

**HYDROMETEOROLOGICAL REPORT NO. 58**  
**(SUPERCEDES HYDROMETEOROLOGICAL REPORT NO. 36)**

**PROBABLE MAXIMUM PRECIPITATION**  
**FOR CALIFORNIA –**  
**CALCULATION PROCEDURES**

**U.S. DEPARTMENT OF COMMERCE**  
**NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION**  
**U.S. DEPARTMENT OF THE ARMY**  
**CORPS OF ENGINEERS**

**Silver Spring, MD**  
**October 1998**



## HYDROMETEOROLOGICAL REPORTS

- No 1 Maximum possible precipitation over the Ompompanoosuc Basin above Union Village, Vt 1943
- No 2 Maximum possible precipitation over the Ohio River Basin above Pittsburgh, Pa 1942
- No 3. Maximum possible precipitation over the Sacramento Basin of California. 1943
- No. 4 Maximum possible precipitation over the Panama Canal Basin. 1943.
- No. 5 Thunderstorm rainfall. 1947.
- No 6 A preliminary report on the probable occurrence of excessive precipitation over Fort Supply Basin, Okla 1938
- No 7 Worst probable meteorological condition on Mill Creek, Butler and Hamilton Counties, Ohio 1937 (Unpublished) Supplement, 1938
- No 8 A hydrometeorological analysis of possible maximum precipitation over St Francis River Basin above Wappapello Mo. 1938
- No 9 A report on the possible occurrence of maximum precipitation over White River Basin above Mud Mountain Dam site, Wash 1939
- No 10 Maximum possible rainfall over the Arkansas River Basin above Caddoa, Colo 1939 Supplement, 1939
- No 11 A preliminary report on the maximum possible precipitation over the Dorena, Cottage Grove, and Fern Ridge Basins in the Willamette Basin, Oregon. 1939
- No 12 Maximum possible precipitation over the Red River Basin above Denison, Tex. 1939.
- No 13. A report on the maximum possible precipitation over Cherry Creek Basin in Colorado 1940
- No 14. The frequency of flood-producing rainfall over the Pajaro River Basin in California. 1940.
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- No 17 Maximum possible precipitation over the Pecos Basin of New Mexico. 1944. (Unpublished)
- No. 18 Tentative estimates of maximum possible flood-producing meteorological conditions in the Columbia River Basin 1945
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- No 20 An estimate of maximum possible flood-producing meteorological conditions in the Missouri River Basin above Garrison Dam site 1945.
- No. 21 A hydrometeorological study of the Los Angeles area. 1939.
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- No 21B Revised report on maximum possible precipitation, Los Angeles area, California. 1945.
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- No. 24 Maximum possible precipitation over the San Joaquin Basin, California. 1947.
- No. 25 Representative 12-hour dewpoints in major United States storms east of the Continental Divide 1947
- No 25A Representative 12-hour dewpoints in major United States storms east of the Continental Divide 2d edition. 1949
- No 26 Analysis of winds over Lake Okeechobee during tropical storm of August 26-27, 1949. 1951
- No 27 Estimate of maximum possible precipitation, Rio Grande Basin, Fort Quitman to Zapata. 1951
- No 28 Generalized estimate of maximum possible precipitation over New England and New York. 1952.
- No. 29 Seasonal variation of the standard project storm for areas of 200 and 1,000 square miles east of 105<sup>th</sup> meridian 1953
- No 30 Meteorology of floods at St Louis. 1953. (Unpublished.)
- No 31. Analysis and synthesis of hurricane wind patterns over Lake Okeechobee, Florida. 1954.
- No. 32 Characteristics of United States hurricanes pertinent to levee design for Lake Okeechobee, Florida. 1954
- No. 33 Seasonal variation of the probable maximum precipitation east of the 105<sup>th</sup> meridian for areas from 10 to 1,000 square miles and durations of 6, 12, 24, and 48 hours 1956.
- No 34 Meteorology of flood-producing storms in the Mississippi River Basin. 1956
- No 35 Meteorology of hypothetical flood sequences in the Mississippi River Basin. 1959.
- No 36 Interim report—probable maximum precipitation in California. 1961 Also available is a supplement, dated October 1969
- No 37 Meteorology of hydrologically critical storms in California 1962
- No 38. Meteorology of flood-producing storms in the Ohio River Basin 1961
- No 39. Probable maximum precipitation in the Hawaiian Islands. 1963.
- No 40. Probable maximum precipitation, Susquehanna River drainage above Harrisburg, Pa. 1965
- No 41. Probable maximum and TVA precipitation over the Tennessee River Basin above Chattanooga. 1965
- No 42. Meteorological conditions for the probable maximum flood on the Yukon River above Rampart, Alaska. 1966.
- No 43. Probable maximum precipitation, northwest states 1966
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- No 45. Probable maximum and TVA precipitation for Tennessee River Basins up to 3,000 square miles in area and durations to 72 hours 1969
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- No 47 Meteorological criteria for extreme floods for four basins in the Tennessee and Cumberland River Watersheds 1973
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(Continued on inside back cover)

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**Prepared By**

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**ABSTRACT**

This study provides estimates of general-storm probable maximum precipitation (PMP) for drainages in California for durations of 1 to 72 hours, for areas of 10 to 10,000 mi<sup>2</sup>, and during any month of the year. The report also provides local-storm PMP for durations of 15 minutes to 6 hours in drainages of 1 to 500 mi<sup>2</sup>. Step-by-step procedures are given along with example calculations. For the first time, the plates accompanying the report and all of the figures are digital products.



# 1. INTRODUCTION

## 1.1 Background

Generalized estimates of probable maximum precipitation (PMP) for Pacific Ocean drainages of California were first published by the National Weather Service (NWS) as Technical Paper No. 38 in 1960, and followed in 1961 by Hydrometeorological Report No. 36 (U. S. Weather Bureau 1961), and a revised report in October 1969 (U. S. Weather Bureau 1969). PMP estimates were provided for general storms from October through April. General-storm estimates of PMP for southeast California (mostly desert) were presented in Hydrometeorological Report No. 49 (Hansen et al. 1977). Hydrometeorological Report No. 49, which examined the Colorado River and Great Basin Drainages, also provided estimates of local-storm PMP for all of California. None of the reports provided general-storm PMP estimates for most of northeast California. In this report, publications in the Hydrometeorological Report series, such as Hydrometeorological Reports No. 36 and 49, will be abbreviated as HMR 36 and HMR 49.

HMR 36 used a mass-conservation model as a primary tool to develop estimates of general-storm PMP in topographic regions, but was unable to account for local convergence, convection, and synergistic effects caused by natural upper-level seeding of low-level clouds in orographic regions (Browning 1980, Hobbs 1989). This last effect is sometimes called the “seeder-feeder” effect. It is caused by convergence of moisture and upward vertical motion on the windward side of a mountain, with precipitation from the upper levels seeding and feeding (enhancing) the lower levels, resulting in increased precipitation on the ground. Presently, no numerical model of atmospheric processes can completely replicate orographic precipitation, especially quantitative amounts, in a reliable manner, especially for extreme general storms (Cotton and Anthes 1989, Katzfey 1995).

HMR 57, a recent PMP study for the Pacific Northwest (Hansen et al. 1994), showed some major differences between general-storm PMP estimates at the California-Oregon border, and local-storm values, especially in the western half of California. In addition, some intense storms that occurred since the publication of HMR 36 had many precipitation amounts that approached, and in a few instances surpassed the PMP estimates given in

HMR 36. As a result, it was decided that PMP estimates for California needed to be examined using new storm data and new techniques for an orographic region, which uses storms as the basis for establishing PMP.

## **1.2 Authorization**

The authorization to develop new PMP estimates for California was given by the United States Army Corps of Engineers Office of Civil Works. Funding for this work was received from the United States Army Corps of Engineers and the Corps of Engineers Los Angeles District Office, South Pacific Division. Appropriations supporting the National Weather Service (NWS) effort were provided through a continuing Memorandum of Understanding between the NWS and the Corps of Engineers (COE). The Bureau of Reclamation (BOR), through its Flood Hydrology Group in Denver, provided insight, ideas, and reviewed the work throughout the study, giving many helpful suggestions and comparisons.

Many review meetings were held from 1992 to 1997 to share the progress being made in the development of California PMP estimates. Regular attendees, known as the Federal Interagency Team, were representatives of the COE (Office of the Chief Engineer, South Pacific Division, and the Los Angeles and Sacramento Districts of the South Pacific Division), BOR, Federal Energy Regulatory Commission, and the NWS. Many comments and suggestions made by this group improved the final estimates presented in this report.

## **1.3 PMP Definition and Philosophy**

The PMP definition used for this report was given in HMR 55A (Hansen et al. 1988) as “theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year.” This is slightly different from the previous definition (American Meteorological Society 1959), which was used in HMR 36. The HMR 36 definition stressed that the estimate was for a particular drainage area. The current definition is more generalized, and emphasizes the control the atmosphere has over a broad geographic region. At the same time, the techniques from this report provide estimates of PMP for specific basins.

## 2. COMPUTATIONAL PROCEDURE

### 2.1 Introduction

The steps to calculate probable maximum precipitation (PMP) for general and local storms in California are provided in this Hydrometeorological (HMR) Report. All tables, figures, and plates are included here. As in the procedures recommended in HMR 55A and HMR 57, these steps produce storm-centered, average depths of PMP applicable to a specific drainage.

General-storm PMP may be determined for durations from 1 to 72 hours over areas from 10 to 10,000 mi<sup>2</sup>, and local-storm PMP may be determined for durations from 15 minutes to 6 hours over areas between 1 and 500 mi<sup>2</sup>. When making PMP estimates for basins less than 500 mi<sup>2</sup>, it is recommended that both general and local-storm PMP be calculated. The larger of these estimates represents the basin PMP. The decision as to which of these results is most critical for the basin involves hydrological considerations related to flooding, and are beyond the scope of this report. The final selection of PMP, local- or general-storm value, is a choice for the user. Seasonal variation of general-storm PMP has been included to aid the user when other hydrologic factors have a bearing on water management decisions. The seasonal information is shown in Figures 2.1 - 2.10.

We have attempted to keep the computational procedure in this report simple and straightforward. The Index PMP map was drawn for the general storm at 1:1,000,000 scale for northern and southern sections of California, with an overlap of at least one degree of latitude. The maps contain latitude and longitude markings, county boundaries, and selected cities or towns. In addition, each index map contains regional boundaries for use with DAD relations. These maps accompany this report, Plates 1 and 2. See Endnote<sup>1</sup> for map supplement requests.

If calculations are being made for a drainage which encompasses more than one DAD region (Figure 2.11, and also outlined on Plates 1 and 2), use proportionally-weighted

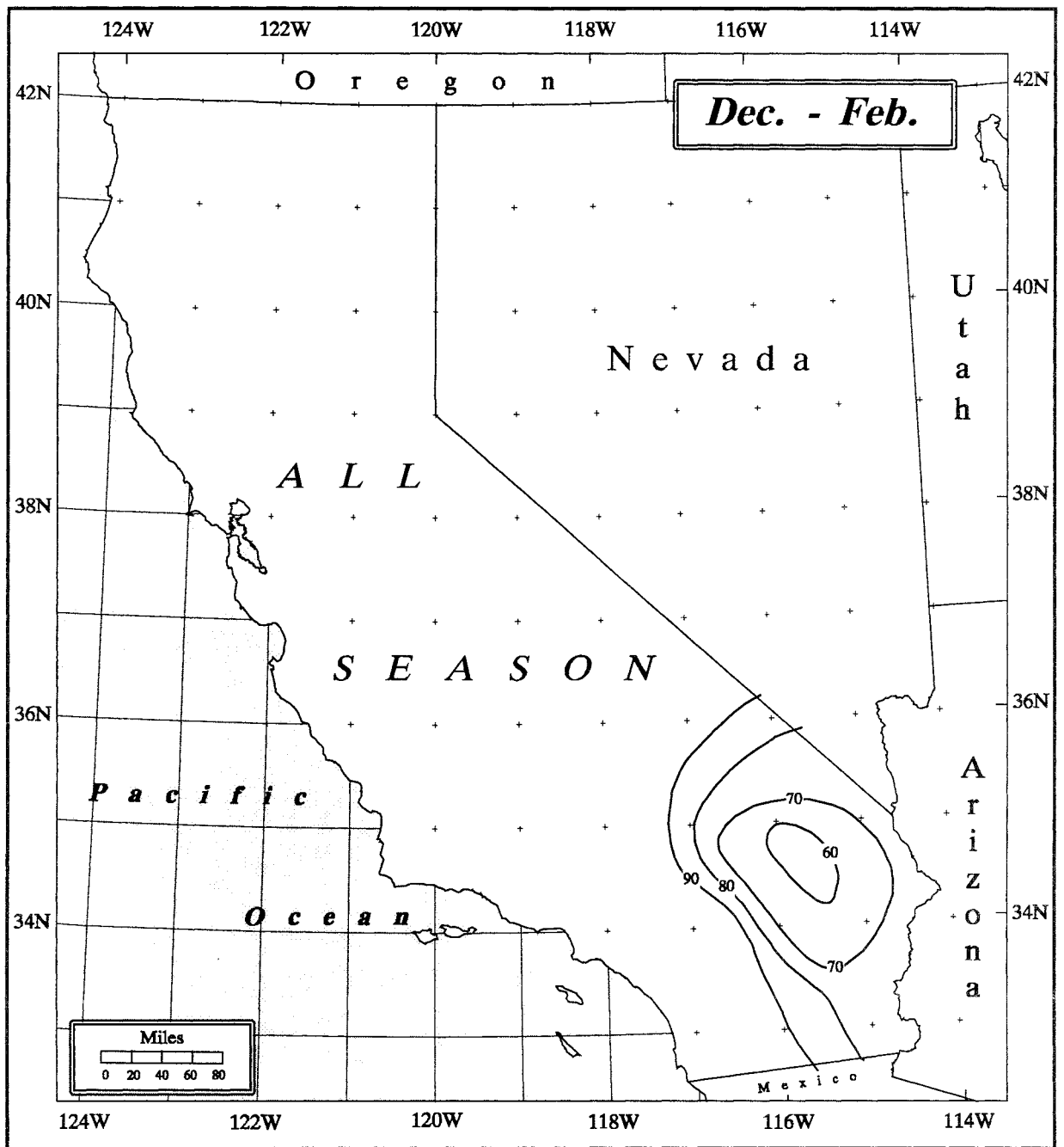
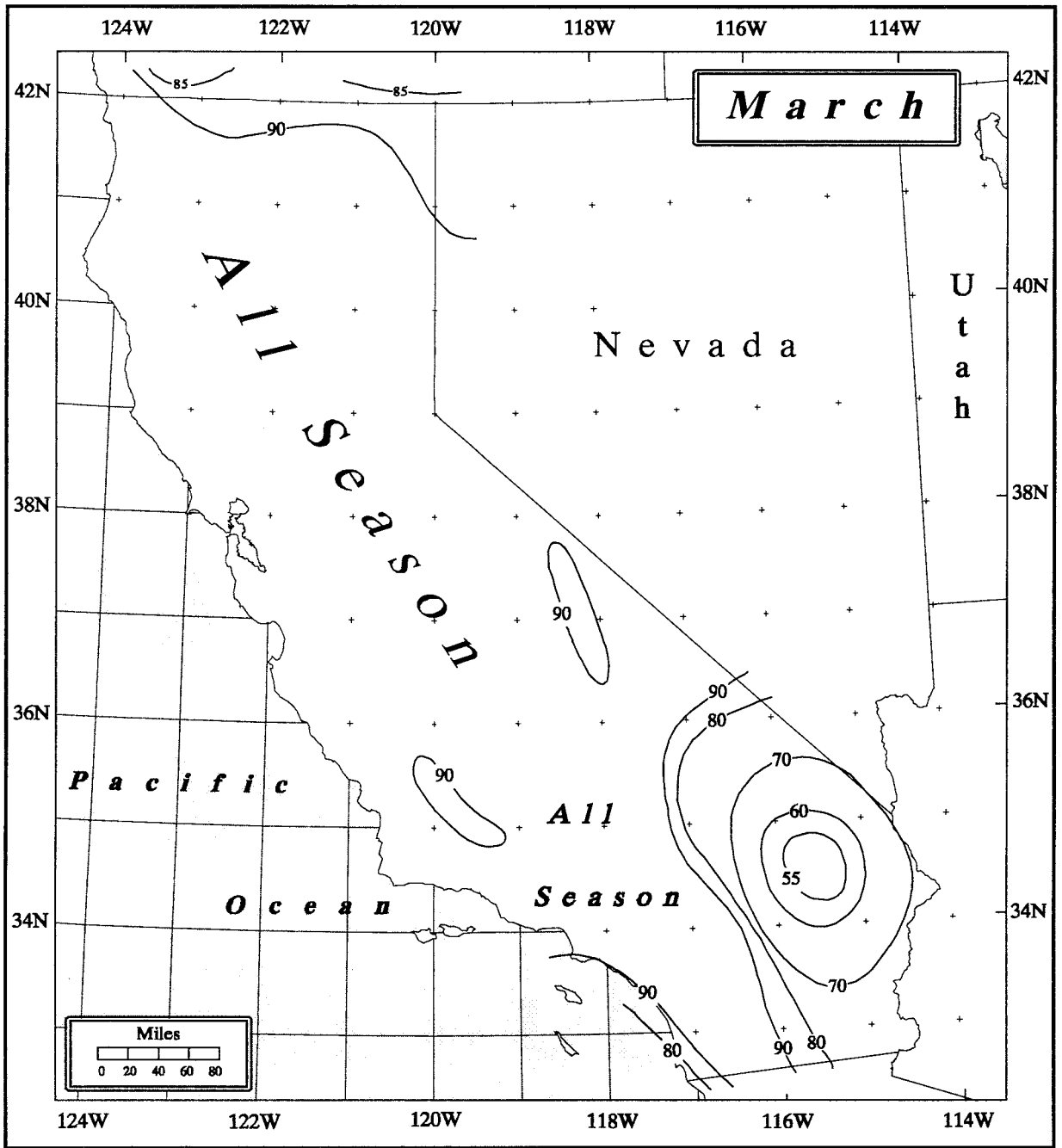
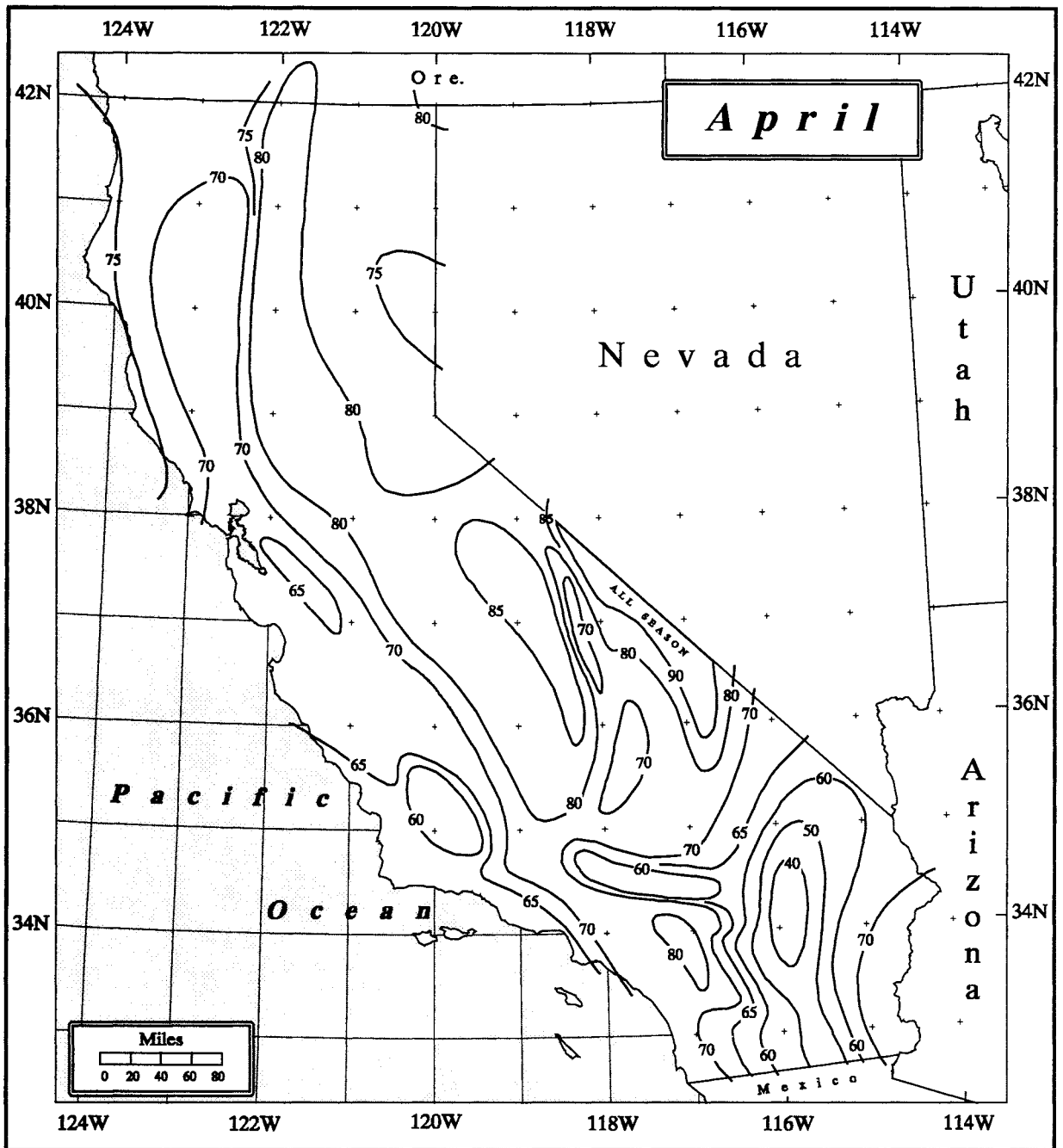


Figure 2.1. 10-mi<sup>2</sup> 24-hour general-storm PMP for December through February in California as a percent of all-season PMP (Plates 1 and 2).

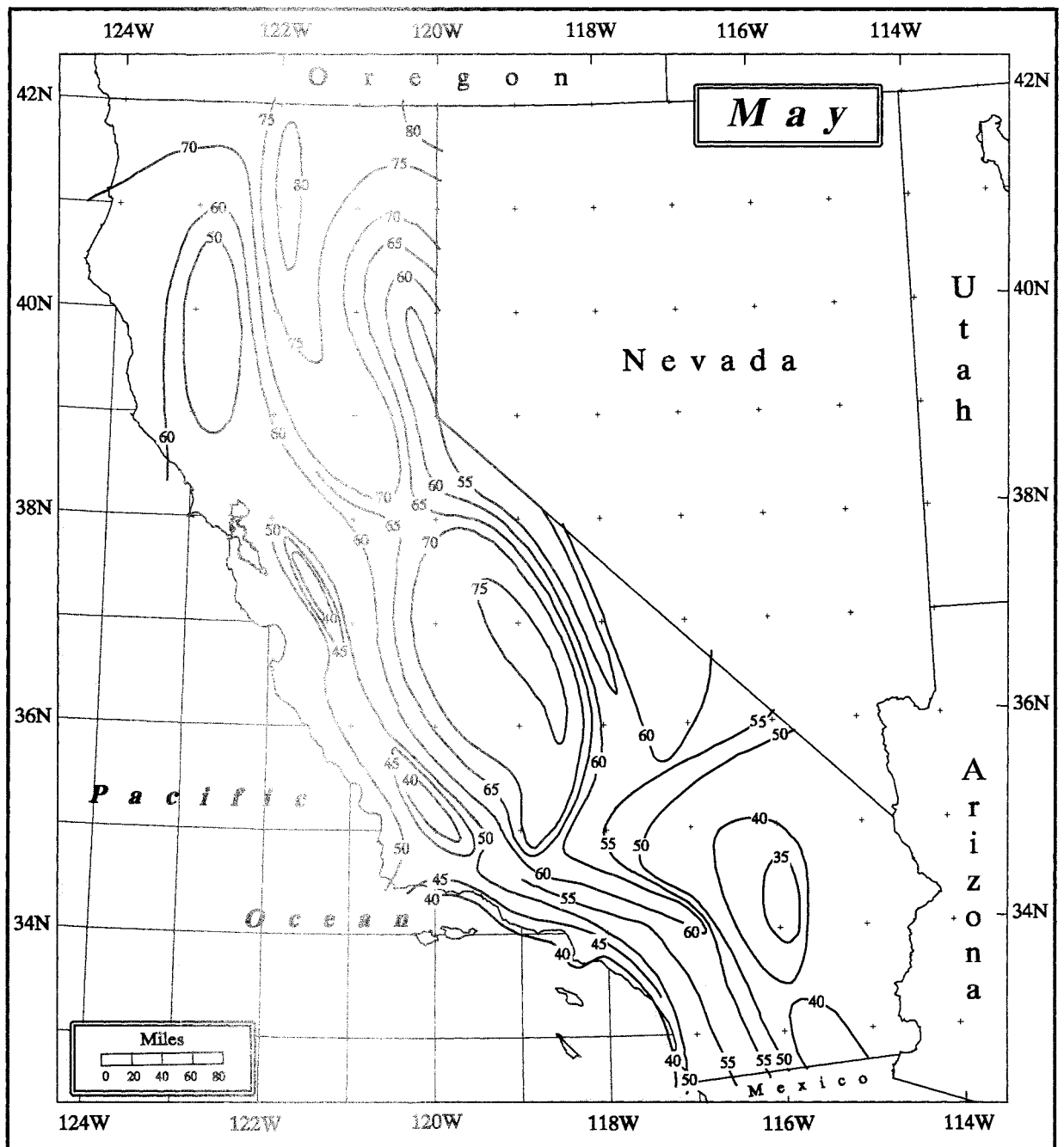




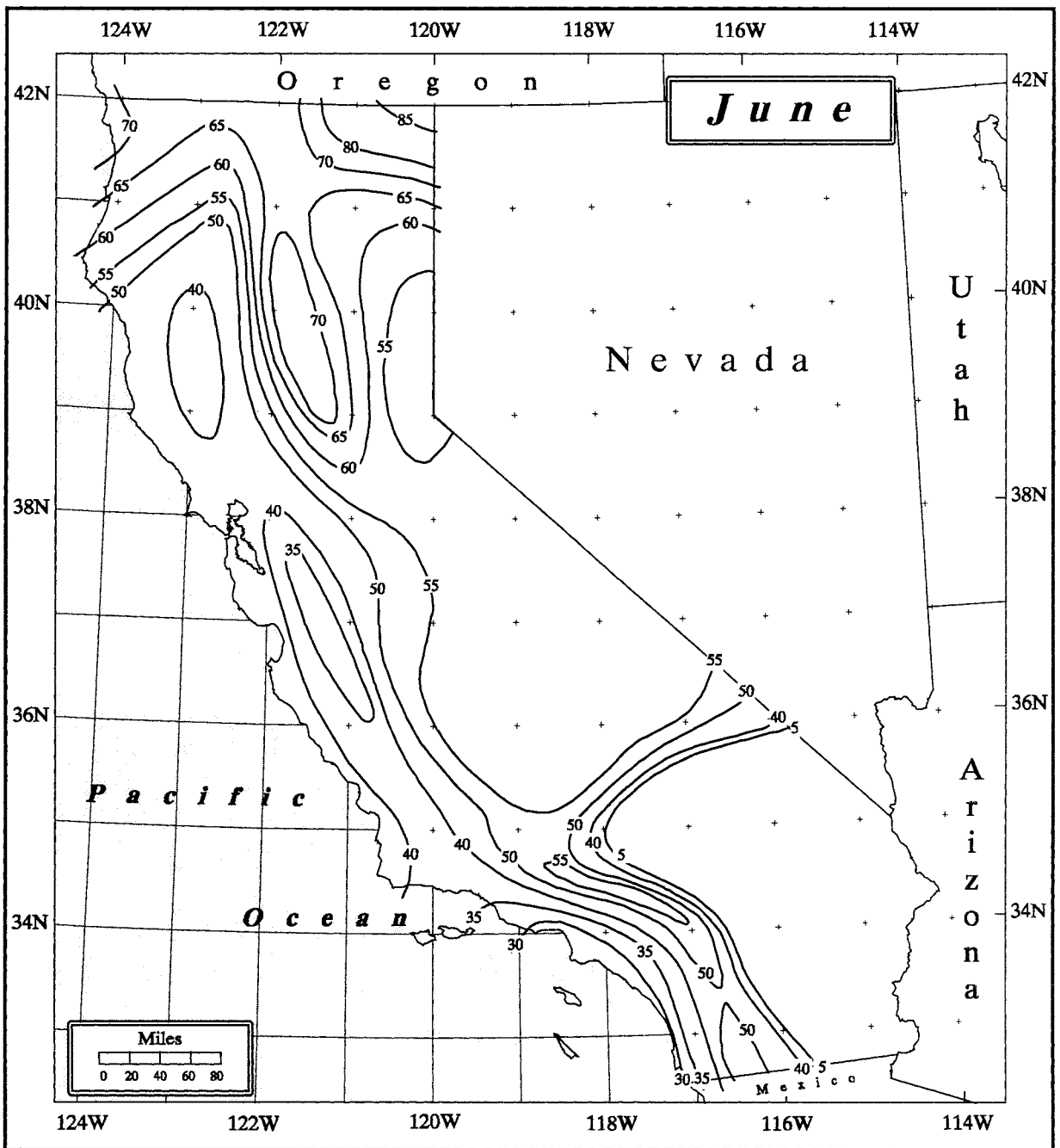
**Figure 2.2.** *10-mi<sup>2</sup> 24-hour general-storm PMP for March in California as a percent of all-season PMP (Plates 1 and 2).*



**Figure 2.3.** *10-mi<sup>2</sup> 24-hour general-storm PMP for April in California as a percent of all-season PMP (Plates 1 and 2).*



**Figure 2.4.** *10-mi<sup>2</sup> 24-hour general-storm PMP for May in California as a percent of all-season PMP (Plates 1 and 2).*



**Figure 2.5.** *10-mi<sup>2</sup> 24-hour general-storm PMP for June in California as a percent of all-season PMP (Plates 1 and 2).*

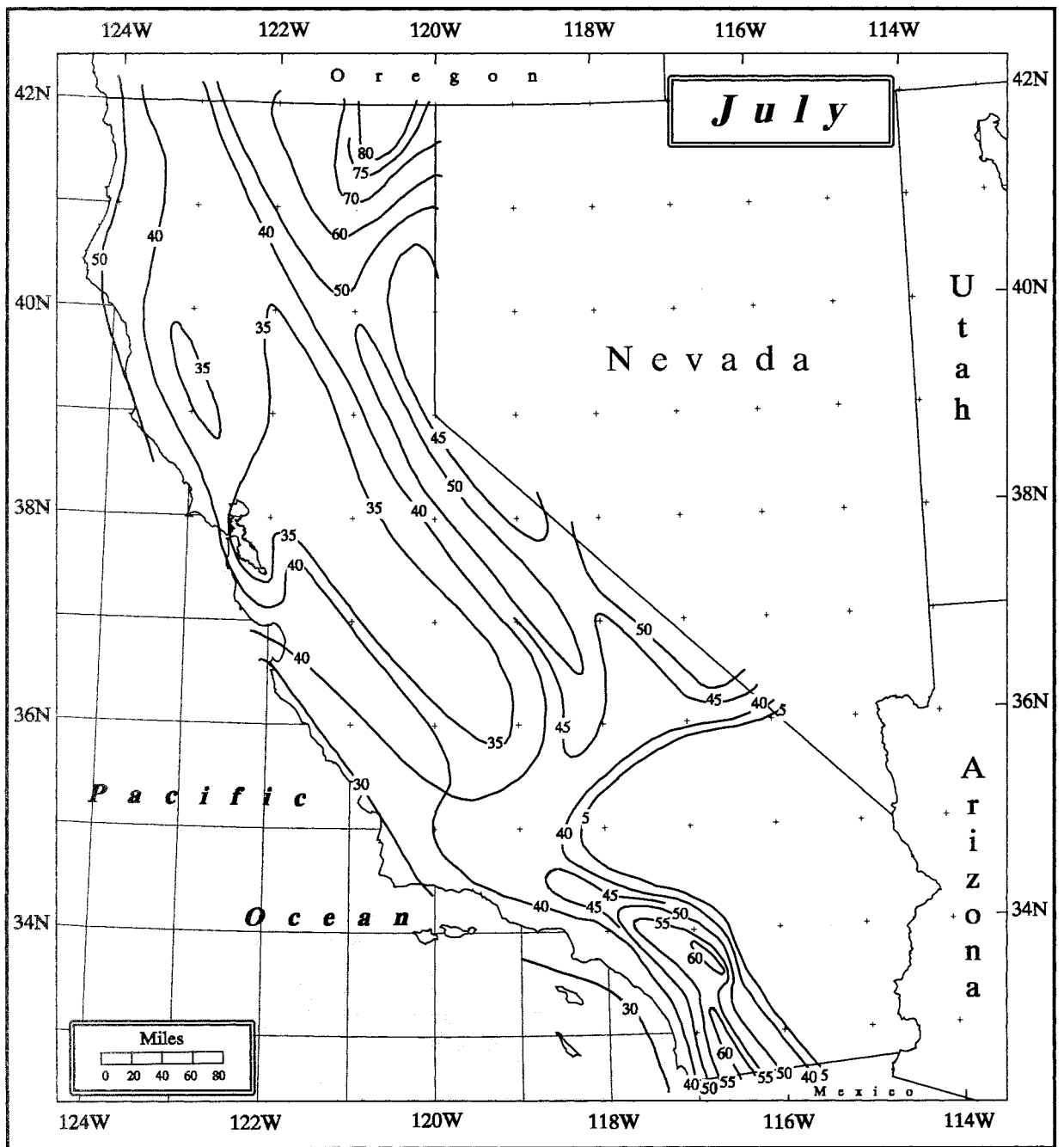
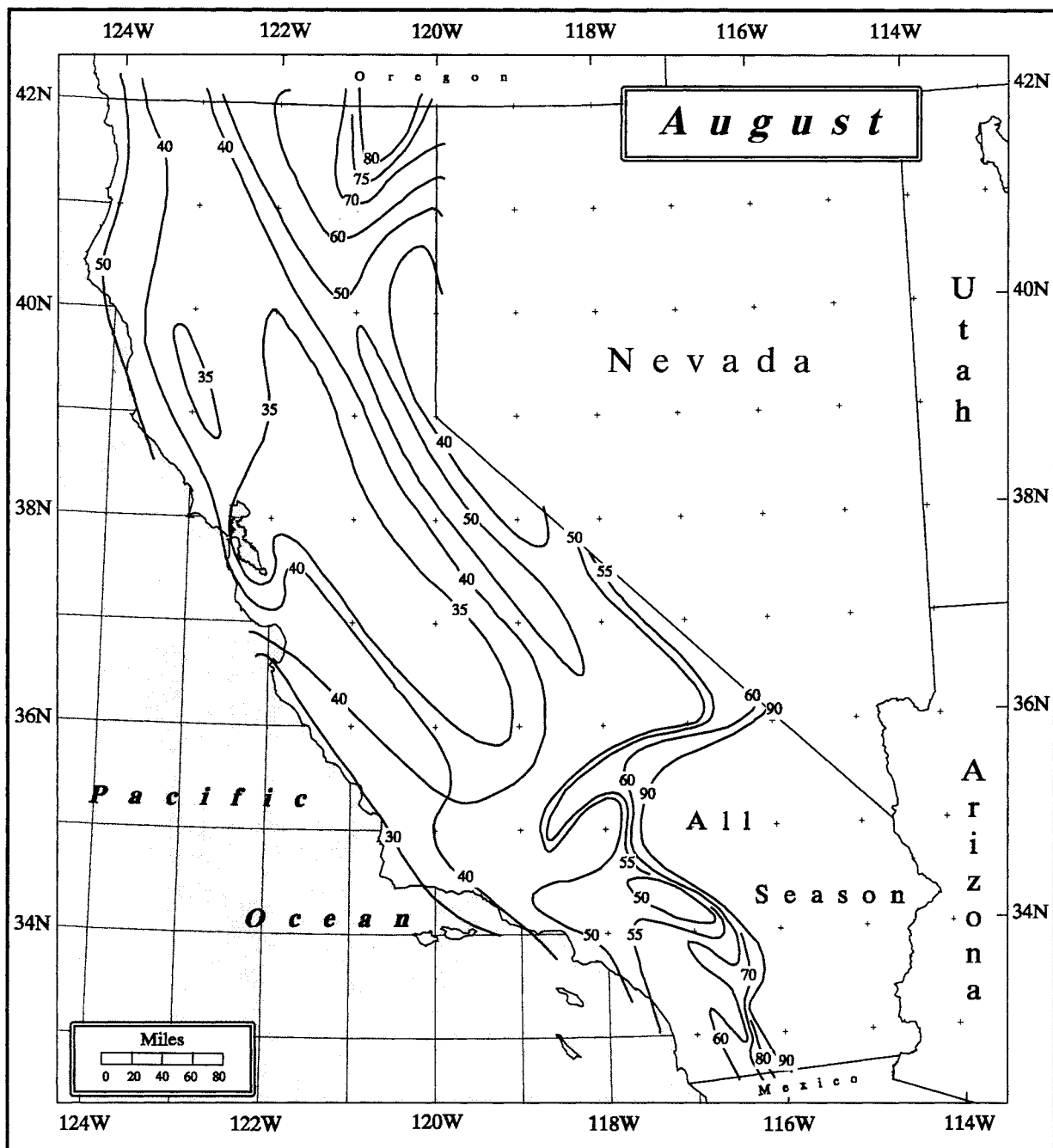
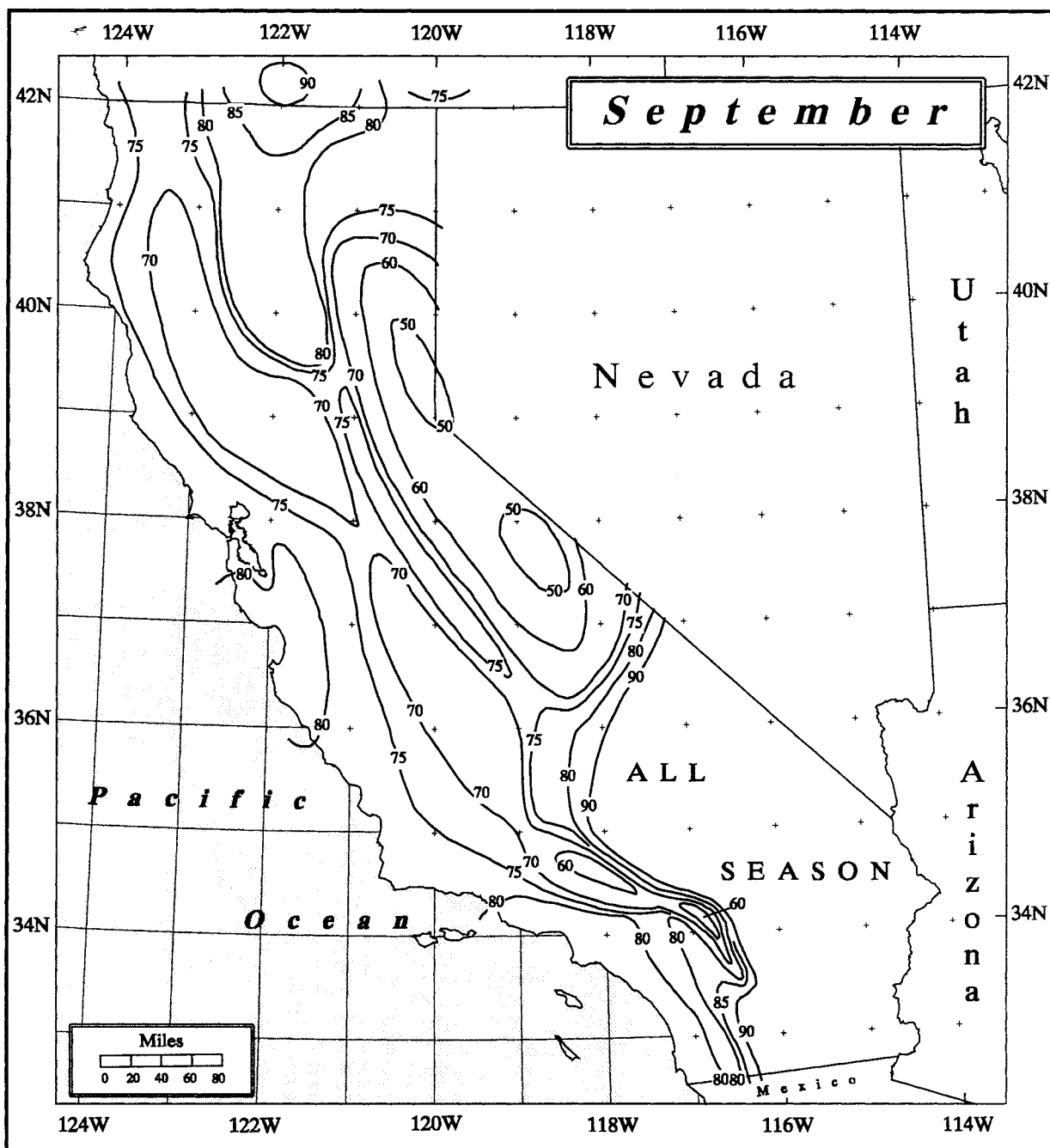


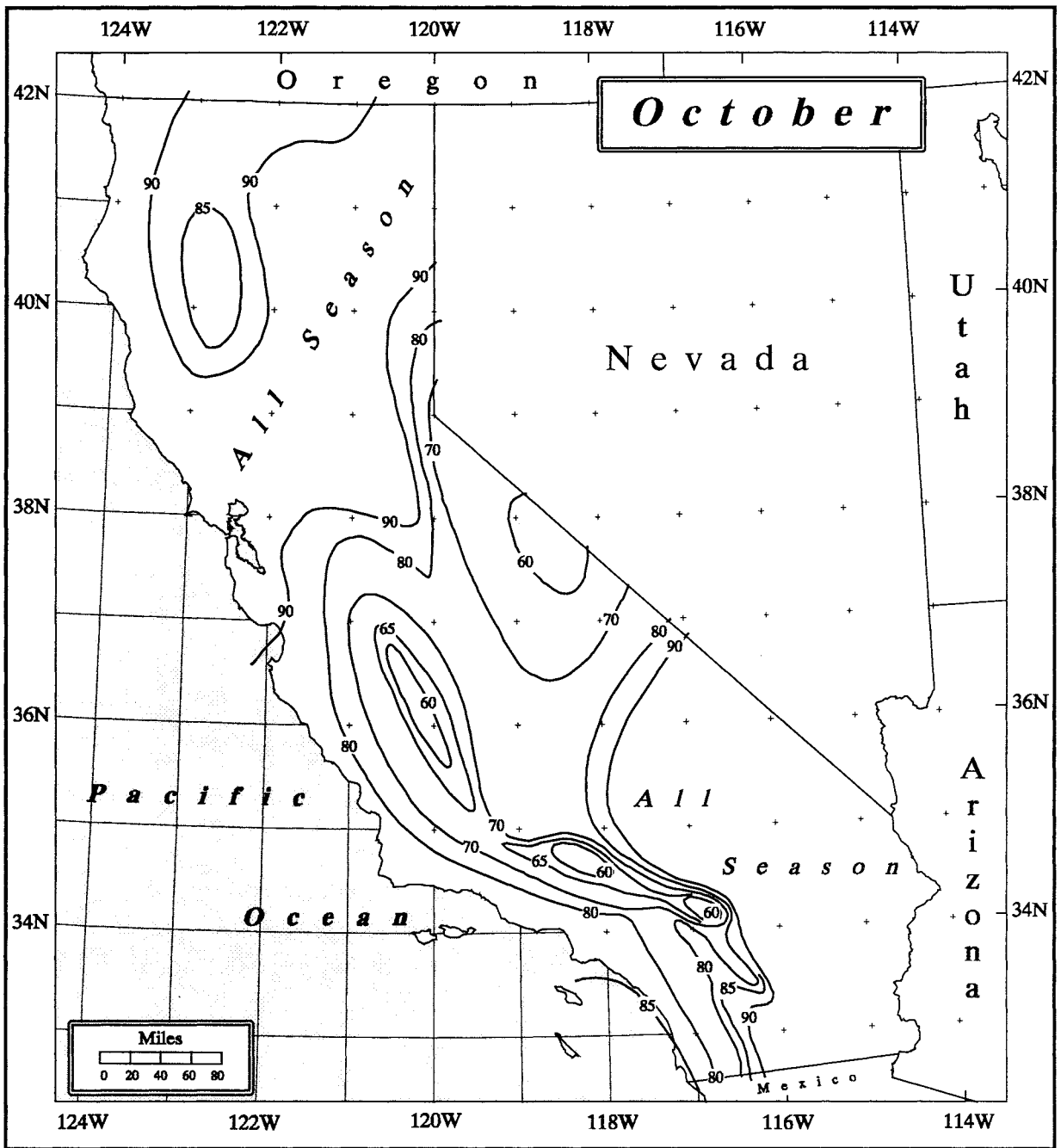
Figure 2.6. 10-mi<sup>2</sup> 24-hour general-storm PMP for July in California as a percent of all-season PMP (Plates 1 and 2).



**Figure 2.7.** *10-mi<sup>2</sup> 24-hour general-storm PMP for August in California as a percent of all-season PMP (Plates 1 and 2).*



**Figure 2.8.** *10-mi<sup>2</sup> 24-hour general-storm PMP for September in California as a percent of all-season PMP (Plates 1 and 2).*



**Figure 2.9.** *10-mi<sup>2</sup> 24-hour general-storm PMP for October in California as a percent of all-season PMP (Plates 1 and 2).*



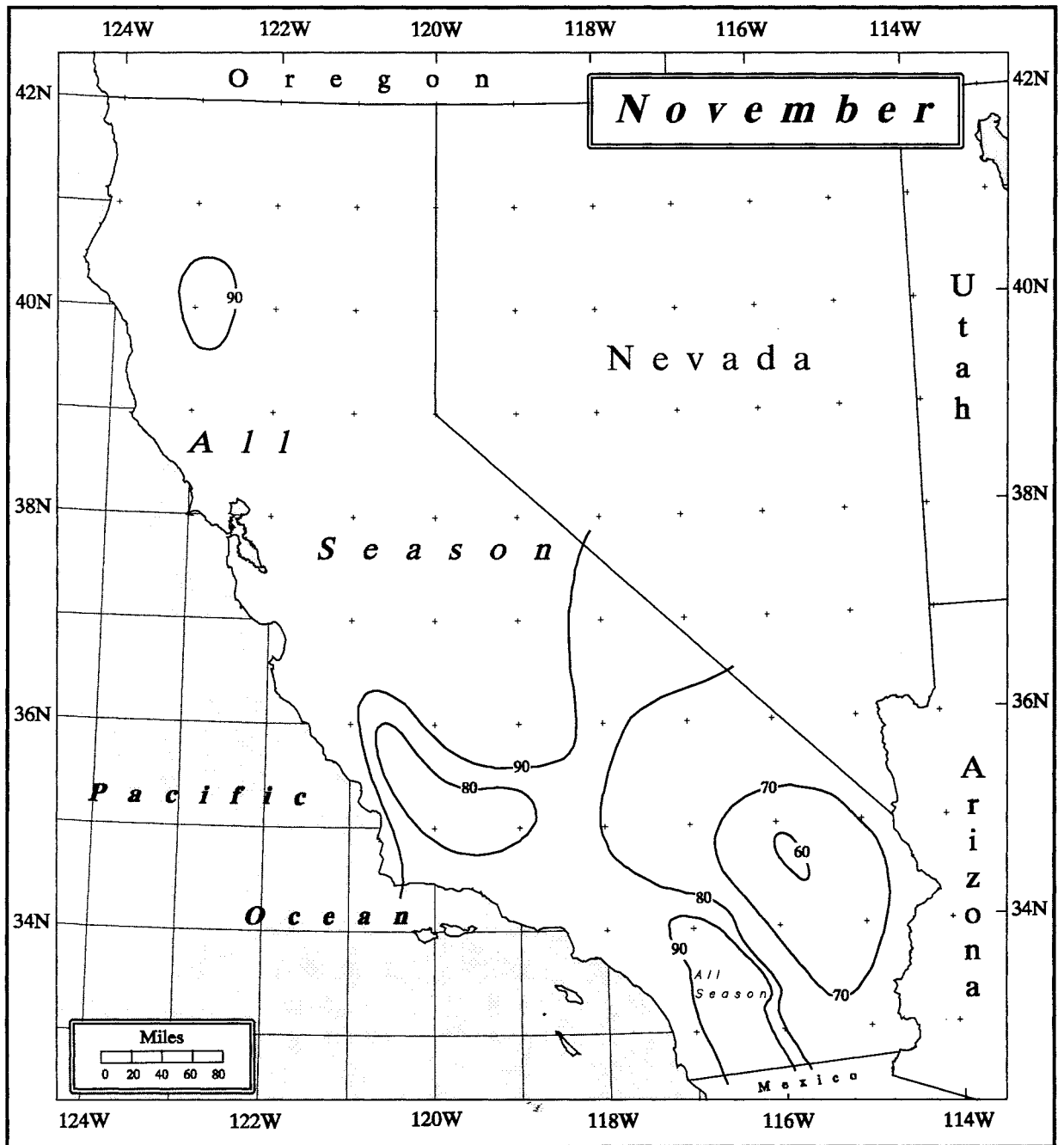


Figure 2.10.  $10\text{-mi}^2$  24-hour general-storm PMP for November in California as a percent of all-season PMP (Plates 1 and 2).

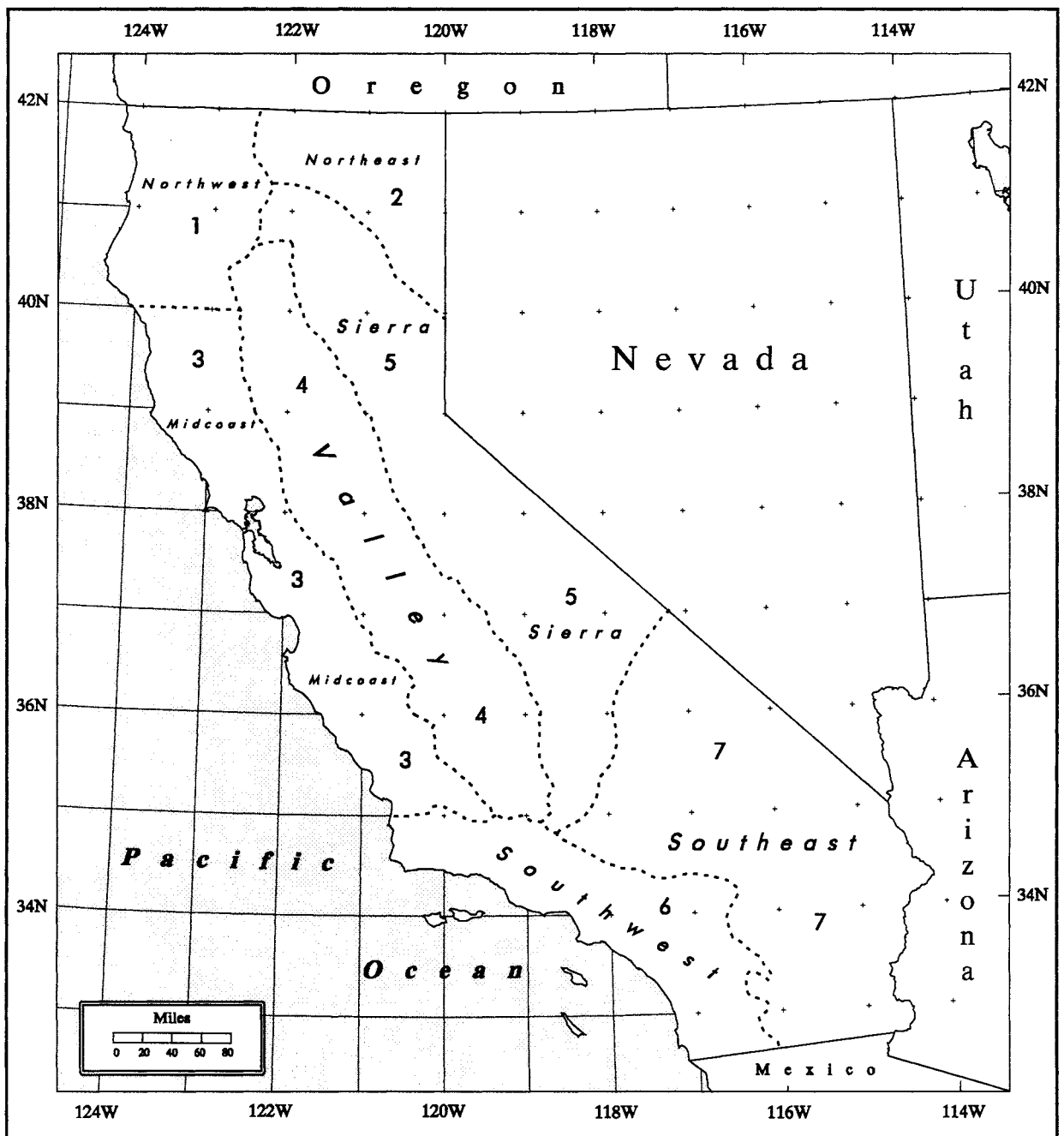


Figure 2.11. Regional boundaries for development of depth-area-duration relations.

results; i.e., calculate results for each subregion separately and then combine the PMP values in a manner proportional to the area of each subregion. For example, for a drainage of 100 area units which encompasses three subregions each having areas of 70, 20, 10 units respectively, the resulting average value for the drainage, R, is:

$$R = ((R_1) 70 + (R_2)20 + (R_3)10)/100$$

where  $R_1$ ,  $R_2$ , and  $R_3$  are the average PMP values within each of the subregions within the drainage.

The following sections present the detailed steps needed to specify PMP either for all-season, i.e., an annual maximum, or for any individual month of the year. These steps are comprehensive, in the sense that they are applicable for any and every drainage in California. The procedures outlined here, along with the general-storm Index map, have been peer-reviewed. If a user finds that these steps, with their supporting maps, figures, or diagrams, do not account for some unique hydrometeorological aspect of a particular drainage, he or she should consult the Hydrometeorological Design Studies Center staff of the National Weather Service to determine the best course of action.

## **2.2 General Storm Procedure**

### Step

#### 1. Drainage Outline

Trace the outline of the perimeter of the drainage of concern (at 1:1,000,000 scale) onto a transparent overlay, or define the basin boundary using a Geographic Information System (GIS).

#### 2. User Decision

Decide whether an all-season (annual) PMP value is needed or seasonal PMP is required.

### 3. All-Season Index PMP Estimate

Place the drainage overlay on the appropriate all-season index map and make a uniform grid that covers the drainage. Obtain index map estimates of PMP for each grid point and determine the drainage average index PMP amount. The grid separation size should take into account the gradient of PMP across the drainage, so that reasonably representative results will be obtained. This step can also be done using a GIS or other commercial software. In areas with extreme gradients, such an analysis would be more accurate when using the digital file of Plates 1 or 2, which is available from the Hydrometeorological Design Studies Center.

### 4. Seasonal Index PMP Estimates

*Skip to Step 5 if all-season PMP alone is required. Figures 2.1 to 2.10 are the starting point for seasonal PMP estimates. Determine the average value for each month to the nearest whole percent within the drainage and plot them on graph paper at the midpoint of each month. Draw a smooth curve through the points. In doing this a range of plus or minus 5 percent is allowed for any percentage at or below 85 percent. Select the percentage at any point in the selected month(s) from the smoothed curve. Any month with a selected percentage higher than 90 percent is treated as a month in which the all-season value of PMP applies, i.e., 100 percent applies to such a month. Multiply the all-season, average value of PMP from Step 3 by the percentage from this step.*

*For each month of interest determine the value of the monthly offset from the all-season envelope (90% or greater) for that month. The offset is determined by "taking the shorter path" or by counting the number of months from the nearest all-season month.*

### 5. Depth-Duration Relations

The depth-duration subregions for California are shown on Figure 2.11. These subregions are also delineated on Plates 1 and 2. For the subregion containing the drainage of interest, read the corresponding depth-duration ratios from Table 2.1

(all-season) or Table 2.2 (seasonally adjusted) and multiply each by the 24-hour result obtained from Step 3 (all-season) or Step 4 (seasonally-adjusted). Use proportionally-weighted results if more than one subregion is subtended by a drainage boundary.

<b>Table 2.1.</b> <i>All-season depth-duration ratios for California regions.</i>						
<i>Duration</i>						
<b>Region</b>	<b>1</b>	<b>6</b>	<b>12</b>	<b>24</b>	<b>48</b>	<b>72</b>
<b>Northwest</b>	0.10	0.40	0.73	1.00	1.49	1.77
<b>Northeast</b>	0.16	0.52	0.69	1.00	1.40	1.55
<b>Midcoastal</b>	0.13	0.45	0.74	1.00	1.45	1.70
<b>C. Valley</b>	0.13	0.42	0.65	1.00	1.48	1.75
<b>Sierra</b>	0.14	0.42	0.65	1.00	1.56	1.76
<b>Southwest</b>	0.14	0.48	0.76	1.00	1.41	1.59
<b>Southeast</b>	0.30	0.60	0.86	1.00	1.17	1.28

## 6. Areal Reduction Factors

Obtain the all-season reduction factors from either Table 2.3, or from Figures 2.12 - 2.17, as appropriate. For a specific month, however, use Tables 2.4 - 2.9 (interpolate to the required drainage area size) using the monthly offset for seasonal PMPs selected in step 4. Multiply the applicable reduction factors by the corresponding 10-mi<sup>2</sup> amounts from Step 5. If the drainage includes more than one subregion, again use proportionately-weighted results.

## 7. Incremental Estimates

If incremental values for the various durations are needed, plot the results from Step 6 on graph paper and draw a smooth curve to obtain intermediate

**Table 2.2.** *Seasonally adjusted 10-mi<sup>2</sup> depth-duration ratios (monthly offsets).*

<i>Northwest</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.102	0.404	0.734	1.000	1.445	1.682
<b>2</b>	0.106	0.416	0.745	1.000	1.386	1.558
<b>3</b>	0.112	0.428	0.759	1.000	1.341	1.469
<b>4</b>	0.121	0.448	0.774	1.000	1.296	1.416
<b>5</b>	0.127	0.464	0.788	1.000	1.267	1.381
<i>Northeast</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.163	0.525	0.693	1.000	1.358	1.473
<b>2</b>	0.170	0.541	0.704	1.000	1.302	1.364
<b>3</b>	0.179	0.556	0.718	1.000	1.260	1.287
<b>4</b>	0.194	0.582	0.731	1.000	1.218	1.240
<b>5</b>	0.203	0.603	0.745	1.000	1.190	1.209
<i>Midcoastal</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.133	0.455	0.744	1.000	1.407	1.615
<b>2</b>	0.138	0.468	0.755	1.000	1.349	1.496
<b>3</b>	0.146	0.482	0.770	1.000	1.305	1.411
<b>4</b>	0.157	0.504	0.784	1.000	1.262	1.360
<b>5</b>	0.165	0.522	0.799	1.000	1.233	1.326
<i>Central Valley</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.133	0.424	0.653	1.000	1.436	1.663
<b>2</b>	0.138	0.437	0.663	1.000	1.376	1.540
<b>3</b>	0.146	0.449	0.676	1.000	1.332	1.453
<b>4</b>	0.157	0.470	0.689	1.000	1.288	1.400
<b>5</b>	0.165	0.487	0.702	1.000	1.258	1.365

**Table 2.2. (cont.)** *Seasonally adjusted 10-mi<sup>2</sup> depth-duration ratios (monthly offsets).*

<i>Sierra</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.143	0.424	0.653	1.000	1.513	1.672
<b>2</b>	0.148	0.437	0.663	1.000	1.451	1.549
<b>3</b>	0.157	0.449	0.676	1.000	1.404	1.461
<b>4</b>	0.169	0.470	0.689	1.000	1.357	1.408
<b>5</b>	0.178	0.487	0.702	1.000	1.326	1.373
<i>Southwest</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.143	0.485	0.764	1.000	1.368	1.511
<b>2</b>	0.148	0.499	0.775	1.000	1.311	1.399
<b>3</b>	0.157	0.514	0.790	1.000	1.269	1.320
<b>4</b>	0.169	0.538	0.806	1.000	1.227	1.272
<b>5</b>	0.178	0.557	0.821	1.000	1.199	1.240
<i>Southeast</i>						
<b>Offset</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>1</b>	0.294	0.594	0.856	1.000	1.206	1.347
<b>2</b>	0.283	0.577	0.843	1.000	1.258	1.455
<b>3</b>	0.268	0.561	0.827	1.000	1.300	1.542
<b>4</b>	0.248	0.536	0.811	1.000	1.345	1.600
<b>5</b>	0.236	0.517	0.796	1.000	1.376	1.641

**Table 2.3.** *All-season depth-area relations for California by region.*

<i>Northwest / Northeast</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	87.50	88.50	90.00	91.50	93.00	94.00
<b>100</b>	82.00	84.00	86.00	88.00	89.50	91.00
<b>200</b>	77.00	79.50	82.00	84.00	86.00	87.75
<b>500</b>	69.50	73.00	76.25	78.25	81.00	83.00
<b>1000</b>	63.00	67.50	71.00	73.50	76.50	79.00
<b>2000</b>	55.50	60.50	64.00	67.00	69.50	72.00
<b>5000</b>	42.50	49.50	52.50	56.00	59.00	62.00
<b>10000</b>	32.00	40.00	43.50	47.00	51.00	54.00
<i>Midcoastal</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	87.50	88.75	90.00	91.00	92.00	93.00
<b>100</b>	81.75	83.75	85.50	87.00	88.50	90.00
<b>200</b>	75.75	78.25	80.50	82.50	84.50	86.25
<b>500</b>	67.50	71.00	73.50	76.00	78.50	80.50
<b>1000</b>	60.75	65.50	68.00	70.50	73.00	75.50
<b>2000</b>	53.00	58.50	61.50	64.00	67.00	70.00
<b>5000</b>	38.00	44.50	48.50	52.00	55.00	59.00
<i>Central Valley</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	84.50	87.25	89.50	91.50	92.75	94.00
<b>100</b>	77.25	81.00	84.00	86.50	88.50	90.50
<b>200</b>	70.00	74.50	78.00	81.00	83.00	85.00
<b>500</b>	59.75	64.75	68.75	72.00	74.50	77.00
<b>1000</b>	51.00	56.50	61.00	64.50	67.00	69.50
<b>2000</b>	41.00	47.50	52.00	55.50	58.50	61.50
<b>5000</b>	27.00	33.75	38.50	42.00	45.25	48.50
<b>10000</b>	14.00	21.00	26.00	30.00	33.00	36.50
<b>10000</b>	25.00	34.00	38.00	42.00	45.00	49.00



**Table 2.3 (cont.)** *All-season depth-area relations for California by region.*

<i>Sierra</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	88.00	89.00	90.00	91.00	92.50	94.00
<b>100</b>	82.50	84.00	85.50	87.00	89.25	91.25
<b>200</b>	76.75	78.75	80.75	82.75	85.50	88.25
<b>500</b>	69.25	71.75	74.25	77.00	80.50	83.50
<b>1000</b>	63.25	66.25	69.25	72.25	76.25	79.75
<b>2000</b>	57.00	60.00	63.50	67.00	71.25	75.25
<b>5000</b>	47.50	51.00	55.00	59.00	63.50	68.00
<b>10000</b>	40.00	44.00	48.00	52.50	57.50	62.00
<i>Southwest</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	87.75	88.50	89.50	90.50	91.75	92.75
<b>100</b>	81.75	83.25	84.75	86.25	87.75	89.25
<b>200</b>	75.75	78.00	79.75	81.50	83.75	85.75
<b>500</b>	67.50	70.50	72.50	75.00	77.50	80.00
<b>1000</b>	60.00	63.50	66.00	69.00	71.75	74.75
<b>2000</b>	51.00	56.00	59.00	62.00	65.00	68.00
<b>5000</b>	35.00	41.00	46.00	50.00	52.50	56.00
<b>10000</b>	22.00	30.00	34.00	38.00	42.00	46.00
<i>Southeast</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	100.00	100.00	100.00	100.00	100.00	100.00
<b>50</b>	89.00	90.50	91.75	93.00	94.50	96.00
<b>100</b>	83.50	85.25	87.25	89.00	90.75	92.50
<b>200</b>	76.50	79.75	82.00	84.00	86.00	88.00
<b>500</b>	66.00	70.75	74.00	76.50	78.75	81.00
<b>1000</b>	56.50	63.25	67.00	70.00	72.50	75.00
<b>2000</b>	46.00	54.75	59.00	62.00	64.75	67.50
<b>5000</b>	31.25	41.50	47.00	50.00	52.50	55.50
<b>10000</b>	19.00	30.00	36.00	39.50	42.50	45.00

**Table 2.4.** *Seasonally adjusted areal reduction factors for the Northeast and Northwest regions.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.913	0.930	0.948	0.960	0.967	0.975
<b>100</b>	0.861	0.883	0.905	0.928	0.945	0.960
<b>200</b>	0.785	0.818	0.847	0.871	0.900	0.919
<b>500</b>	0.677	0.725	0.769	0.798	0.835	0.859
<b>1000</b>	0.582	0.644	0.690	0.730	0.762	0.790
<b>2000</b>	0.480	0.559	0.608	0.650	0.680	0.709
<b>5000</b>	0.340	0.436	0.478	0.524	0.561	0.595
<b>10000</b>	0.240	0.338	0.372	0.418	0.467	0.502
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.894	0.921	0.939	0.952	0.959	0.965
<b>100</b>	0.831	0.868	0.892	0.916	0.929	0.941
<b>200</b>	0.753	0.802	0.834	0.858	0.880	0.892
<b>500</b>	0.641	0.702	0.746	0.778	0.806	0.825
<b>1000</b>	0.544	0.617	0.658	0.697	0.728	0.751
<b>2000</b>	0.447	0.528	0.570	0.610	0.639	0.666
<b>5000</b>	0.313	0.401	0.436	0.484	0.519	0.552
<b>10000</b>	0.218	0.302	0.335	0.381	0.428	0.459
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.883	0.916	0.933	0.944	0.950	0.955
<b>100</b>	0.809	0.859	0.882	0.904	0.916	0.926
<b>200</b>	0.729	0.789	0.821	0.844	0.867	0.878
<b>500</b>	0.619	0.687	0.726	0.757	0.785	0.803
<b>1000</b>	0.522	0.596	0.636	0.671	0.697	0.719
<b>2000</b>	0.425	0.500	0.541	0.576	0.605	0.634
<b>5000</b>	0.294	0.374	0.412	0.451	0.481	0.512
<b>10000</b>	0.205	0.284	0.320	0.355	0.393	0.424

**Table 2.4. (cont.)** *Seasonally adjusted areal reduction factors for the Northeast and Northwest regions.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.865	0.902	0.926	0.940	0.946	0.952
<b>100</b>	0.787	0.837	0.869	0.890	0.901	0.913
<b>200</b>	0.696	0.760	0.800	0.821	0.842	0.853
<b>500</b>	0.576	0.649	0.695	0.721	0.747	0.765
<b>1000</b>	0.474	0.555	0.601	0.633	0.658	0.679
<b>2000</b>	0.375	0.464	0.502	0.536	0.563	0.590
<b>5000</b>	0.244	0.337	0.375	0.412	0.435	0.459
<b>10000</b>	0.162	0.248	0.283	0.317	0.354	0.383
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.851	0.893	0.917	0.931	0.946	0.955
<b>100</b>	0.770	0.823	0.851	0.874	0.886	0.898
<b>200</b>	0.672	0.743	0.778	0.801	0.822	0.833
<b>500</b>	0.551	0.627	0.667	0.697	0.722	0.740
<b>1000</b>	0.448	0.538	0.572	0.607	0.635	0.660
<b>2000</b>	0.347	0.445	0.480	0.516	0.546	0.572
<b>5000</b>	0.216	0.322	0.352	0.392	0.425	0.453
<b>10000</b>	0.141	0.228	0.261	0.298	0.339	0.367

**Table 2.5.** *Seasonally adjusted areal reduction factors for the Midcoastal region.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.903	0.915	0.928	0.943	0.957	0.975
<b>100</b>	0.846	0.868	0.886	0.908	0.930	0.949
<b>200</b>	0.775	0.804	0.832	0.856	0.885	0.909
<b>500</b>	0.663	0.710	0.750	0.778	0.815	0.838
<b>1000</b>	0.564	0.630	0.671	0.706	0.738	0.770
<b>2000</b>	0.458	0.536	0.584	0.621	0.655	0.690
<b>5000</b>	0.308	0.392	0.441	0.486	0.523	0.566
<b>10000</b>	0.188	0.287	0.325	0.374	0.412	0.456
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.885	0.906	0.919	0.935	0.949	0.965
<b>100</b>	0.817	0.853	0.872	0.896	0.914	0.931
<b>200</b>	0.743	0.787	0.820	0.843	0.866	0.882
<b>500</b>	0.627	0.688	0.727	0.758	0.786	0.805
<b>1000</b>	0.527	0.603	0.639	0.673	0.704	0.732
<b>2000</b>	0.427	0.506	0.547	0.582	0.616	0.648
<b>5000</b>	0.283	0.360	0.403	0.450	0.484	0.525
<b>10000</b>	0.170	0.257	0.293	0.340	0.378	0.417
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.874	0.902	0.913	0.927	0.940	0.955
<b>100</b>	0.795	0.844	0.862	0.885	0.901	0.917
<b>200</b>	0.719	0.775	0.807	0.830	0.852	0.869
<b>500</b>	0.606	0.673	0.708	0.739	0.766	0.784
<b>1000</b>	0.505	0.583	0.619	0.648	0.674	0.701
<b>2000</b>	0.405	0.480	0.520	0.550	0.583	0.616
<b>5000</b>	0.266	0.336	0.381	0.419	0.448	0.487
<b>10000</b>	0.160	0.241	0.279	0.317	0.347	0.385

**Table 2.5. (cont.)** *Seasonally adjusted areal reduction factors for the Midcoastal region.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.855	0.888	0.907	0.923	0.936	0.952
<b>100</b>	0.774	0.823	0.850	0.871	0.887	0.903
<b>200</b>	0.688	0.746	0.786	0.807	0.827	0.843
<b>500</b>	0.564	0.636	0.677	0.703	0.729	0.747
<b>1000</b>	0.459	0.543	0.584	0.612	0.637	0.662
<b>2000</b>	0.358	0.445	0.483	0.512	0.543	0.574
<b>5000</b>	0.220	0.303	0.347	0.382	0.406	0.437
<b>10000</b>	0.126	0.211	0.247	0.284	0.313	0.348
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	0.000
<b>50</b>	0.842	0.879	0.897	0.915	0.936	0.000
<b>100</b>	0.757	0.809	0.832	0.855	0.872	0.000
<b>200</b>	0.664	0.730	0.765	0.787	0.808	48.000
<b>500</b>	0.539	0.614	0.650	0.679	0.705	1.016
<b>1000</b>	0.434	0.526	0.556	0.587	0.615	0.919
<b>2000</b>	0.331	0.427	0.461	0.493	0.526	0.875
<b>5000</b>	0.196	0.289	0.325	0.364	0.396	0.834
<b>10000</b>	0.110	0.194	0.228	0.267	0.299	0.749

**Table 2.6.** *Seasonally adjusted areal reduction factors for the Central Valley region.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.828	0.886	0.918	0.940	0.952	0.970
<b>100</b>	0.752	0.823	0.866	0.893	0.915	0.934
<b>200</b>	0.663	0.750	0.798	0.832	0.860	0.889
<b>500</b>	0.536	0.638	0.701	0.739	0.775	0.803
<b>1000</b>	0.437	0.541	0.608	0.652	0.683	0.715
<b>2000</b>	0.333	0.440	0.504	0.548	0.582	0.616
<b>5000</b>	0.207	0.295	0.350	0.393	0.432	0.466
<b>10000</b>	0.113	0.182	0.222	0.267	0.302	0.339
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.812	0.877	0.909	0.932	0.944	0.960
<b>100</b>	0.726	0.809	0.853	0.882	0.899	0.916
<b>200</b>	0.636	0.734	0.786	0.819	0.841	0.862
<b>500</b>	0.507	0.618	0.679	0.720	0.748	0.771
<b>1000</b>	0.408	0.518	0.580	0.622	0.652	0.679
<b>2000</b>	0.310	0.415	0.472	0.514	0.547	0.578
<b>5000</b>	0.190	0.271	0.320	0.363	0.400	0.432
<b>10000</b>	0.102	0.162	0.200	0.243	0.277	0.310
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.802	0.872	0.903	0.924	0.935	0.951
<b>100</b>	0.707	0.801	0.843	0.870	0.886	0.902
<b>200</b>	0.615	0.723	0.774	0.806	0.828	0.849
<b>500</b>	0.490	0.605	0.661	0.701	0.729	0.751
<b>1000</b>	0.391	0.500	0.561	0.599	0.624	0.651
<b>2000</b>	0.295	0.394	0.448	0.486	0.518	0.550
<b>5000</b>	0.179	0.253	0.302	0.338	0.371	0.400
<b>10000</b>	0.096	0.153	0.191	0.227	0.254	0.287

**Table 2.6. (cont.)** *Seasonally adjusted areal reduction factors for the Central Valley region.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.785	0.859	0.897	0.920	0.931	0.947
<b>100</b>	0.688	0.780	0.831	0.857	0.873	0.889
<b>200</b>	0.588	0.696	0.753	0.784	0.804	0.825
<b>500</b>	0.456	0.572	0.633	0.668	0.694	0.716
<b>1000</b>	0.355	0.466	0.529	0.565	0.590	0.615
<b>2000</b>	0.260	0.365	0.416	0.452	0.482	0.513
<b>5000</b>	0.148	0.228	0.275	0.309	0.336	0.359
<b>10000</b>	0.076	0.133	0.169	0.203	0.229	0.259
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.772	0.850	0.888	0.912	0.931	0.951
<b>100</b>	0.673	0.768	0.813	0.841	0.858	0.874
<b>200</b>	0.568	0.681	0.733	0.764	0.785	0.805
<b>500</b>	0.436	0.552	0.608	0.645	0.670	0.692
<b>1000</b>	0.336	0.451	0.504	0.542	0.569	0.597
<b>2000</b>	0.241	0.350	0.398	0.435	0.467	0.497
<b>5000</b>	0.131	0.218	0.258	0.294	0.328	0.354
<b>10000</b>	0.066	0.123	0.156	0.191	0.219	0.248

**Table 2.7.** *Seasonally adjusted areal reduction factors for the Sierra region.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.908	0.920	0.933	0.950	0.962	0.985
<b>100</b>	0.851	0.868	0.886	0.908	0.930	0.960
<b>200</b>	0.775	0.799	0.822	0.851	0.880	0.919
<b>500</b>	0.667	0.706	0.745	0.778	0.820	0.859
<b>1000</b>	0.582	0.630	0.676	0.715	0.762	0.810
<b>2000</b>	0.493	0.550	0.603	0.650	0.699	0.749
<b>5000</b>	0.385	0.449	0.501	0.552	0.608	0.653
<b>10000</b>	0.300	0.372	0.410	0.472	0.531	0.577
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.889	0.911	0.924	0.942	0.954	0.975
<b>100</b>	0.821	0.853	0.872	0.896	0.914	0.941
<b>200</b>	0.743	0.782	0.810	0.839	0.861	0.892
<b>500</b>	0.632	0.684	0.722	0.758	0.791	0.825
<b>1000</b>	0.544	0.603	0.644	0.683	0.728	0.770
<b>2000</b>	0.459	0.519	0.565	0.610	0.658	0.703
<b>5000</b>	0.354	0.413	0.457	0.510	0.563	0.605
<b>10000</b>	0.272	0.332	0.370	0.429	0.487	0.527
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.878	0.907	0.918	0.934	0.945	0.965
<b>100</b>	0.800	0.844	0.862	0.885	0.901	0.926
<b>200</b>	0.719	0.770	0.797	0.825	0.847	0.878
<b>500</b>	0.611	0.669	0.703	0.739	0.771	0.803
<b>1000</b>	0.522	0.583	0.623	0.657	0.697	0.737
<b>2000</b>	0.436	0.492	0.537	0.576	0.622	0.669
<b>5000</b>	0.333	0.385	0.432	0.475	0.522	0.561
<b>10000</b>	0.256	0.312	0.353	0.400	0.447	0.487



**Table 2.7. (cont.)** *Seasonally adjusted areal reduction factors for the Sierra region.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.860	0.893	0.912	0.930	0.941	0.961
<b>100</b>	0.778	0.823	0.850	0.871	0.887	0.913
<b>200</b>	0.688	0.742	0.777	0.802	0.823	0.853
<b>500</b>	0.568	0.632	0.673	0.703	0.734	0.765
<b>1000</b>	0.474	0.543	0.588	0.621	0.658	0.697
<b>2000</b>	0.385	0.456	0.498	0.536	0.579	0.623
<b>5000</b>	0.276	0.347	0.393	0.434	0.472	0.503
<b>10000</b>	0.202	0.273	0.312	0.358	0.403	0.440
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.846	0.883	0.902	0.922	0.941	0.965
<b>100</b>	0.761	0.809	0.832	0.855	0.872	0.898
<b>200</b>	0.664	0.725	0.756	0.783	0.803	0.833
<b>500</b>	0.543	0.610	0.646	0.679	0.709	0.740
<b>1000</b>	0.448	0.526	0.560	0.595	0.635	0.676
<b>2000</b>	0.356	0.438	0.476	0.516	0.561	0.604
<b>5000</b>	0.245	0.332	0.369	0.413	0.461	0.496
<b>10000</b>	0.176	0.251	0.288	0.337	0.386	0.422

**Table 2.8.** *Seasonally adjusted areal reduction factors for the Southwest region.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.893	0.915	0.928	0.940	0.952	0.965
<b>100</b>	0.837	0.863	0.881	0.898	0.920	0.939
<b>200</b>	0.770	0.799	0.818	0.842	0.870	0.899
<b>500</b>	0.658	0.696	0.730	0.758	0.795	0.828
<b>1000</b>	0.555	0.611	0.647	0.686	0.723	0.760
<b>2000</b>	0.441	0.513	0.561	0.601	0.636	0.670
<b>5000</b>	0.284	0.361	0.419	0.468	0.499	0.538
<b>10000</b>	0.165	0.254	0.291	0.338	0.384	0.428
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.875	0.906	0.919	0.932	0.944	0.955
<b>100</b>	0.807	0.848	0.867	0.887	0.904	0.921
<b>200</b>	0.739	0.782	0.805	0.829	0.851	0.872
<b>500</b>	0.623	0.674	0.708	0.739	0.767	0.795
<b>1000</b>	0.519	0.585	0.616	0.655	0.690	0.722
<b>2000</b>	0.411	0.484	0.525	0.564	0.598	0.629
<b>5000</b>	0.261	0.332	0.382	0.433	0.462	0.498
<b>10000</b>	0.150	0.227	0.262	0.308	0.353	0.391
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.864	0.902	0.913	0.924	0.935	0.946
<b>100</b>	0.786	0.840	0.858	0.875	0.891	0.907
<b>200</b>	0.715	0.770	0.793	0.815	0.838	0.859
<b>500</b>	0.602	0.660	0.689	0.720	0.747	0.775
<b>1000</b>	0.497	0.566	0.596	0.630	0.661	0.692
<b>2000</b>	0.390	0.459	0.499	0.533	0.566	0.598
<b>5000</b>	0.245	0.310	0.361	0.403	0.428	0.462
<b>10000</b>	0.141	0.213	0.250	0.287	0.323	0.361

**Table 2.8. (cont.)** *Seasonally adjusted areal reduction factors for the Southwest region.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.846	0.888	0.907	0.920	0.931	0.942
<b>100</b>	0.765	0.818	0.845	0.861	0.877	0.894
<b>200</b>	0.683	0.742	0.772	0.793	0.813	0.834
<b>500</b>	0.560	0.624	0.659	0.685	0.712	0.738
<b>1000</b>	0.451	0.527	0.563	0.595	0.624	0.654
<b>2000</b>	0.344	0.426	0.463	0.496	0.527	0.558
<b>5000</b>	0.203	0.279	0.329	0.368	0.387	0.414
<b>10000</b>	0.111	0.186	0.221	0.257	0.292	0.327
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.833	0.879	0.897	0.912	0.931	0.946
<b>100</b>	0.748	0.805	0.827	0.846	0.863	0.879
<b>200</b>	0.660	0.725	0.751	0.774	0.794	0.814
<b>500</b>	0.536	0.602	0.633	0.662	0.688	0.713
<b>1000</b>	0.427	0.510	0.536	0.571	0.602	0.635
<b>2000</b>	0.319	0.409	0.443	0.477	0.510	0.541
<b>5000</b>	0.180	0.267	0.308	0.350	0.378	0.409
<b>10000</b>	0.097	0.171	0.204	0.241	0.279	0.313

**Table 2.9.** *Seasonally adjusted areal reduction factors for the Southeast region.*

<i>Offset 1 Month</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.902	0.935	0.945	0.952	0.964	0.970
<b>100</b>	0.838	0.877	0.894	0.912	0.920	0.929
<b>200</b>	0.779	0.832	0.848	0.874	0.880	0.891
<b>500</b>	0.713	0.760	0.776	0.807	0.820	0.837
<b>1000</b>	0.643	0.702	0.725	0.745	0.763	0.780
<b>2000</b>	0.561	0.622	0.647	0.655	0.675	0.690
<b>5000</b>	0.389	0.477	0.522	0.535	0.553	0.573
<b>10000</b>	0.253	0.355	0.427	0.444	0.464	0.484
<i>Offset 2 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.921	0.944	0.954	0.960	0.972	0.980
<b>100</b>	0.869	0.892	0.908	0.924	0.936	0.947
<b>200</b>	0.813	0.849	0.861	0.887	0.900	0.918
<b>500</b>	0.753	0.785	0.800	0.828	0.850	0.871
<b>1000</b>	0.688	0.733	0.761	0.781	0.799	0.821
<b>2000</b>	0.602	0.659	0.691	0.698	0.717	0.735
<b>5000</b>	0.423	0.519	0.572	0.578	0.597	0.618
<b>10000</b>	0.279	0.397	0.474	0.488	0.506	0.529
<i>Offset 3 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.932	0.949	0.960	0.968	0.982	0.990
<b>100</b>	0.892	0.902	0.918	0.936	0.950	0.962
<b>200</b>	0.840	0.862	0.874	0.902	0.914	0.933
<b>500</b>	0.779	0.802	0.822	0.850	0.872	0.894
<b>1000</b>	0.718	0.759	0.787	0.811	0.834	0.857
<b>2000</b>	0.634	0.695	0.728	0.738	0.759	0.773
<b>5000</b>	0.450	0.556	0.605	0.621	0.644	0.667
<b>10000</b>	0.297	0.423	0.497	0.523	0.552	0.573

**Table 2.9. (cont.)** *Seasonally adjusted areal reduction factors for the Southeast region.*

<i>Offset 4 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.952	0.964	0.967	0.972	0.986	0.994
<b>100</b>	0.917	0.926	0.932	0.951	0.965	0.976
<b>200</b>	0.879	0.896	0.898	0.927	0.941	0.961
<b>500</b>	0.838	0.849	0.859	0.893	0.916	0.939
<b>1000</b>	0.791	0.815	0.833	0.859	0.883	0.907
<b>2000</b>	0.719	0.750	0.783	0.794	0.815	0.829
<b>5000</b>	0.543	0.618	0.664	0.680	0.711	0.743
<b>10000</b>	0.376	0.484	0.562	0.585	0.612	0.634
<i>Offset 5 Months</i>						
<b>Area (mi<sup>2</sup>)</b>	<b>1 hr</b>	<b>6 hr</b>	<b>12 hr</b>	<b>24 hr</b>	<b>48 hr</b>	<b>72 hr</b>
<b>10</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>50</b>	0.968	0.974	0.977	0.981	0.986	0.990
<b>100</b>	0.938	0.941	0.952	0.968	0.981	0.993
<b>200</b>	0.910	0.916	0.923	0.951	0.964	0.984
<b>500</b>	0.876	0.880	0.894	0.924	0.948	0.971
<b>1000</b>	0.836	0.841	0.875	0.896	0.915	0.934
<b>2000</b>	0.776	0.781	0.820	0.825	0.841	0.855
<b>5000</b>	0.612	0.646	0.709	0.714	0.729	0.753
<b>10000</b>	0.432	0.526	0.608	0.622	0.639	0.662

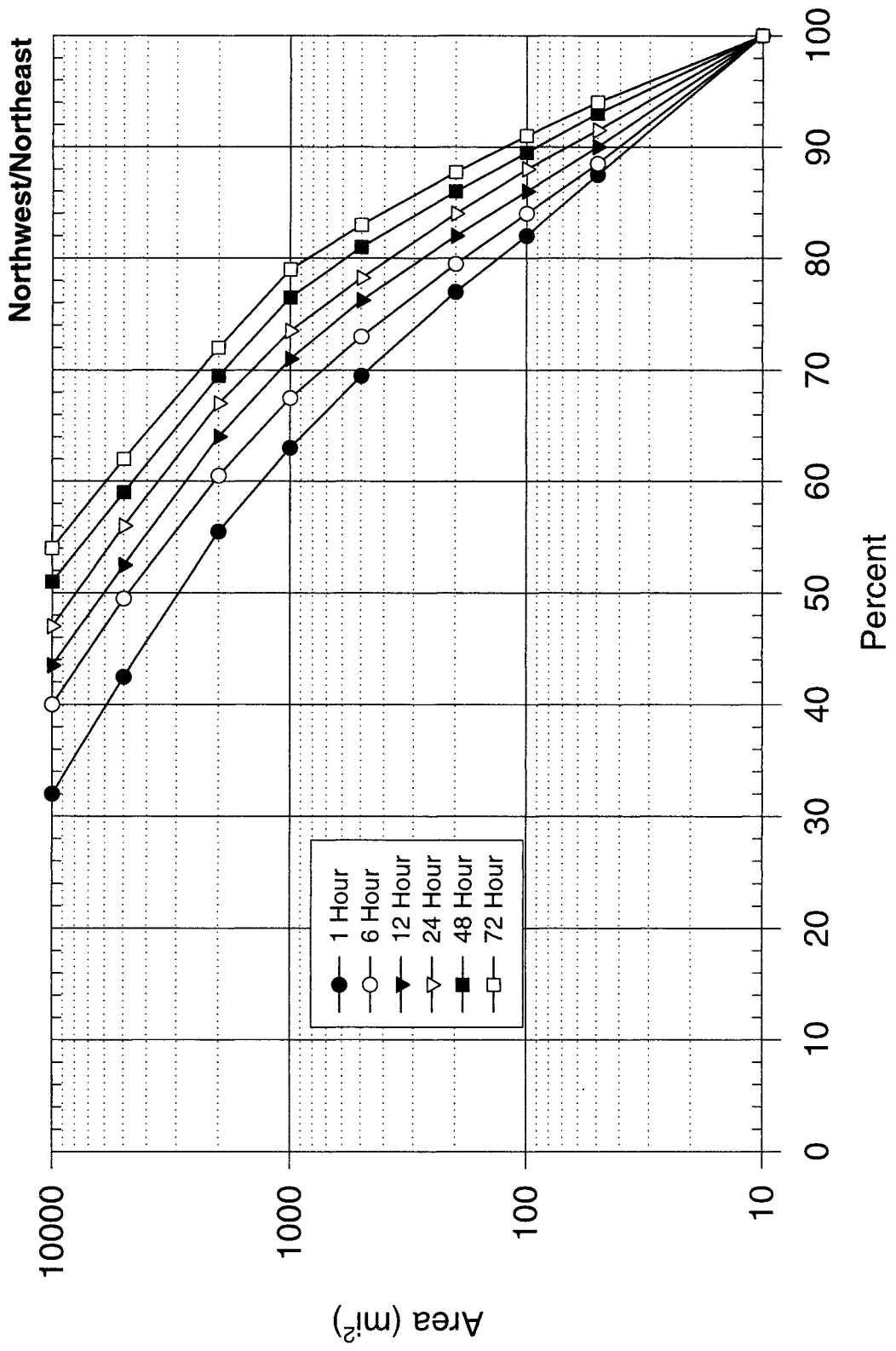


Figure 2.12. Depth-area relations for the California Northwest/Northeast region for 1 to 72 hour durations.

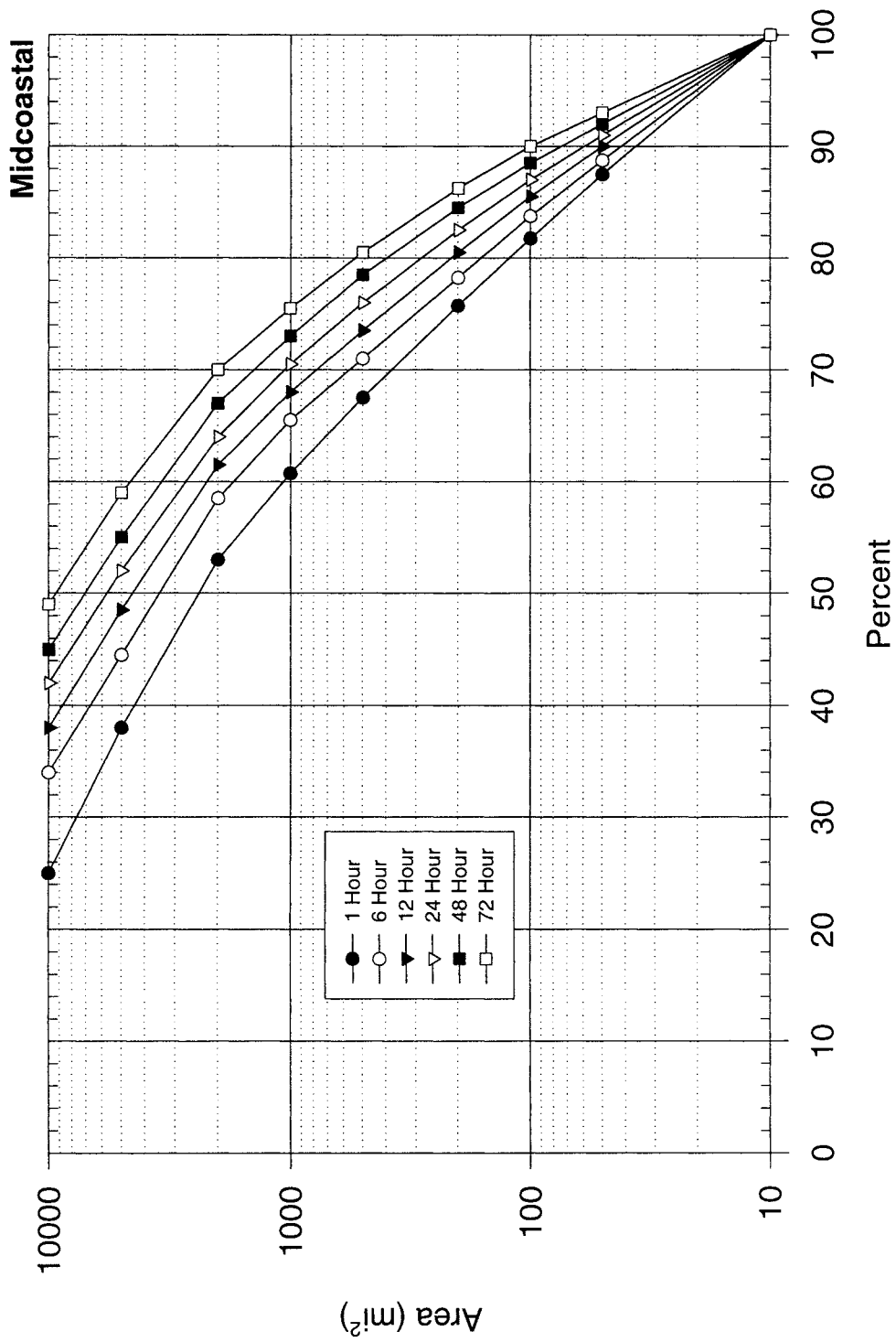


Figure 2.13. Depth-area relations for the California Midcoastal region for 1 to 72 hour durations.

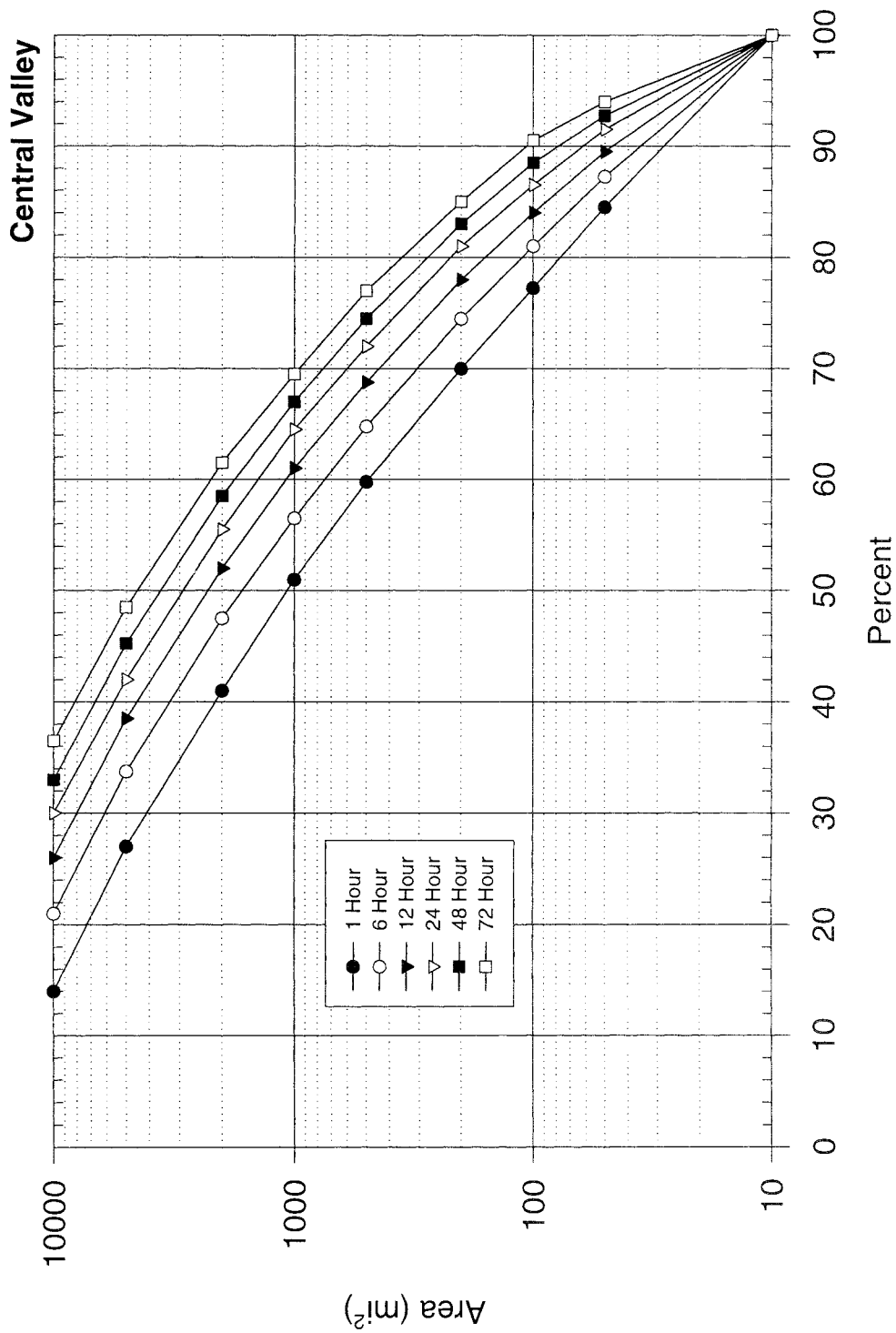


Figure 2.14. Depth-area relations for the California Central Valley region for 1 to 72 hour durations.



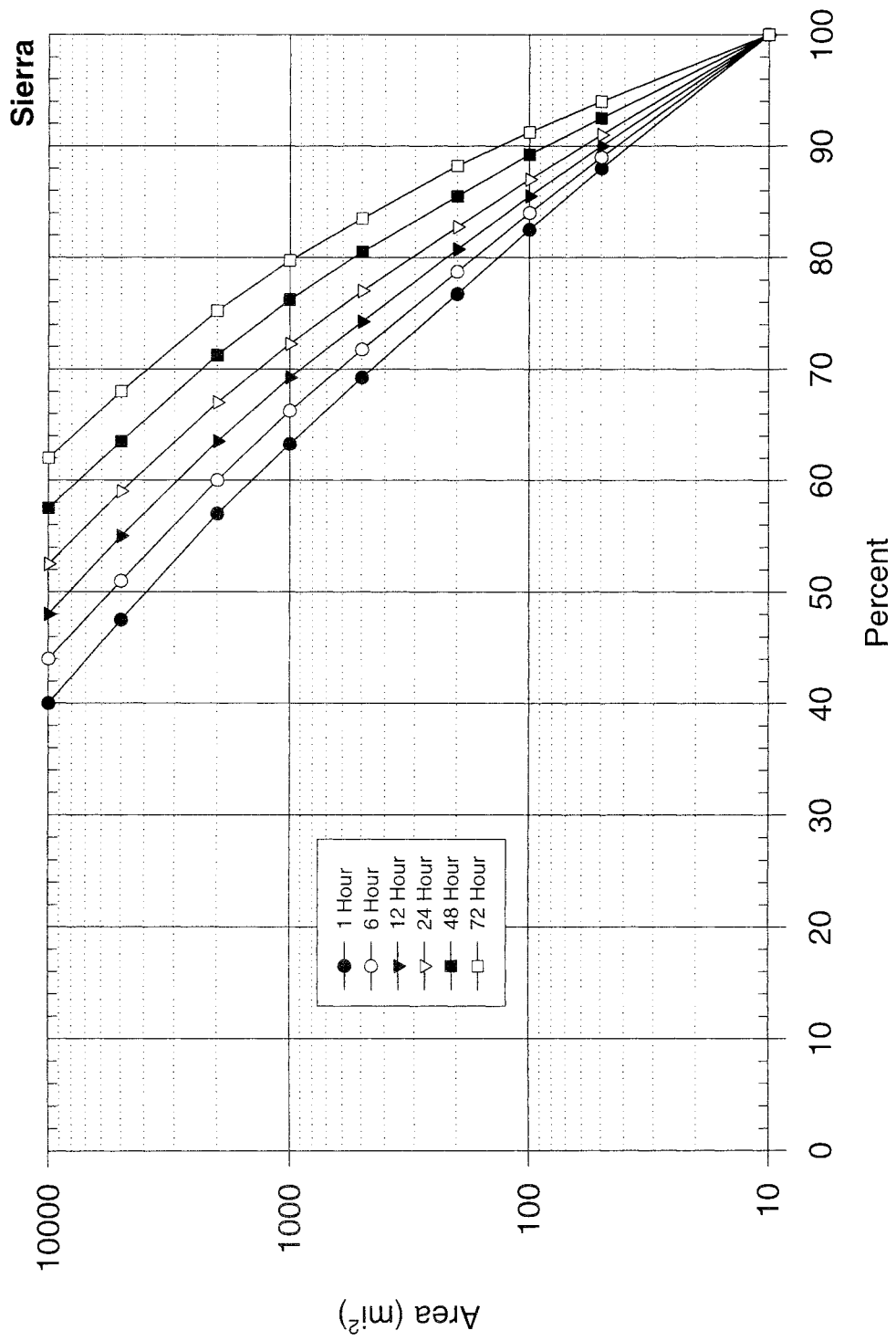


Figure 2.15. Depth-area relations for the California Sierra region for 1 to 72 hour durations.

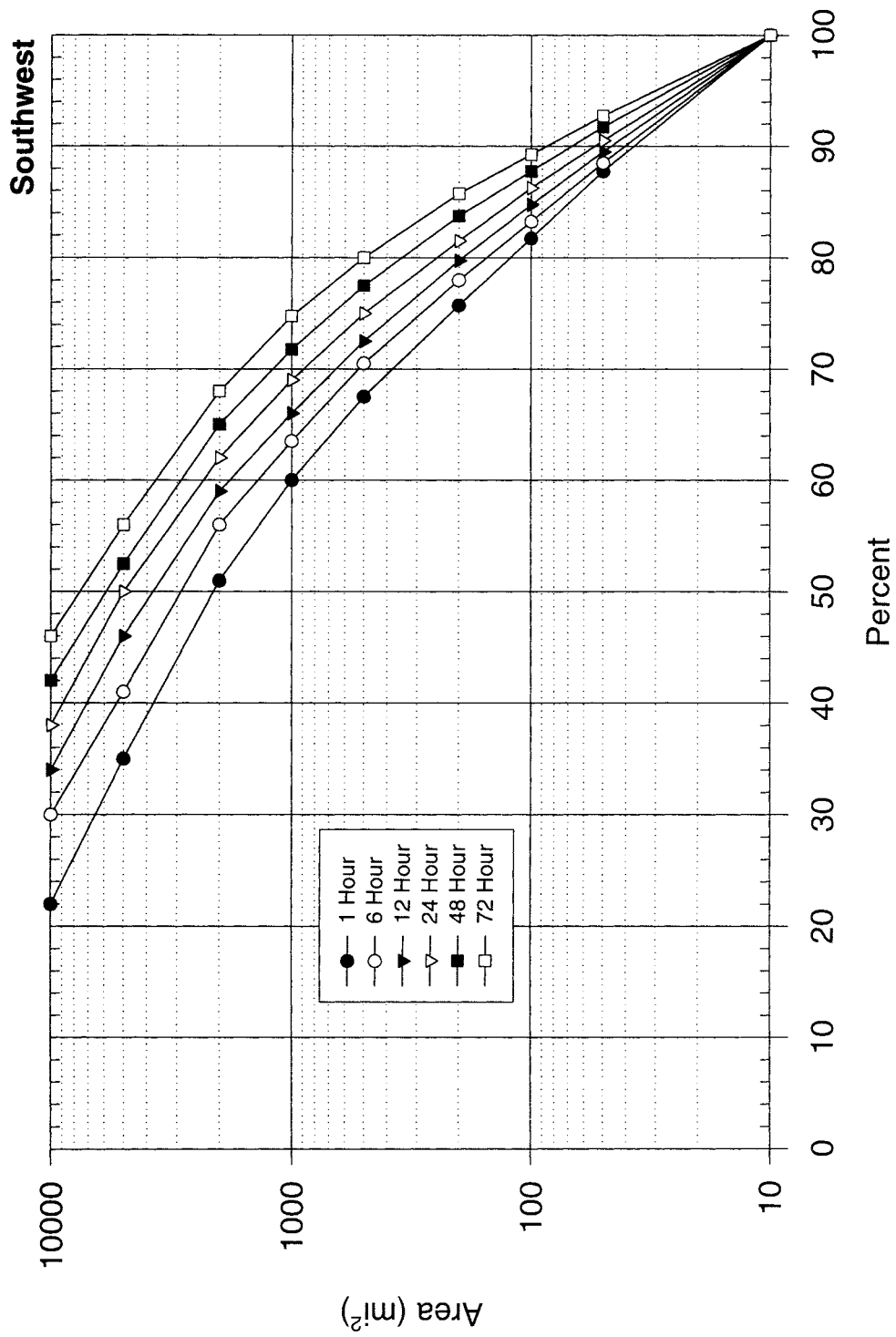


Figure 2.16. Depth-area relations for the California Southwest region for 1 to 72 hour durations.

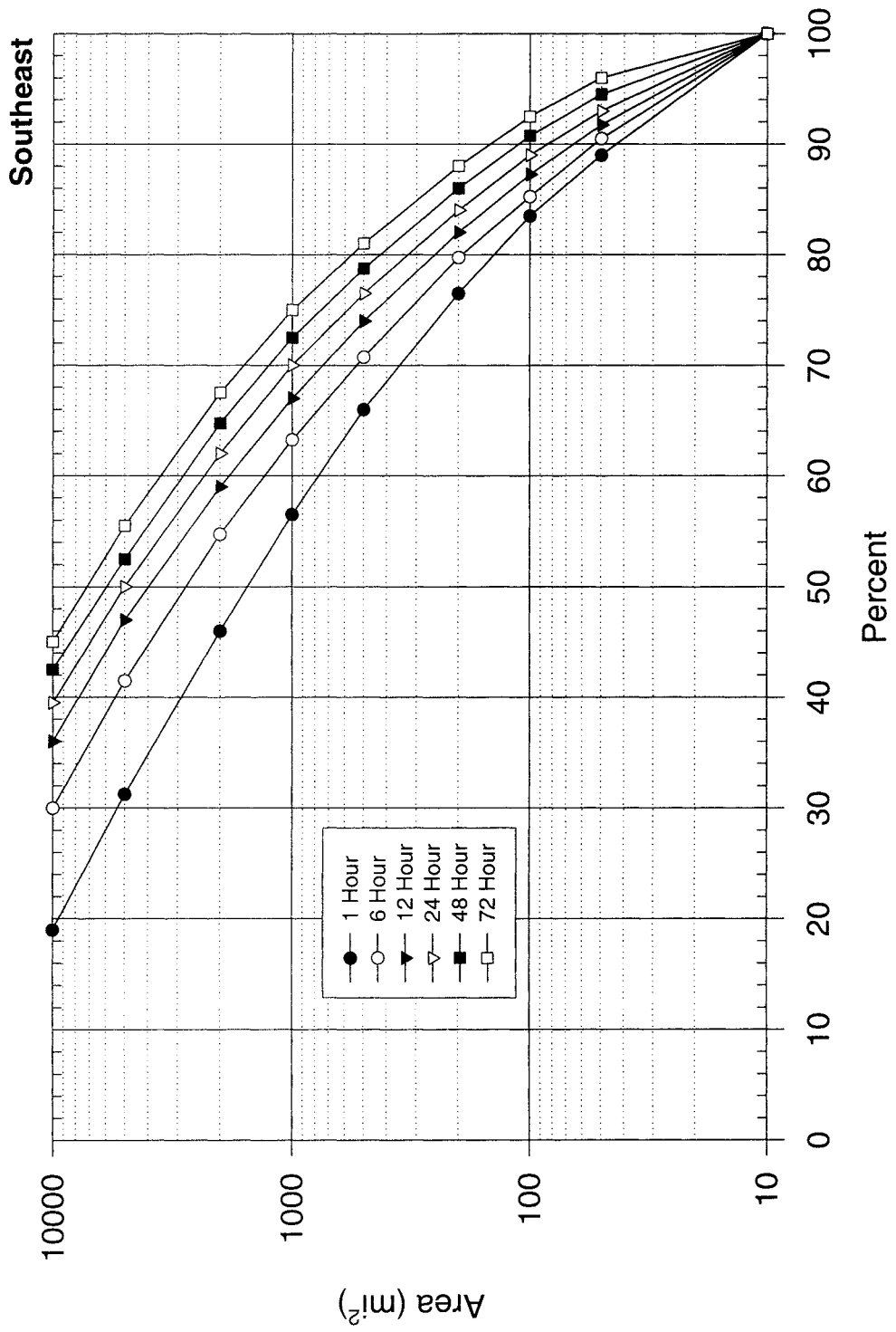


Figure 2.17. Depth-area relations for the California Southeast region for 1 to 72 hour durations.

cumulative 6-hour values. A margin of plus or minus 0.5 inch is permissible in drawing this curve due to various roundings in Steps 1 to 6. Subtract each cumulative 6-hour depth from the depth of the next longer cumulative 6-hour duration. Some applications may require hourly increments. If this is the case, the smooth curve is subdivided into 72 cumulative hourly amounts and each cumulative hourly depth is subtracted from the depth at the next cumulative 1-hour longer duration.

8. Snowmelt parameters, temporal, and areal distributions.

During peer review a consensus recommendation was to include some procedures in the report to deal with these items. These items had not been within the scope originally formulated for the study. The snowmelt procedure from HMR 36 is incorporated in this report and found in the Appendix.

Chronological partitioning of the PMP and its areal distribution were not studied in this report. We would recommend that the user employ historical storms or divide the 72-hour PMP into 6-hour increments. Then arrange the final storm configuration into a front-, middle-, or end-loaded temporal distribution depending on the water management decisions that are required. One possible way of doing this is as follows:

A. For DAD regions 1-6 (Figure 2.11), group the four heaviest 6-hour values of the 72-hour PMP in a 24-hour sequence.

B. Within the maximum 24-hour period arrange the four 6-hour values as follows. Place the second highest 6-hour values next to the highest, the third highest on either side of the first two 6-hour values, and the fourth highest at either end.

C. The 24-hour largest 6-hour values may be positioned anywhere in the 72-hour storm period. The remaining eight 6-hour amounts may be positioned anywhere else.

A hydrologist may experiment with different temporal sequences to uncover any factors that would make a particular sequence more critical than another for a basin

of concern. Selection of a particular sequence for a basin is a decision for the user.

One way of distributing the storm spatially is by developing an isopercental analysis based on the 100-year precipitation frequency maps from NOAA Atlas 2 (Miller et al., 1973). This approximation was used to develop the individual storm analyses for this study, and has been used on other occasions to represent storm distributions.

Another approximation can be made by using a significant storm with a sufficient number of observations to draw a storm pattern over the basin of interest. If such a storm has been observed, then the storm pattern can be used to define an isopercental analysis for the PMP distribution. However, only a few California storms have sufficient detail to define a storm pattern over the complex terrain.

### **2.3 Example of General-Storm PMP Computation**

The 973-mi<sup>2</sup> Auburn drainage above Folsom Lake is used as an example for the general-storm PMP. The Auburn drainage is located in the Sierra subregion or region 5. In this example, we will use the steps of Section 2.2. First, we will calculate the all-season PMP for the drainage, and then the PMP for the "off-season" month of May.

#### **All-Season Calculation**

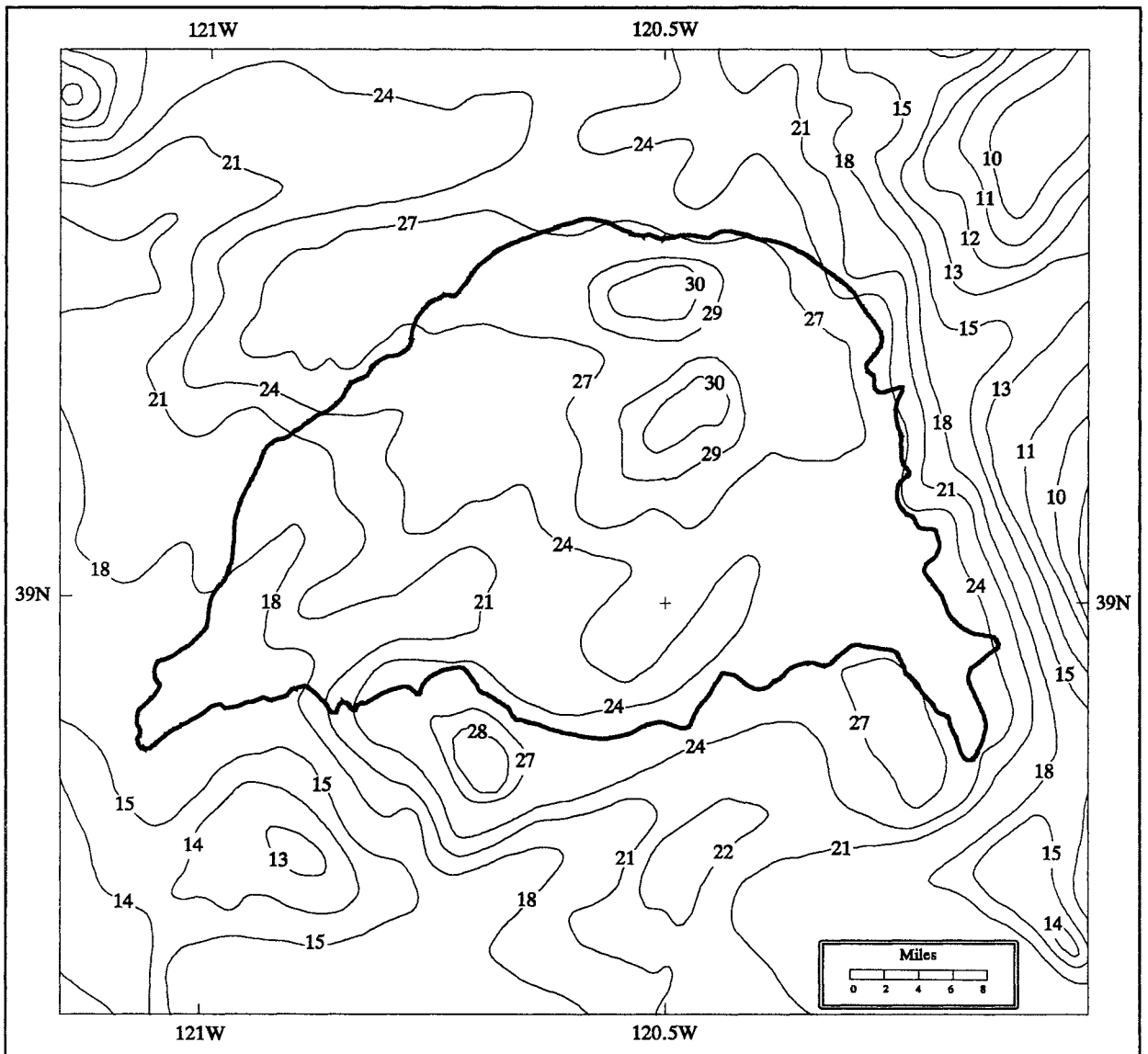
##### Step

##### 1. Drainage Outline

The Auburn drainage is outlined on a section of the 24-hour, general-storm PMP Index in Figure 2.18, at a scale of 1:1,000,000.

##### 2. User Decision

We will do an all-season PMP calculation.



**Figure 2.18.** *Contours of general-storm index PMP in and around the 973-mi<sup>2</sup> Auburn drainage (heavy solid line) in California.*

3. All-Season Index PMP Estimate

Figure 2.18 shows the contours of index (10-mi<sup>2</sup>, 24-hour) PMP superimposed on the outline of the Auburn drainage. It's average value is 24.6 inches.

4. Seasonal Index PMP Estimates

Skip this step.

5. Depth-Duration Relations

The Auburn drainage is within the Sierra classification (region 5) except for a very small portion near the dam site which may be regarded as inconsequential. Table 2.1 gives the ratios for durations from 1 hour to 72 hours.

<b>Ratios for Auburn drainage</b>						
Duration (hours)						
	1	6	12	24	48	72
All-Season	.14	.42	.65	1.00	1.56	1.76

Multiply the result from Step 3, the average 10-mi<sup>2</sup>, 24-hour PMP of 24.6 inches, by these ratios to produce the following 10-mi<sup>2</sup> depths of all-season PMP for Auburn:

<b>Auburn drainage 10-mi<sup>2</sup> PMP</b>						
Duration (hours)						
	1	6	12	24	48	72
All-Season Depth (inches)	3.4	10.3	16.0	24.6	38.4	43.3

6. Areal Reduction Factors

Using the Auburn drainage area of 973 mi<sup>2</sup> and Figure 2.15, we get the following reduction ratios:

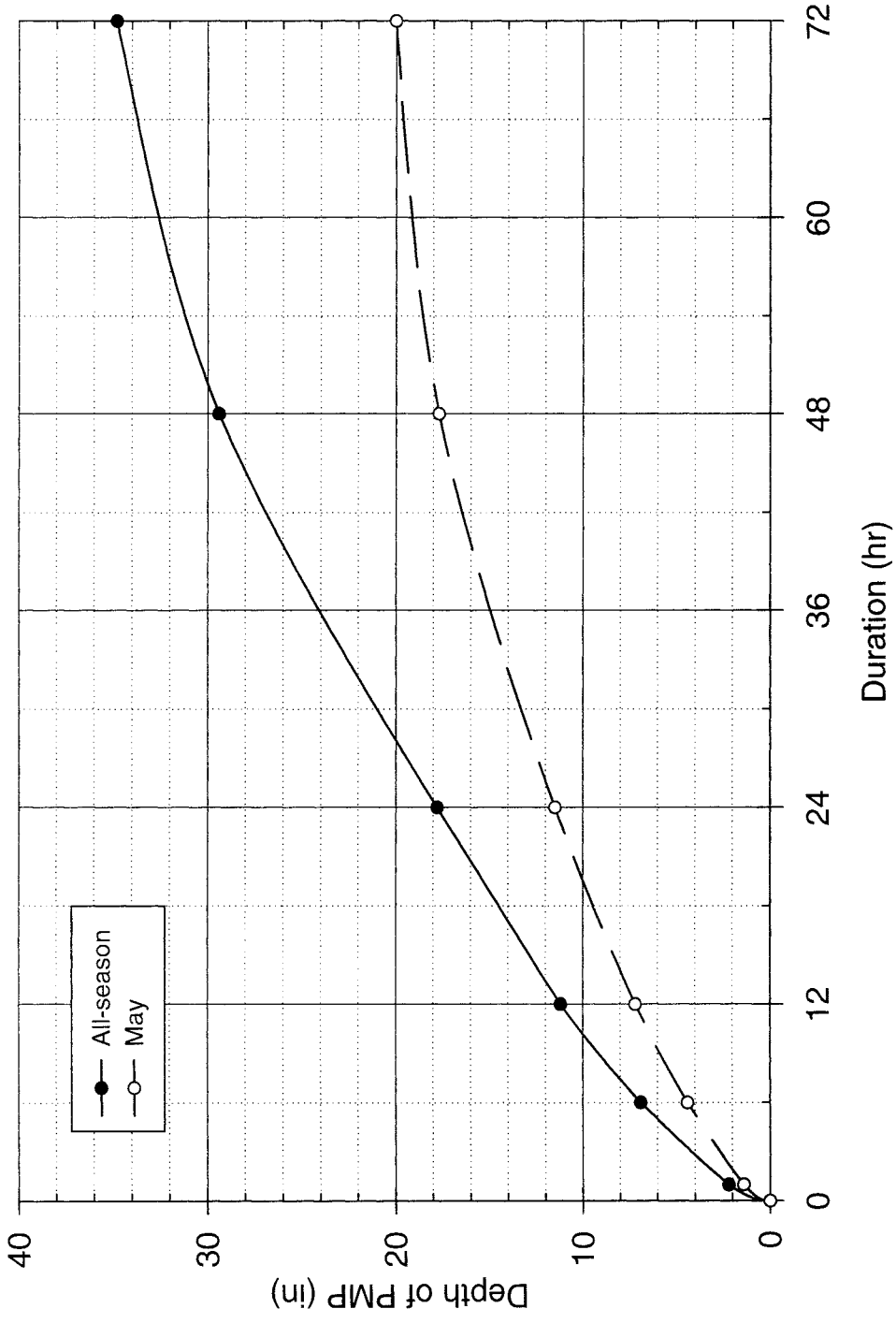
<b>Reduction factors for Auburn drainage</b>						
Duration (hours)						
	1	6	12	24	48	72
All-Season	.64	.67	.70	.72	.77	.80

The depths from Step 5 are multiplied by these ratios to obtain the all-season, storm-centered average depths of PMP for the 973-mi<sup>2</sup> area of the Auburn drainage:

<b>Auburn drainage average PMP depths</b>						
Duration (hours)						
	1	6	12	24	48	72
All-Season Depth (inches)	2.2	6.9	11.2	17.7	29.6	34.6

The results are plotted in Figure 2.19 as a solid line.





**Figure 2.19.** Depth-duration curves for storm-centered, average depth of all-season (solid) and May (dotted) PMP for the 973-mi<sup>2</sup> Auburn drainage in California.

7. Incremental Estimates

Cumulative depths at 6-hour increments, extracted from the curve of Figure 2.19 are:

6-hour cumulative depths												
Duration (hours)												
	6	12	18	24	30	36	42	48	54	60	66	72
All-Season PMP (inches)	6.9	11.2	14.6	17.7	20.8	23.8	26.7	29.6	31.6	32.7	33.7	34.6

The 6-hour incremental amounts are obtained by subtracting each (cumulative) durational amount from the next larger amount to get:

6-hour incremental depths												
Duration (hours)												
	6	12	18	24	30	36	42	48	54	60	66	72
All-Season PMP Increment (inches)	6.9	4.3	3.4	3.1	3.1	3.0	2.9	2.9	2.0	1.1	1.0	0.9

8. Temporal Distribution, Areal Distribution, and Snowmelt Parameters

Using the rules from Step 8 the twelve 6-hour increments from Step 7 could be distributed as following: 3.1, 3.0, 2.9, 2.9, 3.1, 4.3, 6.9, 3.4, 1.1, 0.9, 2.0, 1.0

The areal distribution can be found by following Step 8 in Section 2.2.

For snowmelt parameters see the Appendix. A completed example for the all-season month of November may be found there.

## Seasonal or Monthly PMP Calculation

### Step

#### 1. Drainage Outline

As with the all-season example, the outline of the drainage depicted nominally at a scale of 1:1,000,000 in Figure 2.18 is the of Auburn drainage.

#### 2. User Decision

We will calculate seasonal PMP for the month of May.

#### 3. All-Season Index PMP Estimate

Even though we are doing PMP for May which is not an all-season month, we need an all-season index value as a starting point. As with the previous all-season example, Figure 2.18 shows the average depth to be 24.6 inches.

#### 4. Seasonal Index PMP estimates

Figure 2.4 shows the variation of general-storm PMP for the month of May as a percentage of all-season PMP (Plates 1 and 2). We determined an average value of 68 percent (to the nearest whole percent) for the Auburn drainage. This percentage was multiplied by the average depth from Step 3, and gives an average value of PMP of 16.7 inches for May. The nearest all-season month is March (Figure 2.2), and the monthly offset is 2.

#### 5. Depth-Duration Relations

As indicated earlier, the Auburn drainage is within the Sierra classification (region 5) except for a very small portion near the dam site which is inconsequential. Table 2.2 shows that the seasonally adjusted 10-mi<sup>2</sup> depth-duration ratios for May or a two-month offset are:

<b>Ratios for Auburn drainage</b>						
Duration (hours)						
	1	6	12	24	48	72
May	.148	.437	.663	1.00	1.451	1.549

The 10-mi<sup>2</sup> depth of May PMP is obtained by multiplying the average 24-hour, 10-mi<sup>2</sup> PMP for May (16.7 inches) at Auburn by ratios for 1 hour to 72 hours. These are shown below:

<b>Auburn drainage 10-mi<sup>2</sup> PMP</b>						
Duration (hours)						
	1	6	12	24	48	72
May Depth (inches)	2.5	7.3	11.1	16.7	24.2	25.9

6. Areal Reduction Factors

Interpolating to 973 mi<sup>2</sup> from Table 2.7 (Sierra region, offset of 2), we obtain the following reduction ratios:

<b>Reduction factors for Auburn drainage</b>						
Duration (hours)						
	1	6	12	24	48	72
May	.548	.607	.648	.687	.731	.773

Multiplying these ratios by the corresponding May PMP depths from Step 5 gives the following storm-centered average depths of PMP across the 973-mi<sup>2</sup> Auburn drainage for May:

<b>Auburn average drainage (973-mi<sup>2</sup>) PMP depths</b>						
Duration (hours)						
	1	6	12	24	48	72
May Depth (inches)	1.4	4.4	7.2	11.5	17.7	20.0

7. Incremental Estimates

The results from Step 6 are also plotted in Figure 2.19 and a curve (dotted line) is drawn for these results. Cumulative depths at 6-hour increments to the nearest tenth of an inch, extracted from the curves, are as follows:

<b>6-hour cumulative depths</b>												
Duration (hours)												
	6	12	18	24	30	36	42	48	54	60	66	72
May PMP (inches)	4.4	7.2	9.4	11.5	13.3	15.0	16.4	17.7	18.5	19.1	19.6	20.0

To obtain 6-hour PMP values, subtract each (cumulative) amount from the next larger amount to get:

<b>6-hour incremental depths</b>												
Duration (hours)												
	6	12	18	24	30	36	42	48	54	60	66	72
May PMP Increment (inches)	4.4	2.8	2.2	2.1	1.8	1.7	1.4	1.3	0.8	0.6	0.5	0.4

8. Temporal Distribution, Areal Distribution, and Snowmelt Parameters

A possible temporal precipitation (inches) sequence for the twelve 6-hour increments in May is: 0.6, 0.8, 2.2, 4.4, 2.8, 2.1, 1.8, 1.7, 1.4, 1.3, 0.5, 0.4

This is a possible sequence from the guidelines mentioned is Step 8 of Section 2.2. The areal distribution of isohyets can be obtained using the guidance from Step 8 of Section 2.2. No snowmelt parameters are required for May, since they are only valid for October through April.

## 2.4 Local Storm Procedures

Two options are available for obtaining the local-storm PMP values. They are:

- A. Obtain the average depth of PMP for a drainage without specifying its areal distribution, or
- B. Specify the areal distribution of the precipitation from a PMP storm within a drainage.

Option A requires Steps 1-5 below; Option B requires that Steps 1 and 2 are used followed by Step 6. If Option B is selected, a drainage average depth of the isohyetal precipitation pattern for various PMP storm placements must be chosen. There will be as many average depths for the drainage as there are placements for the PMP storm. The average depths of precipitation in a drainage obtained from Option B will be less than the average depth of PMP from Option A unless the drainage has the exact boundary shape shown in Figure 2.20.

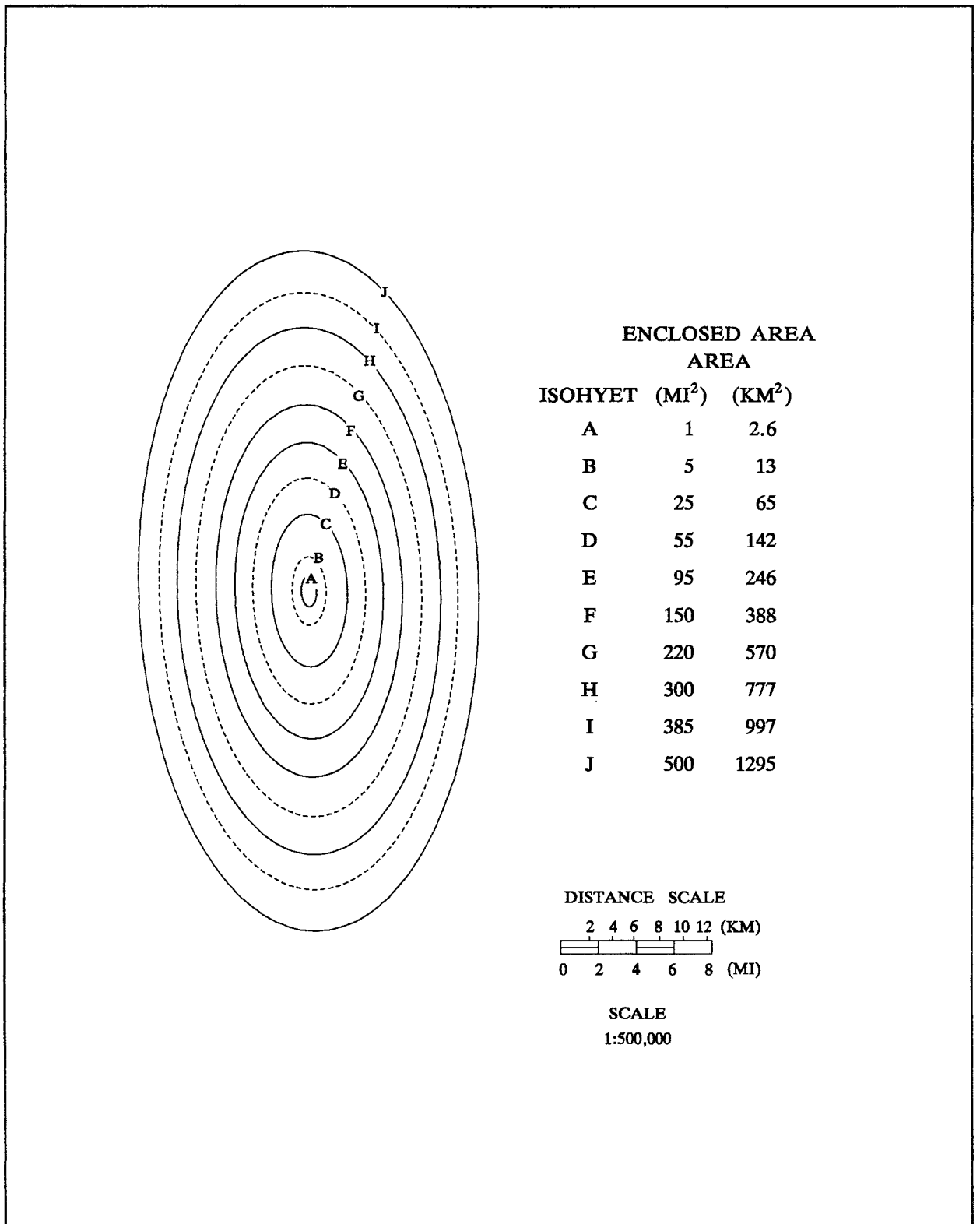
### Step

#### 1. One-hour, 1-mi<sup>2</sup> local-storm PMP

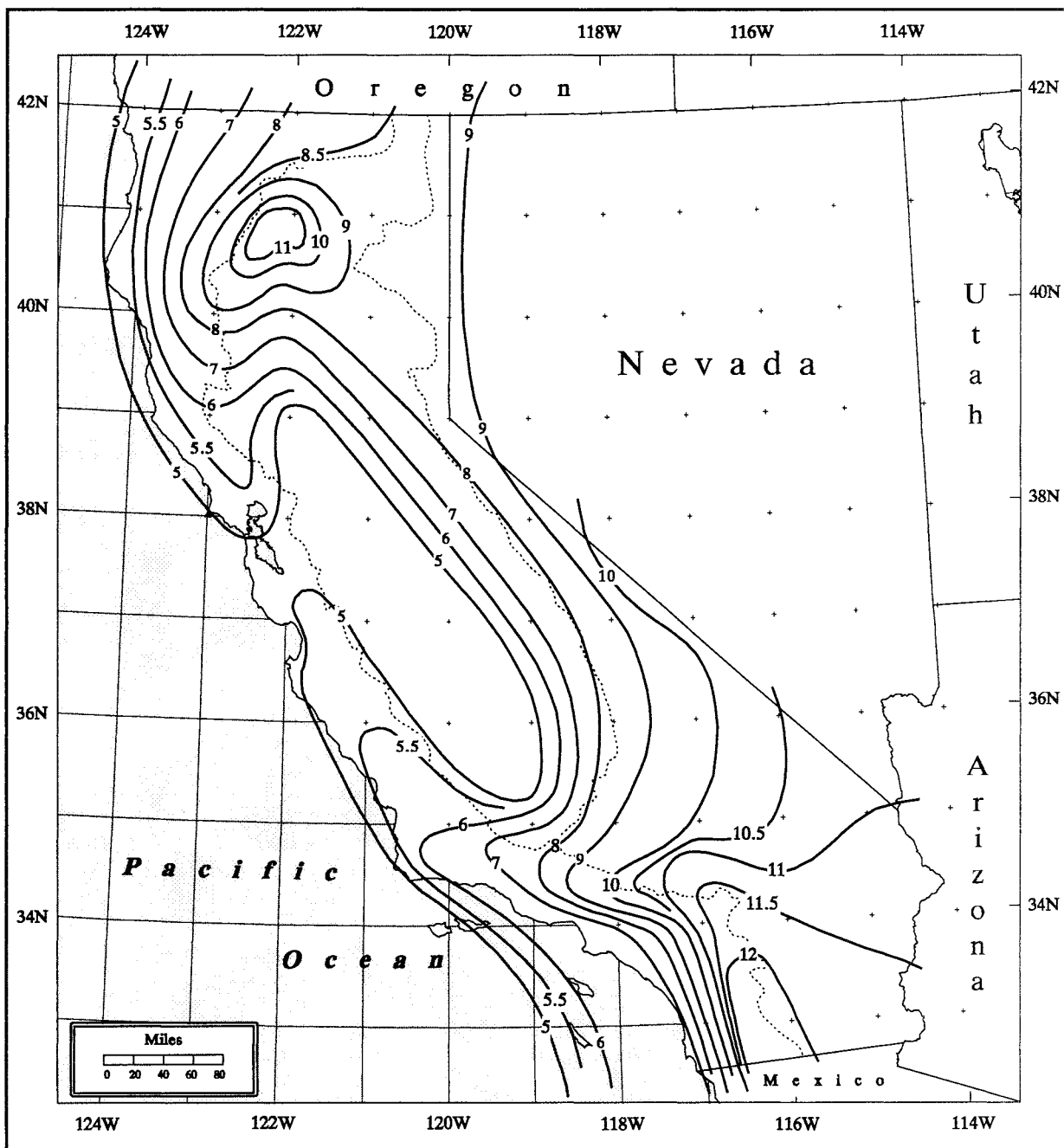
Locate the basin on Figure 2.21 and determine the basin-average, 1-hour, 1-mi<sup>2</sup>, local-storm index value of PMP. Use linear interpolation.

#### 2. Adjustment for Mean Drainage Elevation

Determine the mean elevation of the drainage. No adjustment is necessary for elevations of 6,000 feet or less. If the mean elevation is greater than 6,000 feet,



**Figure 2.20.** *Idealized isohyetal pattern for local-storm PMP areas up to 500 mi<sup>2</sup>.*



**Figure 2.21.** California local-storm PMP precipitation estimates for 1 mi<sup>2</sup>, 1 hour (inches).



reduce the PMP from Step 1 by 9 percent for every 1,000 feet above the 6,000-foot level. Figure 2.22 can be used to graphically determine this value.

As an example of the elevation adjustment let us assume we have a basin with a mean elevation of 8,700 feet (2,700 feet above 6,000 feet). The reduction factor would be 24.3 percent (2.7 times .09), giving an elevation-adjusted PMP of 76 percent (rounded) of full 1-hour, 10-mi<sup>2</sup> PMP. Had Figure 2.22 been used, a value of about 76 percent is read off the line labeled pseudo-adiabat for an elevation of 8,700 feet.

### 3. Adjustment for Duration

The 1-mi<sup>2</sup> local-storm PMP estimates for durations less than 1 hour are obtained from Figure 2.23, as a percentage of the 1-hour amount from Step 2. For durations greater than 1 hour, determine the location of the basin on Figure 2.24, which provides a 6-hour to 1-hour ratio of the local-storm PMP. Multiply this ratio by the 1-hour local-storm PMP to obtain the 6-hour local-storm PMP. The four multipliers on Figure 2.24 are defined as A (1.15), B (1.2), C (1.3), and D (1.4) and correspond to the A, B, C, and D of Figure 2.23. Local-storm PMP amounts for durations of 1 to 6 hours can be obtained from Figure 2.23 or Table 2.10 for specific durations.

### 4. Adjustment for Basin Area

Figures 2.25 to 2.28 give the area reductions to 500 mi<sup>2</sup> depending on the 6-hour depth-duration ratio used in Step 3. The reductions obtained for the selected durations and area of the basin then are multiplied respectively by the results from Step 3, and a smooth curve is drawn on graph paper for the plotted values to get estimates for durations not specified.

### 5. Temporal Distribution

Review of local-storm temporal distributions for this region show that most local storms have durations less than 6 hours and that the greatest 1-hour amount occurs

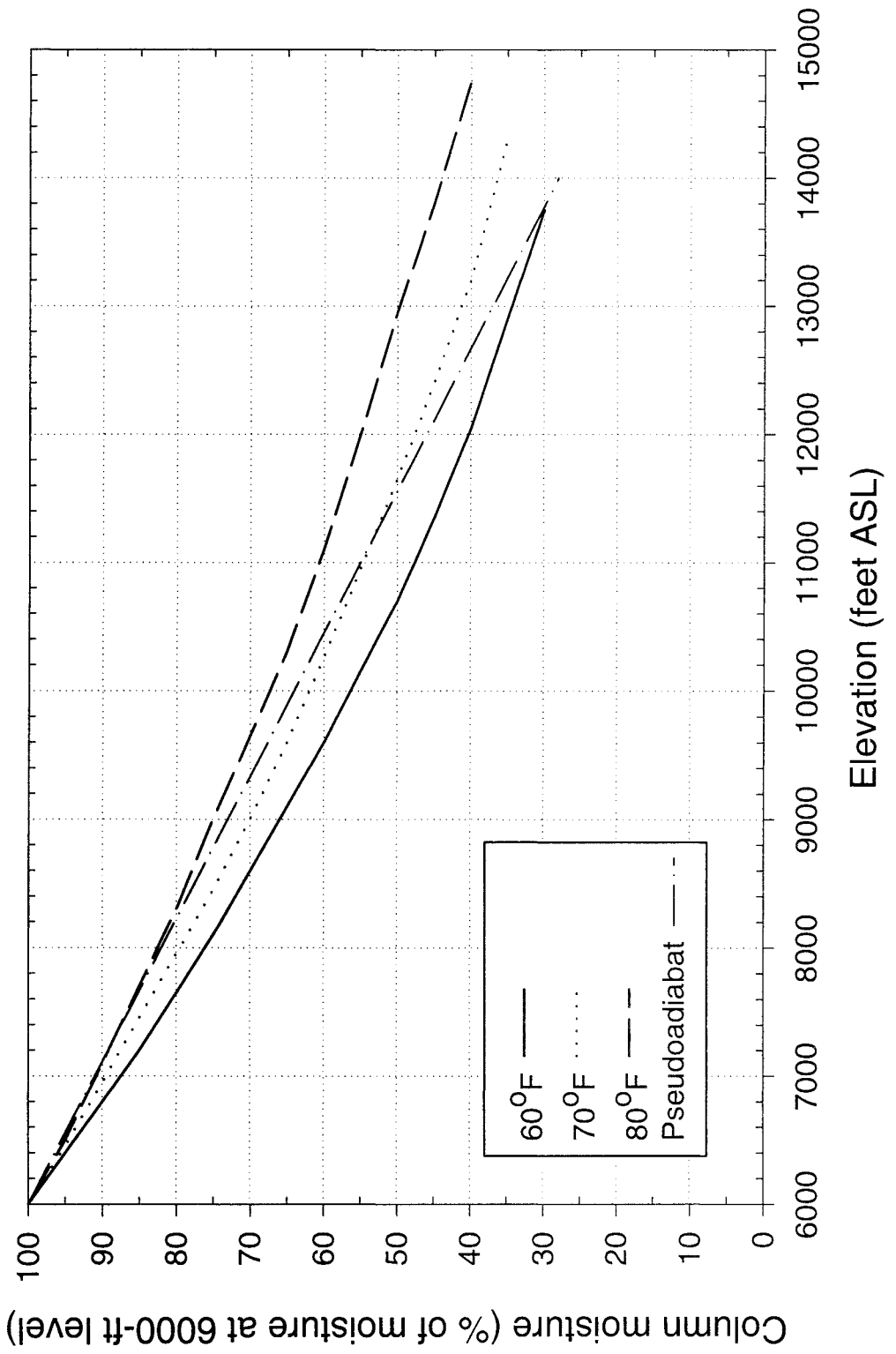
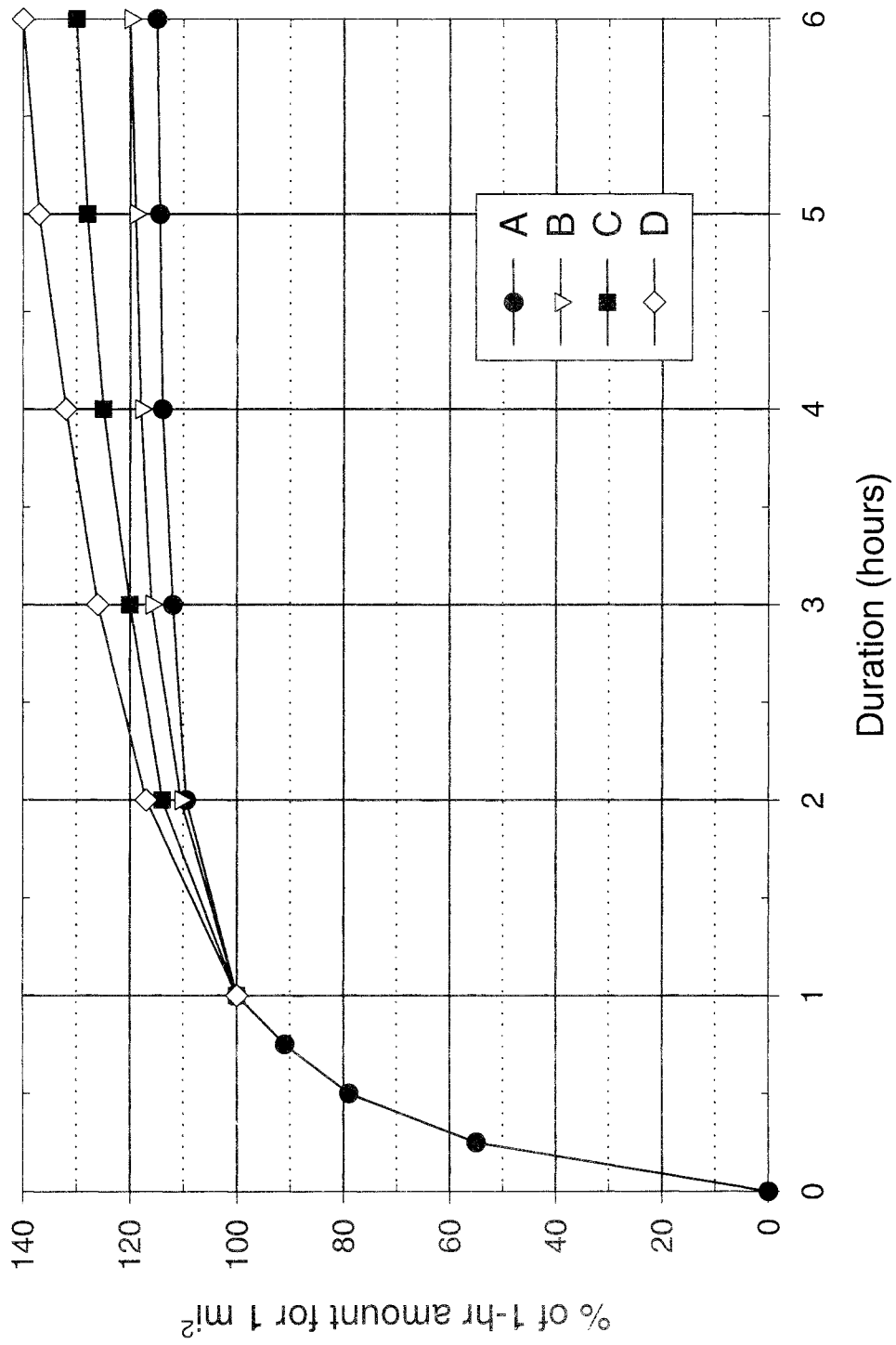
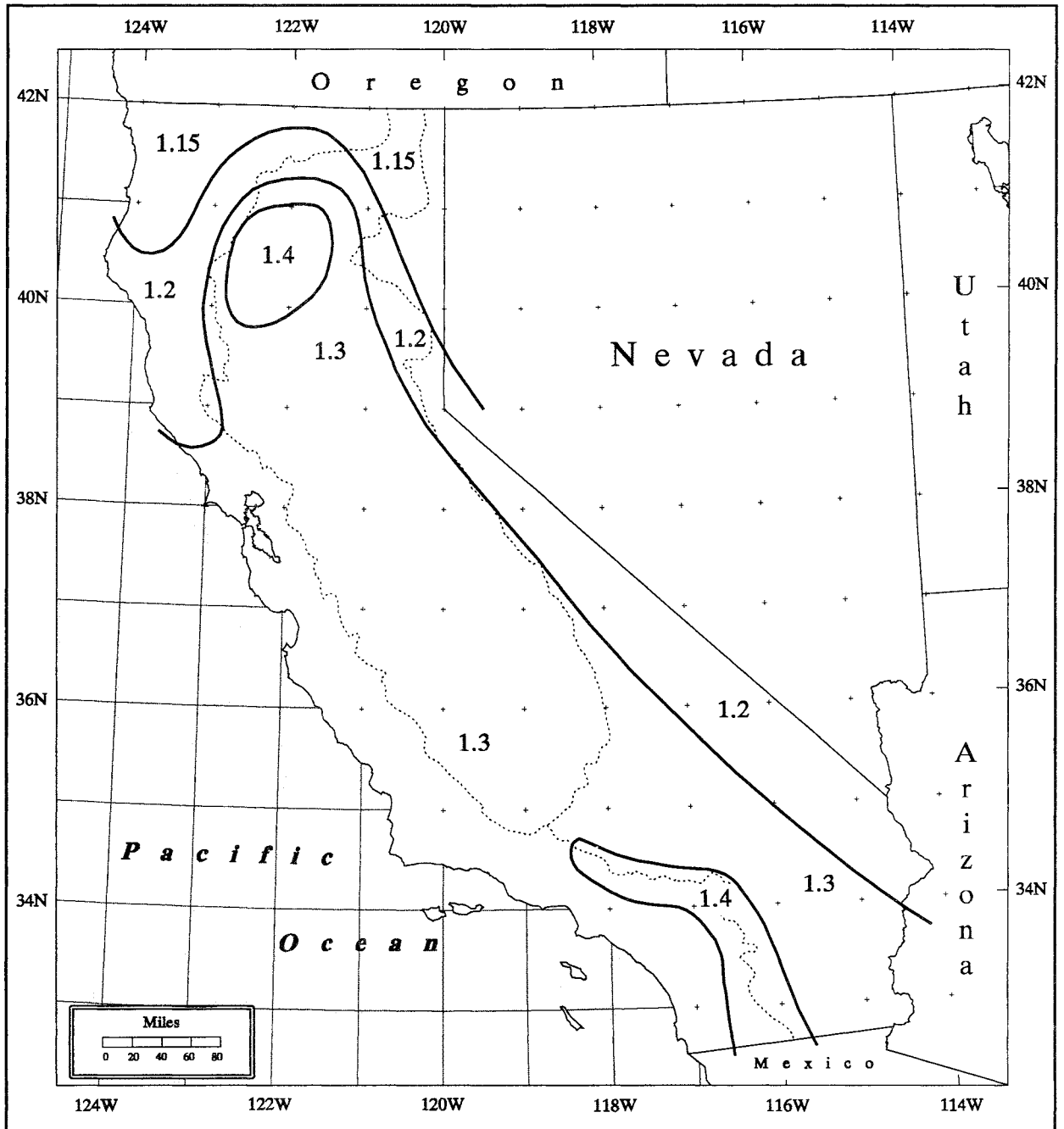


Figure 2.22. Pseudoadiabatic decrease in column moisture for local-storm basin elevations.



**Figure 2.23.** Depth-duration relations for California for 6-hour to 1-hour ratios. The ratios are mapped in Figure 2.24; A = 1.15, B = 1.2, C = 1.3, D = 1.4.



**Figure 2.24.** California local-storm PMP 6-hour to 1-hour ratios for  $1 \text{ mi}^2$ . For use with Figure 2.23; A = 1.15, B = 1.2, C = 1.3, D = 1.4.

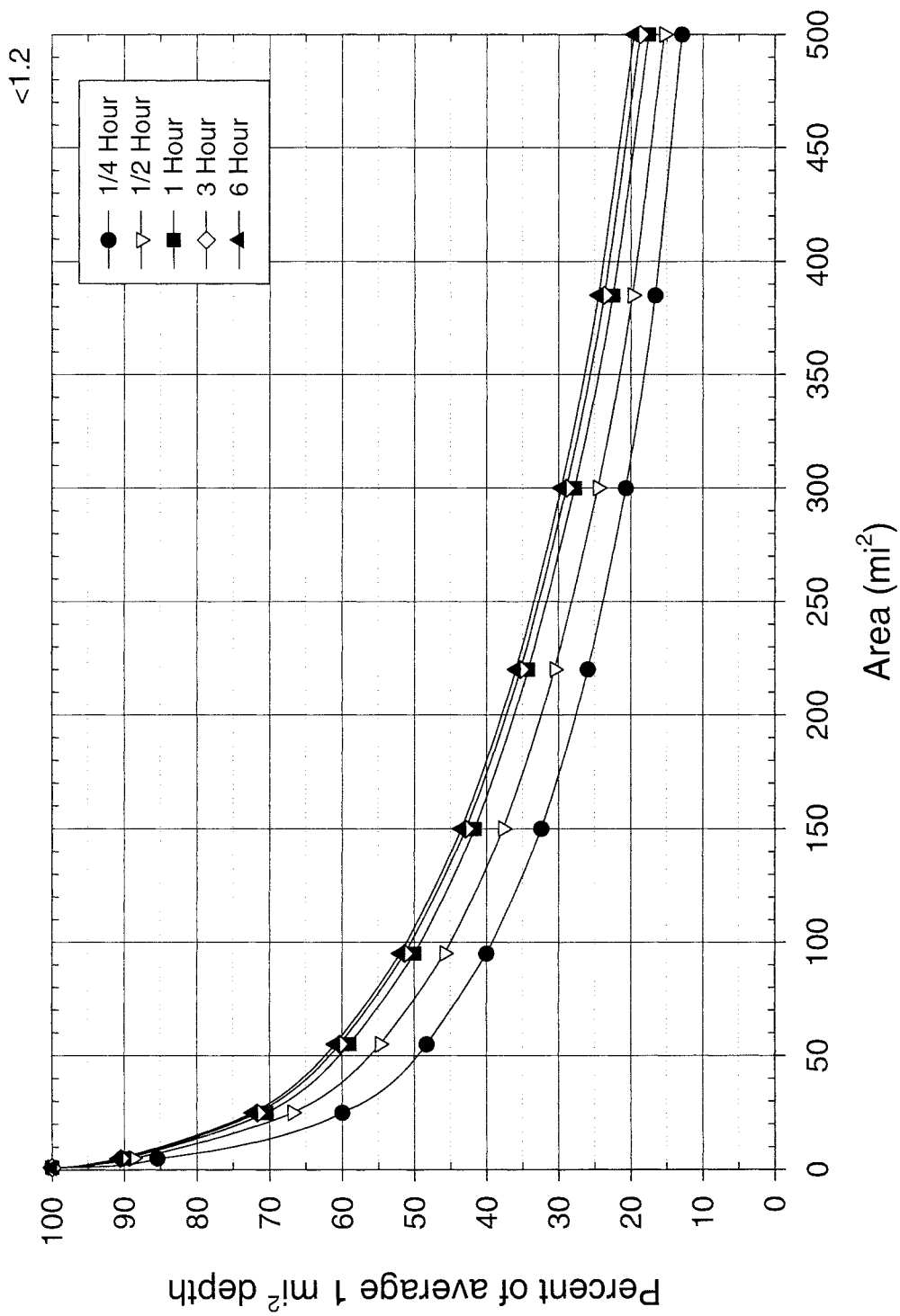


Figure 2.25. Depth-area relations for California local-storm PMP for a 1-mi<sup>2</sup>, 6-hour to 1-hour depth-duration ratio less than 1.2.

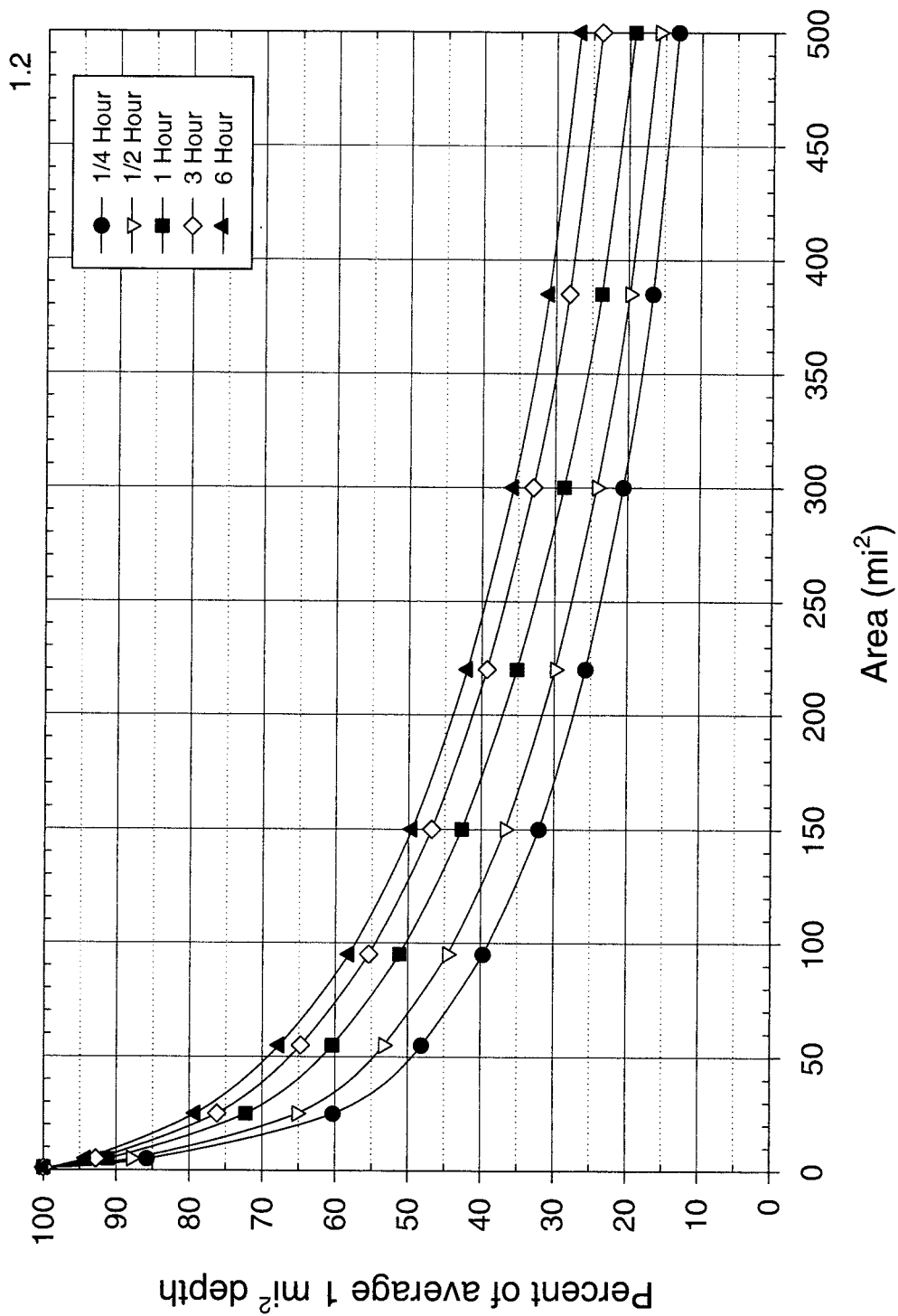


Figure 2.26. Depth-area relations for California local-storm PMP for a 1-mi<sup>2</sup>, 6-hour to 1-hour depth-duration ratio equal to 1.2.

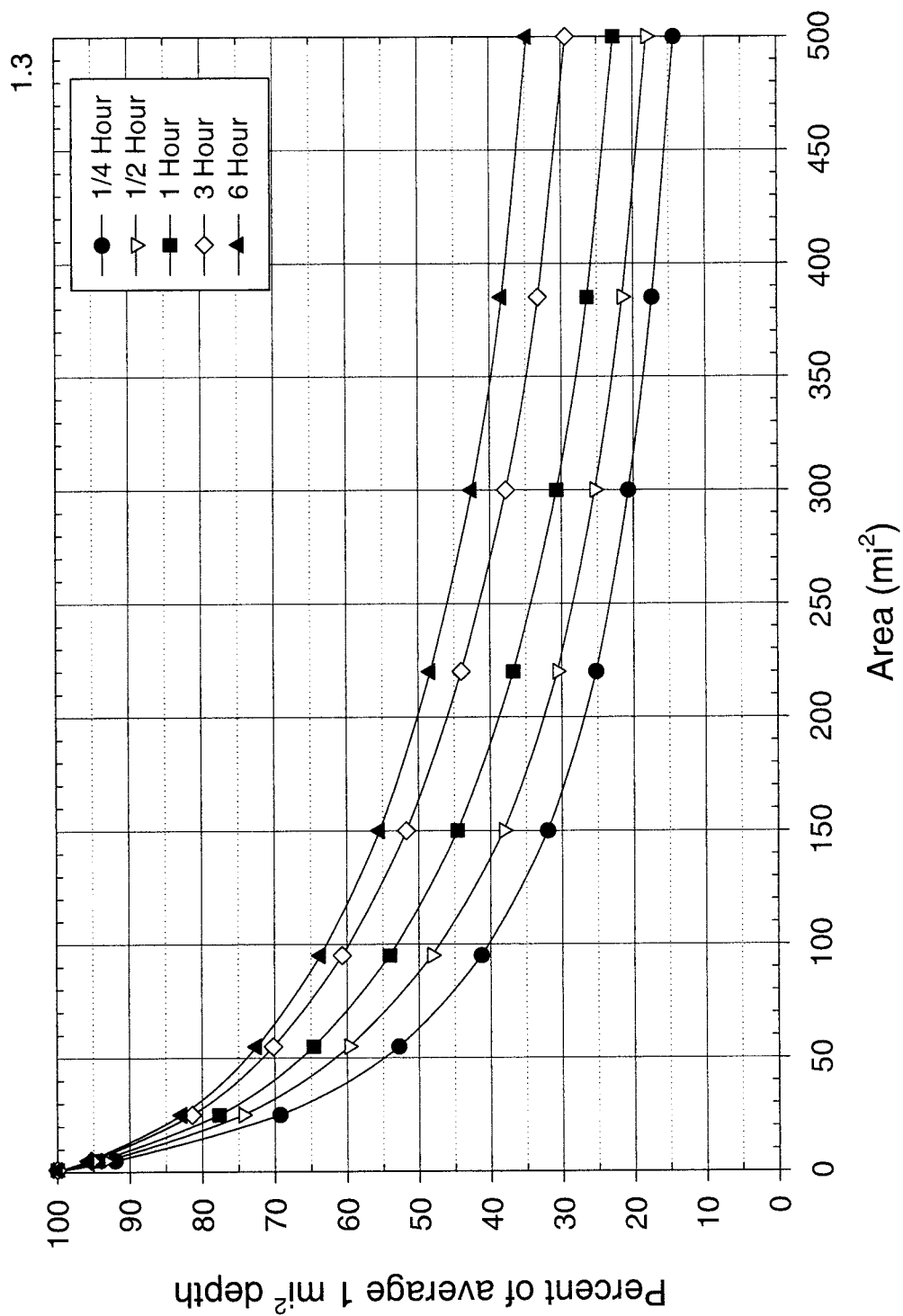
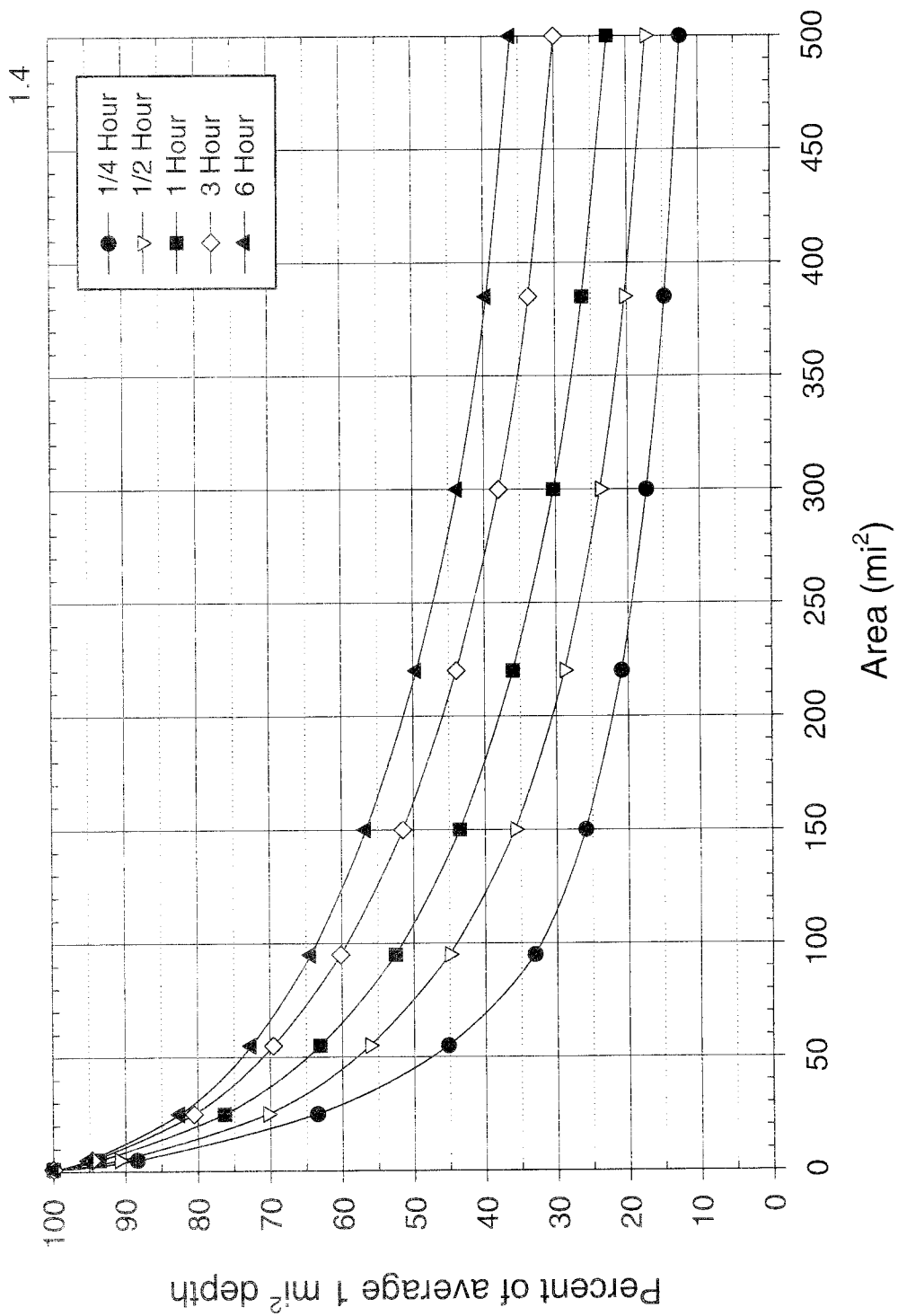


Figure 2.27. Depth-area relations for California local-storm PMP for a 1-mi<sup>2</sup>, 6-hour to 1-hour depth-duration ratio equal to 1.3.



**Figure 2.28.** Depth-area relations for California local-storm PMP for a 1-mi<sup>2</sup>, 6-hour to 1-hour depth-duration ratio equal to 1.4.



in the first hour. The recommended sequence of hourly increments is as follows: arrange the hourly increments from largest to smallest as obtained directly by successive subtraction of values read from the smoothed depth-duration curve. The most intense 1-hour of precipitation occurs in the first hour of the storm, the second most intense hour in the second hour, and so forth.

**Table 2.10.** *Depth-duration relations (percent of 1-hour amount) for 1-mi<sup>2</sup> PMP for California local storms.*

Relationship Designator (see Figure 2.23)				
Duration (hours)	A	B	C	D
0	0	0	0	0
1/4	55	55	55	55
1/2	79	79	79	79
3/4	91	91	91	91
1	100	100	100	100
2	109.5	110.5	114	117
3	112	116	120	126
4	114	118	125	132
5	114.5	119	128	137
6	115	120	130	140

## 6. Areal Distribution for Local-Storm PMP

The elliptical pattern in Figure 2.20 and the tabulated percentages in Tables 2.11 to 2.14, are used to describe the areal distribution of precipitation of a local PMP storm. The 2:1 ratio of the major to minor axis of Figure 2.20 should be used or “placed” only on a map at a 1:500,000 scale. The average index value from Step 2 (or Step 1 if no elevation adjustment is made) is multiplied by each of the percentages from the appropriate table (Tables 2.11 to 2.14) to obtain the value for each lettered isohyet

**Table 2.11.** Isohyetal label values (percent of 1-hour, 1-mi<sup>2</sup> average depth) to be used in conjunction with isohyetal pattern of Figure 2.20 and basin-average depths from Figure 2.25.

Duration (hours)									
Isohyet	1/4	1/2	3/4	1	2	3	4	5	6
A	55	79	91	100	109.5	112	114	114.5	115
B	35	57	68	74.8	83.5	85.5	87.5	88	88.5
C	24	40	49	56	62.9	4.5	66	66.5	67
D	18.5	30.5	39	43	48	49.5	50.6	51.1	51.5
E	13	22.5	29	32.2	36.6	37.7	38.6	39	39.5
F	7.5	14.0	19	22.4	25	25.7	26.3	26.7	27.0
G	4.5	8.5	12	14.0	16.2	16.8	17.4	17.9	18.2
H	1.8	3.5	5	6.5	8.3	8.8	9.3	9.8	10.3
I	0.4	0.7	0.9	1.1	2.2	2.7	3.2	3.7	4.1
J	0.1	0.3	0.5	0.7	1.2	1.7	2.2	2.6	2.9

**Table 2.12.** Isohyetal label values (percent of 1-hour, 1-mi<sup>2</sup> average depth) to be used in conjunction with the isohyetal pattern of Figure 2.20 and basin-average depths from Figure 2.26 .

Duration (hours)									
Isohyet	1/4	1/2	3/4	1	2	3	4	5	6
A	55	79	91	100	110.5	116	118	119	120
B	35.5	55	68	78	88	95	99	101	102.5
C	24	39	49	57	66	72	75	77	78.5
D	19	30	39	44	51.5	56	58.5	60	61
E	13.5	22	28	33	39	42.7	44.5	46	47
F	8.5	15	20	23	28	31.5	33.5	35	36
G	5.5	9.5	13	15	19	22	24	25	26
H	2	4.5	6.0	7.5	11.5	14.5	16.5	17.5	18.5
I	1	2	3	4	8	11	13	14.5	15.5
J	1	2	3	4	7	10	12	13.5	14.5

**Table 2.13.** Isohyetal label values (percent of 1-hour, 1-mi<sup>2</sup> average depth) to be used in conjunction with the isohyetal pattern of Figure 2.20 and basin-average depths from Figure 2.27.

Duration (hours)									
Isohyet	1/4	1/2	3/4	1	2	3	4	5	6
A	55	79	91	100	114	120	125	128	130
B	44	66	77.6	86	100	106	111	114	116
C	26	44	53.6	61	74	81	86	89	91
D	17	31	40.2	46.5	58	65	70	73	75
E	11	20	26.8	32.5	42	49	54	57	59
F	6.6	13	19	24	32	38	43	46	48
G	6.5	11	14	16	23	28	33	36	38
H	5	8	10.5	12	17.5	21.5	25.5	29	31
I	3	6.0	8.5	10.5	16	20	24	27.5	30
J	2.5	5.5	8	10	15	19	23	26.5	29

**Table 2.14.** Isohyetal label value (percent of 1-hour, 1-mi<sup>2</sup> average depth) to be used in conjunction with the isohyetal pattern of Figure 2.20 and basin-average depths from Figure 2.28.

Duration (hours)									
Isohyet	1/4	1/2	3/4	1	2	3	4	5	6
A	55	79	91	100	117	126	132	137	140
B	39	61	74	84	100	109	115	120	123
C	24	42	52	60	76	85	91	96	99
D	15	28	37	44	59	67	73	78	81
E	9	19	26	32	44	52	58	63	67
F	6	13.5	19	24	34	40	45	50	54
G	6	10	13.5	16	24	30	35	39	42
H	4	7	10	13	19	24	28	32	35.5
I	3.3	6.5	9	11	18	23	27	31	34.5
J	3	5.5	8	10	17	22	26	30	33.5

(A - J). Once the labels have been determined for each application, the pattern can be moved to different placements on the basin. In most instances, the greatest volume of precipitation will be obtained when the pattern is centered in the drainage. However, peak flows may actually occur with placements closer to the drainage outlet. The basin-averaged depth of precipitation is obtained for chosen local PMP storm placements, by using planimetry, a GIS, or other area-averaging methods.

## **2.5 Example of Local-Storm PMP Calculation**

We have selected a small area in southeastern California known as the McCoy Wash to illustrate the steps for calculating local-storm PMP. The Wash has an area size of 167 mi<sup>2</sup> and its boundary, along with selected contours of elevation, is shown in Figure 2.29. We will illustrate both options A and B referenced in the previous section.

### **Local-Storm PMP for McCoy Wash**

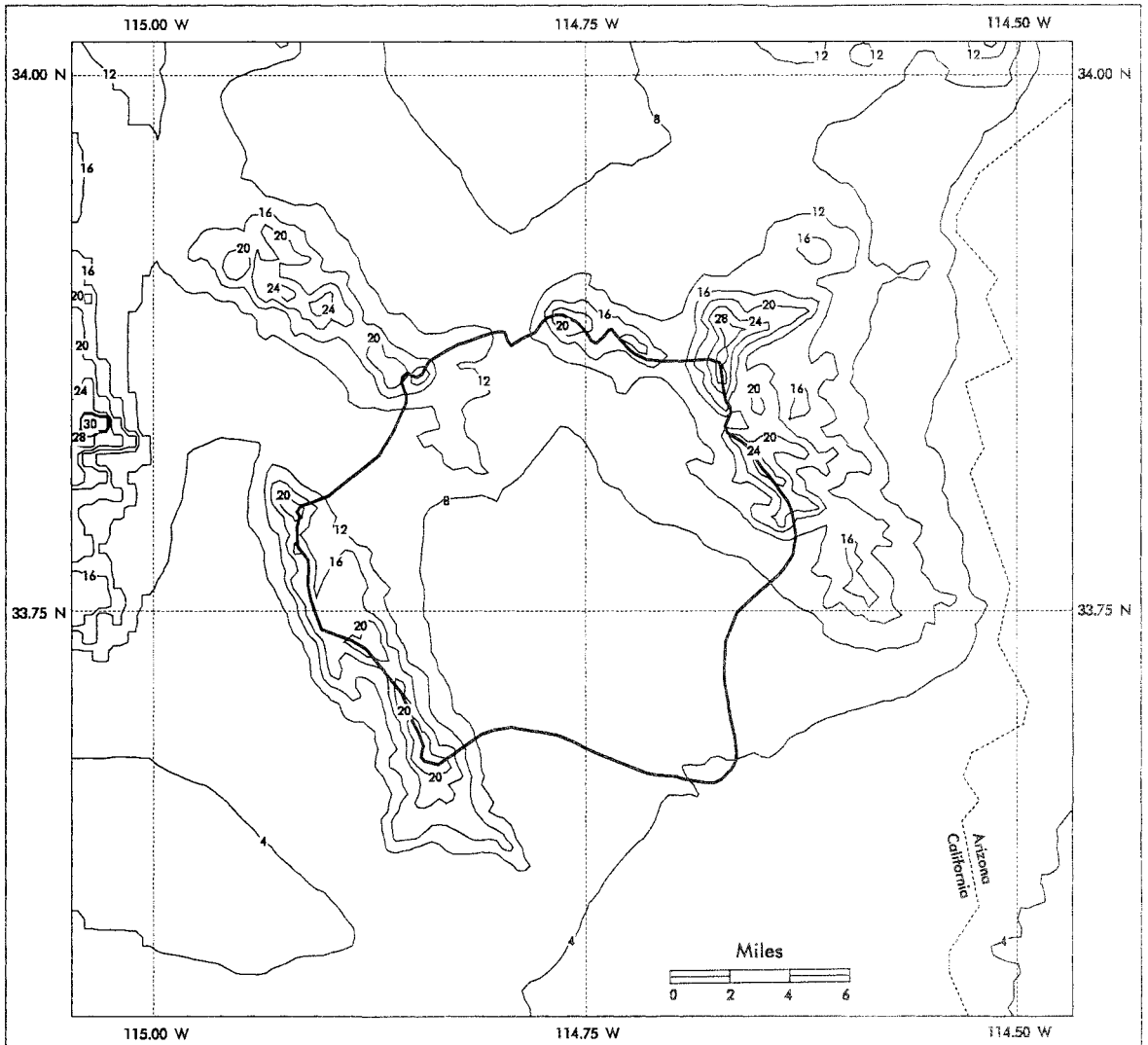
#### Step

#### 1. One-hour, 1-mi<sup>2</sup> PMP

The centroid of the Wash is near latitude 33.75° N and longitude 114.75° W. Interpolation to this centroid on Figure 2.21 gives an average local PMP value (1-hour, 1-mi<sup>2</sup>) of 11.4 inches to the nearest tenth of an inch. Interpolation was appropriate here since there is little, if any, gradient of index values across the Wash. For locations where significant gradients of index values exist, an average index value should be found.

#### 2. Adjustment for Mean Drainage Elevation

The mean elevation of the Wash is well below 6,000 feet as shown on Figure 2.29. No elevation adjustment is needed, and the local-storm PMP from Step 1 remains at 11.4 inches.



**Figure 2.29.** McCoy Wash, California drainage boundary (solid, heavy line) with elevation contours (solid, thin lines) in hundreds of feet.

3. Adjustment for Duration

The value of the 6-hour to 1-hour ratio near the Wash's centroid found in Figure 2.24 is 1.3. The depth-duration curve which applies here is curve "C" from Figure 2.23, and column "C" from Table 2.10 is also applicable.

Multiplication of the column "C" percentages by the average depth from Step 2 gives the average 1-mi<sup>2</sup> values for the Wash:

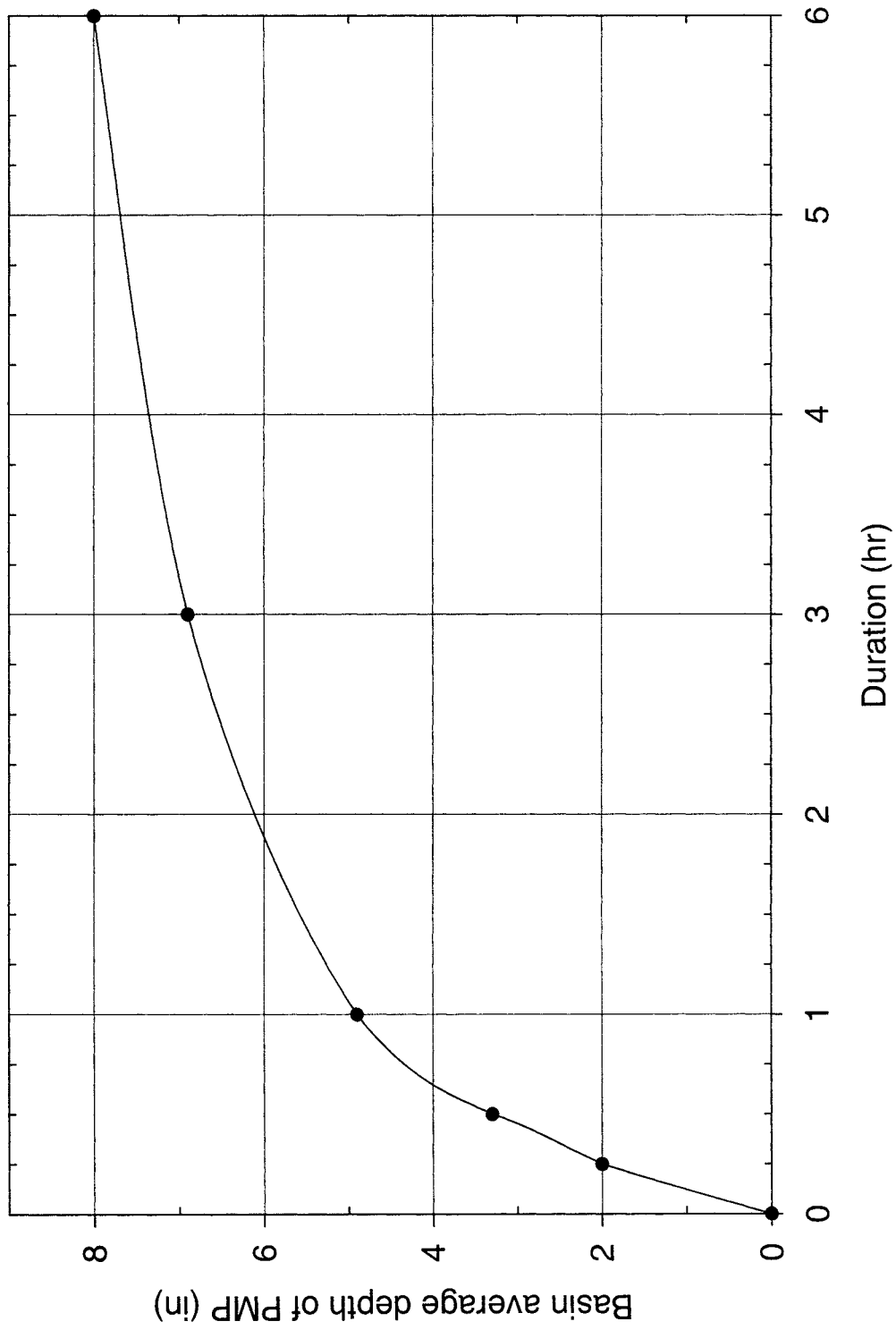
Duration (hours)									
	1/4	1/2	3/4	1	2	3	4	5	6
1-mi <sup>2</sup> Average Depth (inches)	6.3	9.0	10.4	11.4	13.0	13.7	14.3	14.6	14.8

4. Adjustment for Basin Area

Figure 2.27 gives the depth-area relations for a 6-hour to 1-hour ratio of 1.3. The reduction ratios used to obtain average depths basin from 1-mi<sup>2</sup> depths for the 167 mi<sup>2</sup> and their depths are:

Duration (hours)					
	1/4	1/2	1	3	6
Reduction Ratio	.31	.37	.43	.50	.54
167-mi <sup>2</sup> Average Depth (inch)	2.0	3.3	4.9	6.9	8.0

These results are shown, and a smooth curve fitted to these depths as shown in Figure 2.30.



**Figure 2.30.** Average depth of local-storm PMP for the 167-mi<sup>2</sup> McCoy Wash, California.

5. Temporal Distribution

The smoothed cumulative hourly values from Step 4 and the incremental hourly values resulting from successive subtractions are:

Hourly Intervals						
	1	2	3	4	5	6
Cumulative PMP (inch)	4.9	6.1	6.9	7.4	7.7	8.0
Incremental PMP (inch)	4.9	1.2	0.8	0.5	0.3	0.3

The highest increment to lowest increment sequence shown above is the recommended chronology for local-storm PMP at McCoy Wash.

6. Areal Distribution of Local-Storm PMP

The areal distribution of local-storm PMP is given by the isohyets of Figure 2.20. Remember these isohyets are meant to be placed within a basin boundary at the 1:500,000 map scale. For this example, the percentages from Table 2.13 apply for a basin with a 6-hour to 1-hour ratio of 1.3. When the 6-hour to 1-hour ratio is 1.15, 1.2, or 1.4, Tables 2.11, 2.12, or 2.14 apply respectively.

It is important to note that when Tables 2.11 to 2.14 are used in a particular case, that the percentages from the selected table apply only to the 1-mi<sup>2</sup>, 1-hour average local-storm PMP from Step 2, and NOT to the values from Step 3. In this example, the average depth is 11.4 inches, and the isohyetal labels of Table 2.15 result. An average 6-hour depth of 8.0 inches for the 167-mi<sup>2</sup> McCoy Wash Basin is given (Step 4). Using Figure 2.20 the isohyetal labels range from 14.82 inches enclosing 1 mi<sup>2</sup> to 4.33 inches enclosing 220 mi<sup>2</sup> for that duration.

Remember that the isohyetal labels in Step 6 produce the average depths from Step 4 only if the basin in consideration is elliptical with a 2:1 ratio of the major to minor



axis and the ellipses are centered in a "perfect" drainage. The ellipses with the indicated values from this step when placed in an irregularly shaped drainage and then averaged, will produce average depths less than those resulting from Step 4. The PMP level for the drainage comes from Step 4, with the isohyetal labels of Step 6 giving an idea of a possible areal distribution for the storm.

**Table 2.15.** *Isohyetal label values for local-storm PMP, McCoy Wash, California (167 mi<sup>2</sup>).*

Isohyetal Tag (mi <sup>2</sup> )	Duration (hours)								
	1/4	1/2	3/4	1	2	3	4	5	6
A (1)	6.27	9.01	10.37	11.40	13.00	13.68	14.25	14.59	14.82
B (5)	5.02	7.52	8.85	9.80	11.40	12.08	12.65	13.00	13.22
C (25)	2.96	5.02	6.11	9.65	8.44	9.23	9.80	10.15	10.37
D (55)	1.94	3.53	4.58	5.30	6.61	7.41	7.98	8.32	8.55
E (95)	1.25	2.28	3.06	3.71	4.79	5.59	6.16	6.50	6.72
F (150)	.75	1.48	2.17	2.74	3.65	4.33	4.90	5.24	5.47
G (220)	.74	1.25	1.60	1.82	2.62	3.19	3.76	4.10	4.33
H (300)	.57	.91	1.20	1.37	2.00	2.45	2.91	3.31	3.53
I (385)	.34	.68	.97	1.20	1.82	2.28	2.74	3.14	3.42
J (500)	.29	.63	.91	1.14	1.71	2.17	2.62	3.02	3.31

Endnote<sup>1</sup>

Plates 1 and 2 have limited detail in some regions. The Hydrometeorological Design Studies Center will provide supplemental map(s) containing a more complete set of isohyets or digital values for specific drainages areas, upon request.



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# APPENDIX

## Snowmelt Parameters

In HMR 36 a snowmelt procedure was provided. Information was included for determination of temperatures, dew points, precipitation, and winds during and prior to a PMP storm. The development of new snowmelt parameters was beyond the scope of this report. However, during peer review, inclusion of snowmelt parameter procedures was mentioned by most reviewers as highly desirable. This Appendix is in response to those requests.

The core of the Appendix is a worksheet consisting of five sections (A-E). It is essentially the same worksheet that appeared in HMR 36. An example for the Auburn drainage above Folsom Dam is provided for mid-November. The figures referenced in Chapter X of HMR 36 dealing with variation of precipitable water, temperature/elevation relations, temperature prior to a PMP storm, and winds have not been changed except for new figure numbers. The seasonal variation of maximum moisture table (Table 4-1 in HMR 36) was replaced by Table A1. The revision of this table was based on new dew-point data. The durational variation of maximum moisture, Table A2, is unchanged. The seasonal variation of maximum moisture, Table A1, is a function of the regional DAD boundaries for Figure 2.11.

An important part of this methodology is the wind speed expected at the surface of a snow pack; these winds and reduction factors are needed in Steps D.1 and D.2 of the worksheet. The recommended factors for basins not sheltered from the winds by topographic features in advance of a PMP storm are a function of regions.

The factors for the regions are:

Region	Factor
1, 3, 6	.80
2, 5	.75

In cases where basins are sheltered from the winds the reduction factors should reduce the surface winds speeds even more. The amount of the reduction should be decided by the user.

We have assumed that snowmelt is not an important factor for basins in regions 4 and 7. If snowmelt parameters are needed for basins in these regions, use the factor in the above list from the region closest to the basin of concern.

Data values from Figures A1 to A7 may vary, and there will be some difference from user to user. Figure A8 gives the dew-point temperatures for February over California.

<b>Table A1.</b> <i>Monthly variation of maximum moisture (percent/100 of February maximum). See Figure 2.11 for region boundaries.</i>							
Month							
Region	October	November	December	January	February	March	April
3, 4, 6	1.22	1.13	1.08	1.03	1.00	1.03	1.06
7	1.35	1.11	1.03	0.97	1.00	1.03	1.06
1, 2	1.29	1.14	1.12	1.05	1.00	1.00	1.08
5	1.29	1.17	1.11	1.03	1.00	1.03	1.09

<b>Table A2.</b> <i>Durational variation of maximum moisture (percent of 12-hour precipitable water).</i>												
Duration (Hour)	6	12	18	24	30	36	42	48	54	60	66	72
Percent	104	100	97	95	93	91	89	88	86	85	84	83



## Snowmelt Parameters Worksheet

Drainage: \_\_\_\_\_  
 Month: \_\_\_\_\_

Average elevation (nearest 100 feet): \_\_\_\_\_  
 Region: \_\_\_\_\_

### A. Temperatures and Dew Points During PMP Storm

- 1) Average 12-hour February 1000 mb persisting dew point over basin (Figure A8): \_\_\_\_\_
- 2) Precipitable water ( $W_p$ ) for temperature from Step A.1 (Figure A1): \_\_\_\_\_
- 3) Seasonal adjustment for month selected (Table A1): \_\_\_\_\_
- 4) Line 2 \_\_\_\_\_ x line 3 = \_\_\_\_\_

6-Hour Period												
	1	2	3	4	5	6	7	8	9	10	11	12
5) $W_p$ corresponding to 6-hour temperature increments during PMP storm. Line 4 x %'s of Table A2 (inches).												
6) 6-hour incremental sea-level temperatures and dew points from Figure A1 (°F).												
7) Sea-level temperatures and dew points adjusted to average basin elevation. Figure A2 (°F).												
8) Height of 32°F above mean sea-level. Figure A2 (1000's feet). Use dew points from line 6.												

9) The temperatures and elevations in Steps A.7 and A.8 should be arranged in time sequence corresponding to the selected PMP storm sequence (see E).

**B. Temperatures Prior to PMP Storm**

Hours Prior to Storm Onset								
	48	42	36	30	24	18	12	6
1) Differences between temperature at the beginning of storm and at indicated hours prior to storm. From Figure A3, in range from curve A <sub>1</sub> to curve B (°F).								

2) The above differences are added to the initial temperature determined in Step A.9.

**C. Dew Points Prior to PMP Storm**

Hours Prior to Storm Onset								
	48	42	36	30	24	18	12	6
1) Differences between dew point at the beginning of storm and at indicated hours prior to storm. Figure A3, curve C (°F).								

2) The above differences are subtracted from the initial temperature (dew point) determined in Step A.9.

**D. Snowmelt Winds**

6-Hour Period												
	1	2	3	4	5	6	7	8	9	10	11	12
1) Winds from Figure A5 (Regions 1, 3, 6) or A6 (Regions 2, 5) and interpolations at average basin elevation (feet msl) reference Figure A4 (mph).												
2) Winds reduced to surface conditions. See text for factor to be used. Step D.1 winds x factor (mph).												
3) Surface winds adjusted to month selected. Step D.2 winds x _____ (from Figure A7) (mph).												

4) Arrange 6-hour winds (Step D.3) in time sequence similar to arrangement of precipitation and temperatures in PMP storm (see E).

**E. Time Sequence of Temperatures, Winds and Precipitation During PMP Storm**

	6-Hour Period											
	1	2	3	4	5	6	7	8	9	10	11	12
1) Month of concern 6-hourly PMP increments for the selected drainage obtained by procedures of Chapter 2 (inches).												

	Time in Hours From Beginning of Storm											
	6	12	18	24	30	36	42	48	54	60	66	72
2) 6-hour PMP increments arranged according to sequence adopted in Section 2.2, Step 8 (inches).												
3) 6-hour temperatures from A.7 arranged in same sequence (°F).												
4) 6-hour winds from D.3 arranged in same sequence (mph).												
5) Height of freezing level from A.8 in same sequence (1000's feet).												

	Hours Prior to Storm Onset									
	48	42	36	30	24	18	12	6	0	
6) Temperature prior to storm. Differences of B.1 added to the temperature from E.3, 6-hour column.										
7) Dew points prior to storm. Differences of C.1 subtracted from the temperature from E.3, 6-hour column.										

8) Winds prior to storm may be assumed to be the 72-hour duration value from D.3 for two days prior to storm.

Snowmelt Parameters Worksheet  
(Example)

Drainage: Auburn

Average elevation (nearest 100 feet): 4700

Month: Mid-November

Region: Sierra (5)

**A. Temperatures and Dew Points During PMP Storm**

1) Average 12-hour February 1000 mb persisting dew point over basin (Figure A8): 60° F

2) Precipitable water ( $W_p$ ) for 60° F (Figure A1): 1.38

3) Seasonal adjustment for November (Table A1): 1.17

4) 1.38 times 1.17 = 1.61 inches

	6-Hour Period											
	1	2	3	4	5	6	7	8	9	10	11	12
5) $W_p$ corresponding to 6-hour temperature increments during PMP storm. 1.61 x %'s of Table A2 (inches).	1.67	1.61	1.56	1.53	1.50	1.47	1.43	1.42	1.38	1.37	1.35	1.34
6) 6-hour incremental sea-level temperatures and dew points from Figure A1 (°F).	63.8	63.0	62.3	62.0	61.6	61.1	60.8	60.6	60.0	59.9	59.6	59.3
7) Sea-level temperatures and dew points adjusted to 4700 feet elevation. Figure A2 (°F).	51.5	50.7	49.8	49.4	49.0	48.4	48.0	47.6	47.3	47.0	46.7	46.3
8) Height of 32° F above mean sea level. Figure A2 (1000's feet). Use dew points from line 6.	11.6	11.3	10.9	10.8	10.7	10.4	10.2	10.1	9.9	9.8	9.7	9.6

9) The temperatures and elevations in Steps A.7 and A.8 should be arranged in time sequence corresponding to the selected PMP storm sequence (see E).

**B. Temperatures Prior to PMP Storm**

Hours Prior to Storm Onset								
	48	42	36	30	24	18	12	6
1) Differences between temperature at the beginning of storm and at indicated hours prior to storm. From Figure A3, selecting curve A <sub>1</sub> (°F).	10.0	9.5	9.0	8.0	7.0	6.0	4.5	3.5

2) The above differences are added to the initial temperature determined in Step A.9.

**C. Dew Points Prior to PMP Storm**

Hours Prior to Storm Onset								
	48	42	36	30	24	18	12	6
1) Differences between dew point at the beginning of storm and at indicated hours prior to storm. Figure A3, curve C (°F).	3.5	2.5	2.0	2.0	1.5	1.0	1.0	0.5

2) The above differences are subtracted from the initial temperature (dew point) determined in Step A.9.

**D. Snowmelt Winds**

6-Hour Period												
	1	2	3	4	5	6	7	8	9	10	11	12
1) Winds from Figure A6 and interpolations at 4700 feet msl (4700 feet = 840 mb) reference Figure A4 (mph).	78	69	64	60	57	54	52	50	49	48	47	46
2) Winds reduced to surface conditions similar to Auburn. Step D.1 winds x 0.75 (mph).	59	52	48	45	43	40	39	38	37	36	35	35
3) Surface winds adjusted to November. Step D.2 winds x 0.82 (from Figure A7) (mph).	48	42	39	37	35	33	32	31	30	30	29	29

4) Arrange 6-hour winds (Step D.3) in time sequence similar to arrangement of precipitation and temperatures in PMP storm (see E).

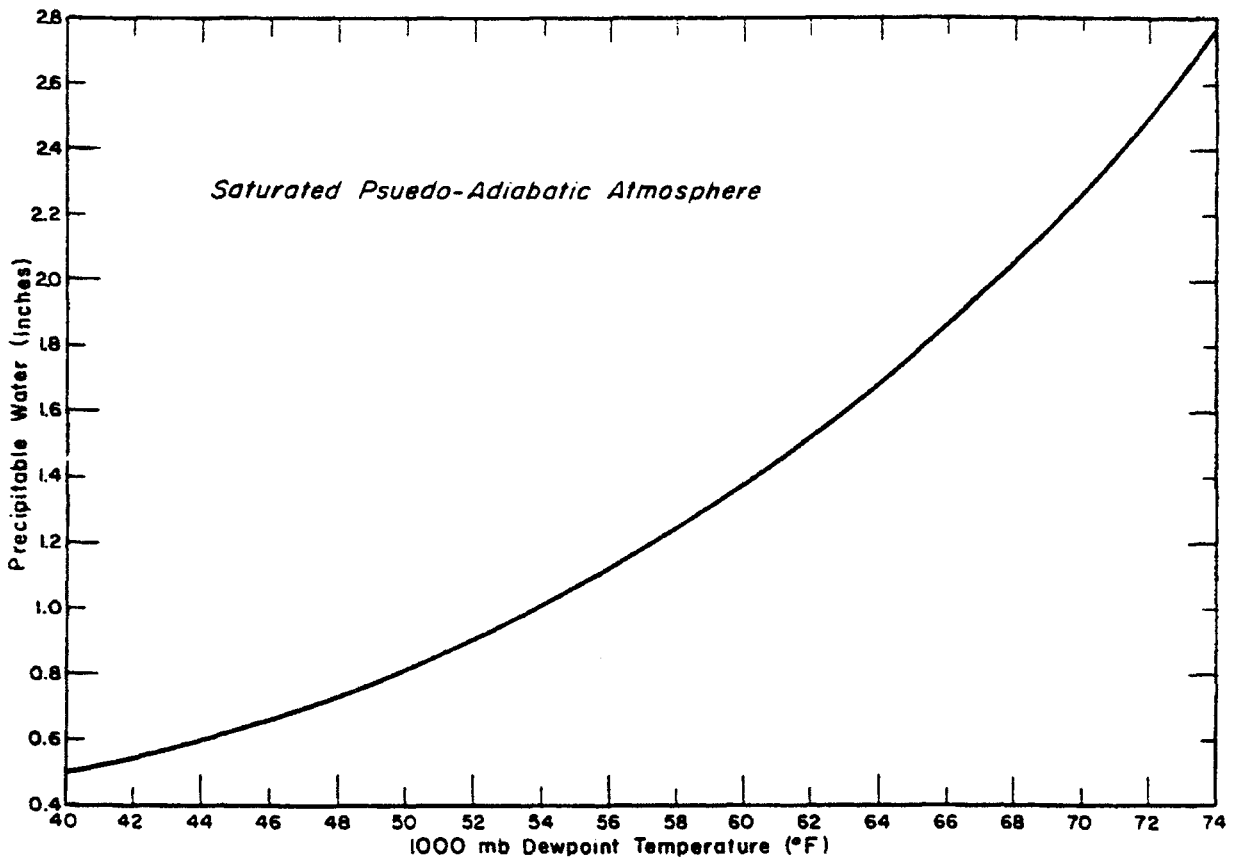
**E. Time Sequence of Temperatures, Winds and Precipitation During PMP Storm**

	6-Hour Period											
	1	2	3	4	5	6	7	8	9	10	11	12
1) November 6-hourly PMP increments for the selected drainage obtained by procedures of Chapter 2 (inches).	6.9	4.3	3.4	3.2	3.0	2.9	2.9	2.8	2.1	1.2	1.1	1.0

	Time in Hours From Beginning of Storm											
	6	12	18	24	30	36	42	48	54	60	66	72
2) 6-hour PMP increments arranged according to sequence adopted in Section 2.2, Step 8 (inches).	3.0	2.9	2.8	2.9	3.2	4.3	6.9	3.4	1.2	1.0	2.1	1.1
3) 6-hour temperatures from A.7 arranged in same sequence (°F).	49.0	48.4	47.6	48.0	49.4	50.7	51.5	49.8	47.0	46.3	47.3	46.7
4) 6-hour winds from D.3 arranged in same sequence (mph).	35	33	31	32	37	42	48	39	30	29	30	29
5) Height of freezing level from A.8 in same sequence (1000's feet).	10.7	10.4	10.1	10.2	10.8	11.3	11.6	10.9	9.8	9.6	9.9	9.7

	Hours Prior to Storm Onset									
	48	42	36	30	24	18	12	6	0	
6) Temperature prior to storm. Differences of B.1 added to the temperature from E.3, 6-hour column.	59.0	58.5	58.0	57.0	56.0	55.0	53.5	52.5	49.0	
7) Dew points prior to storm. Differences of C.1 subtracted from the temperature from E.3, 6-hour column.	45.5	46.5	47.0	47.0	47.5	48.0	48.0	48.5	49.0	

8) Winds prior to storm may be assumed to be 29 mph for two days prior to storm.



**Figure A1.** *Variation of precipitable water with 1000-mb dew point temperature.*

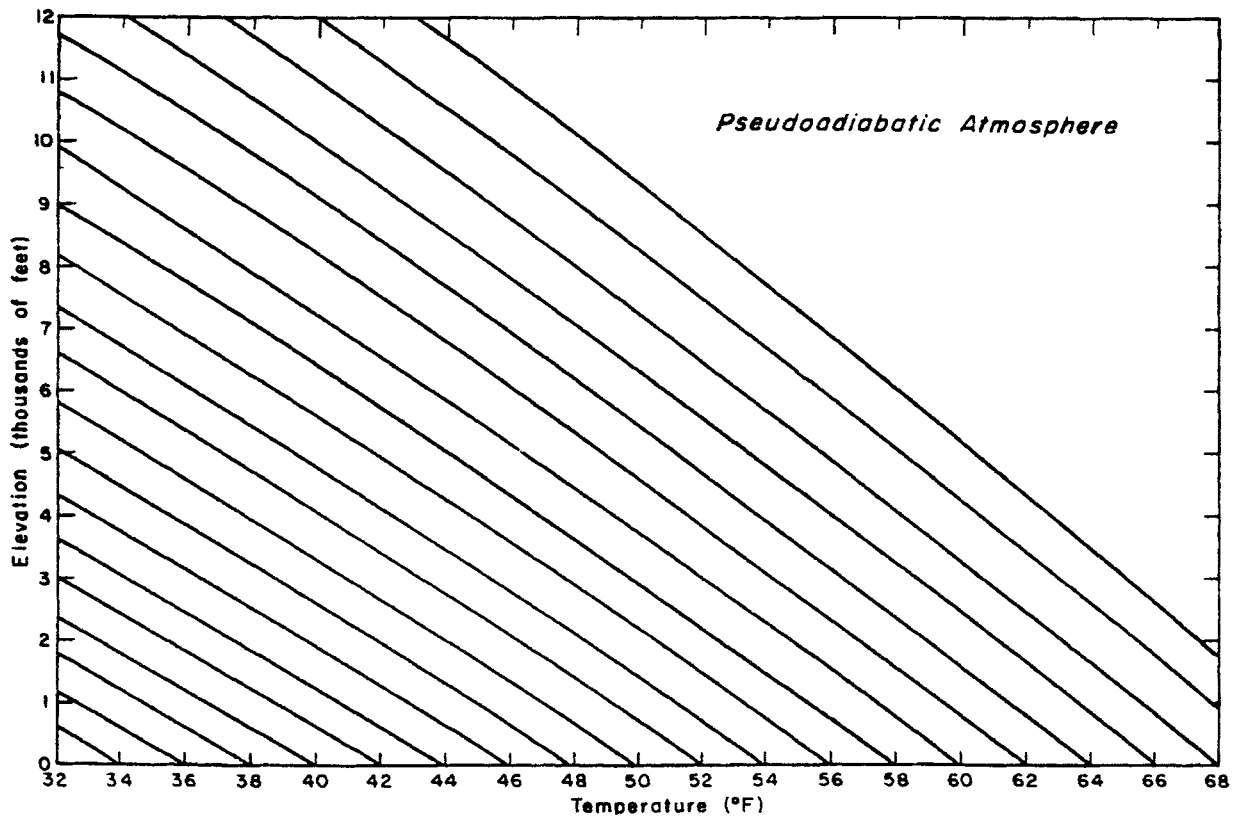


Figure A2. *Decrease of temperature with elevation.*



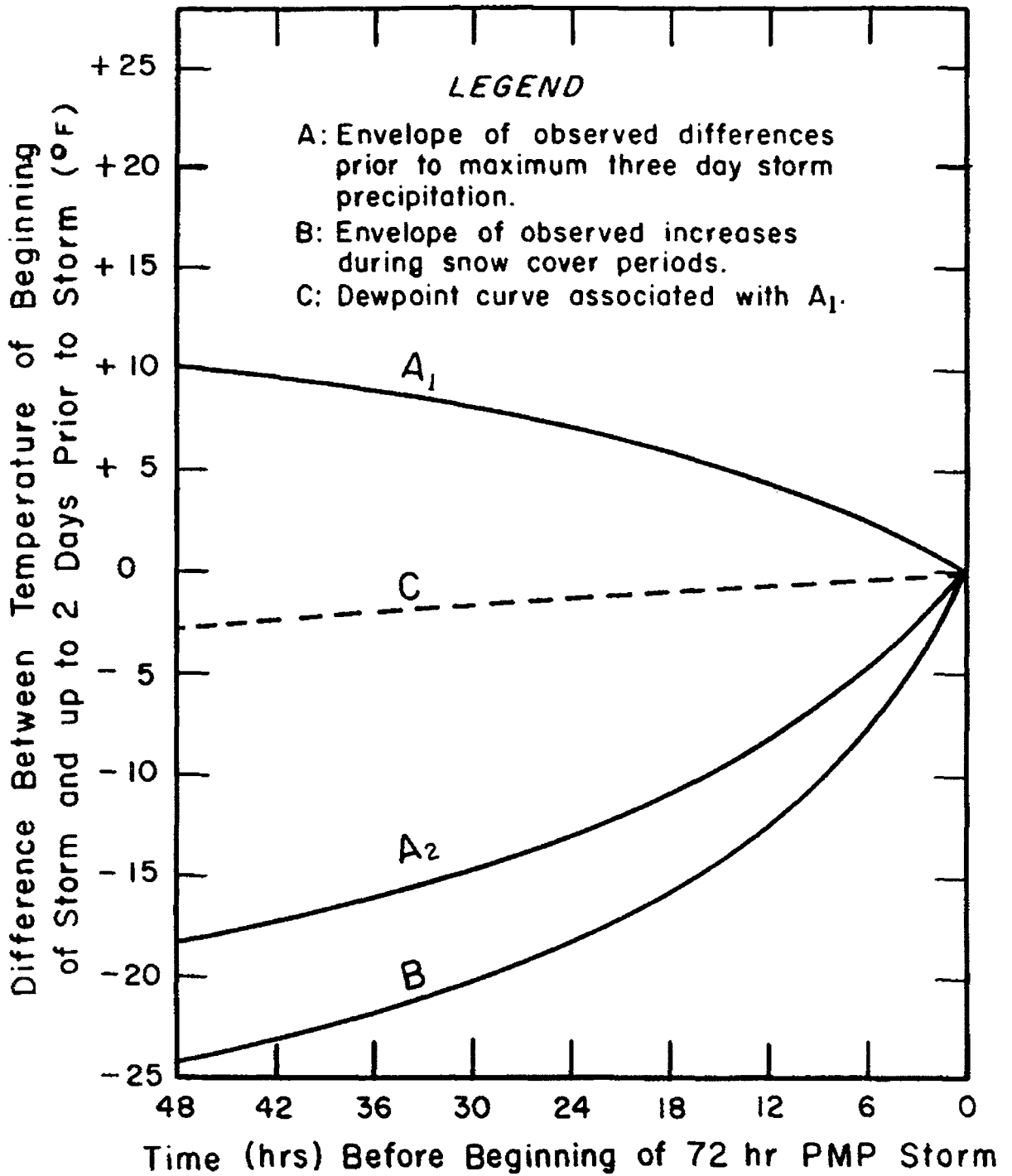


Figure A3. *Temperature prior to a PMP storm.*

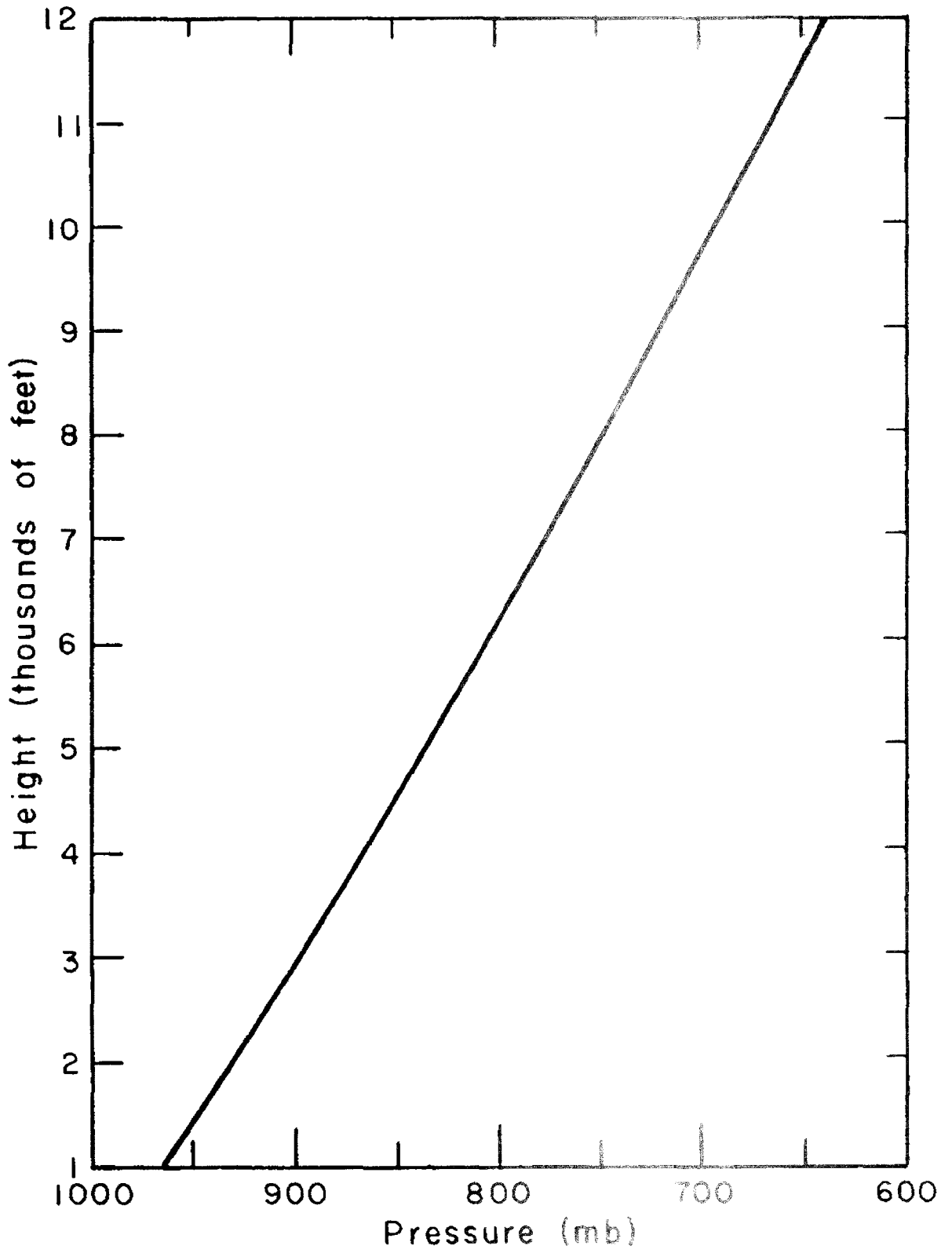


Figure A4. *Pressure-height relation.*

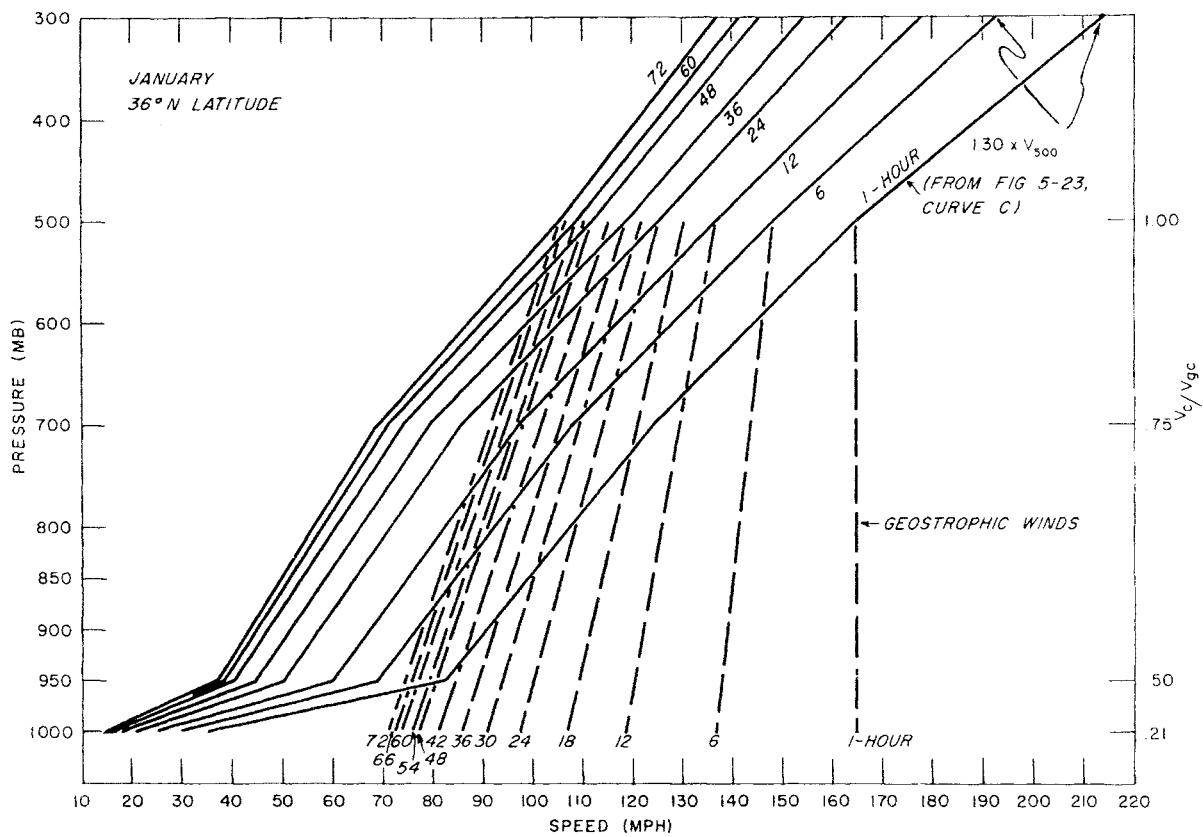
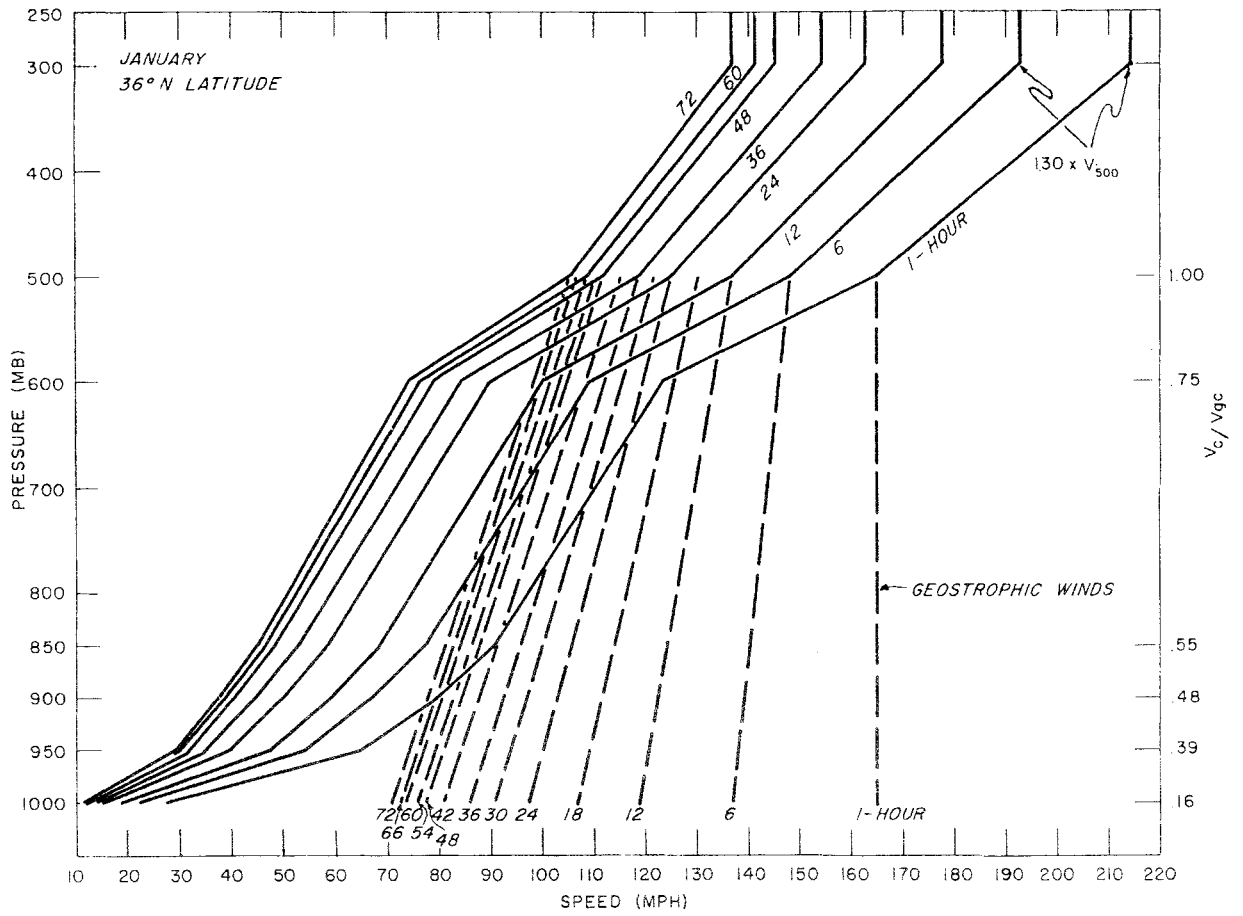


Figure A5. Maximum winds normal to coast range.



**Figure A6.** Maximum winds normal to the Sierra mountains.

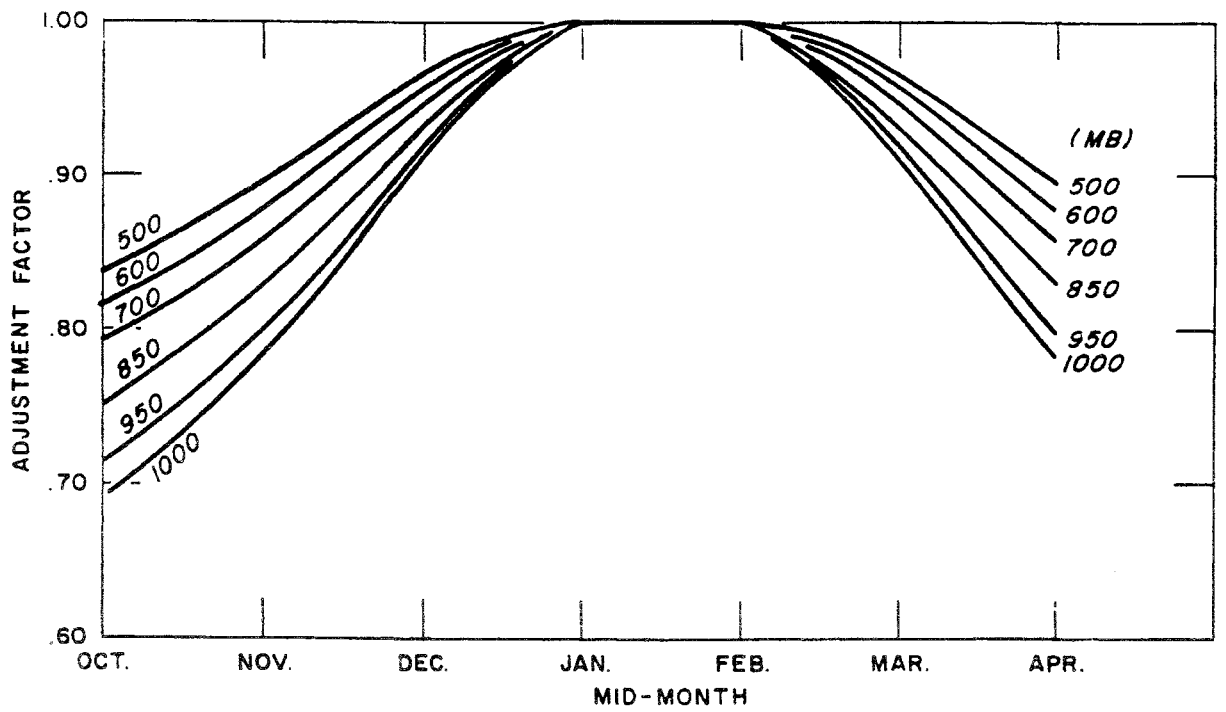


Figure A7. Seasonal variation of maximum winds.

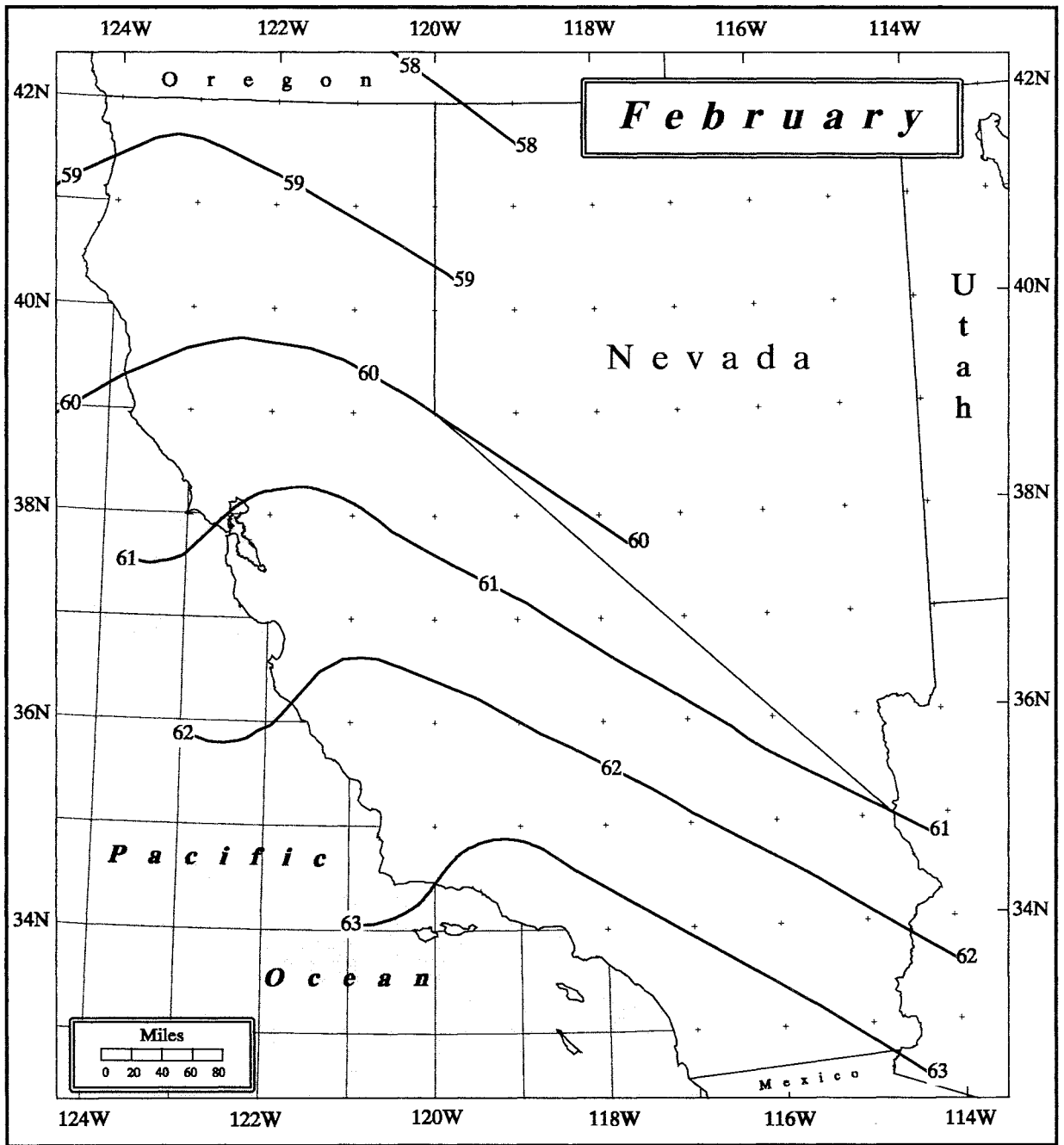
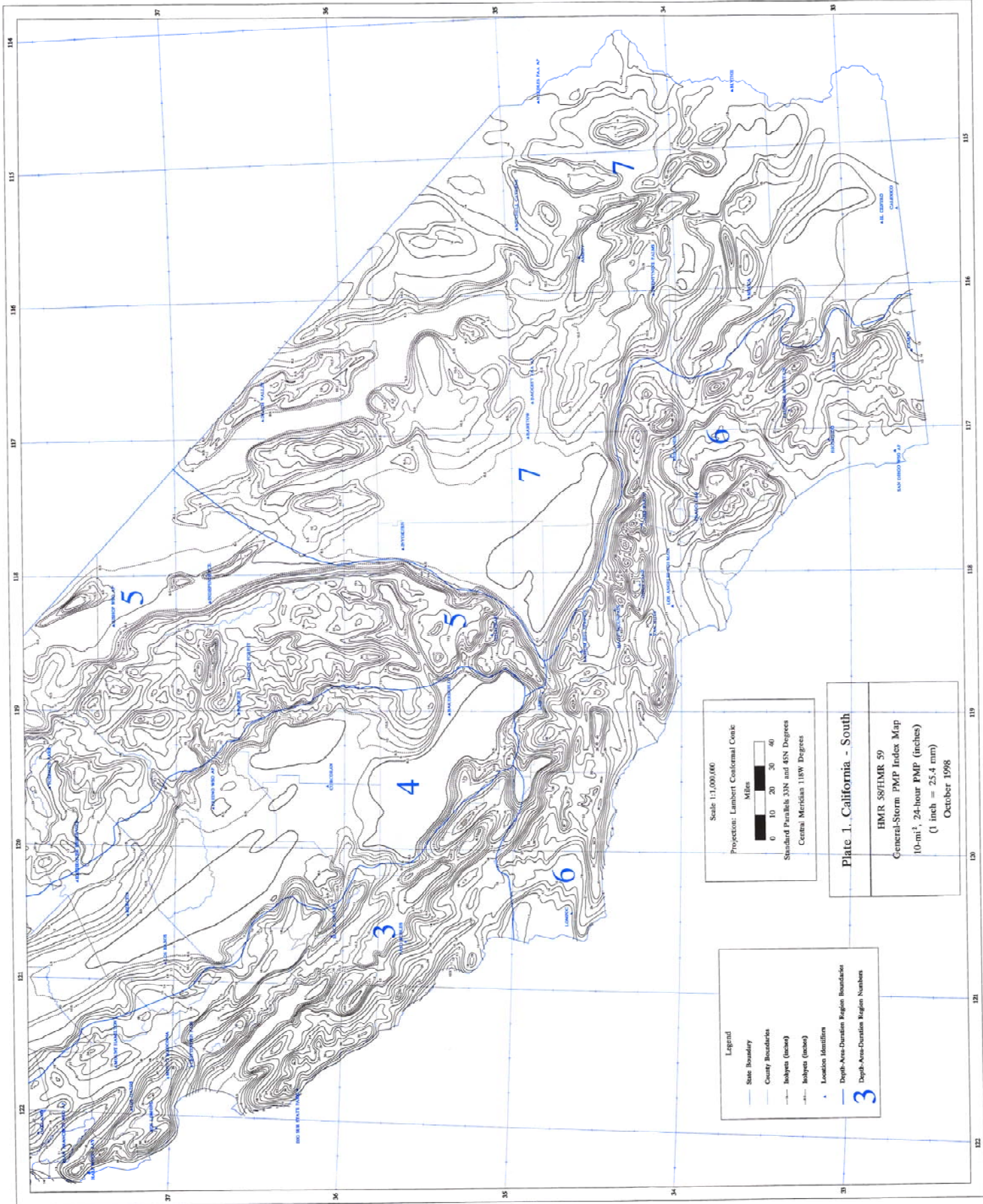


Figure A8. 12-hour maximum persisting 1000-mb dew point temperatures ( $^{\circ}$ F) for February.



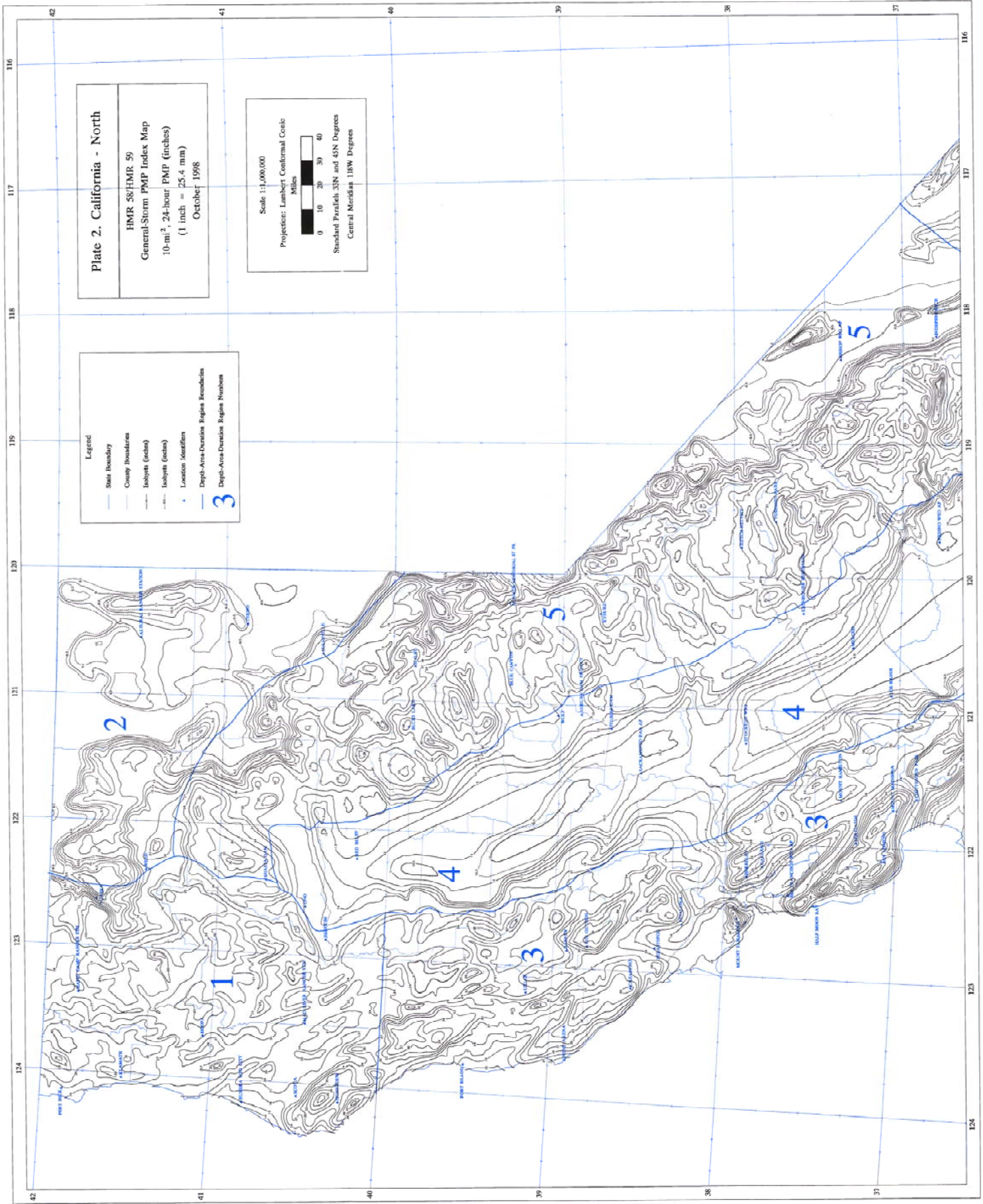
Scale 1:1,000,000  
 Projection: Lambert Conformal Conic  
 Standard Parallels 33N and 45N Degrees  
 Central Meridian 118W Degrees



- Legend**
- State Boundary
  - County Boundaries
  - Isohyets (inches)
  - Isohyets (inches)
  - Location Identifiers
  - Depth-Area-Duration Region Boundaries
  - Depth-Area-Duration Region Numbers

**Plate 1. California - South**  
 HMR 58/FHMR 59  
 General-Storm PMP Index Map  
 10-mi<sup>2</sup>, 24-hour PMP (inches)  
 (1 inch = 25.4 mm)  
 October 1998

**3**



**Plate 2. California - North**

EMR 58/HMR 59  
 General-Storm PMP Index Map  
 10-mi<sup>2</sup>, 24-hour PMP (inches)  
 (1 inch = 25.4 mm)  
 October 1998

**Legend**

- State boundary
- County boundaries
- - - Isobars (feet)
- - - Isobars (inches)
- Location Identifiers
- Depth-Area-Duration Region Boundaries

**3**

Scale 1:1,000,000

Projection: Lambert Conformal Conic

Miles

0 10 20 30 40

Standard Parallels 33N and 45N Degrees  
 Central Meridian 118W Degrees



(Continued from inside front cover)

- No. 49. Probable maximum precipitation estimates, Colorado River and Great Basin drainages. 1977.
- No. 50. The meteorology of important rainstorms in the Colorado River and Great Basin drainages. 1982.
- No. 51. Probable maximum precipitation estimates, United States east of 105<sup>th</sup> meridian. 1978.
- No. 52. Application of probable maximum precipitation estimates—United States east of the 105<sup>th</sup> meridian. 1982.
- No. 53. Seasonal variation of 10-square-mile probable maximum precipitation estimates, United States east of the 105<sup>th</sup> meridian. 1980.
- No. 54. Probable maximum precipitation and snowmelt criteria for southeast Alaska. 1983.
- No. 55. Probable maximum precipitation estimates—United States between the Continental Divide and the 103<sup>rd</sup> meridian. 1984.
- No. 55A. Probable maximum precipitation estimates—United States between the Continental Divide and the 103<sup>rd</sup> meridian. 1988.
- No. 56. Probable maximum and TVA precipitation estimates with areal distribution for Tennessee River drainages less than 3,000 mi<sup>2</sup> in area. 1986.
- No. 57. Probable maximum precipitation—pacific northwest states Columbia River (including portions of Canada), Snake River and pacific coastal drainages. 1994.