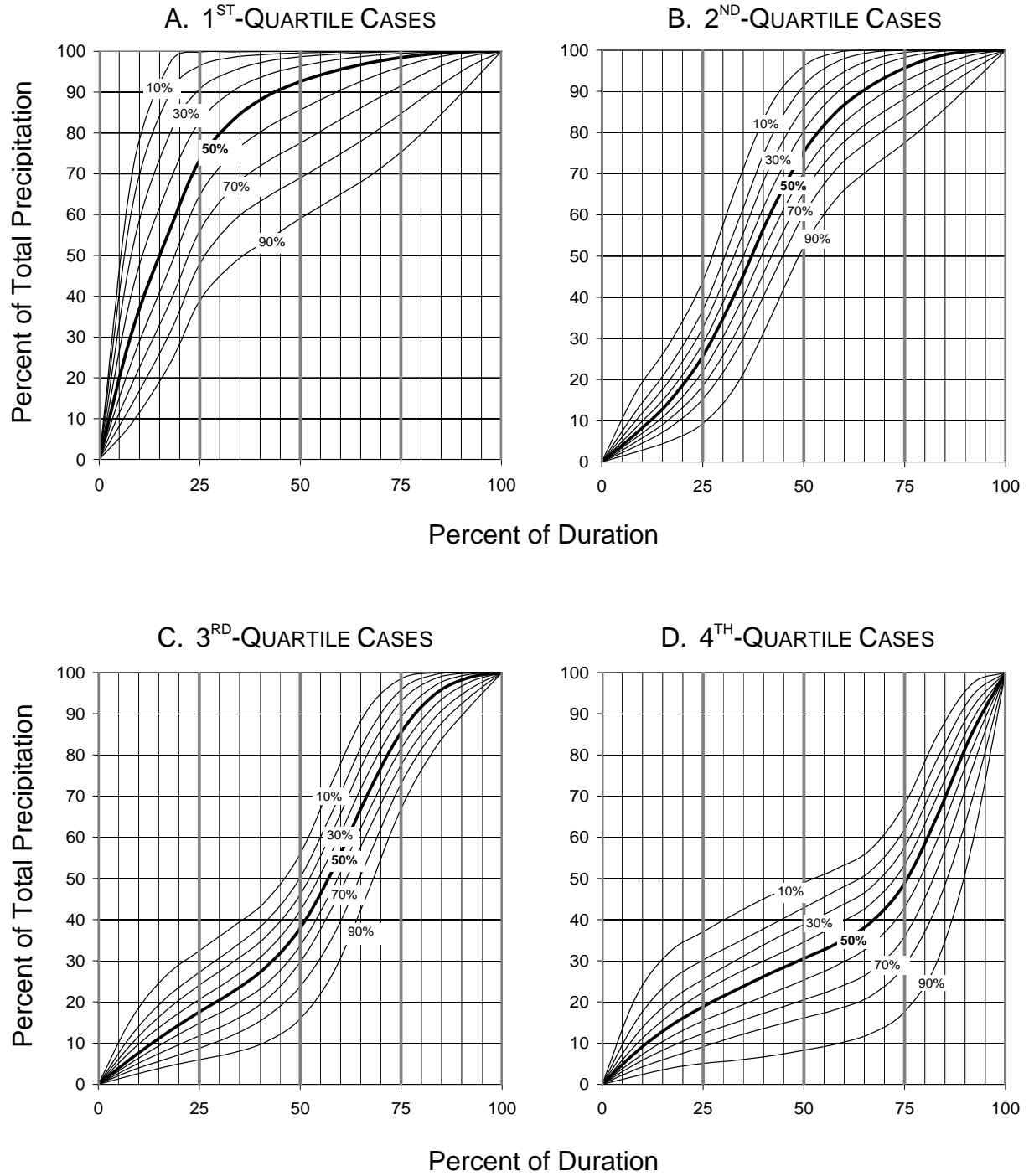
FIGURE A.1.10
TEMPORAL DISTRIBUTION: 96-HOUR DURATION
GENERAL PRECIPITATION AREA

A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Total Precipitation

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Total Precipitation

Percent of Duration

FIGURE A.1.11
TEMPORAL DISTRIBUTION: 96-HOUR DURATION
CONVECTIVE PRECIPITATION AREA

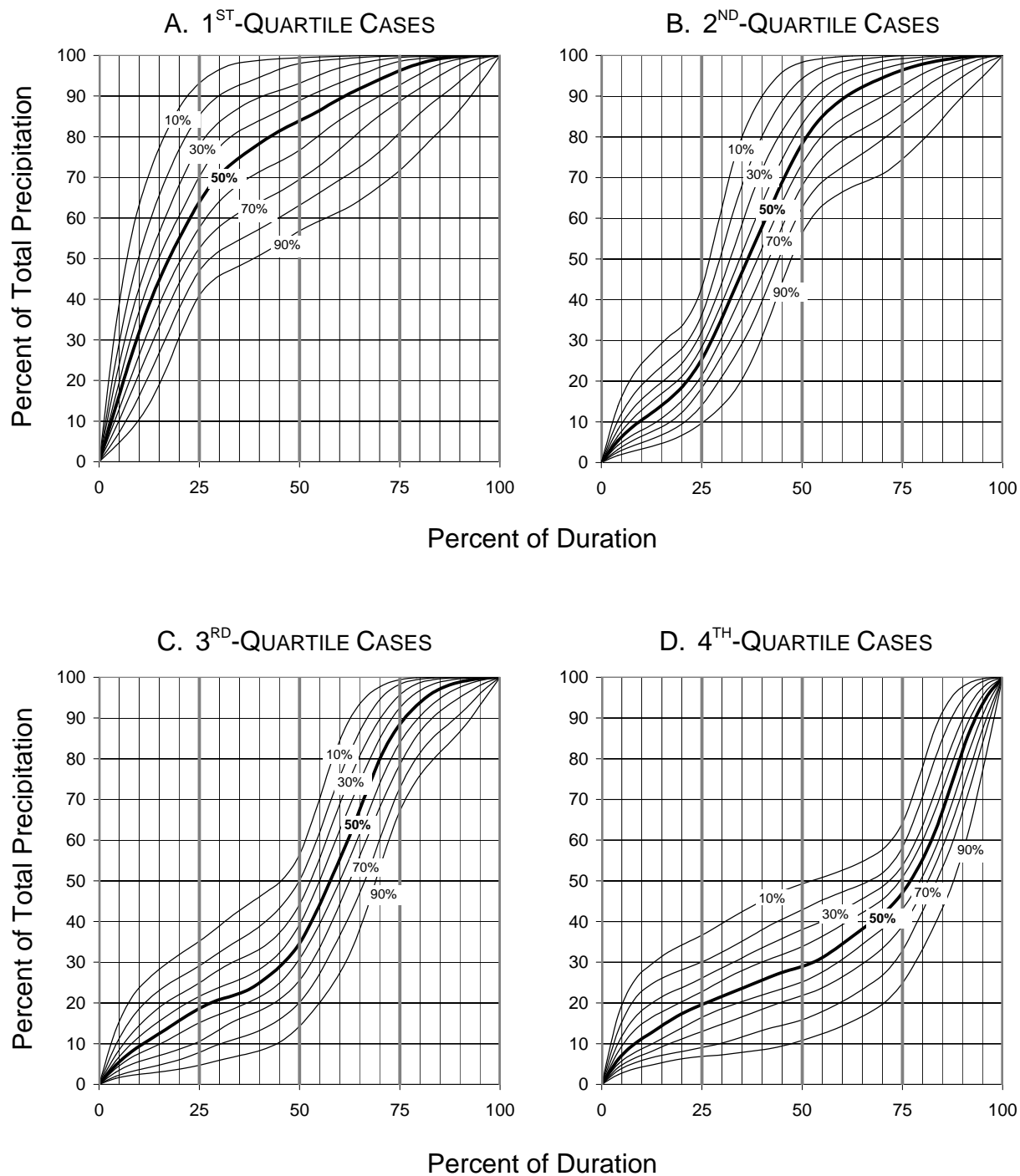### A. 1ST-QUARTILE CASES

B. 2ND-QUARTILE CASES

Percent of Duration

C. 3RD-QUARTILE CASES

D. 4TH-QUARTILE CASES

Percent of Duration