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STANDARD PROJECT STORM PRECIPITATION AND SNOWMELT TEMPERATURE CRITERIA FOR THE 9,570-SQUARE MILE CLEARWATER RIVER DRAINAGE ABOVE SPAULDING, IDAHO

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F.K. Schwarz*

ABSTRACT Standard project storm (SPS) precipitation and snowmelt temperature criteria are developed in this report for the total 9,570 mi^2 drainage of the Clearwater River above Spaulding, Idaho. Temperature criteria for snowmelt are developed for the November through June period with emphasis on SPS-level criteria for the 3-day SPS period and for three antecedent days.

1. INTRODUCTION

Standard project storm precipitation is a relationship of precipitation versus time that is concluded to be reasonably characteristic if large storms that have or could occur. It should neither be so extreme that no storms within a large meteorologically homogeneous region have never exceeded these amounts nor so small the storm amounts would be exceeded frequently. Though no interval can be given this storm, it should be larger than a 100-yr event, yet smaller than the amount with a recurrence interval of several thousand years.

1.1 Approach to SPS Precipitation

A primary method of developing the standard project storm (SPS) precipitation consisted of determining an annual series of maximum 3-day cool-season precipitation events and a series of maximum 3-day precipitation events for the May-June season. These series were used to determine precipitation-frequency values for various recurrence intervals. These values were used as limits for possible SPS amounts. The maximum storms in each of these series also formed input into determining the appropriate SPS values. A 45-yr period was used beginning with 1938-39 and ending with 1982-83. Three auxiliary methods (indirect, rather than direct as in primary method) involved adjustments of PMP for selected regions based on generalized study procedures.

Time and areal distributions for the SPS were primarily derived from the major storms of record over the basin. These storms were from the period used for the direct method approach.

1.2 Approach for Temperature Criteria for Snowmelt

The temperature sequences associated with major 3-day precipitation events resulting from the 45-yr survey for the cool season and for May-June form the

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primary basis for determining appropriate temperature departures from normal temperature ranges, etc. These criteria are reasonably characteristic of the weather situation during the SPS, including temperatures prior to and during major 3-day precipitation period. In addition, a set of mid-month mean 1,000 ft temperature charts were developed for the basin. The adopted temperature departures are applied to these mean values utilizing reasonable elevation variation in temperatures.

1.3 Format of Report

An important part of any study of extreme precipitation amounts for a basin is an understanding of the meteorological causes of precipitation within the region surrounding the basin. Chapter 2 discusses basin precipitation experience. In this chapter, the procedures for selecting the storm sample for statistical analysis is described. Next, the direct method based on basin average precipitation is discussed for determining limits for the SPS precipitation magnitude. Chapter 3 discusses the meteorology of cool-season storms in the Pacific northwest with particular reference to the major storms over the Clearwater River basin. Since storms that can occur during the snowmelt season are also of concern, Chapter 4 discusses the meteorological features of major storms that have occurred during the May-June period. Various indirect procedures are used to determine the magnitude of the SPS amount between the limits described in Chapter 2. These procedures are discussed in Chapters 5, 6 and 7. The final results developed from the information in Chapters 2, 5, 6 and 7 are presented in Chapter 8. Geographical distribution of the average rainfall amounts are discussed in Chapter 9, while the depth-duration characteristics are explained in Chapter 10. Seasonal variation of the SPS precipitation is given in Chapter 11. Chapter 12 covers the development of snowmelt criteria for all months from November through June. The application of both the SPS precipitation values and the snowmelt temperature criteria are discussed in Chapter 13.

The procedures used in this report are not mutually independent. Figure 1 shows in a schematic the interrelation of the various procedures. Figure 2 shows the location of the Clearwater River basin and other regions used in this report to develop estimates for the determining SPS precipitation.

2. COOL-SEASON BASIN-WIDE PRECIPITATION EXPERIENCE

2.1 Introduction

A basic approach used in defining SPS 3-day precipitation in the Clearwater basin was keyed to a comprehensive analysis of precipitation events in the basin itself. Such input is considered invaluable in making decisions on the maximum storm reasonably characteristic of occurrence in the region comprising the Clearwater drainage above Spaulding, Idaho. With actual basin-wide precipitation experience as underpinning, the results of more indirect methods can then be better evaluated in the selection of basin-wide SPS precipitation.

2.2 Observed Basin-wide Maximum 3-day Events

The methods selected to determine the SPS precipitation required determining the annual series of maximum 3-day precipitation events for the cool season as well as individual extreme events. The cool season for this study was defined as the October to March period. The undertaking to determine for many years 3-day annual maximum cool-season precipitation required much initial probing to set up

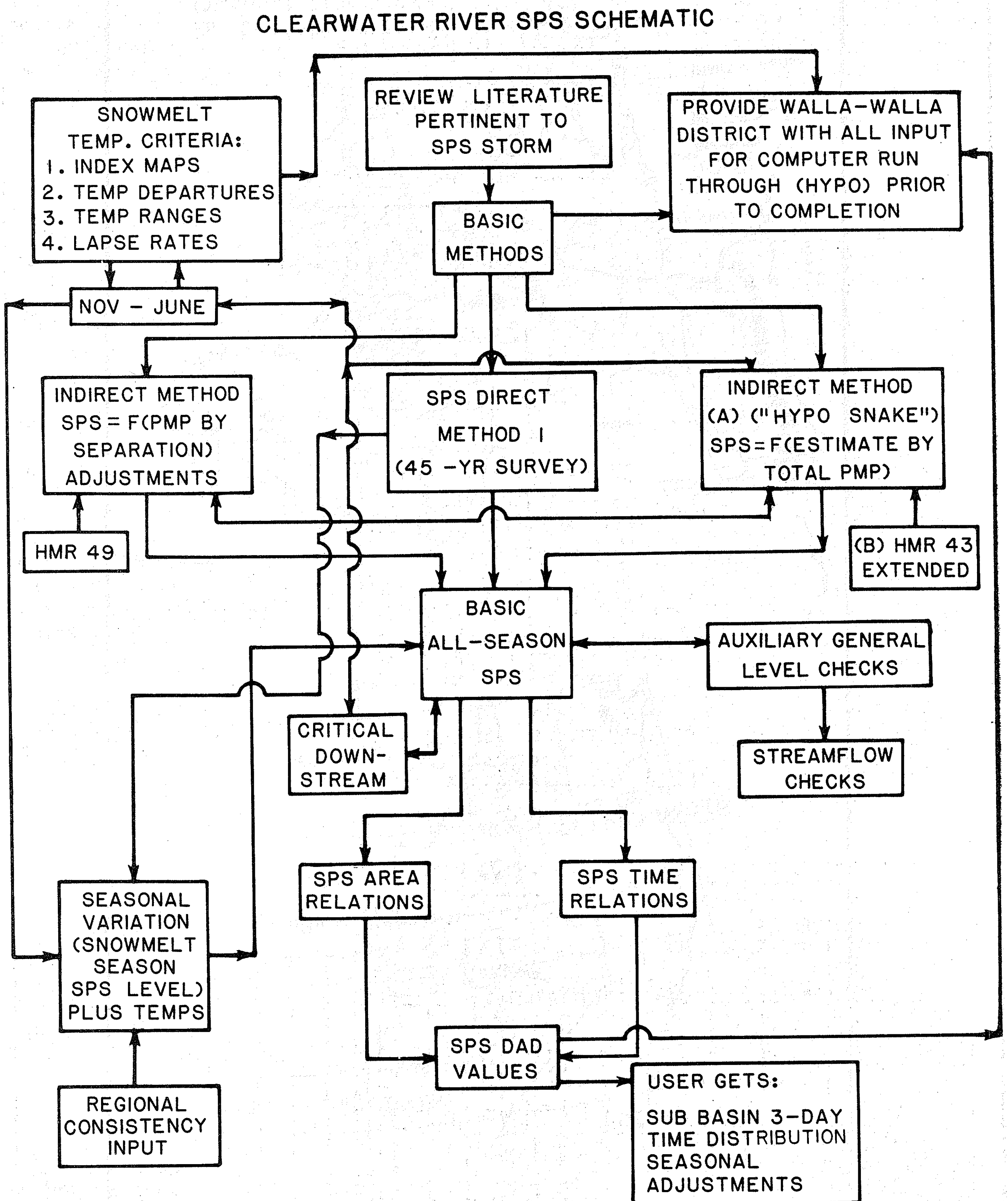

Figure 1.--Schematic showing interrelation of subprojects.

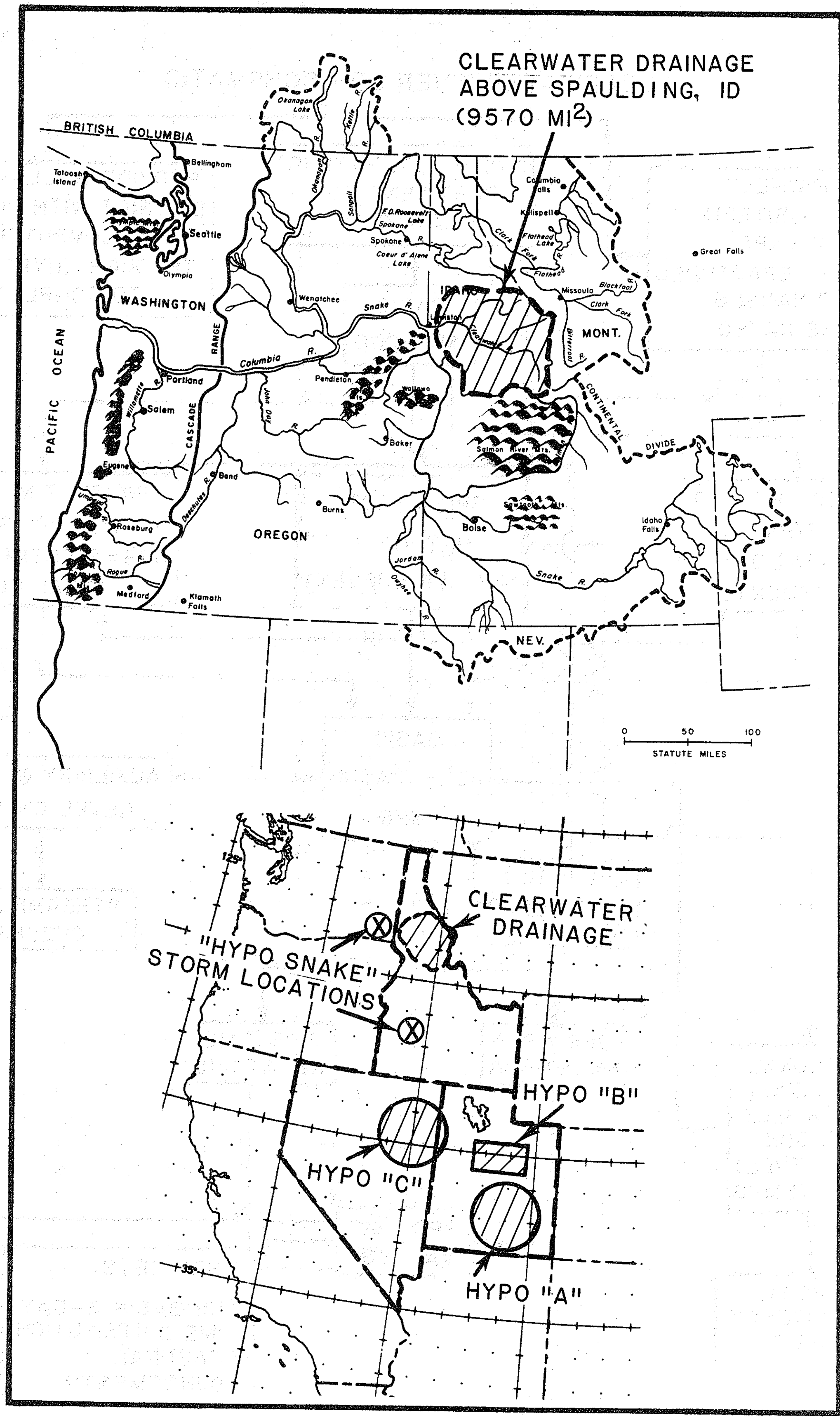

Figure 2.--Maps showing location of Clearwater River basin. Hypo locations were used in indirect procedures discussed in Chapters 5, 6 and 7.

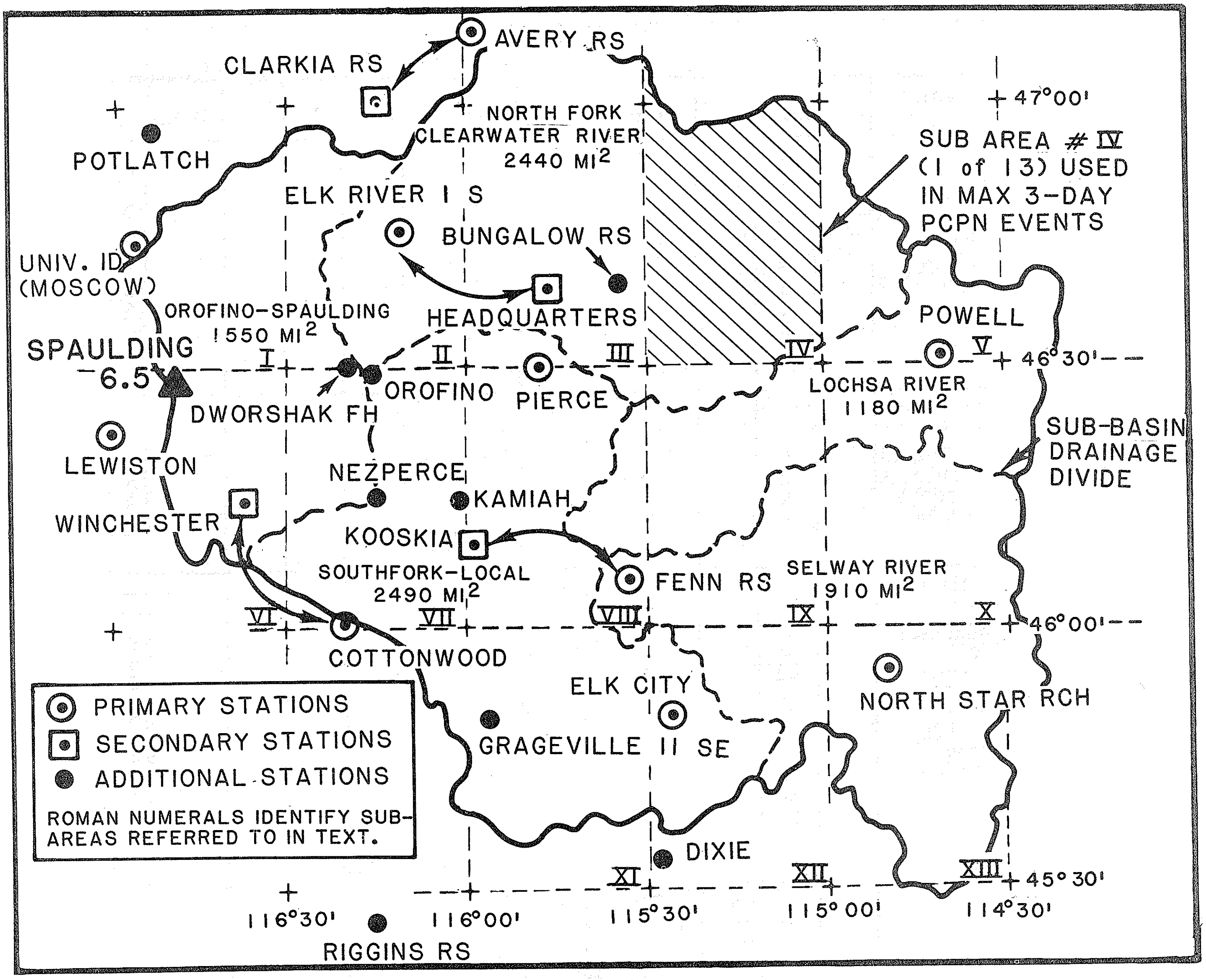

Figure 3.--Clearwater River basin above Spaulding, Idaho showing precipitation stations used in study. Map also shows sub-basins and sub-areas used in study.

a satisfactory procedure, that is, one that had a high probability of obtaining the annual 3-day maximum basin-wide precipitation event with a minimum of effort.

It was considered sufficient in selecting storms to accept the average of some key stations. Among the factors considered in selecting primary (first choice) and secondary (second choice) stations were adequate geographic coverage, the degree a station is representative of a portion of the basin and completeness and length of record. Figure 3 shows location of the within-basin and near-basin stations used (National Climatic Data Center 1938-1983). Figure 4 is the tabulation sheet set up in a fashion to "zero-in" on potential 3-day candidates for annual maximum 3-day basin-wide precipitation events. Of the 45-yr period (i.e., 1938-39 to 1982-83) surveyed, quite a few years resulted in rather easy decisions, some were moderately difficult to zero-in on the cool-season and May-June maximum 3-day event, while a few were quite difficult and required carrying the procedure all the way through to a basin-wide analysis for two or more candidate cases.

YEAR ______

PRIMARY STATIONS		CODE		MONTH ______	DATES		Σ		% M.A.P.
AVERY RS		A							34
COTTONWOOD		E							21
ELK CITY		G							23
ELK RIVER I S		H							39
FENN RS		I							37
LEWISTON		M							13
UNIV. of IDAHO		N							23
PIERCE		R							44
NORTH STAR R.		P							35
POWELL		T							43
SECONDARY									
A*-CLARKIA RS		D							37
F-WINCHESTER		X							28
H-HEADQRTS.		K							46
T-KOOSKIA		L							26
ADDITIONAL									
BUNGALOW RS		B							48
DIXIE		F							29
DWORSHAK FH		AA							25
GRANGEVILLE		J							23
KAMIAH		BB							20
NEZPERCE		O							22
OROFINO		Q							26
POTLATCH		S							25
RIGGINS RS		U							17

* LETTERS REFER TO THE STATIONS FOR WHICH A SUBSTITUTE IS MADE.

Figure 4.--Tabulation sheet.

2.3 Rationale for Organization of Tabulation Sheet

The organization of the tabulation sheet (fig. 4) results from initial probing of numerous experimental cases scattered through a significant period. Basically, it allows for change of station availability through the period of record. It also allows for adequate across-basin sampling (for that period) and also for spectrum sampling of station-to-station variability of mean annual precipitation (MAP). For example, a 1-in. rain for a station with a MAP of 20 in. is more important for singling out annual maximum 3-day events than a 1.50-in. rain for a station with a MAP of 40 in. "Substitute" stations (listed as "secondary" in fig. 3) are provided to increase uniformity of selection across the years in addition to station substitution on the basis of similar MAP. The method proved quite successful for "finding" the 3-day annual maximum for many years without having to carry the procedure through numerous stages. In other words, a painstaking initial probing saved a great deal of time in the long run.

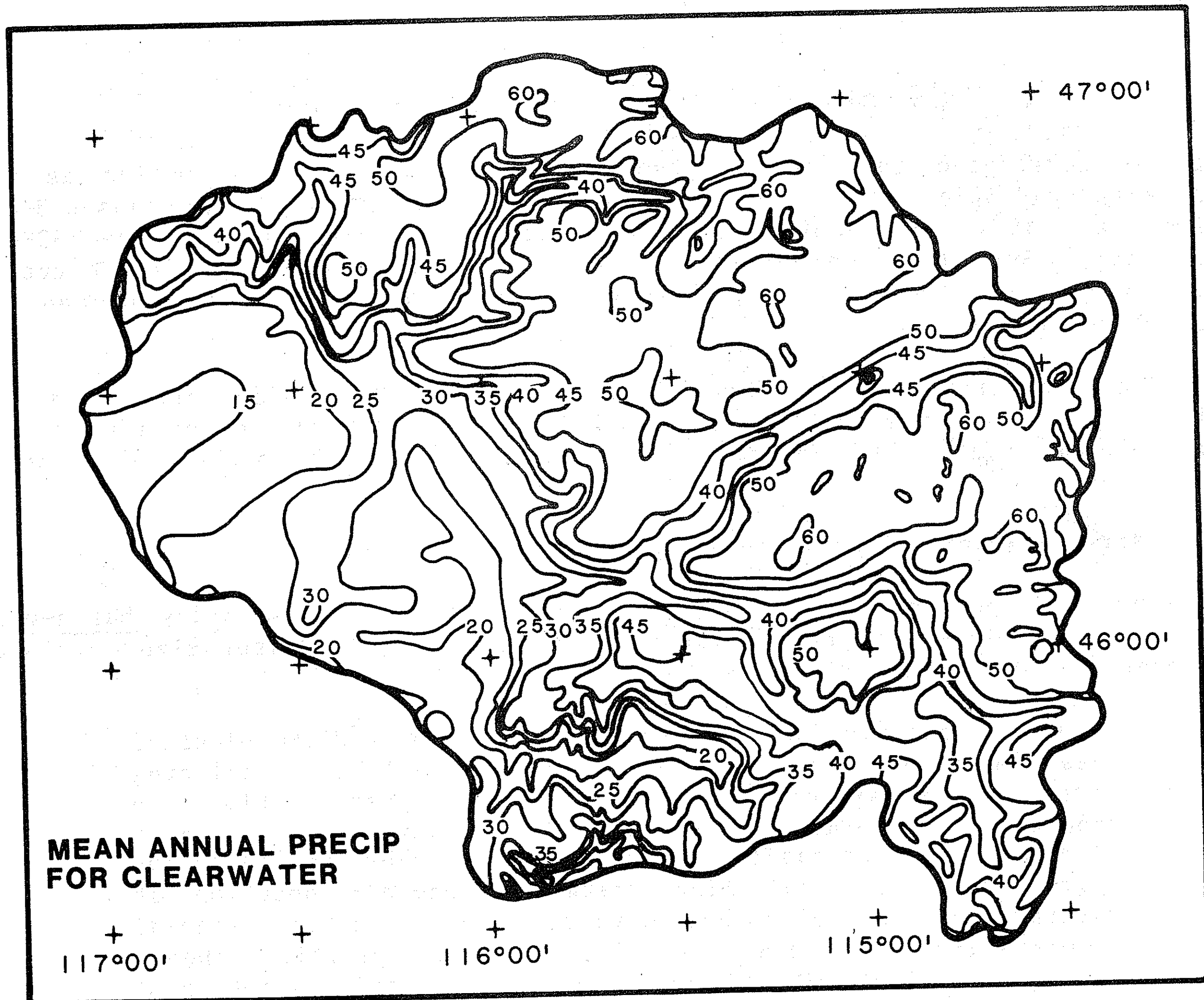

Figure 5.--Mean annual precipitation (MAP) chart for Clearwater drainage.

2.4 Sub-Area Mean Annual Precipitation

A procedure was set up including the use of a detailed MAP chart (fig. 5) (U.S. Weather Bureau, 1965). The average MAP was determined from this chart for 13 sub-areas covering the total Clearwater Drainage. All stations within the basin, primary, secondary, and additional, were used to determine average MAP over the subareas. Sub-area number IV is cross-hatched in figure 3 to illustrate the sub-areas. These were geometrically chosen areas, except for the irregular outer basin limits that permitted the use of 1/4 degree quadralaterals that made for easy computation of sub-area precipitation based upon the percentage of MAP lines from the 3-day storm analyses.* Figure 3 shows in addition to station networks the 13 sub-areas used for obtaining basin-wide precipitation in 3-day events.

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*Thus, for some subareas in some storm events main subbasin averages were quickly obtainable, while other instances somewhat more time was required for further breakdown a subarea into smaller units for percent of MAP determination for that subarea.

2.5 Selection of 3-Day Precipitation Events

It was considered an important task to obtain as much information as was reasonably possible in this project. For this reason, annual cool-season 3-day maxima for a 45-yr period of record were determined, beginning with the 1938-39 water year. Streamflow and other data were used to uncover significant events prior to 1938 that might provide important input to determine the adopted SPS level of precipitation.

Putting precipitation in terms of percent of MAP considerably eased the analyses phase of this project as precipitation expressed as percent of MAP nearly always results in smoother patterns for analysis than do the precipitation amounts.

2.5.1 Brief Synopsis of Full Procedure for Storm Selection

The stepwise procedure used to select the annual maximum 3-day basin-wide cool-season and May-June precipitation events for the Clearwater River drainage is summarized below with brief remarks.

1. "Gestalt" scanning of various forms of Idaho Climatological Data (National Climatic Data Center 1938-1980), including narrative summaries ("zeroing-in" on precipitation in departure-from-normal form and in specific significant precipitation periods); station maximum 24-hr precipitation (given with date for many years of record); notation of outstanding precipitation events (sometimes in special summaries); quick scanning of daily precipitation sheets through the October-March period (quite often this 'quick scan' technique allowed a lot of fast elimination of non-candidate months); scanning for daily amounts in excess of 1 in.

2. Actual (or mental) accounting (tabulation) of primary stations' amounts for candidate storm(s), being constantly aware of each station's approximate mean annual precipitation.

3. If there were only one candidate 3-day storm go to 4. If more than one candidate storm from 2, tabulate for all stations; primary, secondary and additional. Reduce to one storm by inspection of tabulation sheet if possible; otherwise process all candidate storms by completion of step 4 and the following steps.

4. Plot percent of MAP for all available stations for given candidate storm on a basin map.

5. Analyze 3-day percent of MAP chart.

6. For the 13 sub-areas, using quarter degree grid back-up, (see fig. 3) determine percent of MAP of each of the 13 sub-areas. Eyeball any that can be; otherwise weight by 1/16 degree grid or smaller elements, if necessary.

7. Use computation sheet (fig. 6)* to obtain total 3-day precipitation for storm.

In order to make the final choice of which storm provided the maximum 3-day precipitation for some situations, involving two or more near-equal storms, all seven steps are necessary.

2.5.2 Comments on Precipitation Event Selection

Beginning in the 1960's and to the present, the existence of station(s) in the mountainous eastern portion of the basin should make the total analyses more accurate. Certain guiding principals were followed for analyses over the eastern portion of the basin in the earlier years. First, if a reasonably definite trend in the analyzed percentages existed, the trend was extrapolated over the eastern portion of the basin. Second, if a trend suitable for extrapolation did not exist, the procedure was followed of allowing the percentage of the most eastern analyzed lines to prevail without positioning change over the remaining portion of the basin. Most of the more extreme 3-day events have occurred in recent years when eastern basin precipitation sampling existed. That this was not a function of this sampling as indicated by analysis of the eastern portion of the basin using the earlier years techniques. A 20-yr period was checked by assuming no eastern basin sampling (1962-63 through 1982-83). For those 20 years, the annual maximum 3-day event would have been analyzed (by applying the earlier years analysis technique) to give a higher basin average 4 times, a lower average also 4 times and little change 12 times.

Table 1 lists the 14 cases from the 45-yr survey where basin-wide precipitation was at least 2 1/2 in.

2.5.3 Streamflow Check for Candidate Cases

Printouts of daily discharges at all the significant gaging stations on the Clearwater and its tributaries were provided by the Walla Walla District Corps of Engineers Office. These were carefully reviewed with three considerations in mind.

1. To help spot any "candidate" 3-day event that possibly might have been missed.

2. To obtain streamflow verification of significant events uncovered by the basin-wide precipitation survey of the 45-yr record.

3. To "key-in" on any events pre-dating the first season of the 45-yr survey (i.e., 1938-39).

*This is purposely set up so as to systematically produce each subareas amount apportioned over the total basin. The information given in this figure are for the storm of January 5-7, 1969 and are included as an example of a completed computation.

COMPUTATION AVERAGE BASINWIDE PRECIPITATION

DATE 1/5-7/69

A	B	C	D=BxC	E	F=DxE
AREAS	% MAP*	MAP (IN.)	AREA PCPN. (IN.)	WEIGHTING FACTOR $\% \times 10^{-2}$	PCPN. (IN.)
I	7 1/2	25.0	1.88	.052	.098
II	6	38.6	2.32	.082	.190
III	7	47.6	3.33	.100	.333
IV	10	54.6	5.46	.088	.480
V	8	53.9	4.31	.051	.220
VI	8	20.2	1.62	.059	.095
VII	7	22.2	1.55	.092	.143
VIII	7	37.7	2.64	.088	.232
IX	10	48.4	4.84	.088	.426
X	8	52.5	4.20	.093	.391
XI	8	29.9	2.39	.072	.172
XII	9	38.8	3.50	.057	.199
XIII	6	43.2	2.59	.078	.202
					$\Sigma =$ 3.18

MOISTURE EVALUATION:

* MAP= MEAN ANNUAL PRECIPITATION

Figure 6.--Basin-wide precipitation computations.

Table 1.--Basin-wide 3-day events with precipitation at least 2.50 in.

Date	Basin 3-Day Precipitation (in.)
December 11-13, 1946	3.70
December 22-24, 1964	3.56
February 18-20, 1968	3.41
January 5-7, 1969	3.18
November 30-December 2, 1975	3.11
December 1-3, 1977	3.04
October 31-November 2, 1942	2.74
December 28-30, 1945	2.58
January 13-15, 1975	2.56
January 5-7, 1948	2.56
January 5-7, 1983	2.54
January 18-20, 1970	2.53
January 16-18, 1953	2.52
October 10-12, 1962	2.52

From the survey, 8 sites provided a total of 155 high flow cases (above selected thresholds) to check. The checking resulted in the following:

1. The 6 major 3-day events (i.e., 3 in. or more basin-wide precipitation) were all well substantiated by the streamflow data.

2. A number of pre-1938 high flow cases (cool-season) were discovered. The main contender with the 45-yr survey result was December 1933 which produced two large 3-day events.

3. Although the survey of streamflow uncovered a number of possible "candidate" events none stood up as really significant when processed using basin-wide precipitation. Quite a few were events involving less intense, but still rather large, precipitation over more than 3 days.

2.6 Statistical Analyses of Results

The Fisher Tippett Type I Extreme Value Distribution was used in the analyses of this 45-yr record of annual maximum 3-day basin-wide precipitation events. Through no goodness of fit tests were made, comparison of plotted data with the computed curve indicated, this distribution fit the data. This distribution is the one used previously in other National Weather Service precipitation-frequency studies for this region and duration (Miller 1981). Results of the plot and statistical analyses are shown in Figure 7. Preliminary analyses were tried prior to the completion of the full 45-yr period. These showed that when 30-yr or more period of record was used, the stability of the distribution was obvious. The fitted line is extrapolated to produce estimated values for return periods of several hundred years, a requirement, in spite of increased uncertainties, that is necessitated for obtaining estimates by this technique that are in the expected magnitude of SPS precipitation.

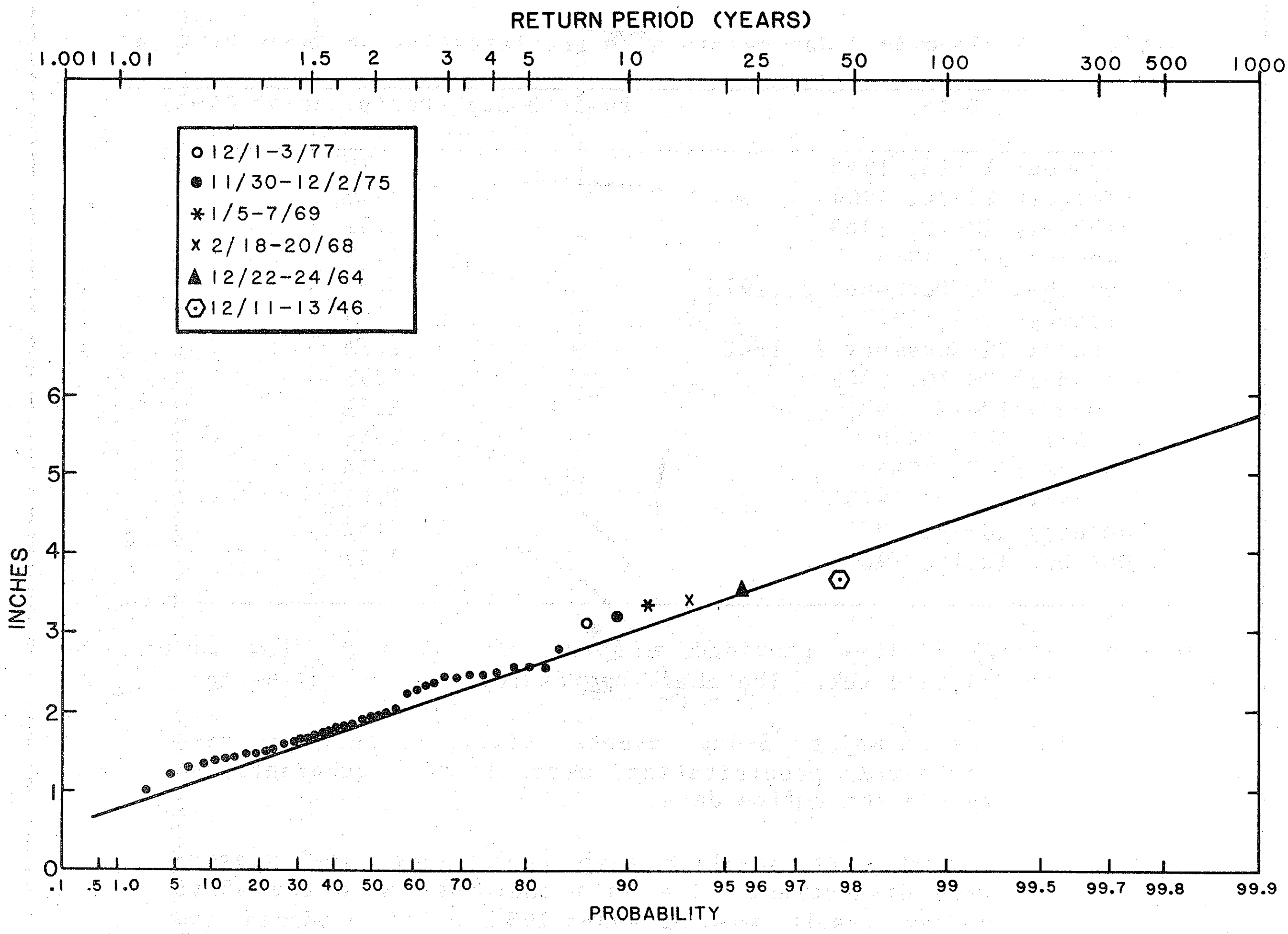


Figure 7.--Statistical analysis of cool-season 3-day average basin precipitation (45 yr).

2.7 Monthly Distribution of 3-Day Precipitation Events

The six major 3-day events which produced basin-wide precipitation of at least 3 in. (see table 1) showed December to be the predominate month. The percent of MAP analyses for these six events are shown in Figures 8 through 13.

For a further definition of seasonal (or monthly) aspects of the basin-wide 3-day events, the 45 annual maximum 3-day events for the October through March season were summarized by months, first, considering all cases; then only those producing basin precipitation of more than 2.50 in. in three days. Results are shown in histogram form in Figure 14 The two adjoining months of December and January predominate.

2.8 Multiple Uses of 45-yr Survey Results

In addition to the statistical analysis of the 45-yr of 3-day events as input to the selection of an appropriate level of SPS basin-wide precipitation, other important uses were obtained from the results of this direct method approach to SPS. The utility of the results was greatly enhanced by meteorological analyses of the major precipitation events, not only from the cool-season survey, but from analyses for May and June from a separate 45-yr survey (see

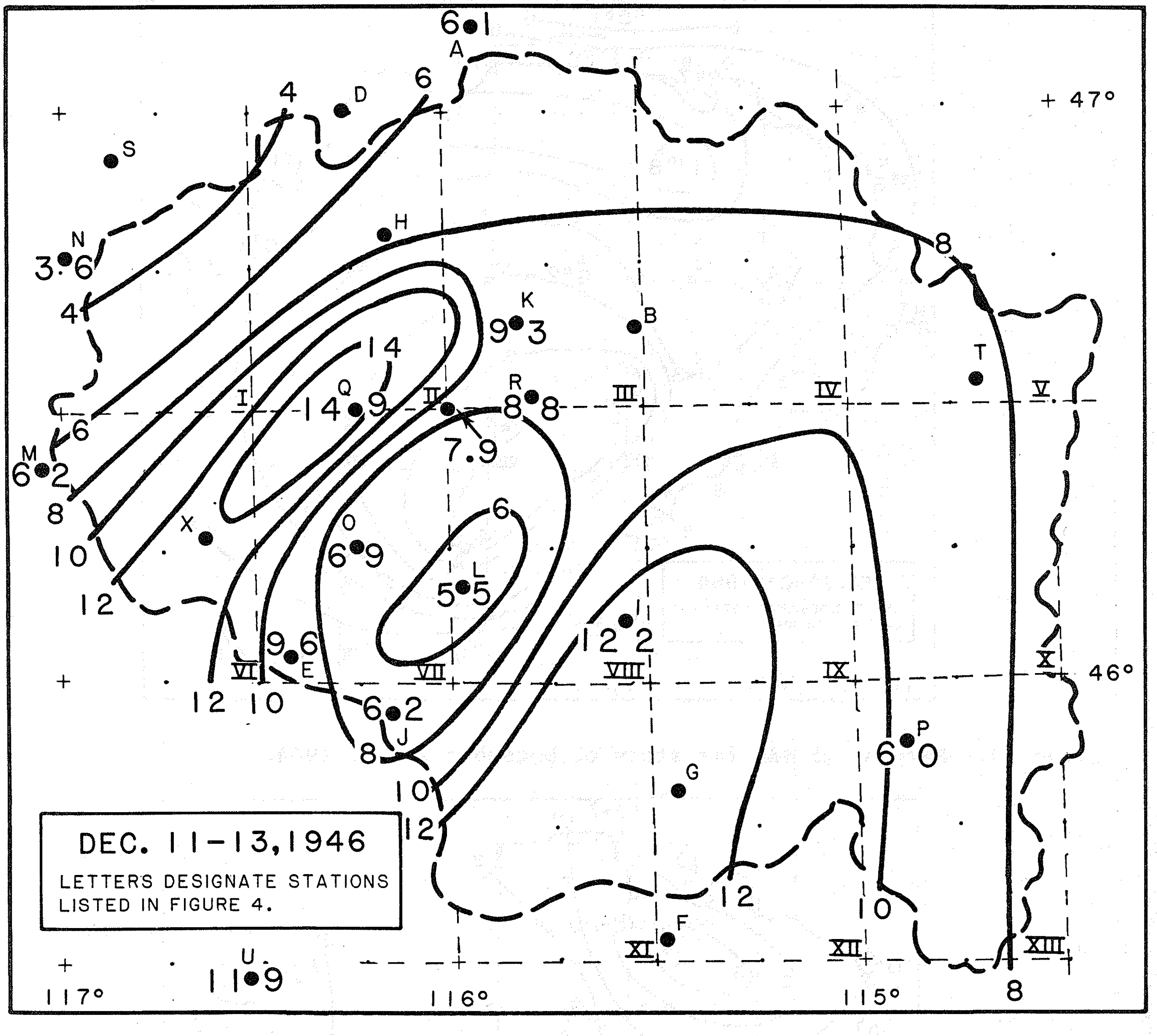


Figure 8.--Percent of MAP for storm of December 11-13, 1946. Letters designate stations listed in figure 4.

chapt. 11). The results of the two 45-yr surveys with accompanying meteorological analyses of major resulting 3-day events provided the underpinning for the following input to various portions of this report:

1. Appropriate SPS geographical distribution of basin-wide precipitation resulted primarily from evaluation of the major 3-day events (chapt. 9).

2. The major 3-day events for both the main cool-season and the May-June period provide essential input to time-distribution of SPS precipitation (chapt. 10).

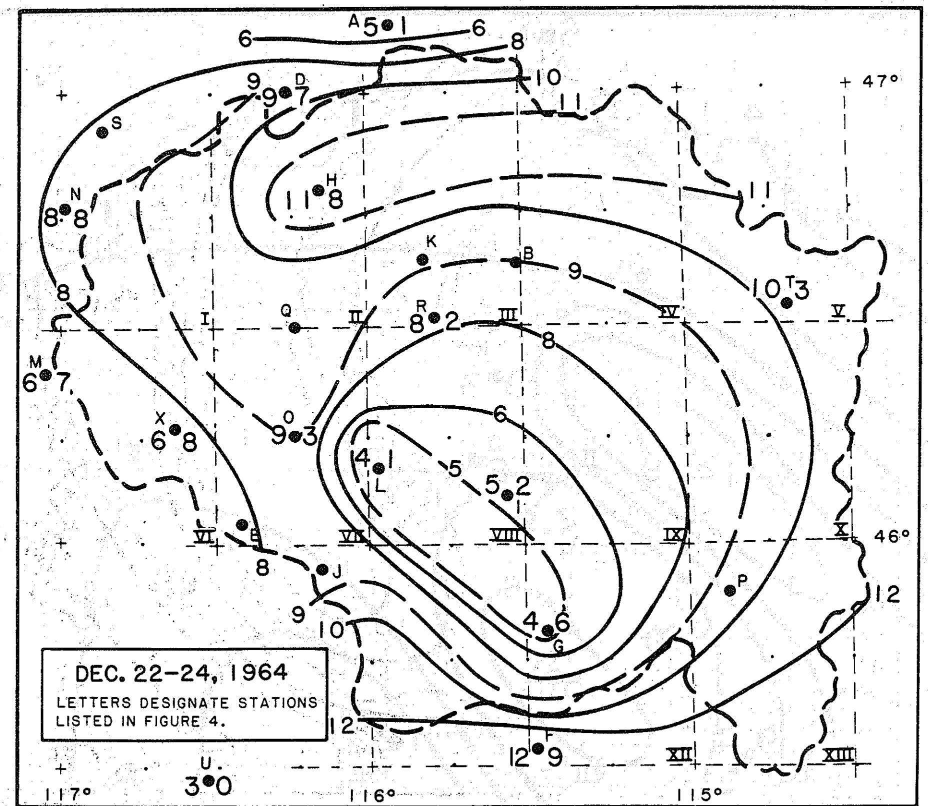


Figure 9.--Percent of MAP for storm of December 22-24, 1964.

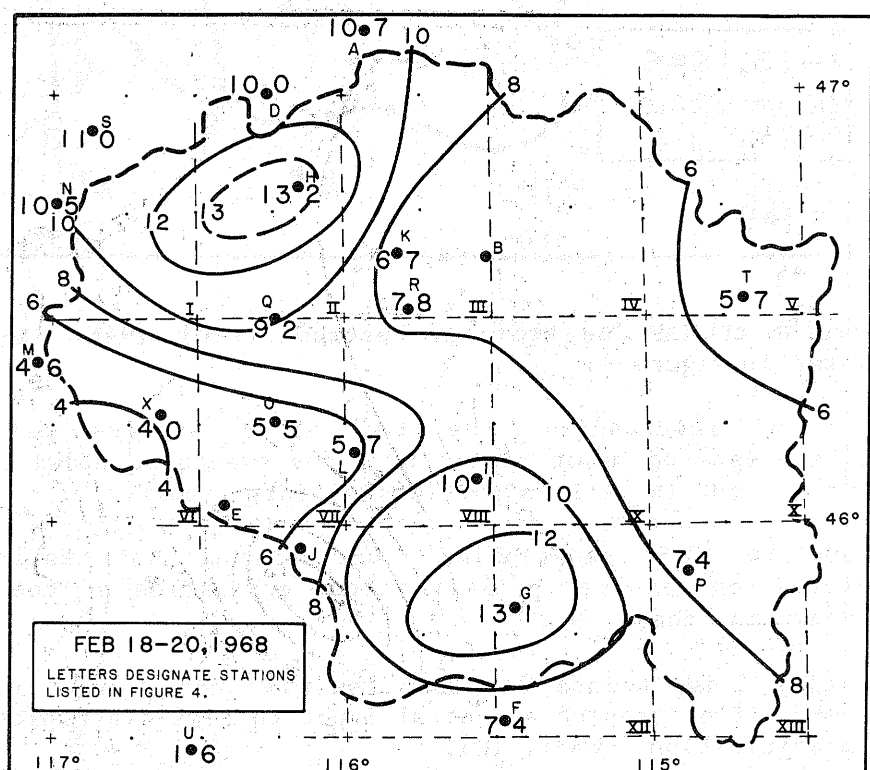


Figure 10.--Percent of MAP for storm of February 18-20, 1968.

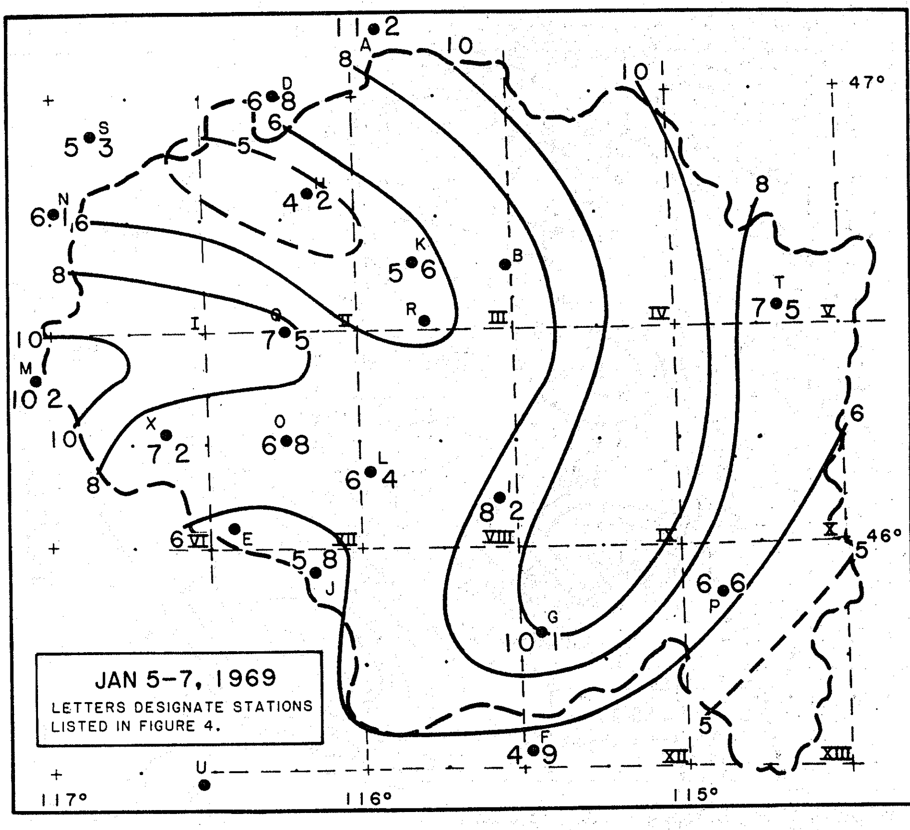


Figure 11.--Percent of MAP for storm of January 5-7, 1969.

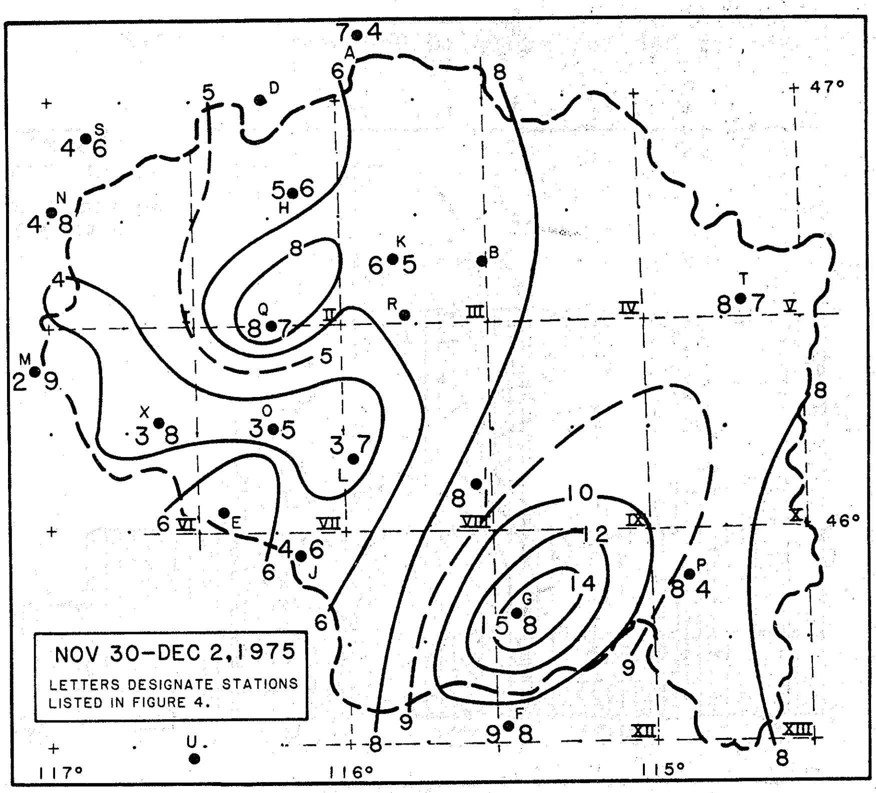


Figure 12.--Percent of MAP for storm of November 30-December 2, 1975.

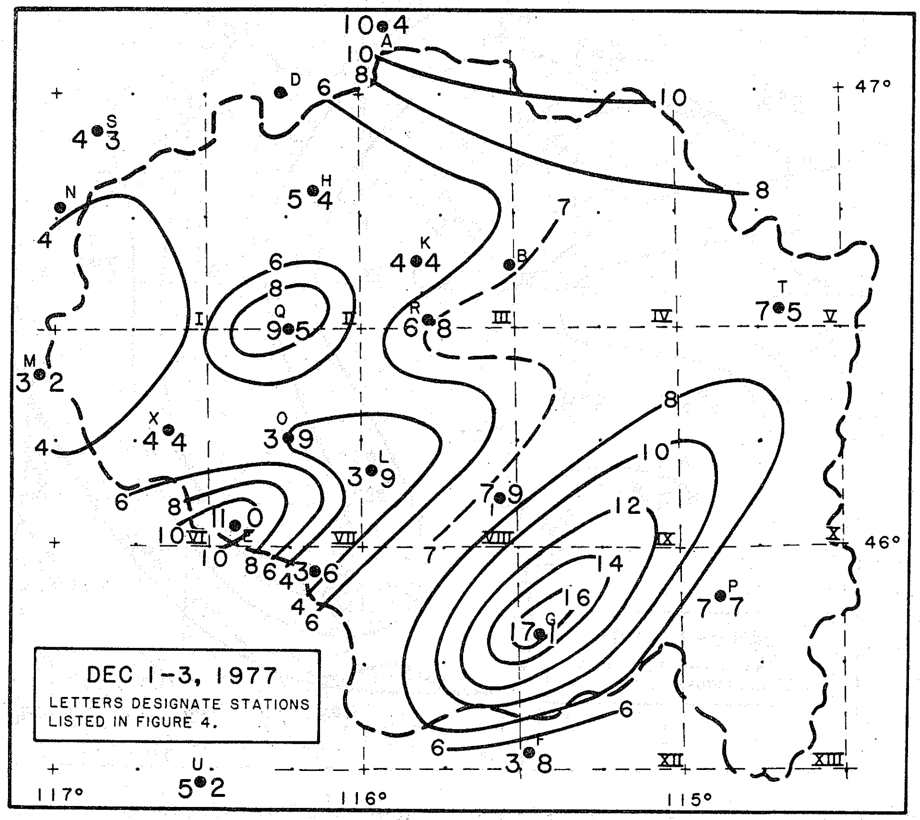


Figure 13.--Percent of MAP for storm of December 1-3, 1977.

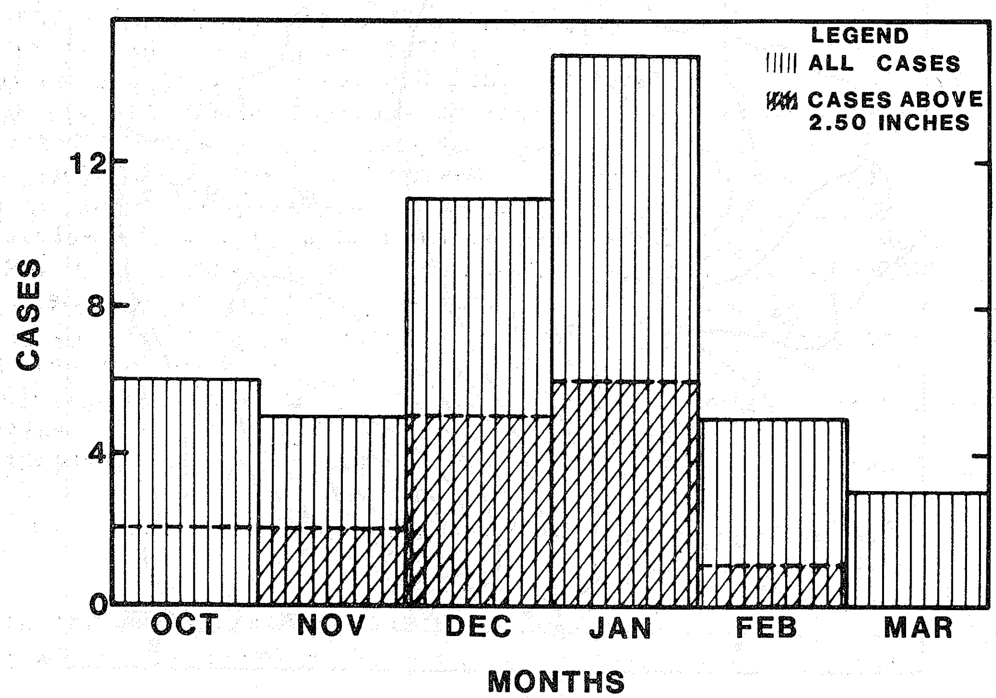


Figure 14.--Monthly distribution of maximum annual 3-day events.

3. Comparison and synthesis of the two separate surveys provided important input to seasonal variation (chapt. 11).

4. Temperatures during 3-day major events and for 3 days prior to these events were the primary input to selection of appropriate "SPS-level" temperature criteria for snowmelting for 6-day periods, including the 3-day SPS event (chapt. 12).

3. METEOROLOGY OF MAJOR COOL-SEASON STORMS

3.1 Introduction

The fact that major western United States storm events from the Sierra Nevada and Cascade ranges have also produced major storm events well inland emphasizes the importance of large scale weather features in controlling the precipitation regime of the entire western United States. A few major events that make this obvious were the storms of January 1943, December 1955 and December 1964. Yet, it is important to determine what specifically characterizes the major precipitation producing events over the Clearwater drainage. It is important, not only as a significant input regarding evaluation of the magnitude of the precipitation event most characteristic of the total Clearwater drainage, but also as important information for definition of the time and areal distribution characteristics and of appropriate SPS level of snowmelt temperature criteria, both during and antecedent to the 3-day SPS.

Discussions of the meteorological storm features in this chapter are directed primarily to determine the meteorological causes of the SPS type 3-day precipitation event over the total basin. Additional meteorological discussion may be found in Chapter 10 concerning time distribution of SPS precipitation and in Chapter 12 relating to snowmelt characteristics. Publications that provided meteorological input for the discussions of the storm events included, in addition to the basic climatological data (National Climatic Data Center 1938-1983), the Monthly Weather Review (National Weather Service 1873-1973, American Meteorological Society 1974-1983), the Weekly Weather and Crop Bulletin National (Weather Service 1913-1983).

3.2 Specific 3-Day Cool-Season Precipitation Events

The magnitude of the 3-day basin-wide precipitation was the main criteria for selection of events for meteorological evaluation. However, in specific cases the distribution of precipitation and/or the temperature departures were additional selection criteria.

3.2.1 December 11-13, 1946 Storm

In this 3-day event, a large portion of the Clearwater basin received precipitation exceeding 8 percent of the MAP, ranging upward to nearly 15 percent. The percent of MAP analysis for this event was shown in Figure 8. Temperature departures during this storm were generally 10° or more above normal. The time distribution of precipitation in this storm, as in many of the cool-season events, emphasized the early portion of the storm.

Weather maps (Environmental Data and Information Service 1899-1971) for this storm are shown in Figures 15 and 16. Surface features emphasized a fast flow from a westerly direction which was related to the well above normal temperatures. Complex frontal conditions affected the northern portion of the basin. Significantly, northwest flow at upper levels was characteristic of this storm with the major trough of low pressure well to the east.

3.2.2 January 5-7, 1969 Storm

During the month of January 1969, precipitation was above normal over the entire northwest (fig. 17). In this particular storm, a total basin-wide 3-day precipitation of 3.18 in. occurred. The percent of MAP analysis for the storm is shown in Figure 11. Approximately one-half of the basin received 8 percent or more of MAP.

Extremely low temperatures prevailed just to the north and east of the basin (fig. 17) as shown by Monthly Weather Review (National Weather Service 1873-1973) and Weekly Weather and Crop Bulletin (National Weather Service 1973-83) charts. However, in the basin itself, the first day of the event saw well above normal temperatures which then lowered to just a few degrees above normal for the second and third days. However, in the basin prior to the onset of this event well below normal temperatures were characteristic.

Aloft in this event west-northwest to northwest flow predominated during this 3-day event, a characteristic common to many of the major cool-season events. At the surface, consistent with a persisting flow aloft, a quasi-stationary front existed with a progression of low-pressure disturbances. The weather maps for this event are shown in Figures 18 and 19.

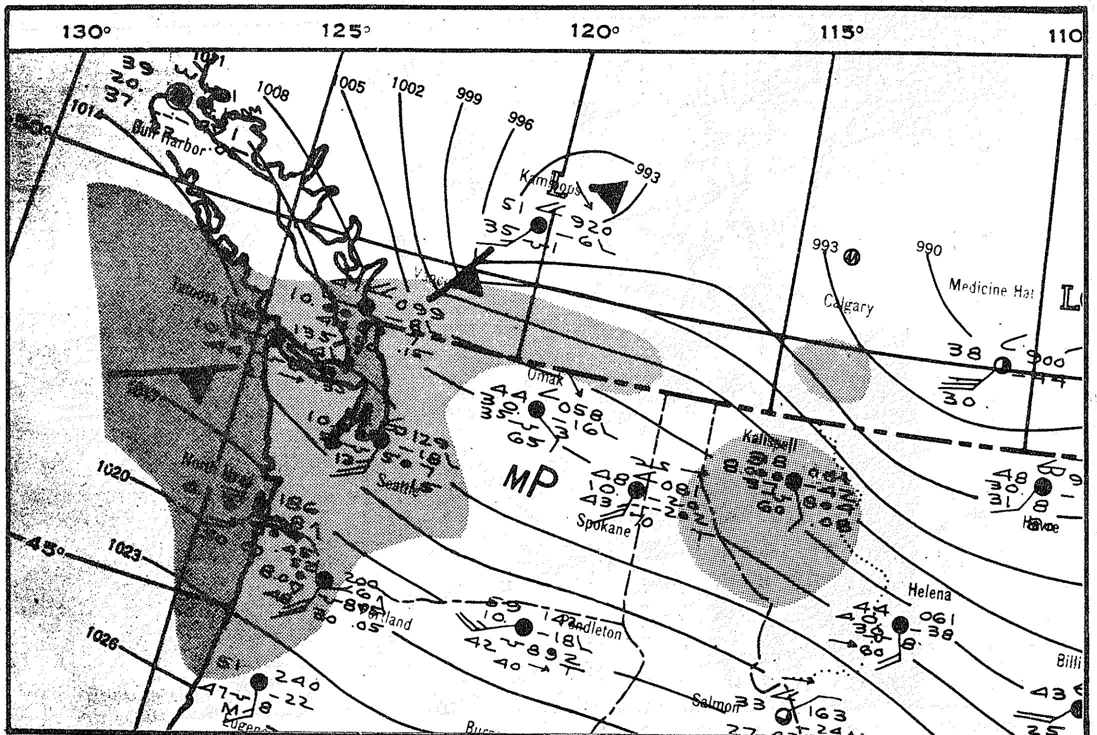
3.2.3 January 13-15, 1975 Storm

The 3-day basin-wide precipitation for this storm was 2.56 in. The percent of MAP analysis for this storm is shown in Figure 20, showing an elongated 8 percent or higher area north to south across the central portion of the basin. This was primarily a 2-day event with more than 50 percent of the 3-day precipitation in less than 1 day. Mass curves of rainfall for selected stations are shown in Figure 36.

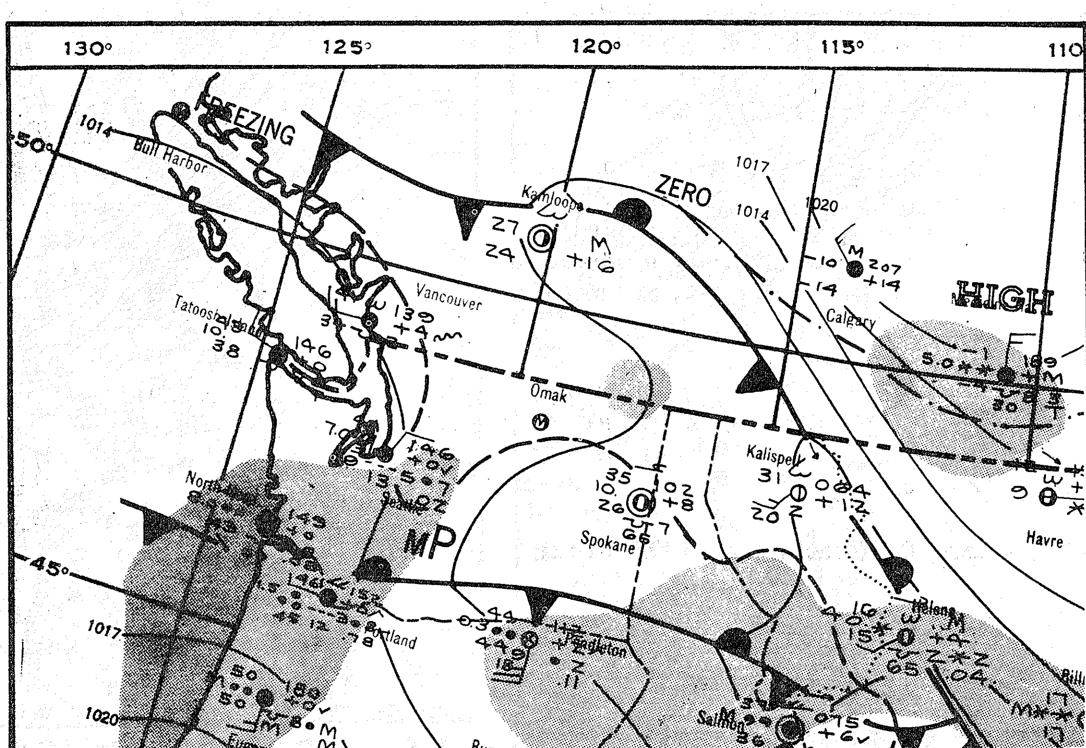
Weather maps for this storm are shown in Figure 21. Broadscale features both at the surface and aloft were similar to the January 1969 case (sec. 3.2.2). A quasi-stationary surface front was oriented generally west-east with accompanying northwest flow aloft.

3.2.4 November 30-December 2, 1975 Storm

The precipitation in this storm concentrated in 2 days or less. The short duration of this storm was even more marked than the January 1975 case. The basin-wide 3-day precipitation was 3.11 in. The percent of MAP analysis for this 3-day event was shown in Figure 12. Large percent of mean annual values prevailed, especially over the Selway basin and to a lesser extent over the North Fork of the Clearwater River. Lowest percents were in the extreme western portion of the basin. Mass curves of rainfall for selected stations for this storm are shown in Figure 36.



DEC 11, SFC MAP (0630 Z)



DEC 12, SFC MAP (0630 Z)

Figure 15.--Surface weather maps for December 11 and 12, 1946.

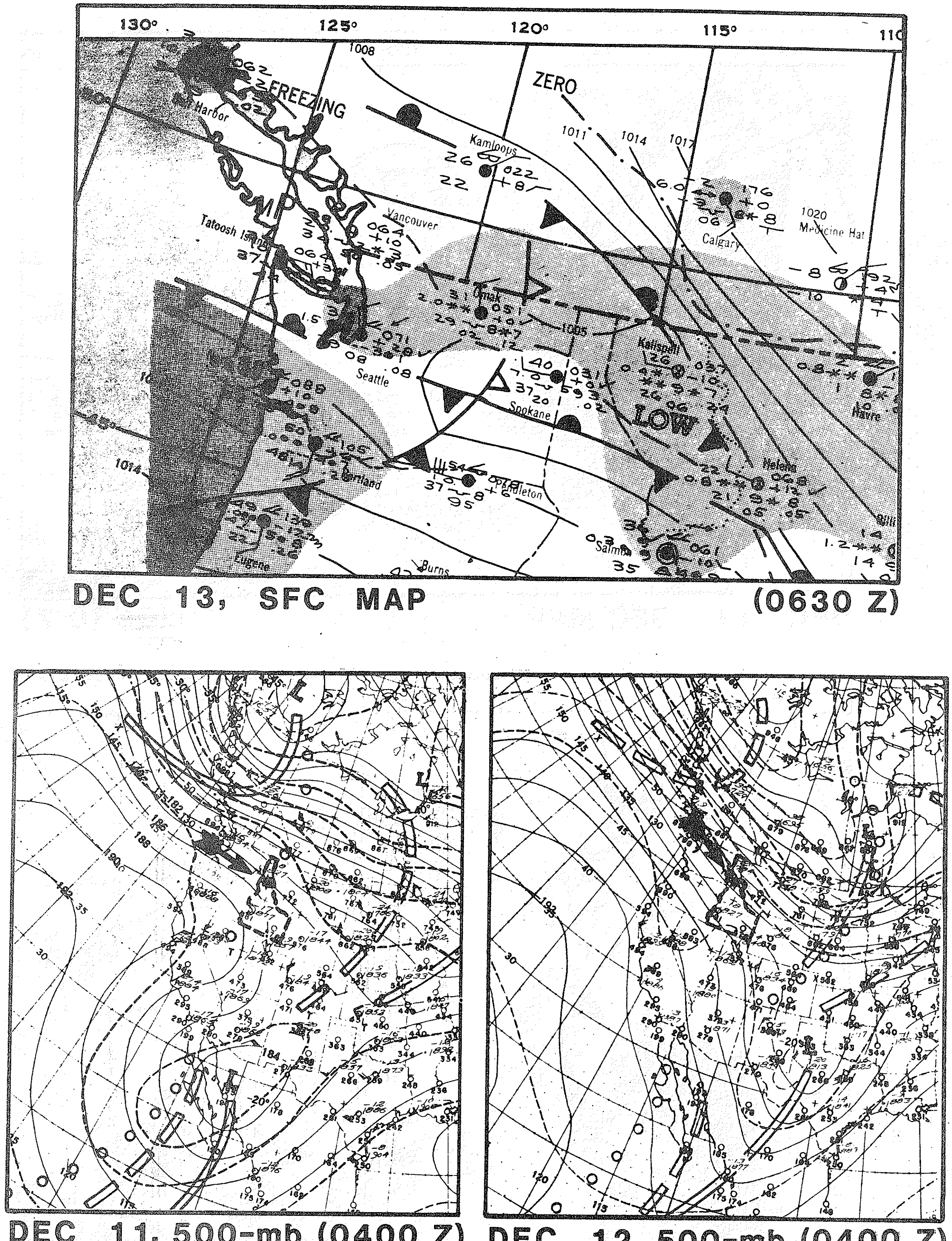
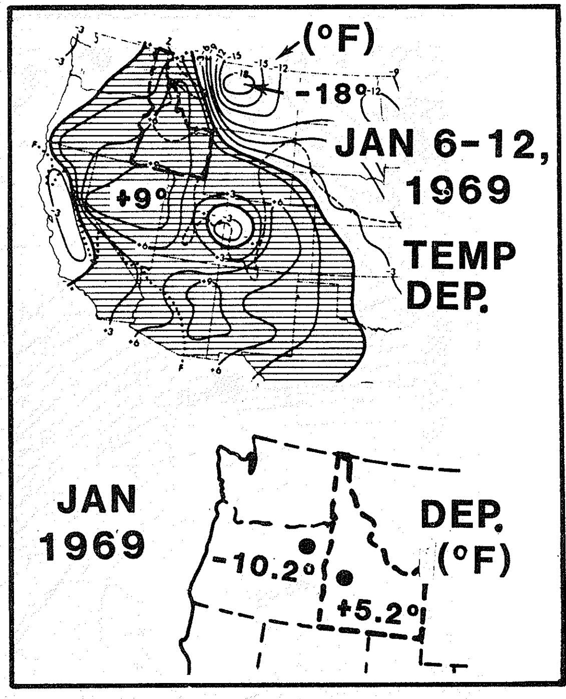


Figure 16.--Surface weather map for December 13, 1946 and 500-mb charts for December 11 and 12, 1946.



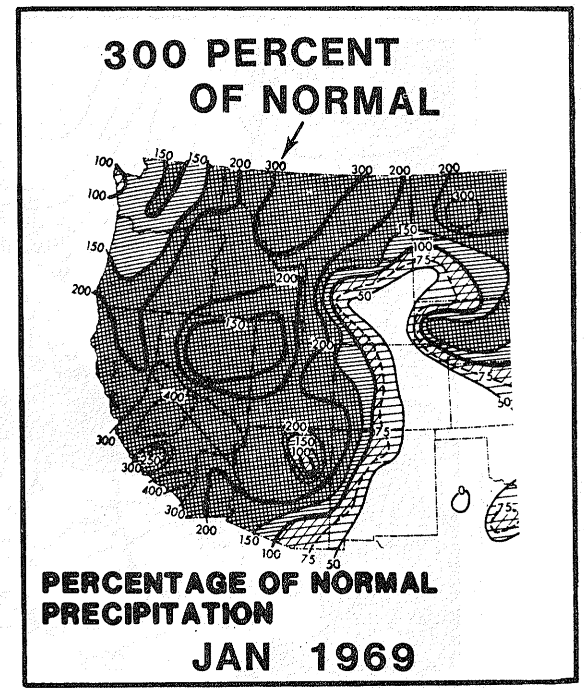
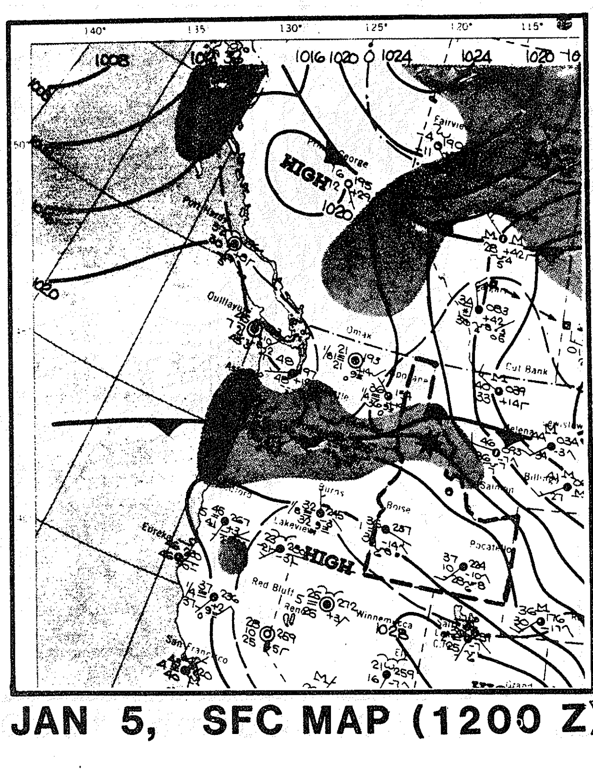


Figure 17.--Departure from normal of precipitation and temperature for January 1969.



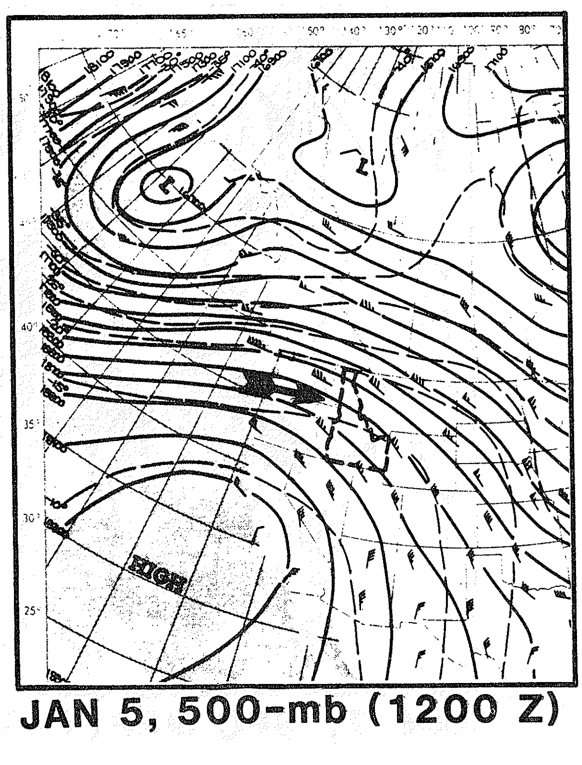
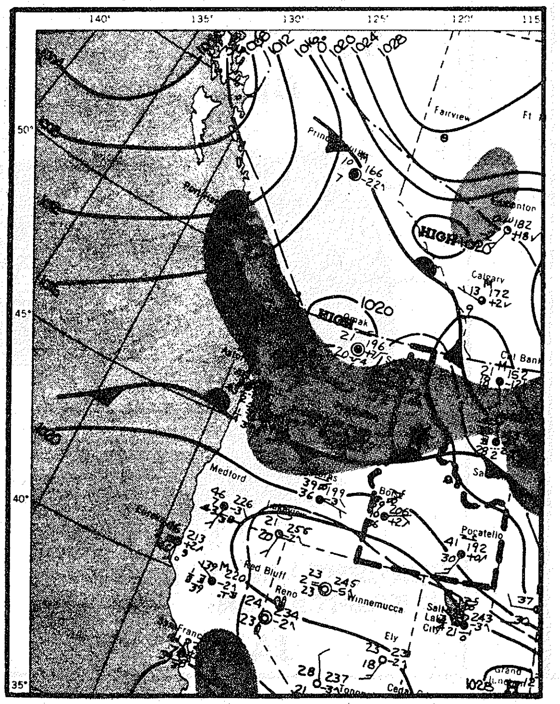
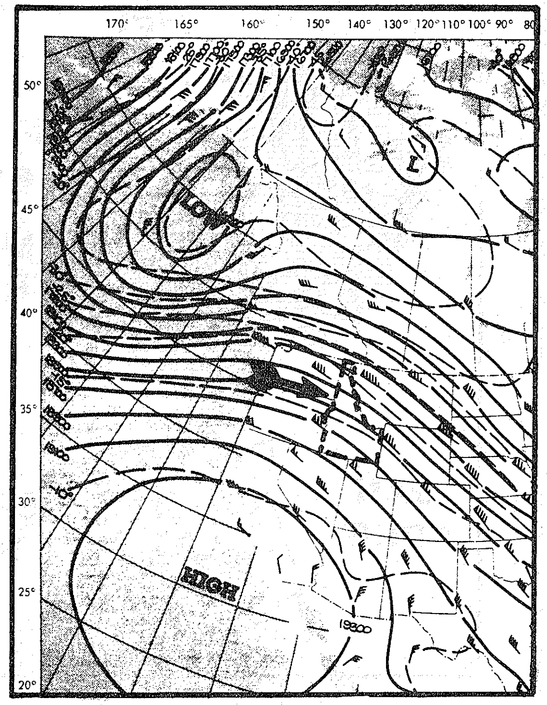


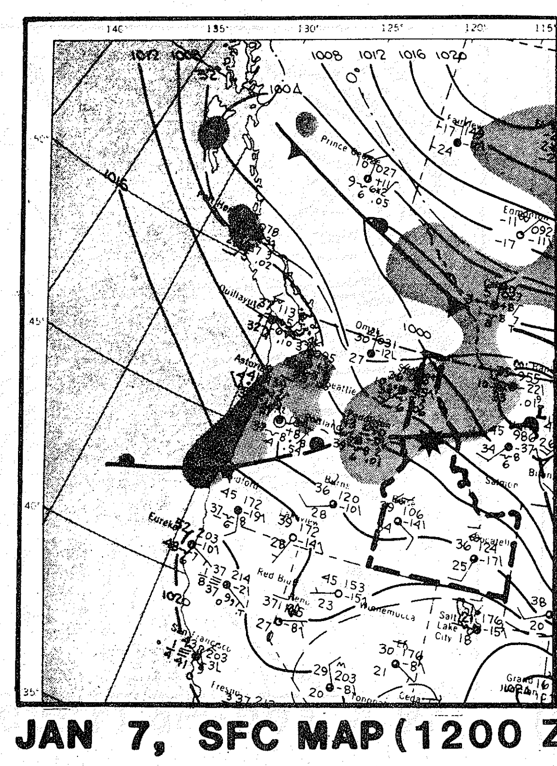
Figure 18.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for January 5, 1969.



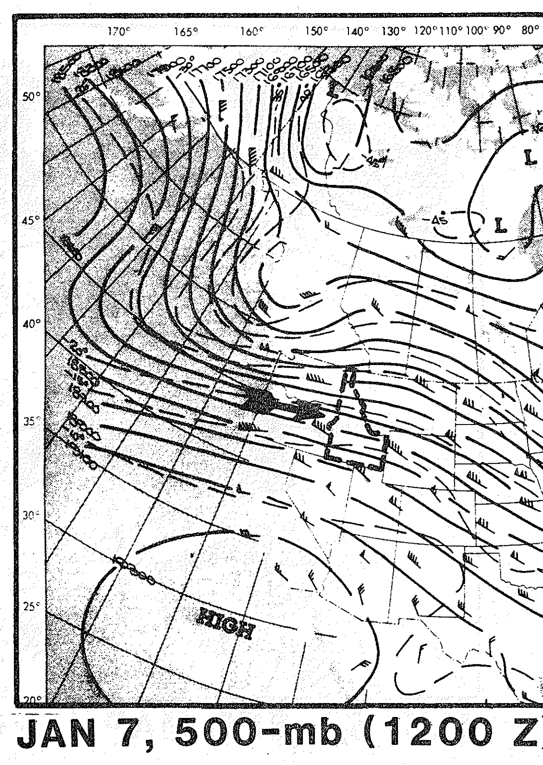
JAN 6, SFC MAP (1200 Z)



JAN 6, 500-mb (1200 Z)



JAN 7, SFC MAP (1200 Z)



JAN 7, 500-mb (1200 Z)

Figure 19.--Surface weather maps and 500-mb charts for January 6-7, 1969.

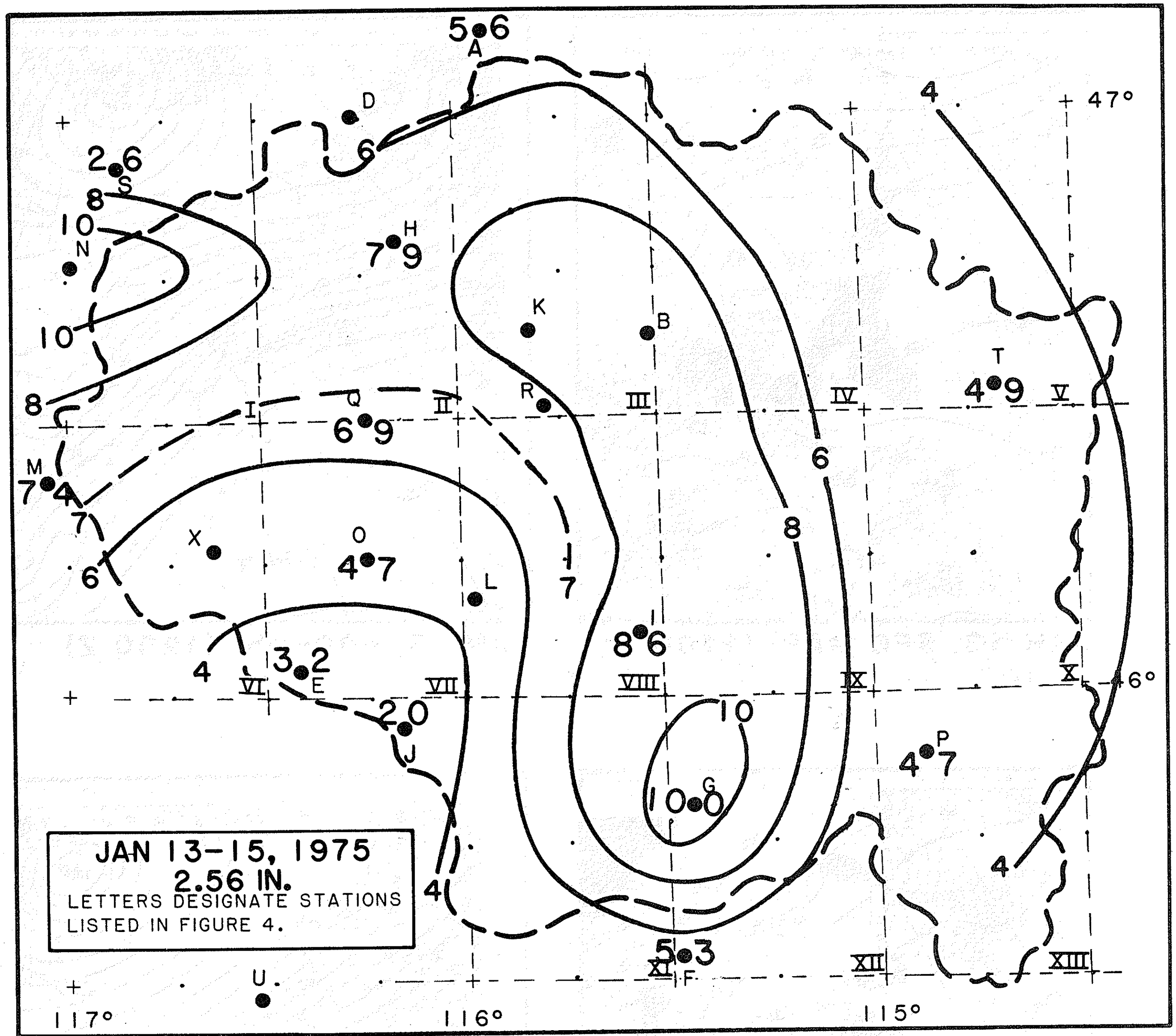


Figure 20.--Percent of MAP for storm of January 13-15, 1975.

Extremely low temperatures were entrenched over the basin prior to this 3-day event extending into the beginning of the 3-day event. Temperatures then rose sharply to more than 15° above normal at the close of the event.

At the surface (weather maps shown in fig. 22 and 23) a northwest to southeast frontal system existed with minor low pressure disturbances moving along the front. The positioning of the front across the northern portion of the basin early on December 1 allowed the westerly flow to bring in the air of markedly increased warmth to the south of the front. Substantial shifting of the frontal system was prevented by a persisting and strong northwesterly flow aloft over the surface frontal position. This northwest flow aloft appears to be a very important characteristic of most major 3-day precipitation events in the Clearwater basin.

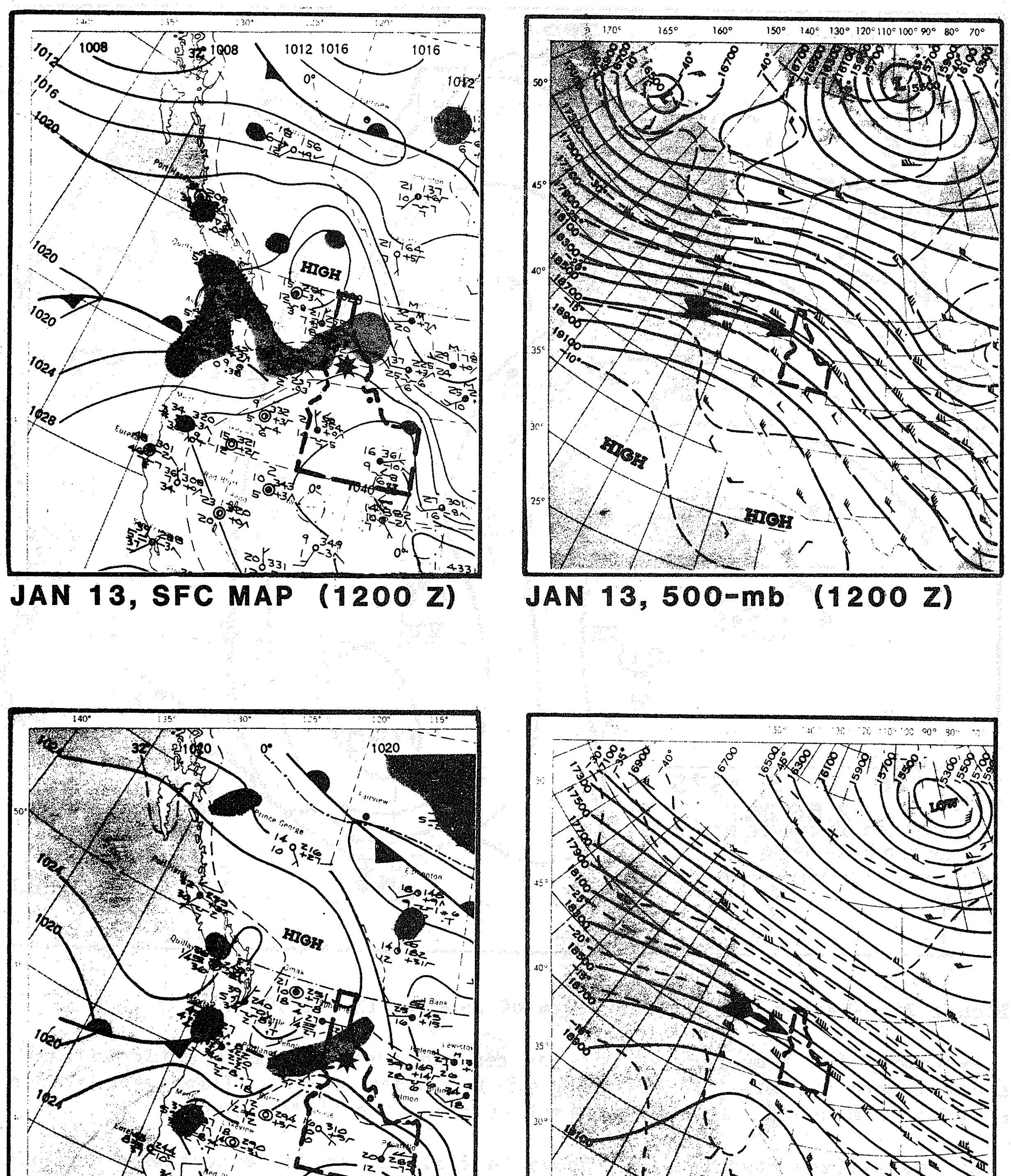
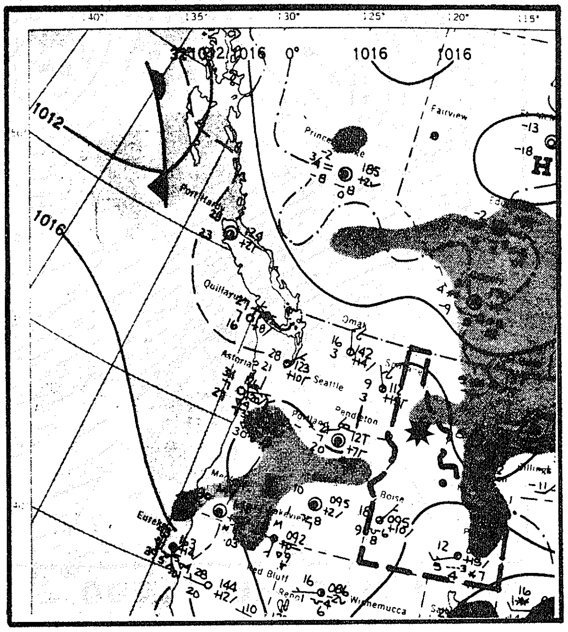
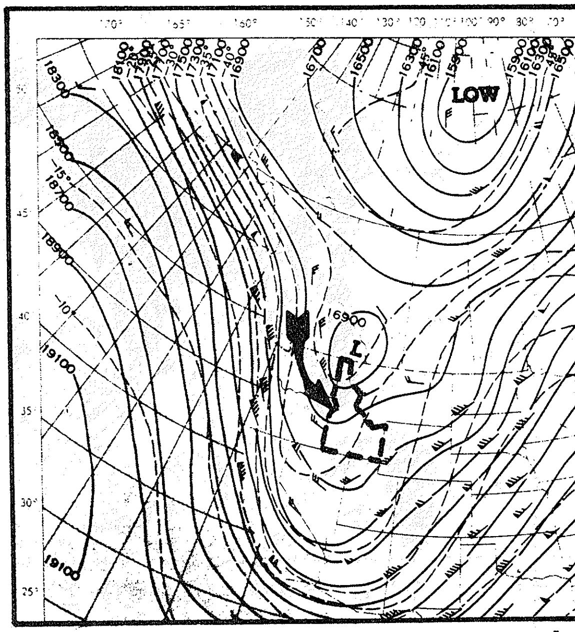


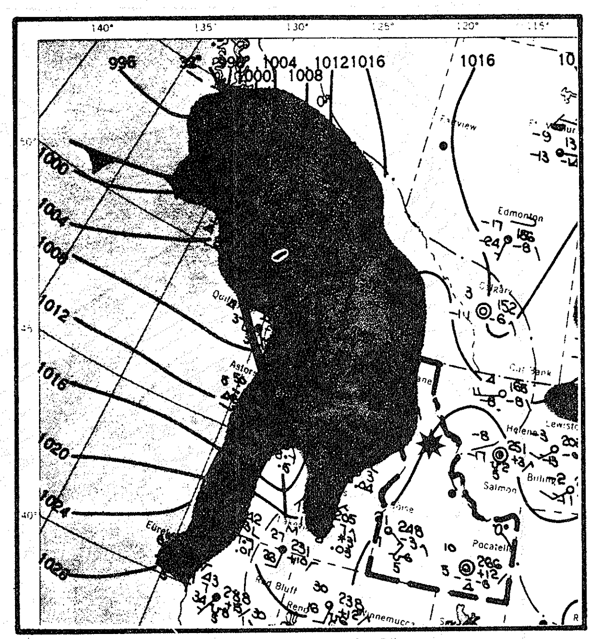
Figure 21.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for January 13 and 14, 1975.



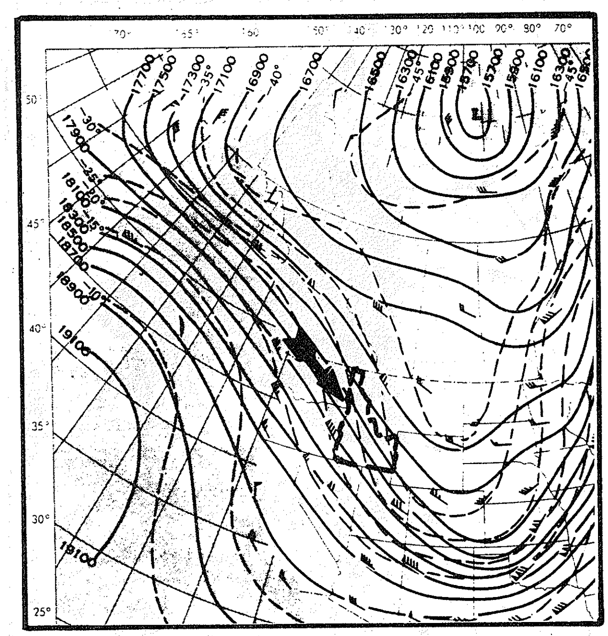
NOV 29, SFC MAP (1200 Z)



NOV 29, 500-mb (1200 Z)

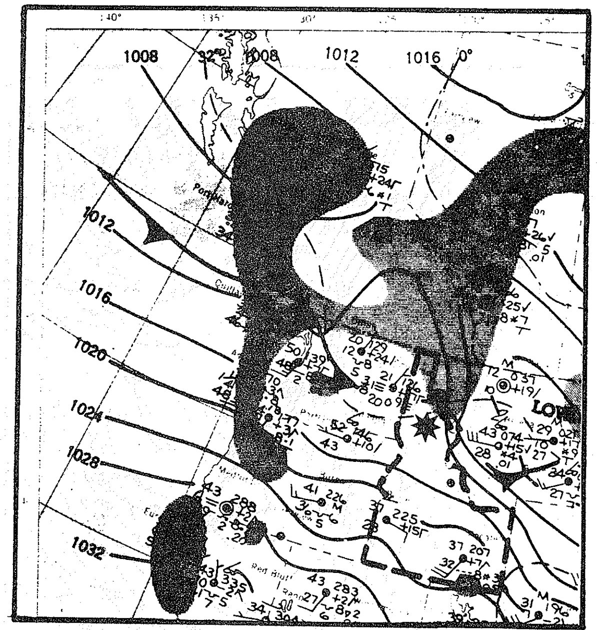


NOV 30, SFC MAP (1200 Z)

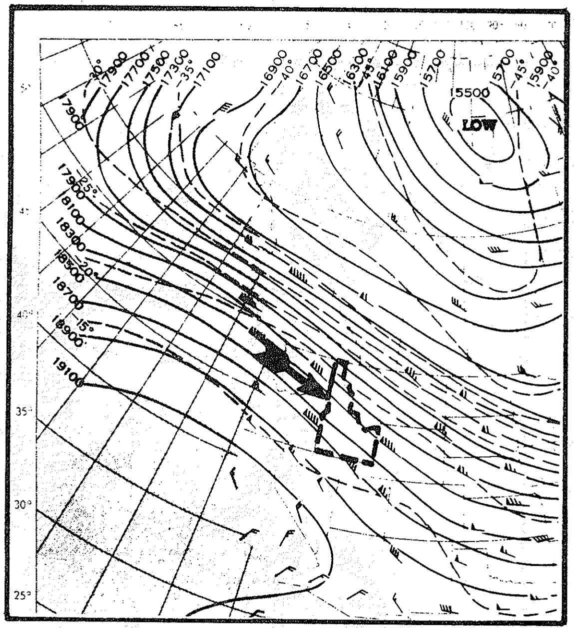


NOV 30, 500-mb (1200 Z)

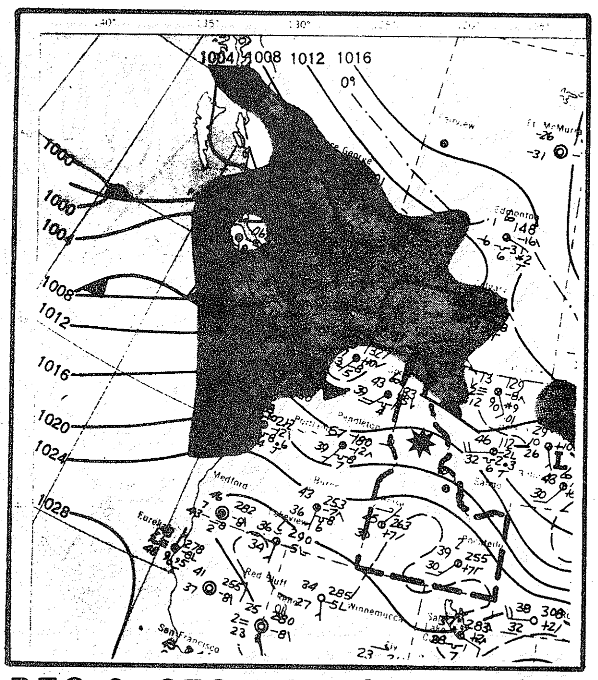
Figure 22.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for November 29 and 30, 1975.



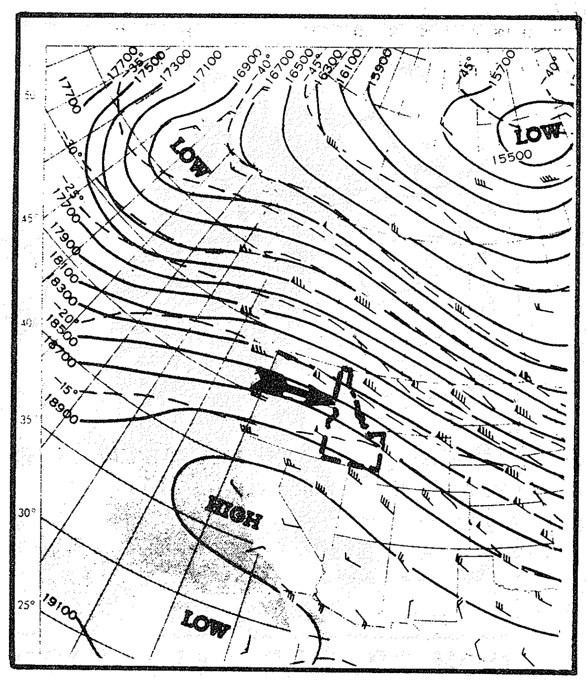
DEC 1, SFC MAP (1200 Z)



DEC 1, 500-mb (1200 Z)



DEC 2, SFC MAP (1200 Z)



DEC 2, 500-mb (1200 Z)

Figure 23.--Surface weather and 500-mb charts (7:00 a.m. EST) for December 1 and 2, 1975.

3.2.5 December 1-3, 1977 Storm

The precipitation from December 1-4, 1977 produced two overlapping 3-day periods with very similar basin-wide 3-day totals, but the December 1-3, 1977 period was slightly higher with a basin-wide precipitation of 3.04 in. Figure 13 showed the percent of MAP for this event. The percent of MAP pattern was strikingly similar to the November 30-December 2, 1975 event (sec. 3.2.4). This was another storm that was primarily a 2-day event with 50 percent or more of the precipitation in the storm generally occurring the first day (see mass curves of rainfall fig. 36).

Weather maps for this storm are shown in Figures 24 and 25. Temperatures during this 3-day event averaged 5-15°F above normal, rising from near normal the first day (December 1). Again, the characteristic northwest flow aloft prevailed. The surface conditions favored brisk westerly winds with nearby frontal systems affecting the precipitation.

3.2.6 December 22-24, 1964 Storm

This storm was of a widespread destructive nature and has been documented by Wheeler (1965). He concluded "Never before in our history have we experienced floods of this category on both sides of the Cascade Mountains at the same time. Literally speaking, our whole state was experiencing a major, if not record, flood in every stream and minor tributary."

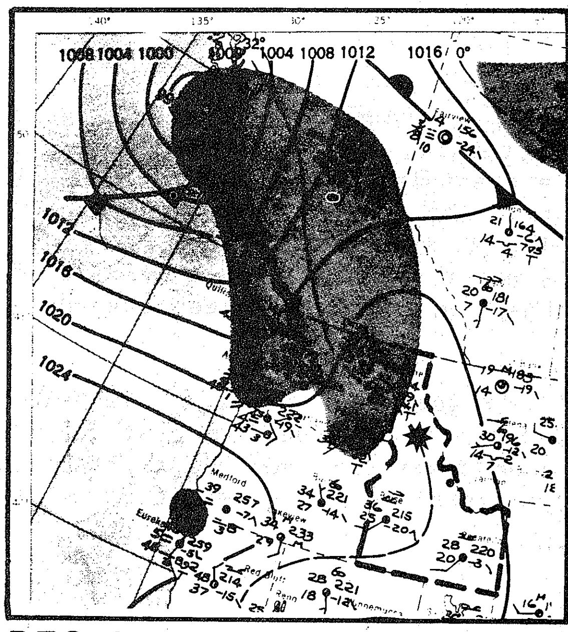
The present discussion is limited to conditions that produced heavy rain over the Clearwater River drainage. This was one of the "truest" 3-day events from the 45-yr survey (see mass curves of rainfall in fig. 36). The precipitation was significantly spread over the full 3-day period. The percent of MAP analysis (fig. 9) shows especially large percent of MAP over most of the northern third of the basin.

Extremely cold air was entrenched over the basin 3 to 6 days prior to the occurrence of this 3-day event, averaging generally 20°F or more below normal. These cold conditions modified substantially a day or two before the 3-day event. The extreme contrast in air masses is demonstrated by the upper left panel of Figure 26 where the strongly contrasting temperature departures for the week ending December 27, are shown.

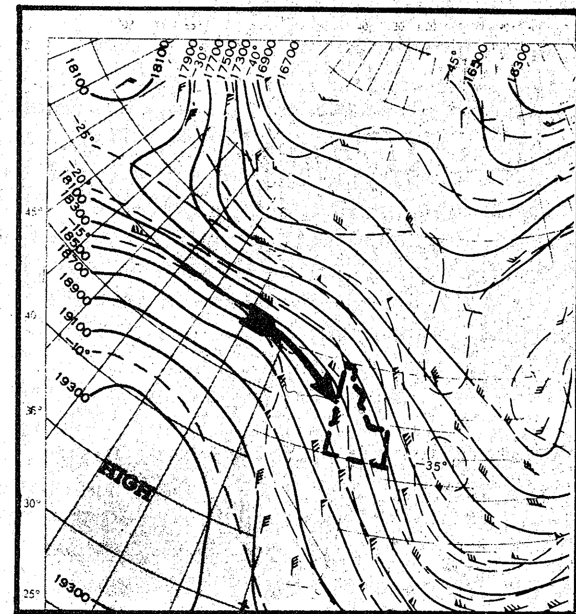
Figures 26 and 27 show the weather maps for this storm. A surface front near the boundary of the strongly contrasting air masses aligned west-northwest to east-southeast and was subject to fluctuations as waves moved along the frontal surface. Persisting west-northwest to northwest flow aloft kept this surface front from being subject to large fluctuations.

3.2.7 February 18-20, 1968 Storm

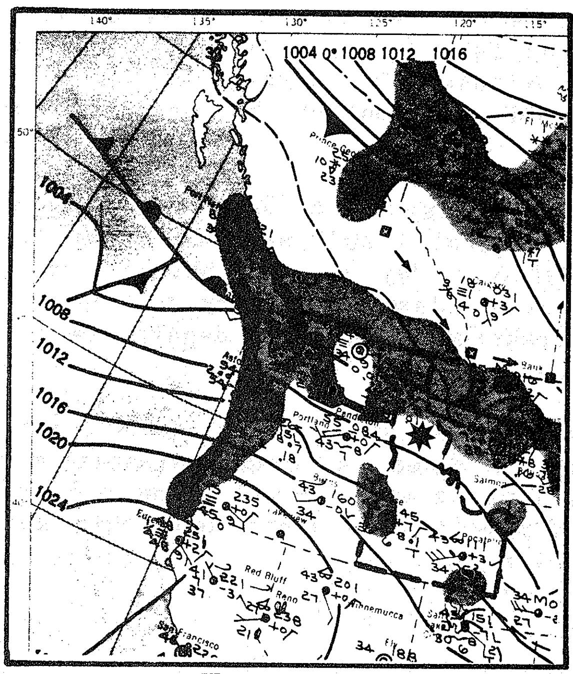
In this cool-season basin-wide 3-day precipitation event, 50 percent or more of the precipitation occurred on the first day (fig. 37) as rather brisk west-southwest to southwest flow at low levels upwind were accompanied by west-northwest to northwest flow aloft with the basin just to the east of a ridge aloft. The rainfall analysis in percent of MAP for this storm is shown in Figure 10. Below normal temperatures characterized this situation for many days



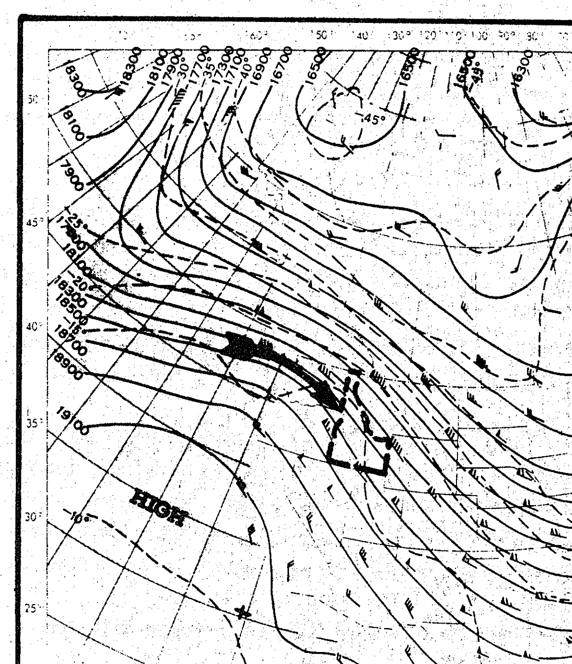
DEC 1, SFC MAP (1200 Z)



DEC 1, 500-mb (1200 Z)

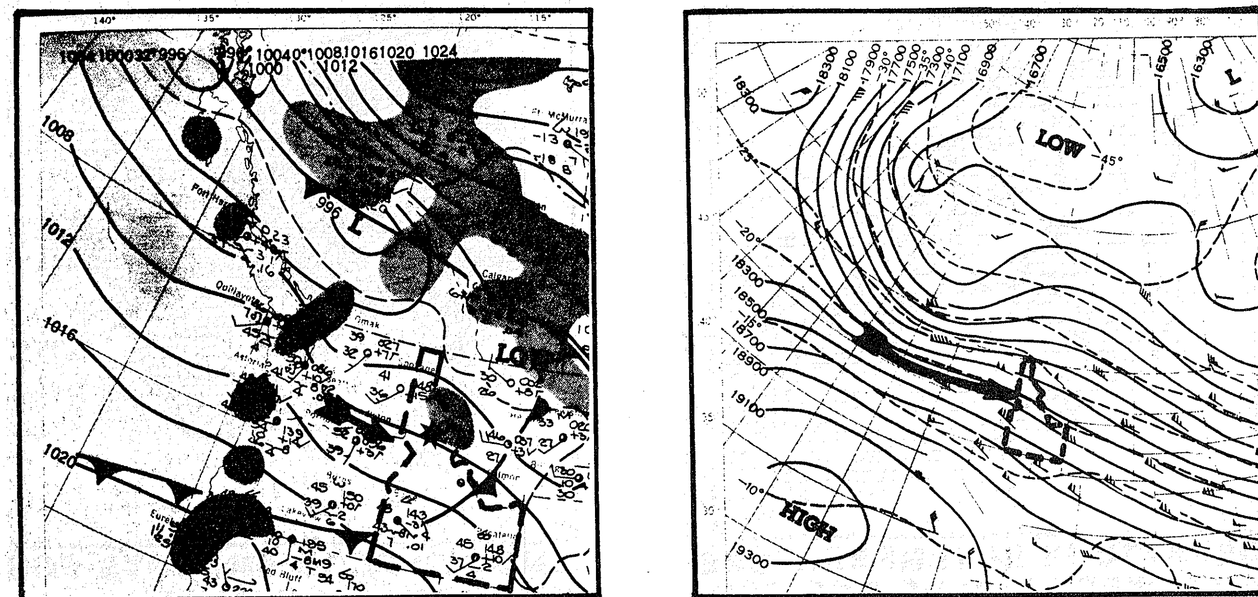


DEC 2, SFC MAP (1200 Z)



DEC 2, 500-mb (1200 Z)

Figure 24.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for December 1 and 2, 1977.



DEC 3, SFC MAP (1200 Z)

DEC 3, 500-mb (1200 Z)

Figure 25.--Surface weather map and 500-mb chart (7:00 a.m. EST) for December 3, 1977.

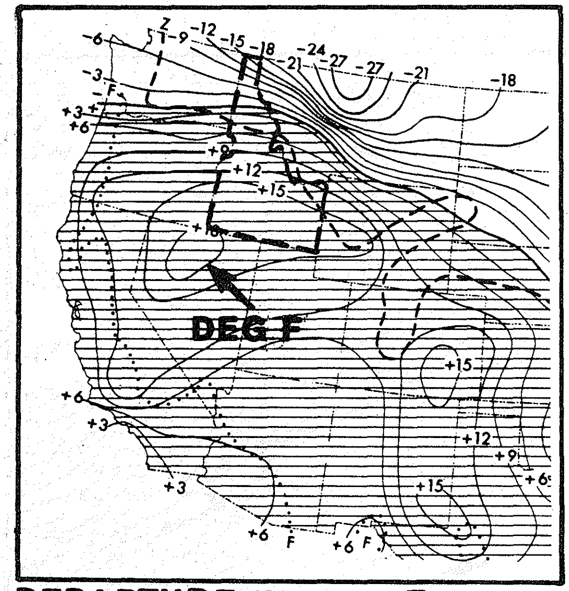
prior to the gradual warming that heralded this event. Temperatures rose steadily above normal prior to the storm to more than 10°F above normal for most of the 3-day event (see fig. 106). Thus, this 3-day event seemed to "compromise" or combine opposing features in a manner that perhaps is a prototype to the SPS event for the Clearwater drainage. The surface and 500-mb weather systems for this storm are shown in Figures 28 and 29, respectively.

3.2.8 January 18-20, 1970 Storm

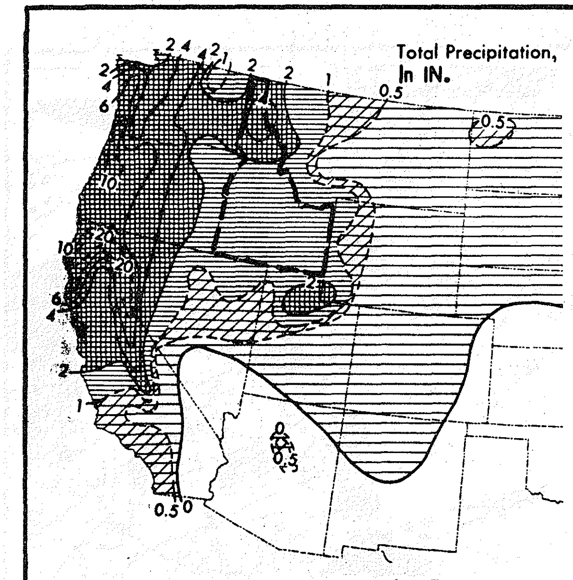
This storm was the first of two successive Januarys (i.e., 1970-1971) that produced the annual maximum 3-day basin-wide event with a basin average precipitation more than 2 in., but less than 3 in. The storms previously discussed all produced more than 3 in. of precipitation, except the January 13-15, 1975 storm (sec. 3.2.3). Although the flow aloft was again rather persistent in direction, except for January 13-15 1975, it averaged more from a westerly direction than many of the other cases. This enabled the surface front, again generally oriented from the northwest to southeast, to fluctuate more than appears to be the case normally. Figures 30 and 31 show the surface and upper air map sequences. Figure 37 shows mass curves of rainfall for selected stations.

3.2.9 January 8-10, 1971 Storm

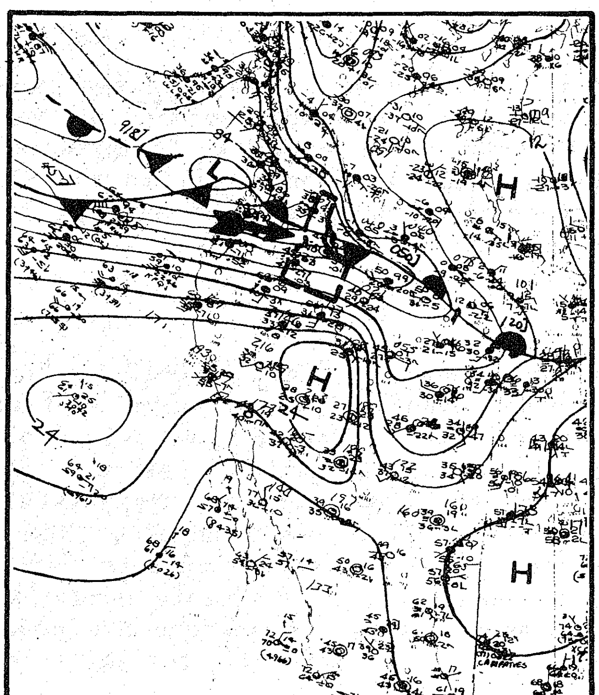
This is the second of two successive Januarys producing the maximum 3-day cool-season precipitation events for their respective seasons. This storm concentrated its precipitation in the eastern, or upstream portion of the drainage with 6 percent or higher percentages of MAP over most of the eastern



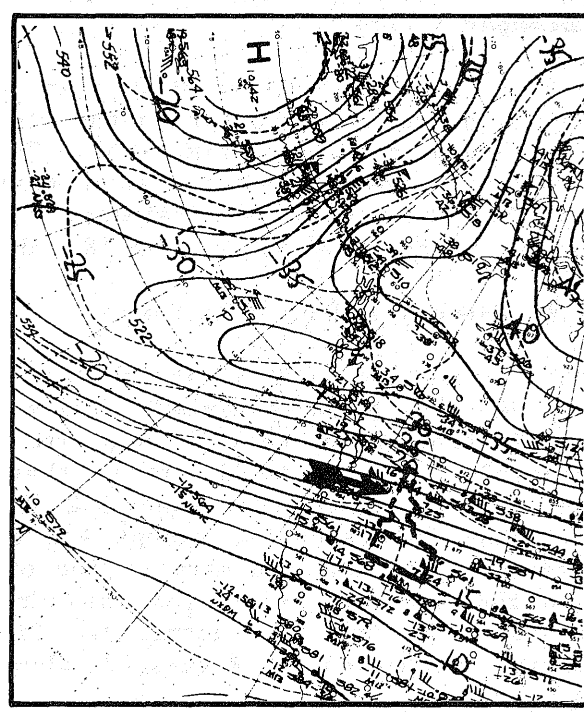
DEPARTURE IN TEMPERATURE FOR WEEK ENDING DEC 27th.



SMOOTH PCPN AMOUNTS FOR WEEK ENDING DEC 27th.

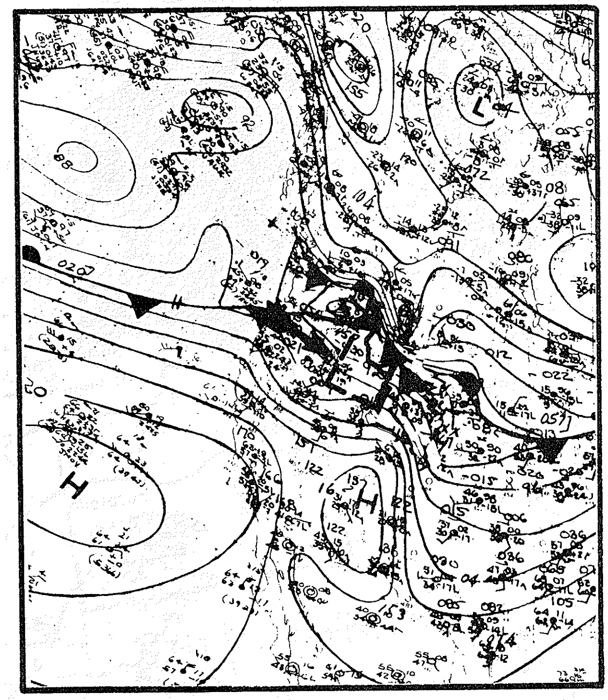


DEC 22, SFC MAP (1200 Z)

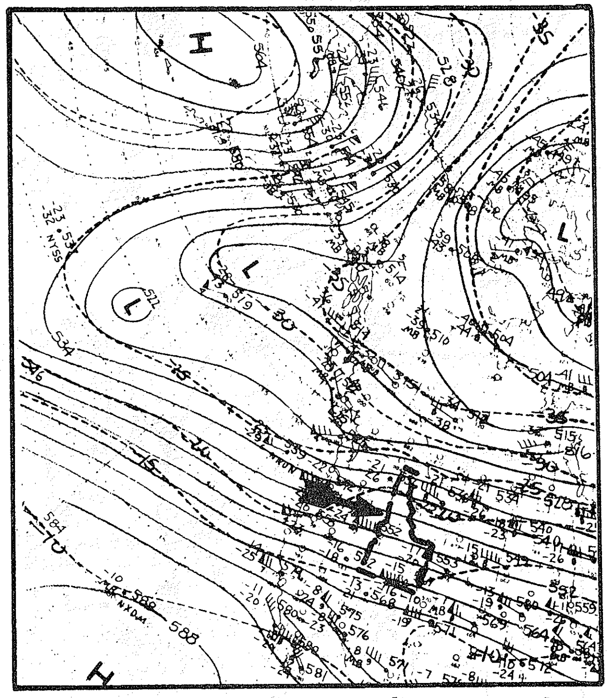


DEC 22, 500-mb (1200 Z)

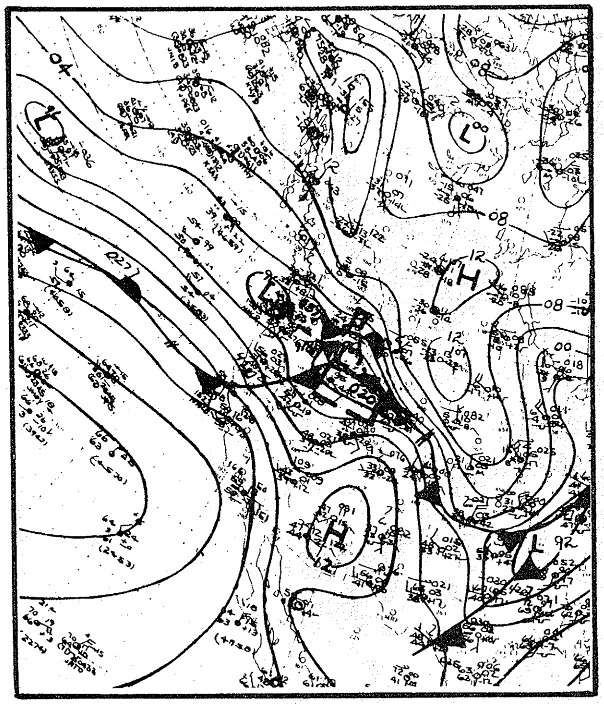
Figure 26.--Departure from normal temperature and smoothed precipitation isohyets for week ending December 27, 1964, surface weather map and 500-mb chart (7:00 a.m. EST) for December 22, 1964.



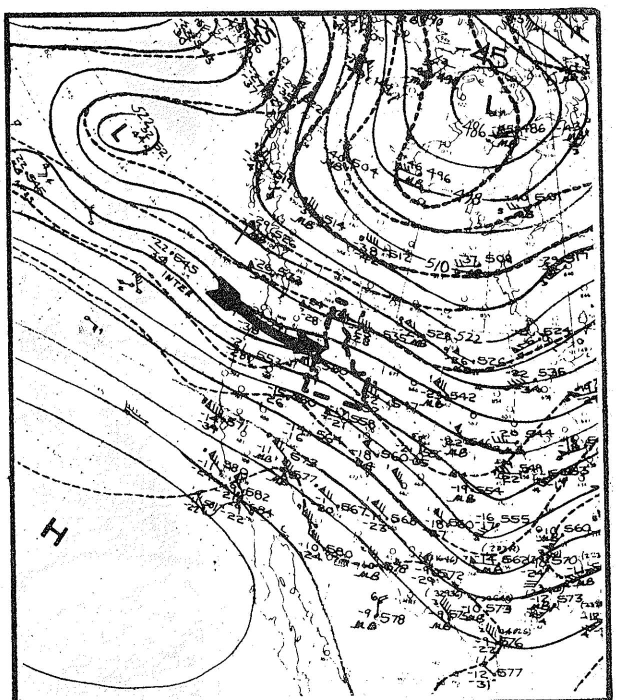
DEC 23, SFC MAP (1200 Z)



DEC 23, 500-mb (1200 Z)

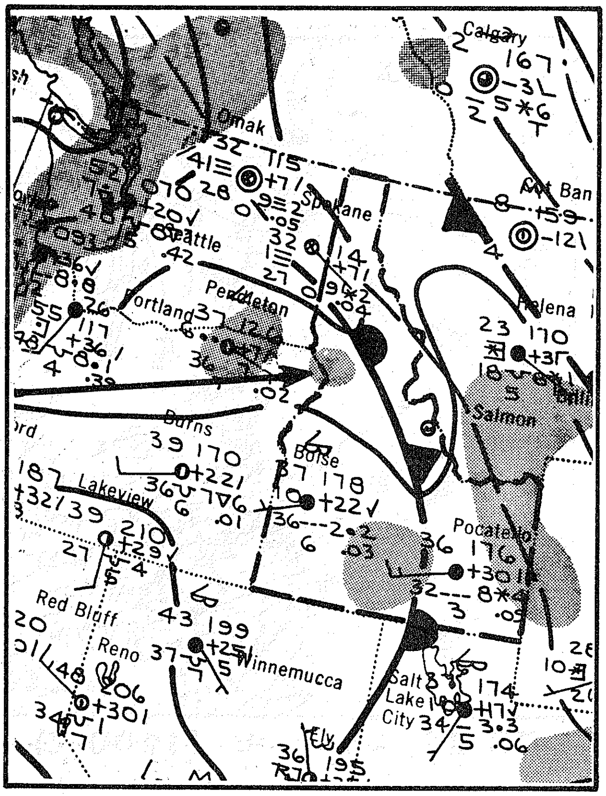


DEC 24, SFC MAP (1200 Z)

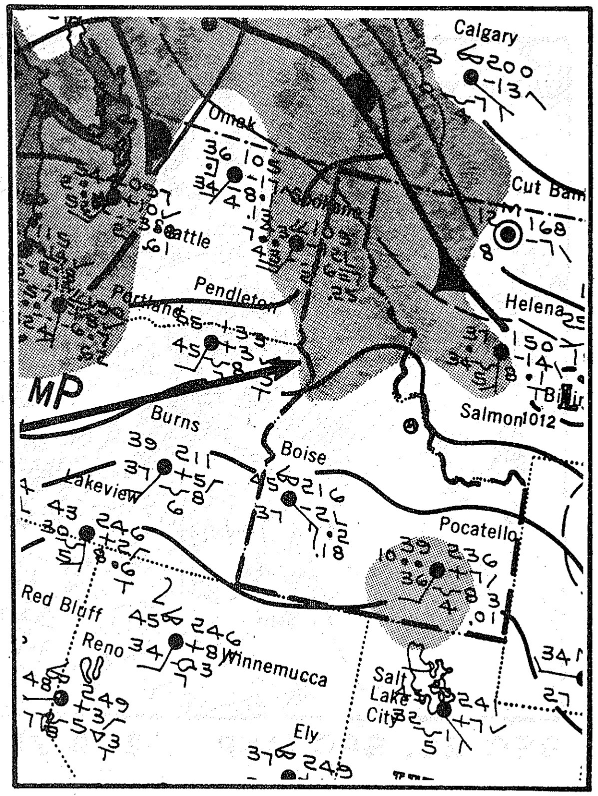


DEC 24, 500-mb (1200 Z)

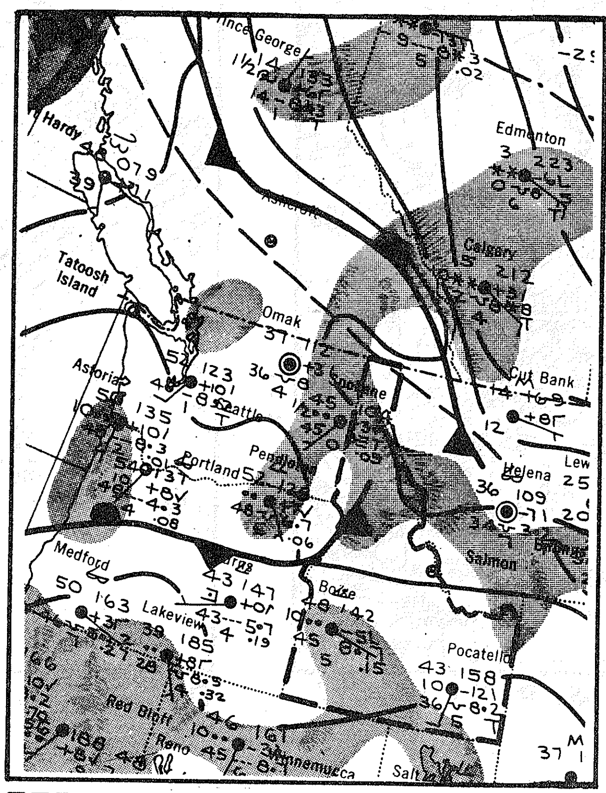
Figure 27.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for December 23 and 24, 1964.



FEB 18, SFC MAP (0600 Z)

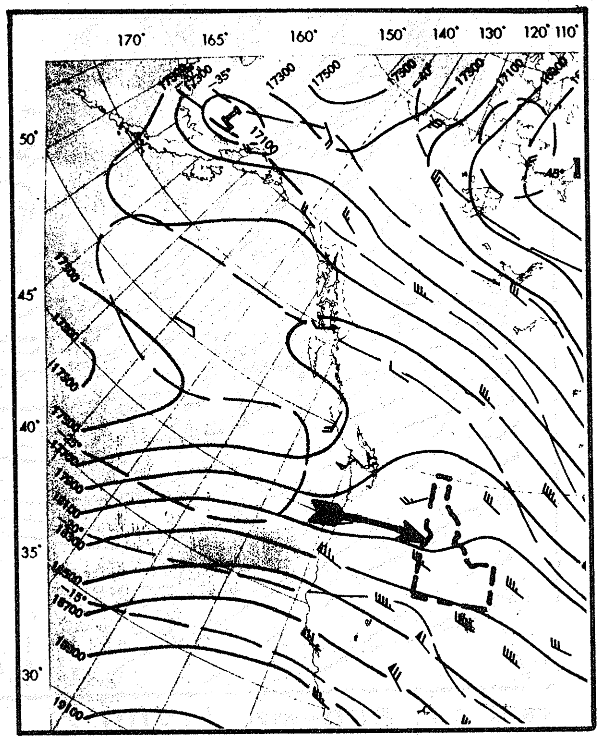


FEB 19, SFC MAP (0600 Z)

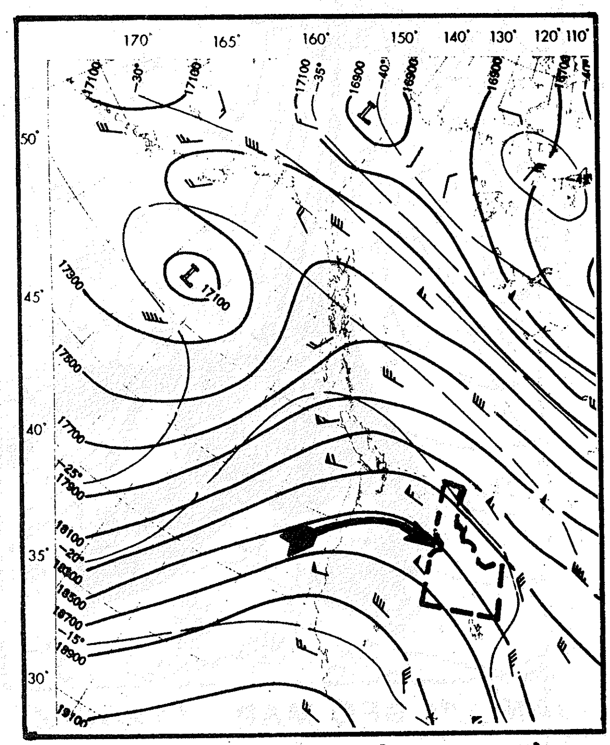


FEB 20, SFC MAP (0600 Z)

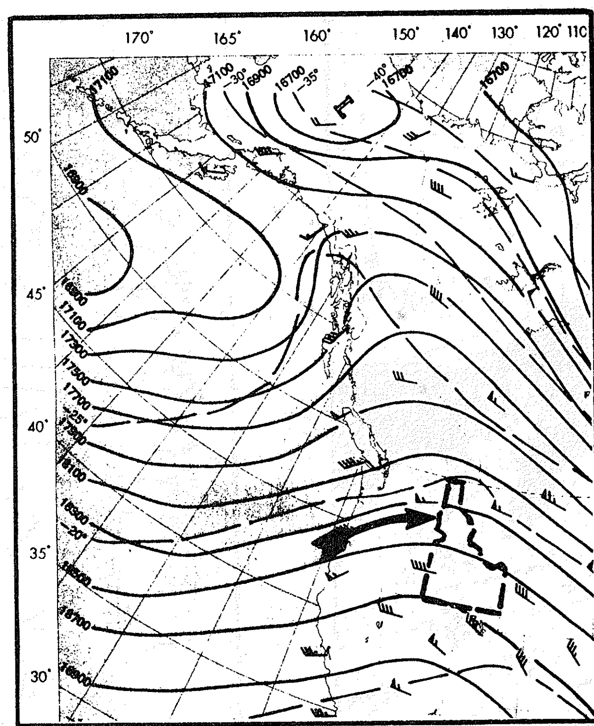
Figure 28.--Surface weather maps for February 18, 19 and 20, 1968.



FEB 18, 500-mb (0000 Z)



FEB 19, 500-mb (0000 Z)



FEB 20, 500-mb (0000 Z)

Figure 29.--Upper air (500 mb) charts for February 18, 19 and 20, 1968.

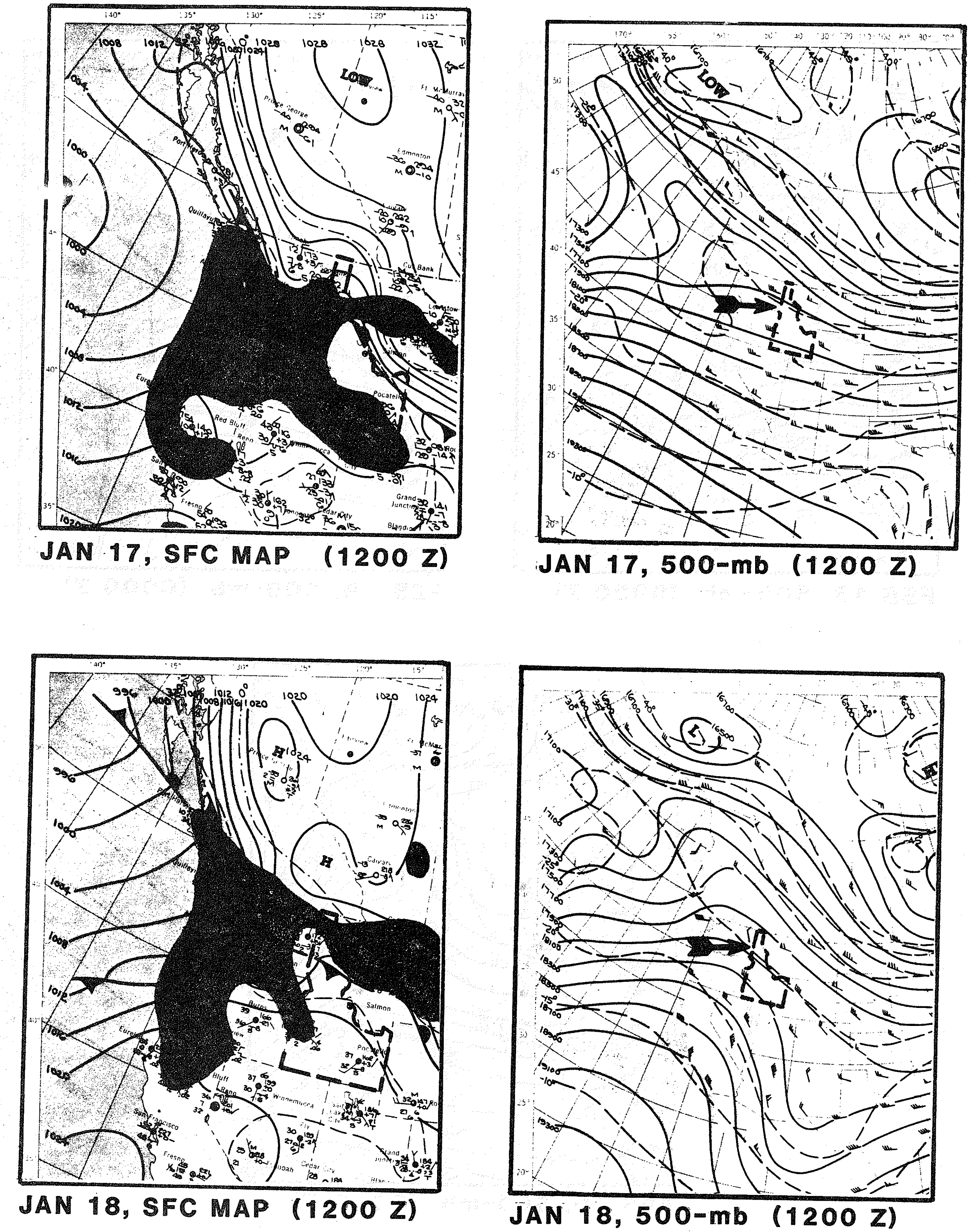
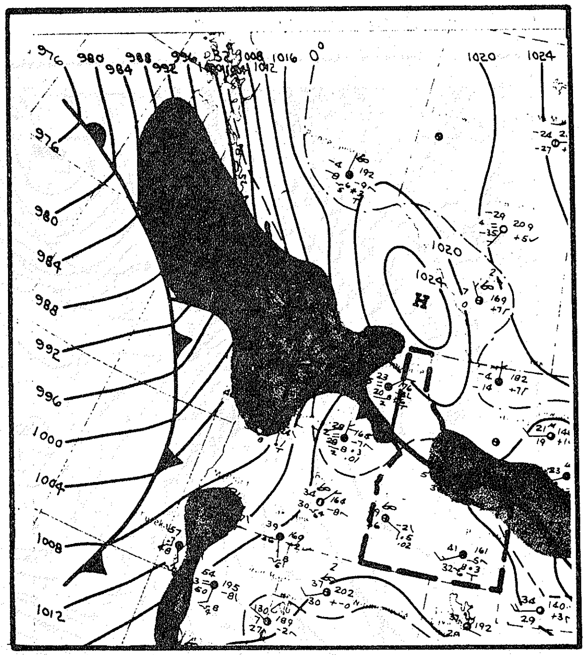
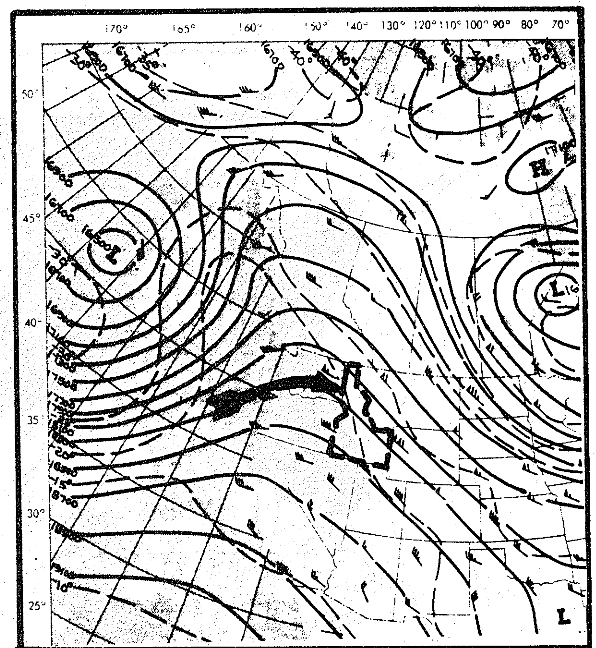


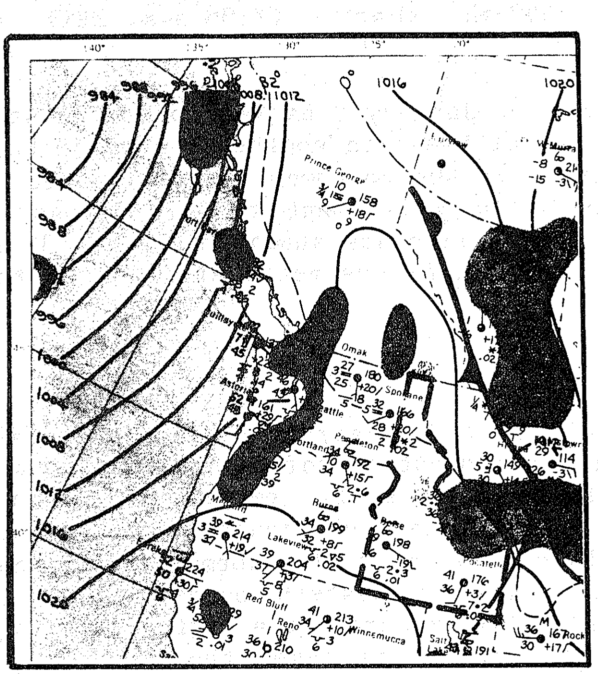
Figure 30.--Surface weather maps and 500-mb charts (7:00 a.m. EST) for January 17 and 18, 1970.



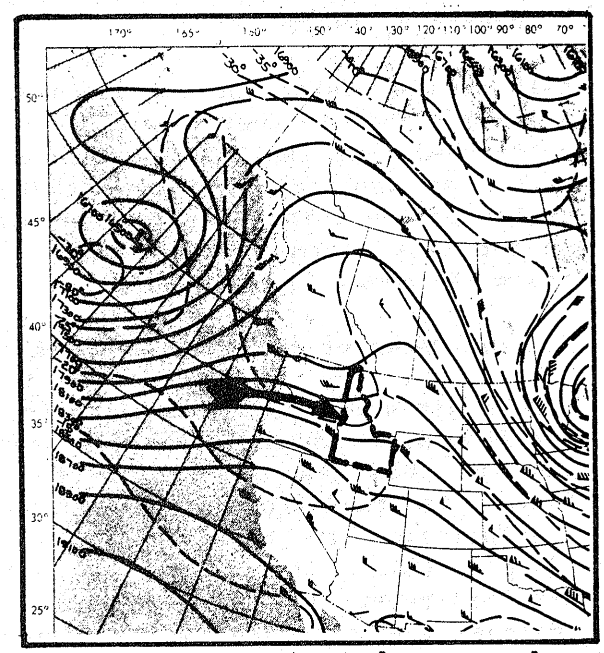
JAN 19, SFC MAP (1200 Z)



JAN 19, 500-mb (1200 Z)

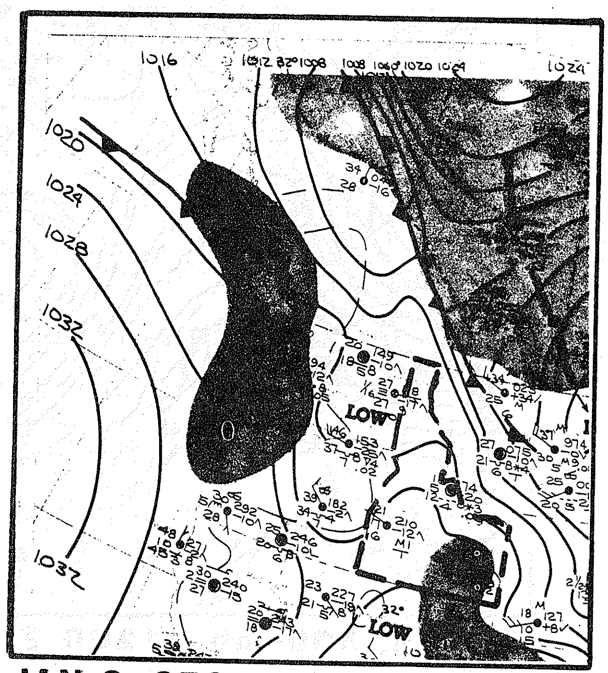


JAN 20, SFC MAP (1200 Z)

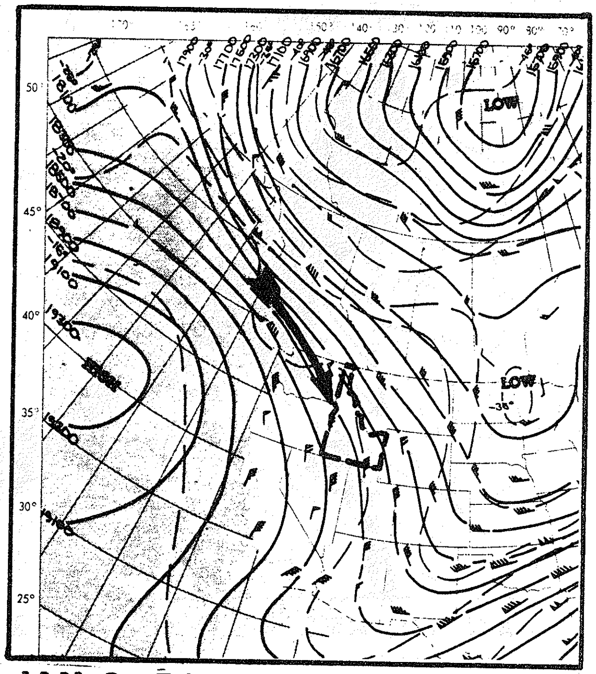


JAN 20, 500-mb (1200 Z)

Figure 31.--Surface weather maps and 500-mb charts for January 19 and 20, 1970.



JAN 8, SFC MAP (1200 Z)



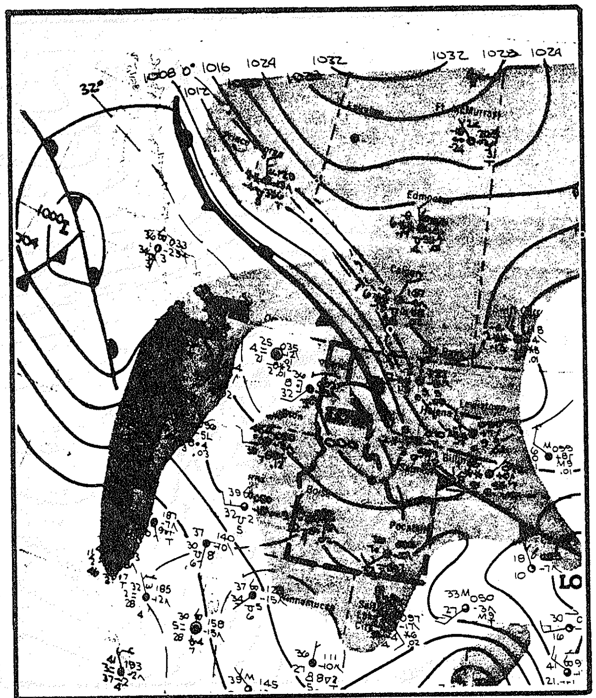
JAN 8, 500-mb (1200 Z)

Figure 32.--Surface weather map and 500-mb chart (7:00 a.m. EST) for January 8, 1971.

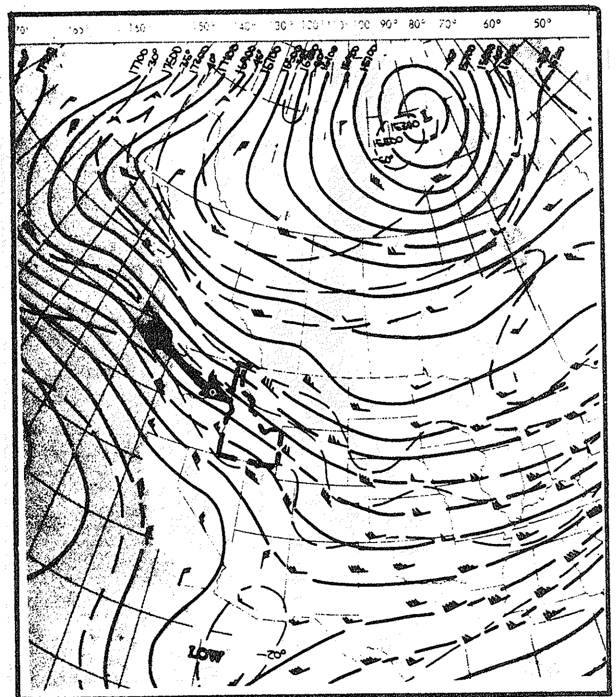
half of the basin. Strong north winds aloft on January 8 backed to northwest on January 9 and to westerly on January 10. A northwest to southeast surface front entrenched near the Divide (with arctic air near the northwest border) moved but little as another front from the Pacific (January 9) swept rapidly across the region on the 10th. The weather maps for this period are shown in Figures 32 and 33 for this storm. Mass curves of precipitation for selected stations in this storm are shown in figure 37.

3.2.10 December 20-22, 1972 Storm

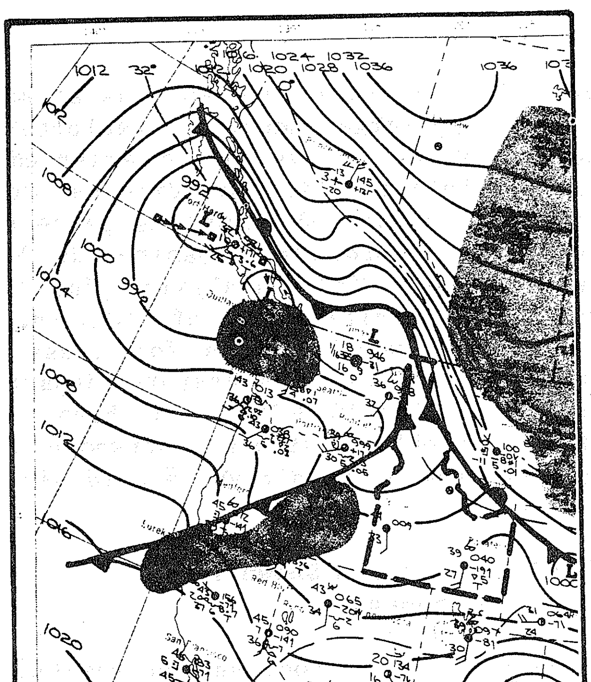
This situation had features quite similar to the January 1971 case, especially the flow aloft which involved a backing from northwest or north-northwest to west and, in this case even to west to southwest as a small low-pressure center formed in the flow aloft offshore. This difference caused more of the precipitation to be delayed to the third day than is normally the case (Chapter 10). Arctic air was entrenched near the eastern border as in the previous case. A surface front again swept rapidly across the region, leaving a residual Low offshore, while compared to the preceding case, the northwest to southeast flow was situated farther to the north and east. Weather maps are shown in Figures 34 and 35 for this case. Mass precipitation curves for the December 1972 storm for selected stations are shown in Figure 37.



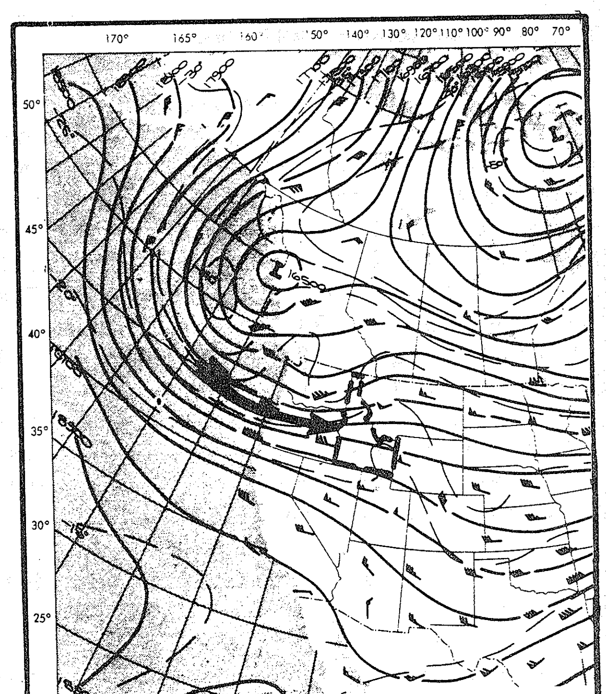
JAN 9, SFC MAP (1200 Z)



JAN 9, 500-mb (1200 Z)



JAN 10, SFC MAP (1200 Z)



JAN 10, 500-mb (1200 Z)

Figure 33.--Surface weather maps and 500-mb charts for January 9 and 10, 1971.

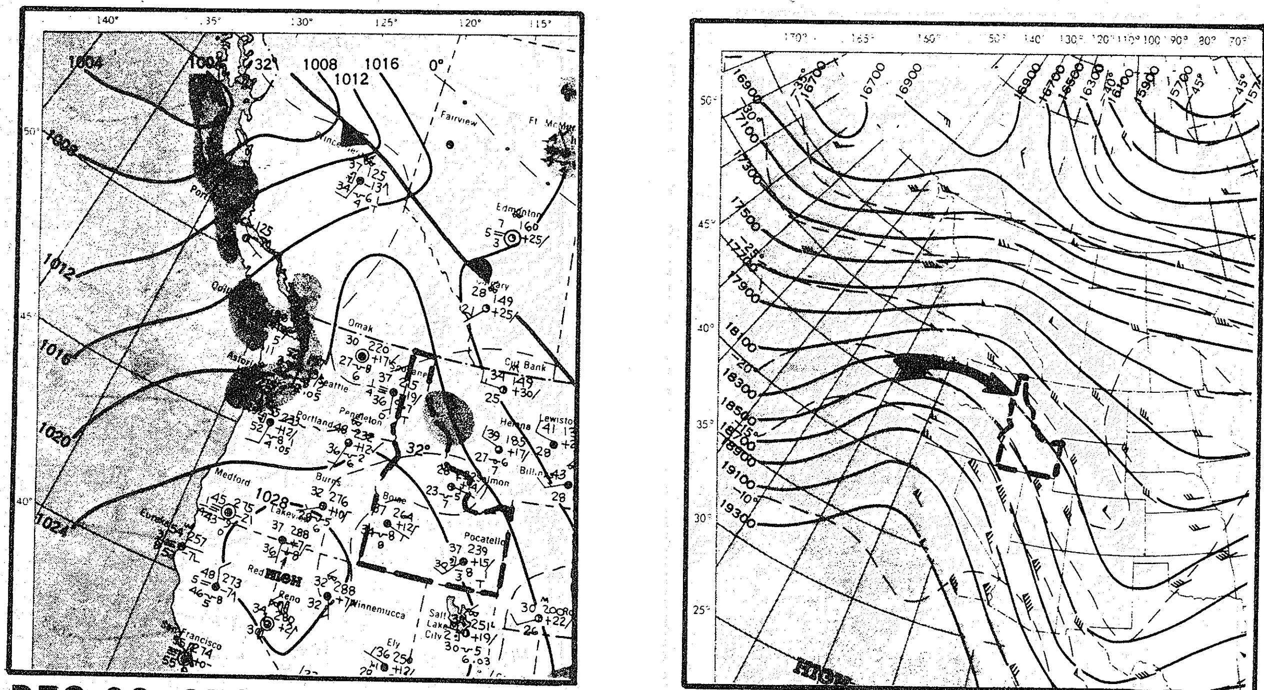


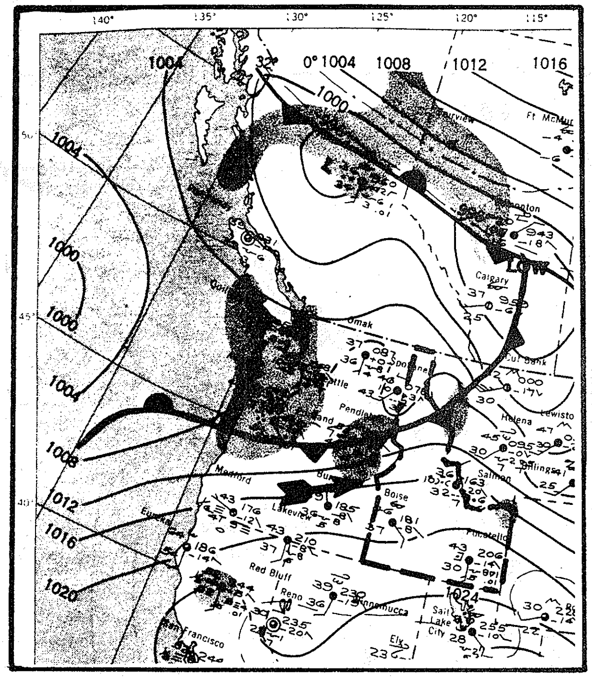
Figure 34.--Surface weather map (7:00 a.m. EST) and 500-mb chart for December 20, 1972.

3.2.11 December 1933 Case

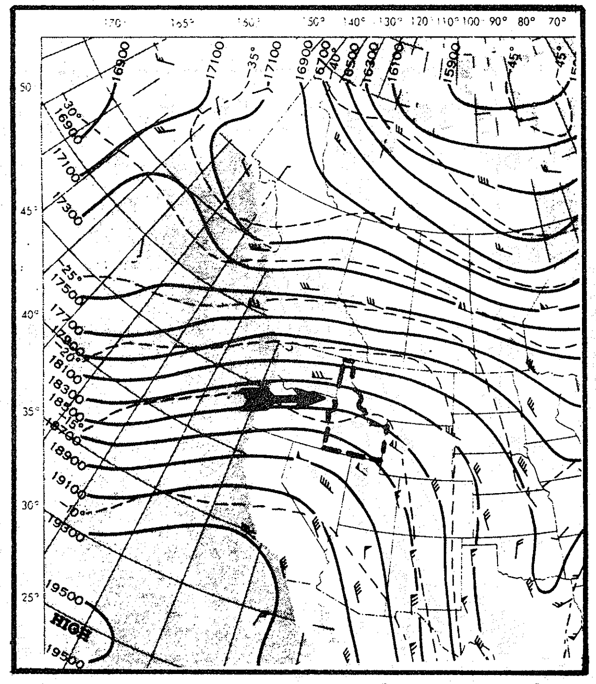
December 1933 (predating the 45-yr survey of this study) was an unusual month for the Clearwater basin. In addition to a very large number of precipitation days during December 1933, there were two large 3-day "events" experienced in this month. Because this month is unusual, special attention was directed to it even though it fell outside the 45-yr data base. Figure 38 shows the percent of MAP analysis for the December 9-11, 1933 storm which produced a basin-wide 3-day precipitation of 3.32 in. The percent of MAP analysis for the December 20-22, 1933 event which produced basin precipitation of 2.95 in. is shown in Figure 39. Figures 40 and 41 show the weather maps for these two December 1933 3-day events. The December 1933 monthly temperature departure chart Monthly Weather Review (National Weather Service 1873-1973) is shown as an inset in Figure 41. The events were characterized by strong offshore low-pressure systems that provided strong surges of warm moist air while cold air was extended east of the Divide.

3.3 Significance of Meteorological Features Shown in Major 3-Day Cool-Season Events

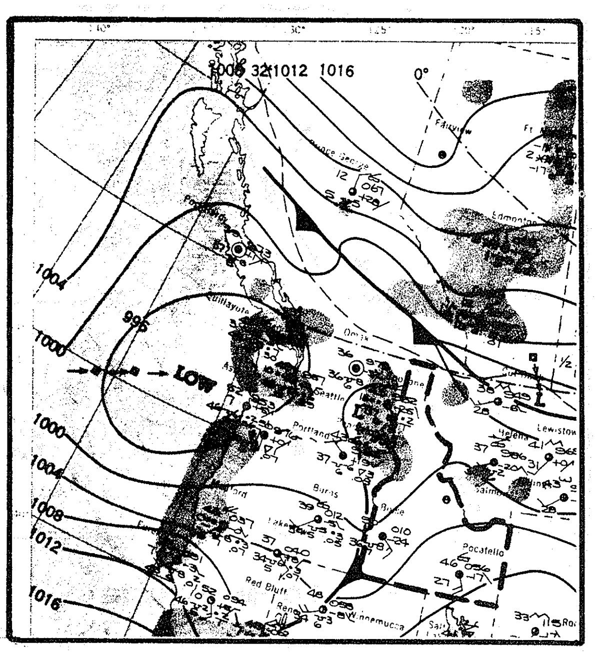
An evaluation and summation of the significant 3-day cool-season events, as discussed for individual storm events in section 3.2, results in certain conclusions pertinent to the development of the basin-wide 3-day SPS evént, time and areal distribution of the precipitation in this 3-day event and to prevailing temperature regimes suitable for snowmelting conditions at an SPS level. Some of the more important conclusions, especially in relation to the basin-wide 3-day SPS precipitation follow. Other conclusions, in part stemming from the



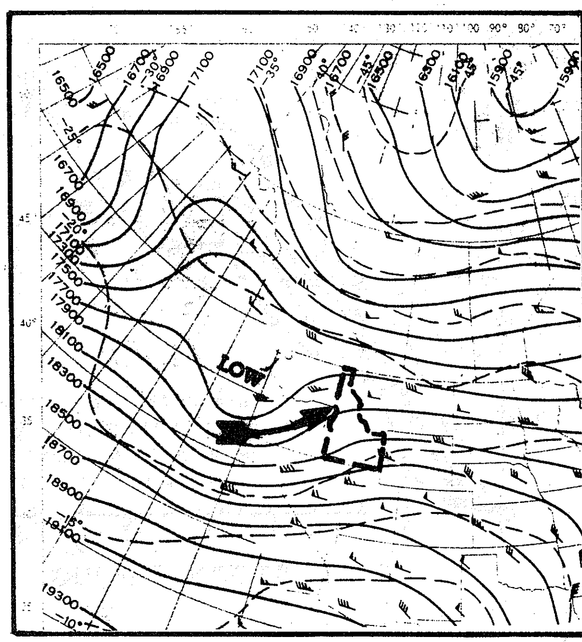
DEC 21, SFC MAP (1200 Z)



DEC 21, 500-mb (1200 Z)



DEC 22, SFC MAP (1200 Z)



DEC 22, 500-mb (1200 Z)

Figure 35.--Surface weather maps and 500-mb charts for December 21 and 22, 1972.

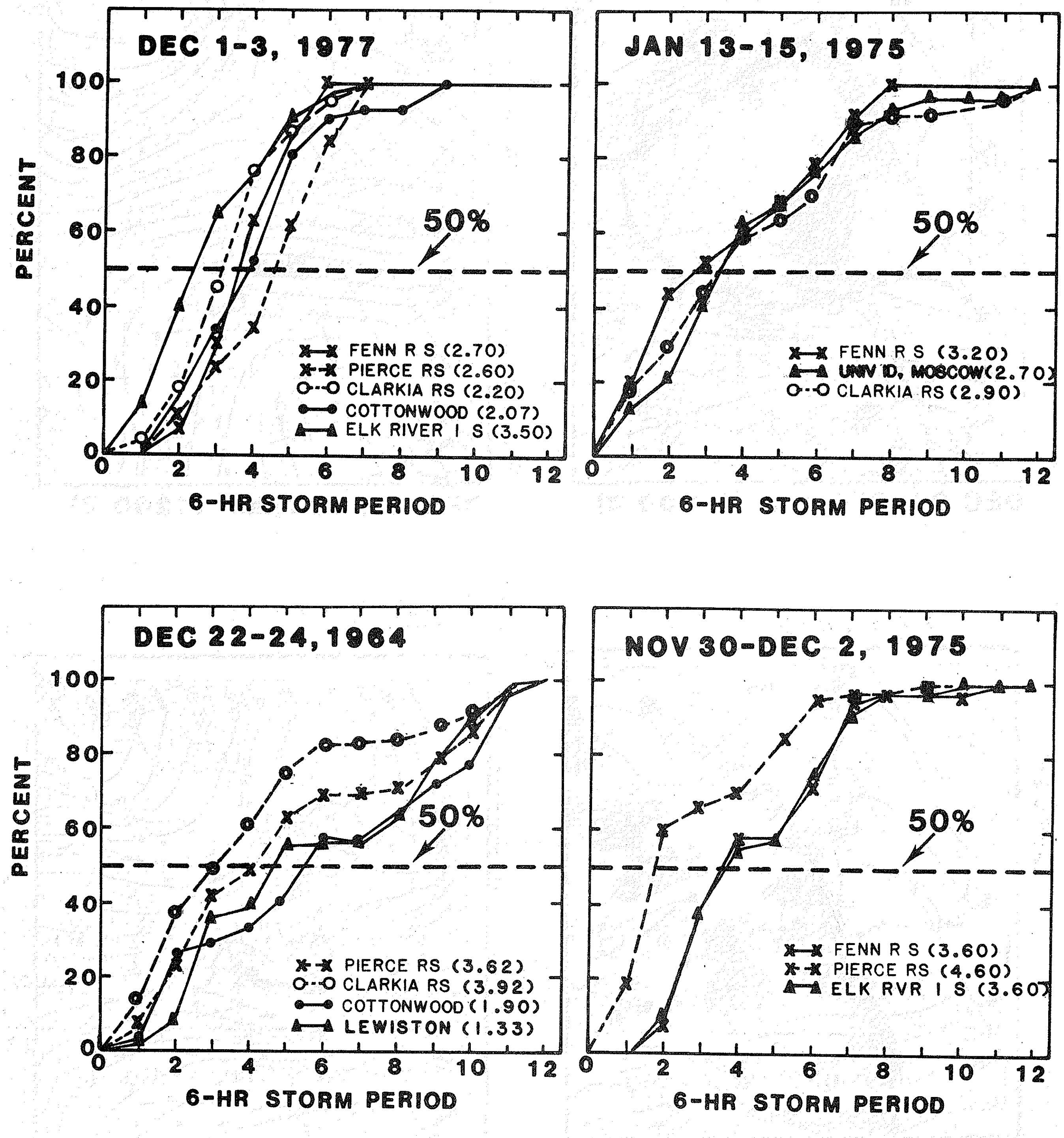


Figure 36.--Mass curves of rainfall for the January 13-15, 1975; November 30-December 2, 1975; December 22-24, 1964; and December 1-3, 1977 storms.

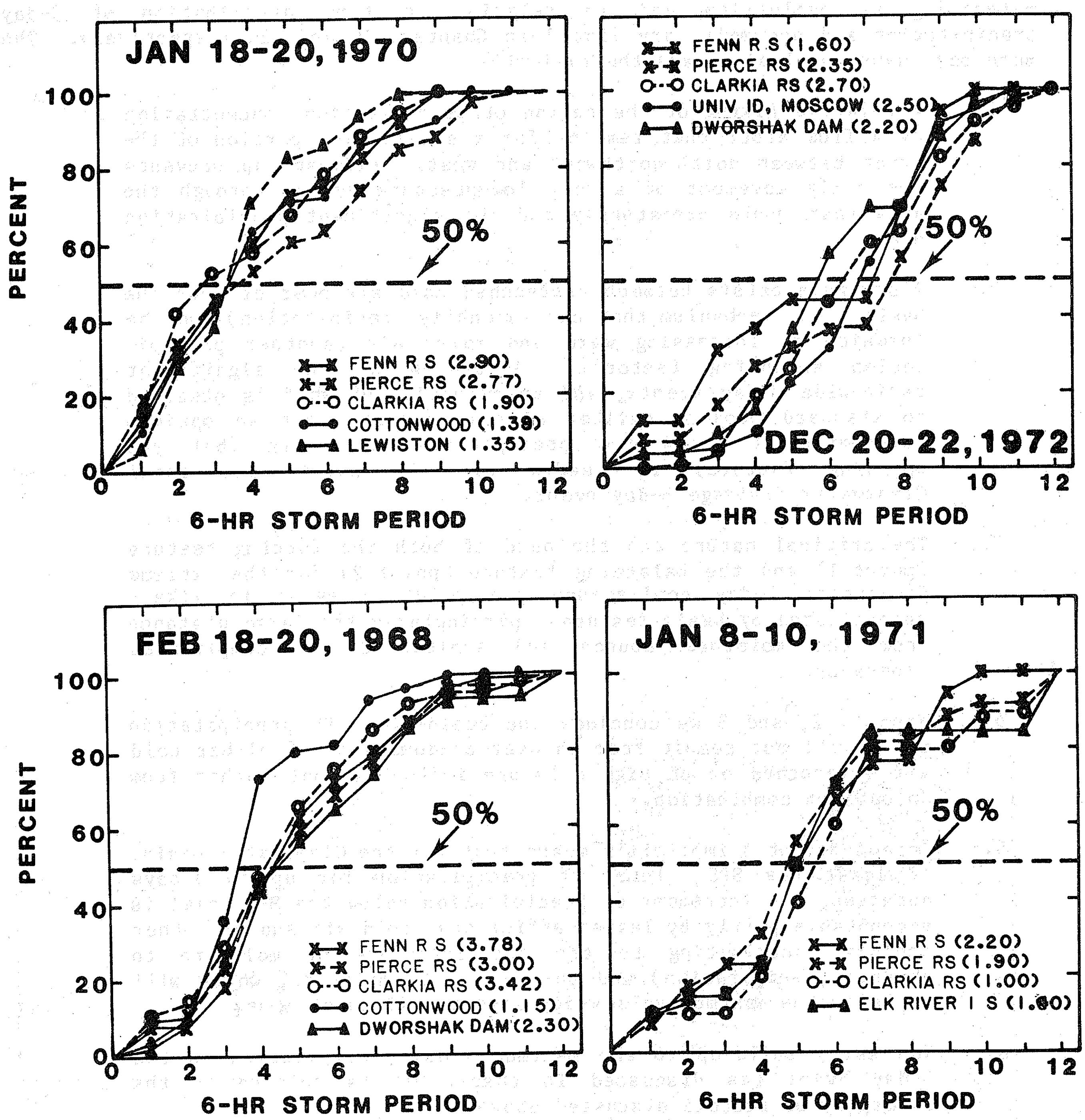


Figure 37.--Mass curves of rainfall for the February 18-20, 1968; January 18-20, 1970; January 8-10, 1971; and December 20-22, 1972 storms.

meteorological evaluation and in relation to time distribution of 3-day precipitation and snowmelt, are listed in Chapters 10 and 12, respectively. The more pertinent conclusions are the following:

1. A relative fixing of the region of precipitation concentration by a flow aloft that remains for a significant portion of the event between north-northwest and west. This set-up prevents the early movement of a deep low-pressure system through the area that would prematurely end the significant precipitation event.

2. A struggle exists between entrenched cold air over or near the basin (a mechanism that can intensify precipitation) and the invasion of increasing warm and moist air (another precipitation enhancing factor). A review of the significant basin-wide 3-day events, and an extension of what is observed to standard project caliber storms, suggest that an optimum compromise of those two precipitation enhancing (but yet opposing factors) is needed for the significant total Clearwater drainage 3-day event.

3. The critical nature and the need of both the forcing feature (point 1) and the balancing feature (point 2) for the extreme Clearwater 3-day cool-season precipitation event is likely necessitated by basin features, particularly the large distance from the moisture source and sheltering and complicated orography.

4. From 1, 2, and 3 we conclude the basin-wide SPS precipitation event will not result from an over-predominance of either cold air entrenched or of high moisture inflowing, but rather from an optimum combination.

5. Acceptance of 4 implicitly means that for the Clearwater basin, at least the SPS level of precipitation for up to 3 days duration, the increment of precipitation below the PMP level is accountable partly by lesser efficiency (cold air and all other factors contributing to the efficient use of moisture to produce precipitation) and partly due to moisture, which will be below the maximum values assigned to PMP conditions.

6. The early build-up to the maximum 1-day precipitation in the 3-day event (as discussed in chapt. 10) is related to the interplay of factors discussed above.

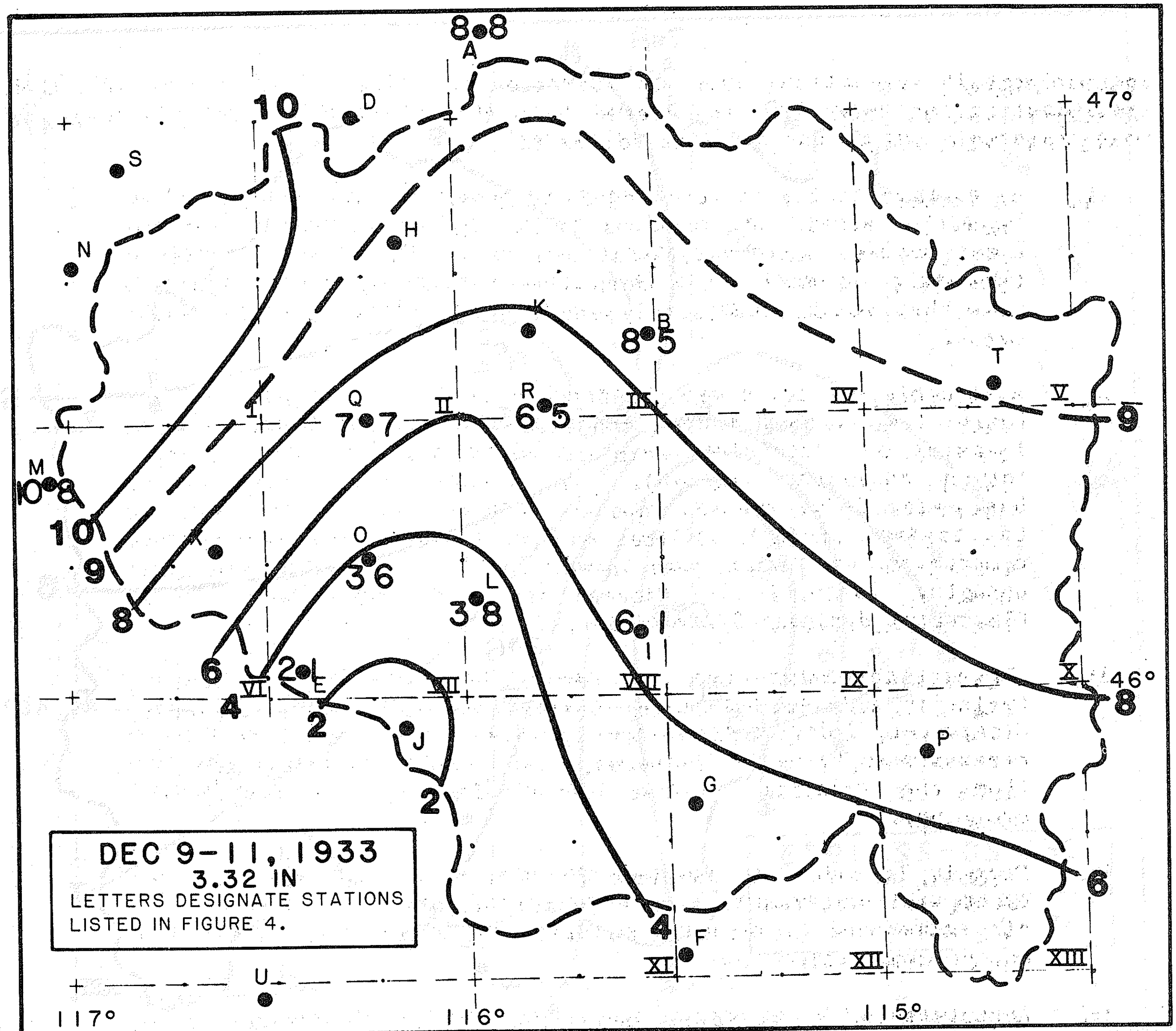


Figure 38.--Percent of MAP for storm of December 9-11, 1933.

4. METEOROLOGY OF MAJOR MAY-JUNE BASIN-WIDE 3-DAY PRECIPITATION EVENTS

4.1 Introduction

Much of the information in the introduction to the cool-season meteorology of storms also applies to major May-June events. One perhaps important difference relates to the frequency of correlation of major mean coastal and interior events. The correlation frequency of these warmer season events is considerably reduced. However, in most cases Pacific Ocean influences predominate.

The objectives of a study of May-June events remain the same as with the major cool-season events. Briefly these are:

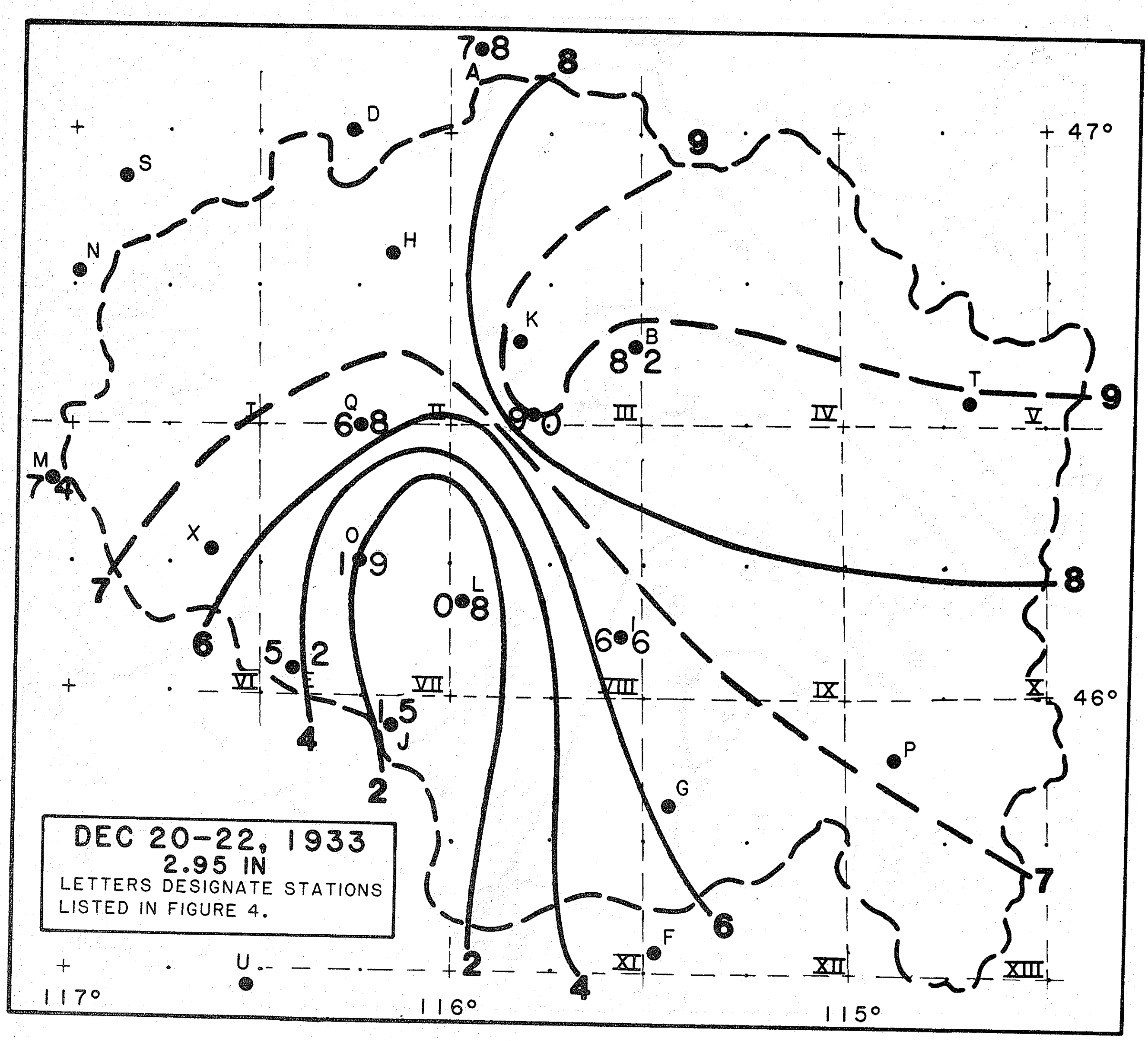


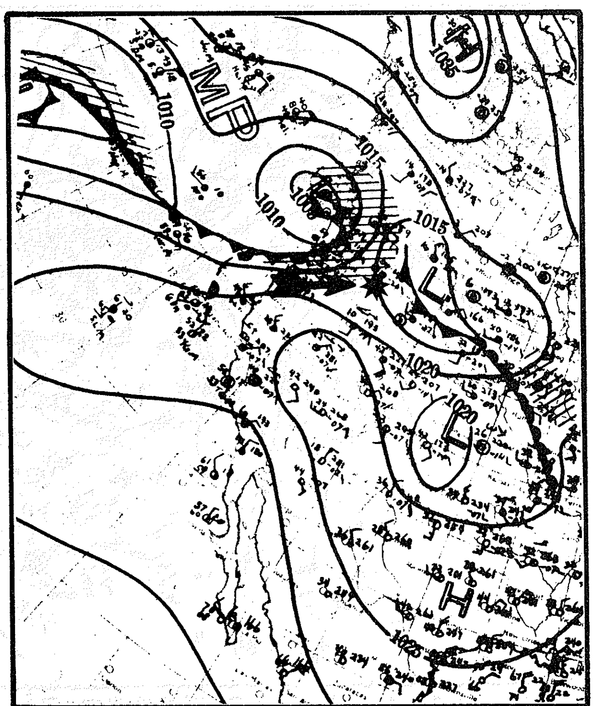
Figure 39.--Percent of MAP for storm of December 20-22, 1933.

1. to help set the May-June 3-day SPS precipitation magnitude

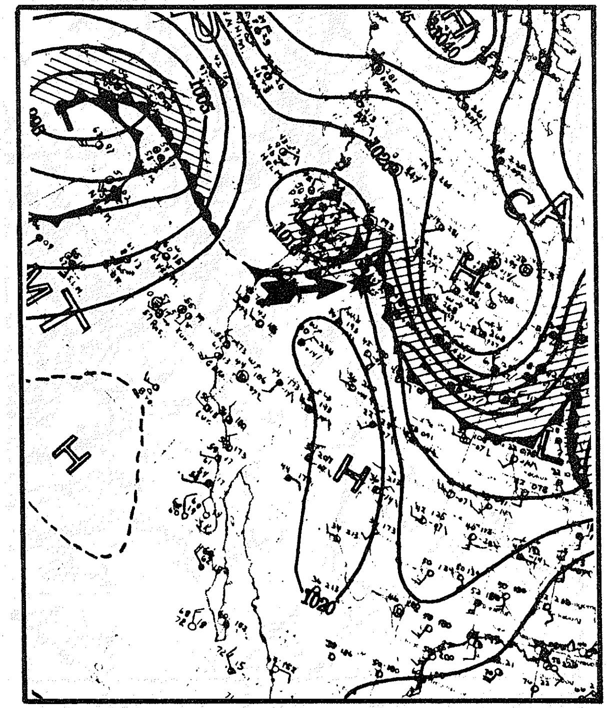
2. to derive SPS level appropriate geographical (i.e., areal) and time distribution of the 3-day SPS May-June event

3. to derive appropriate SPS-level May-June temperature departures for snowmelt

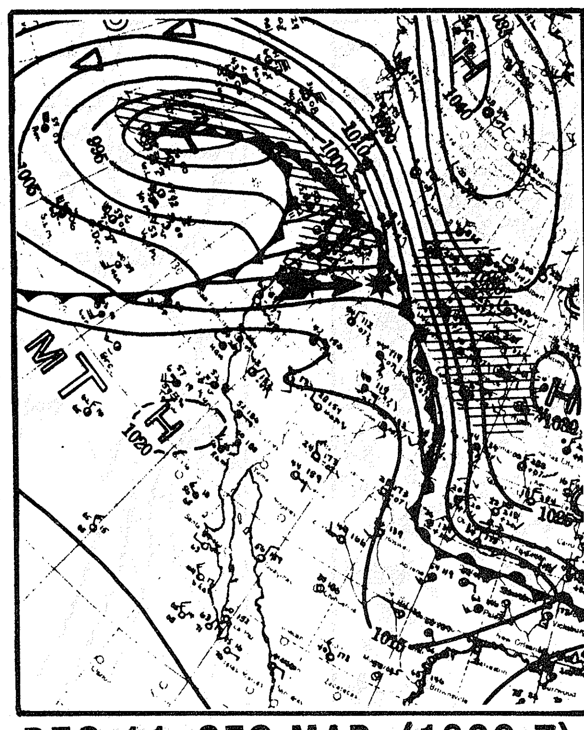
As with the meteorological discussion of the cool-season events, the May-June meteorological discussion here relates primarily to the more significant broadscale meteorological features. Some additional meteorological discussion is in the time-distribution and snowmelt temperature Chapters, 10 and 12, respectively.



DEC 9, SFC MAP (1300 Z)

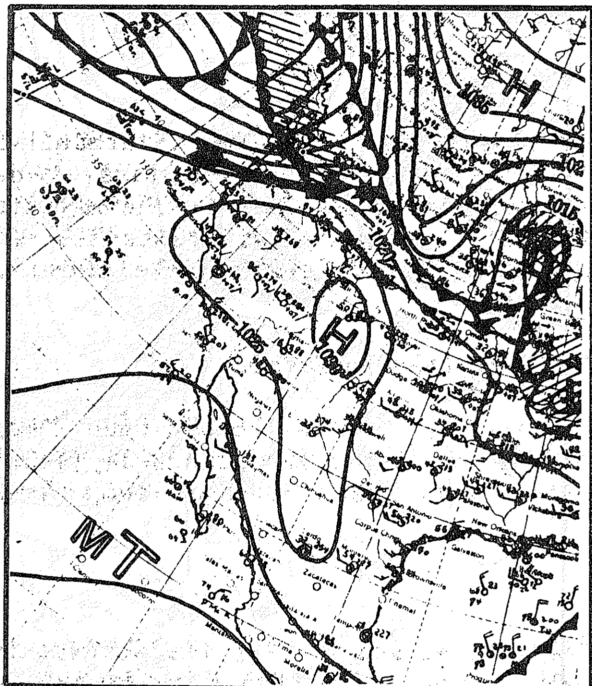


DEC 10, SFC MAP (1300 Z)

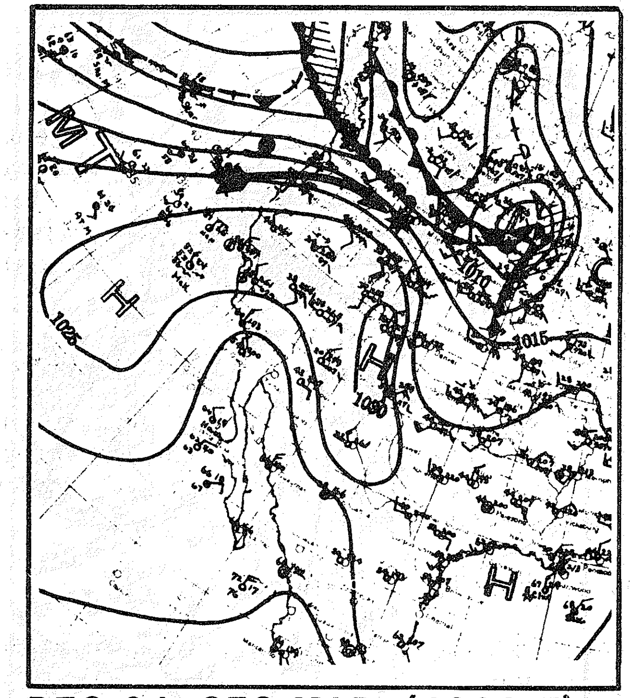


DEC 11, SFC MAP (1300 Z)

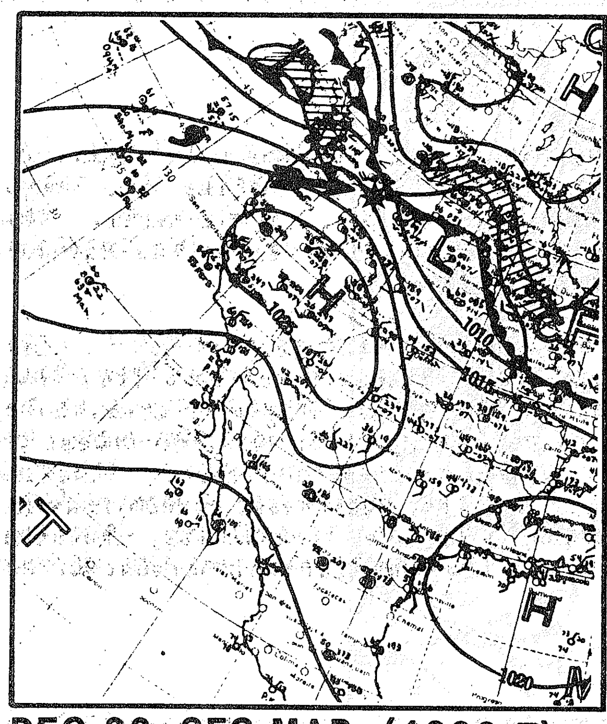
Figure 40.--Surface weather maps for December 9-11, 1933.



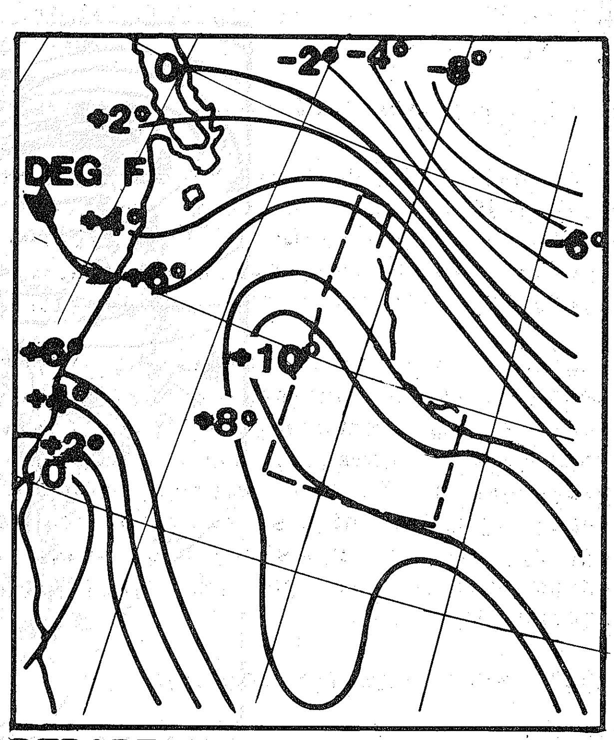
DEC 20, SFC MAP (1300 Z)



DEC 21, SFC MAP (1300 Z)



DEC 22, SFC MAP (1300 Z)



DEPARTURE FROM NORMAL TEMPARTURE (°F)-DEC 1933

Figure 41.--Surface weather maps for December 20-22, 1933, and departure from normal temperatures (°F).

4.2 Overview

A review of many May-June 3-day events indicated considerable more variability in the types of meteorological situations conductive to rather large 3-day events. Some were reasonably similar to the cool-season events, but the majority had distinctively different meteorological characteristics. Two events that had meteorological features similar to the major cool-season events were those of May 10-12, 1967 and June 4-6, 1974.

4.3 Specific May-June 3-Day Precipitation Events

As with the cool-season events, the magnitude of the basin-wide 3-day precipitation was the primary basis for selection of major May-June 3-day events for meteorological clarification. However, secondary bases, such as temperature regimes also played a role.

4.3.1 May 10-12, 1967 Storm

Weather maps for this storm are shown in figures 42 and 43. At the surface the main feature was a frontal system stretching in a northwest to southeast orientation near the Continental Divide. The flow aloft was generally from a west-southwest to a southwest direction, but velocities were apparently too low to have much affect on movement of the surface frontal position. The early peaking of precipitation in this storm (fig. 90) resembled the cool-season cases more than most of the May-June cases. The percent of MAP analyses for this storm is shown in Figure 44.

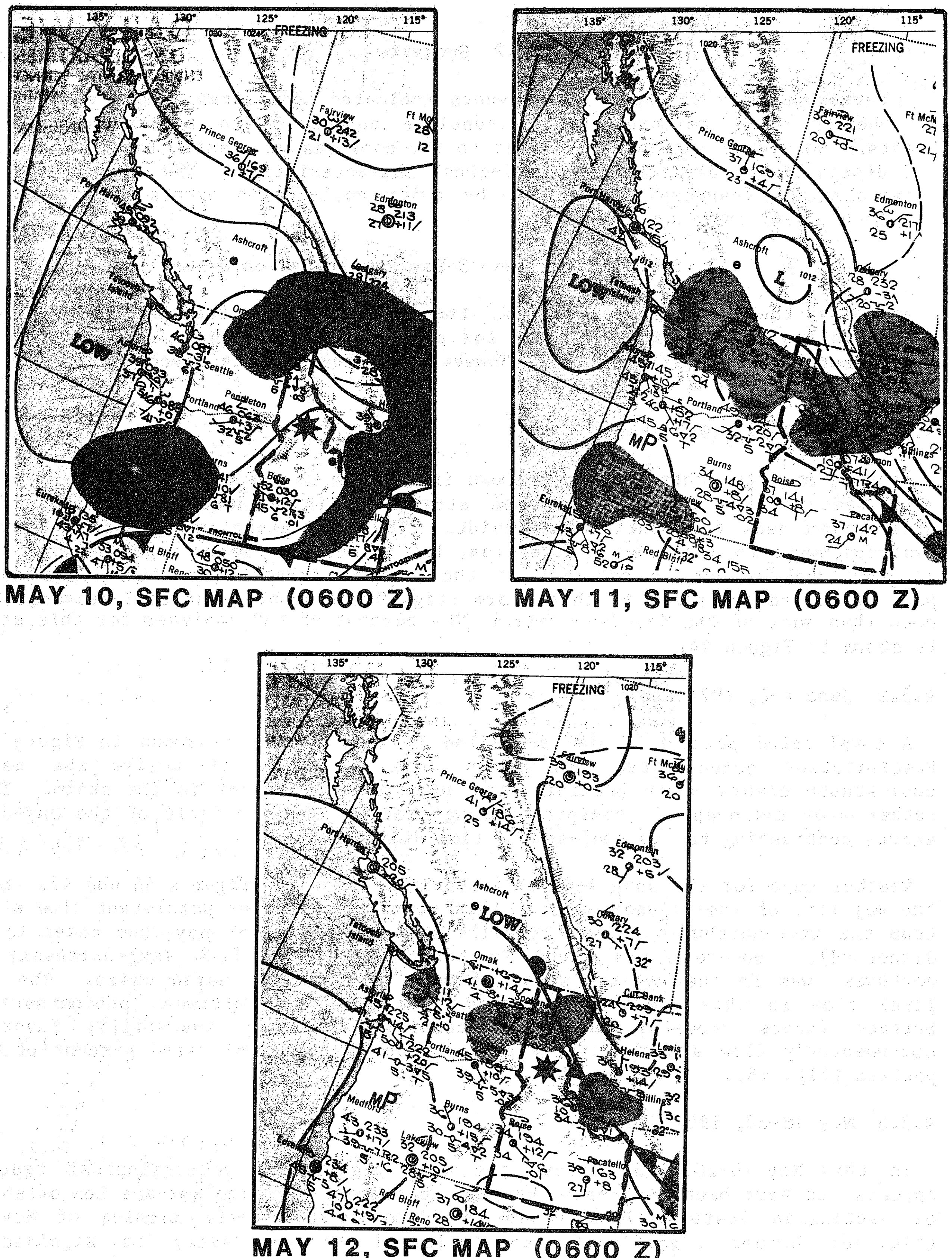
4.3.2 June 4-6, 1974 Storm

A complicated percent of MAP prevailed in this storm, as shown in Figure 45. Precipitation concentrated mostly on June 5 making it unlike the major cool-season events where precipitation concentrated earlier in the storm. This rather slow build-up of precipitation was rather characteristic of the May-June events contrasting to the cool-season time distribution.

Weather maps for the June 4-6, 1974 storm are shown in Figures 46 and 47. Like the majority of cool-season events, this storm had a rather persistent flow aloft from the west-northwest to west (unlike most of the other May-June cases to be discussed). However, the trend in this case, going from west-northwest to northwest was in the reverse sense of most of the cool-season cases. The low level flow in this storm also showed flow from the northwest predominating. Surface fronts crossing the basin combining with an instability favoring northwesterly flow are the likely explanation of the complicated percent of MAP pattern (fig. 45).

4.3.3 May 18-20, 1957 Storm

In this May 18-20, 1957 event, the most significant meteorological feature appears to have been its rapid changing character. A large surface Low offshore of Washington State with a front in Idaho on the early morning of May 18 (fig. 48) became significant, as indicated by the delay in significant precipitation until the 19th. The Idaho surface Low then develops in a southeasterly direction (fig. 48). This rather unusual movement of the surface

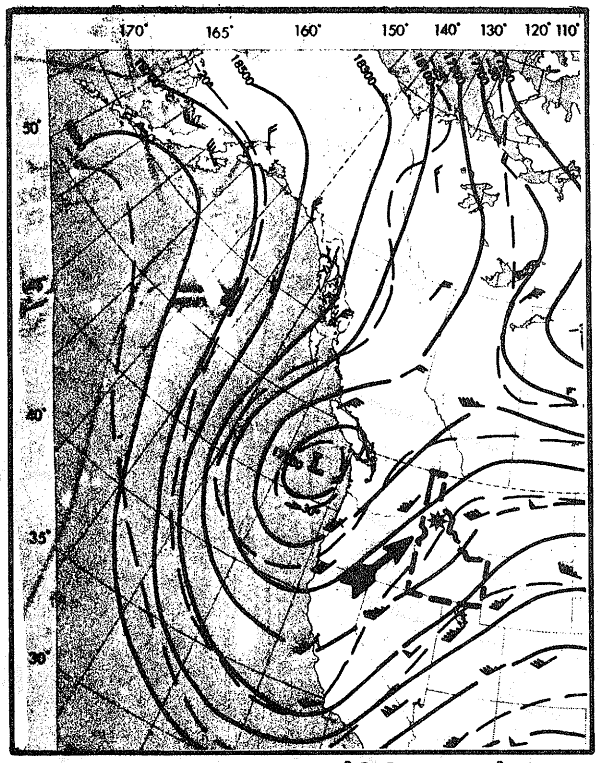


MAY 10, SFC MAP (0600 Z)

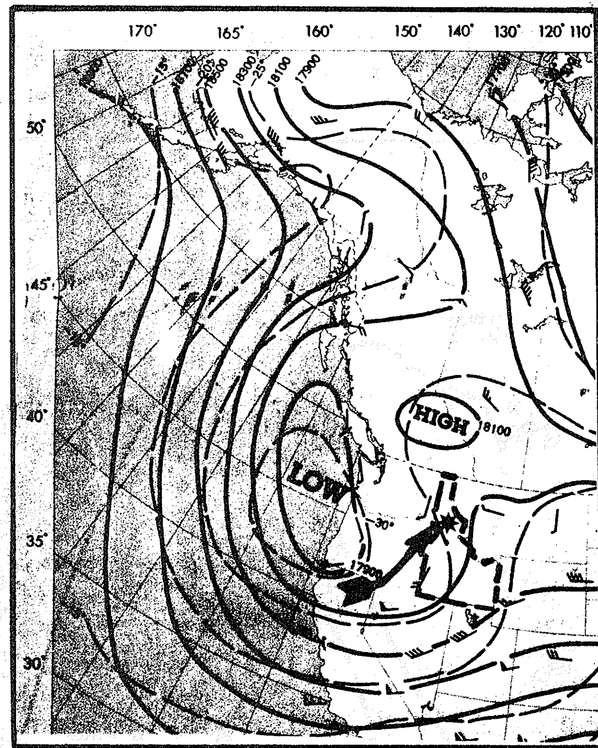
MAY 11, SFC MAP (0600 Z)

MAY 12, SFC MAP (0600 Z)

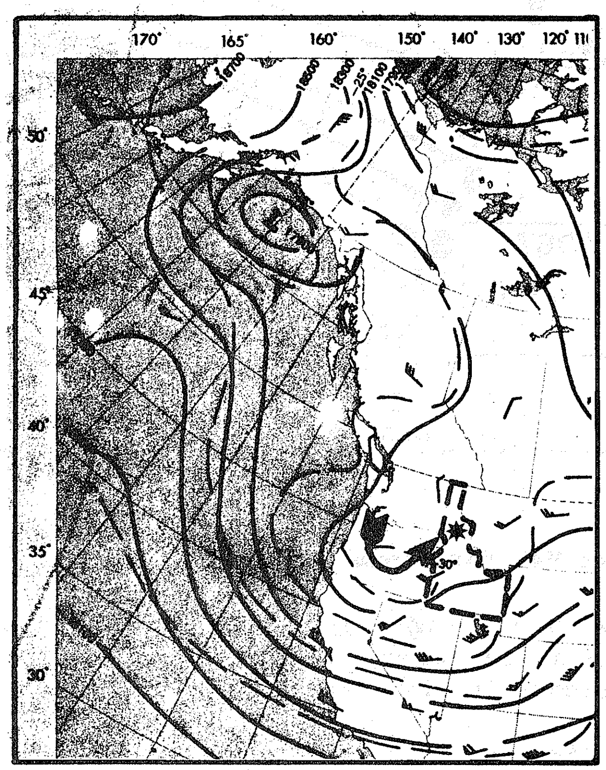
Figure 42.--Surface weather maps for May 10-12, 1967 (1:00 a.m. EST).



MAY 9, 500-mb (0000 Z)



MAY 10, 500-mb (0000 Z)



MAY 11, 500-mb (0000 Z)

Figure 43.--500-mb charts for May 9-11, 1967.

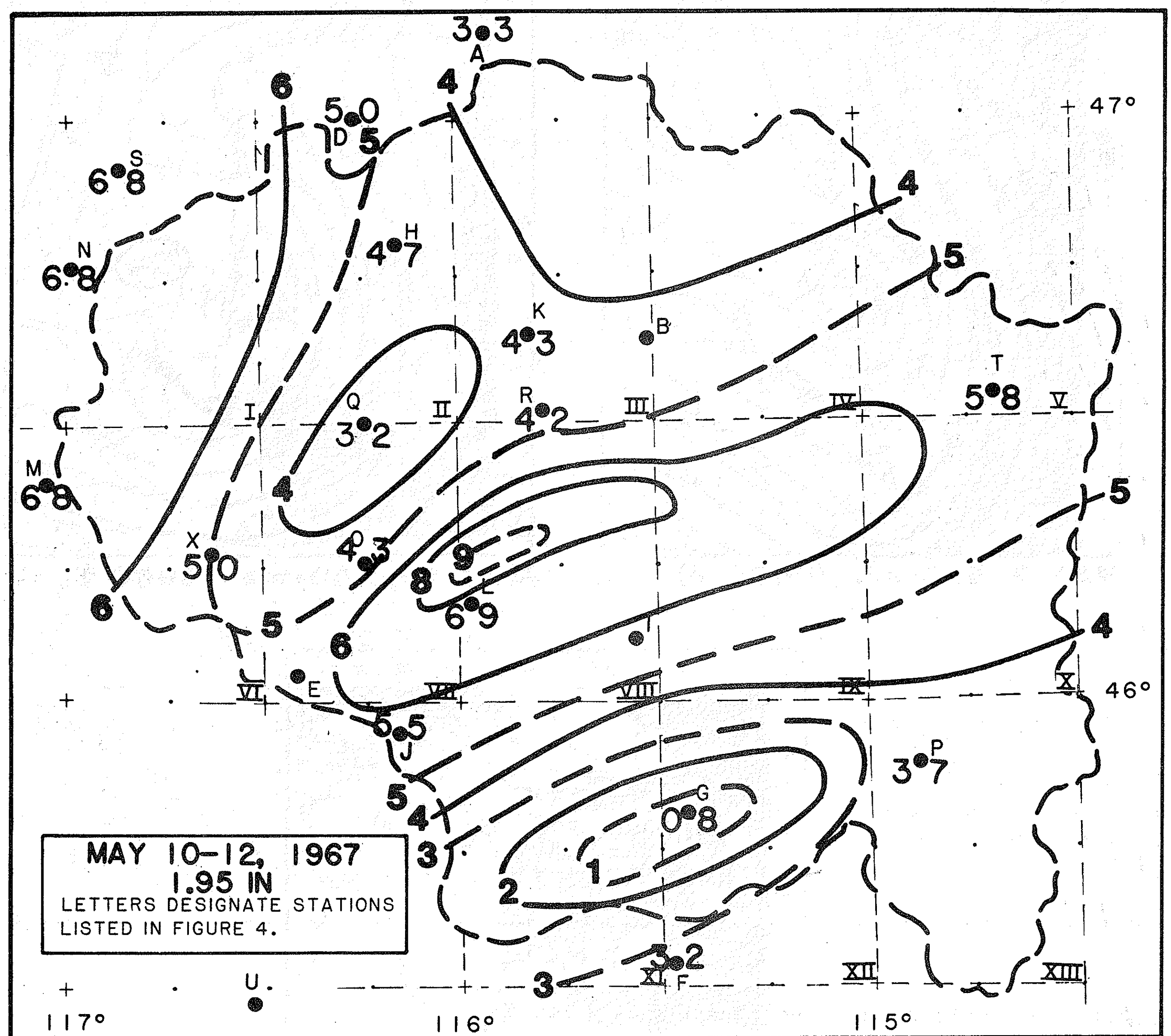


Figure 44.--Percent of MAP for storm of May 10-12, 1967.

Low was associated with a change in flow aloft from a south to south-southwest direction (May 17) to a deep trough of low pressure producing a flow aloft over Idaho with 180° difference in wind direction over the basin (fig. 49).

The percent of MAP analysis for this event is shown in Figure 50. Interestingly, a large downstream centering of the precipitation (in percent of MAP) produced a rather simple pattern.

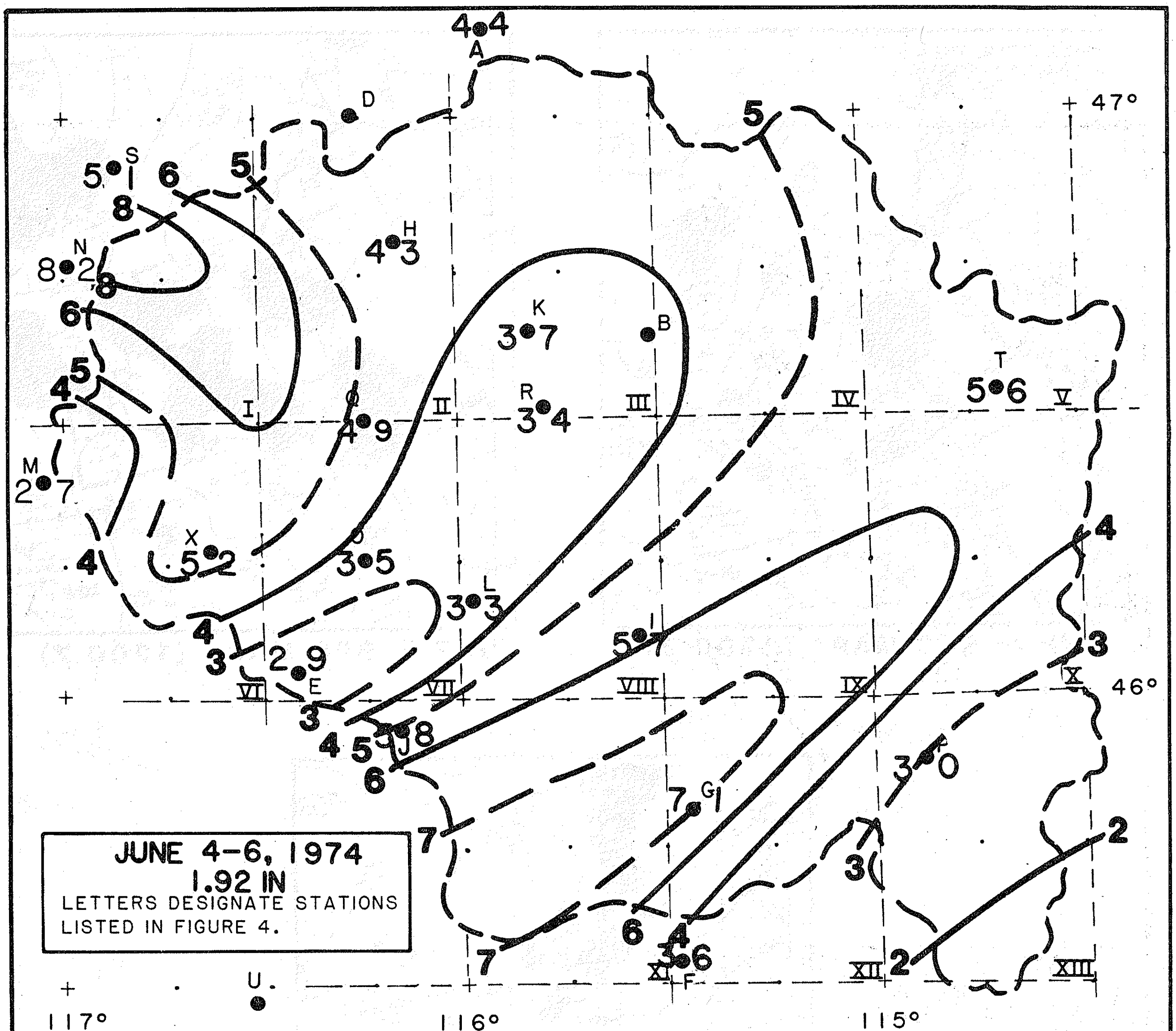
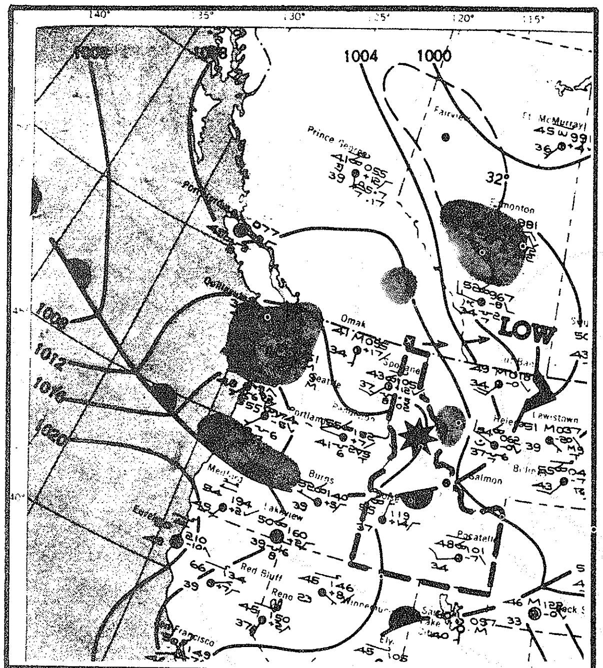


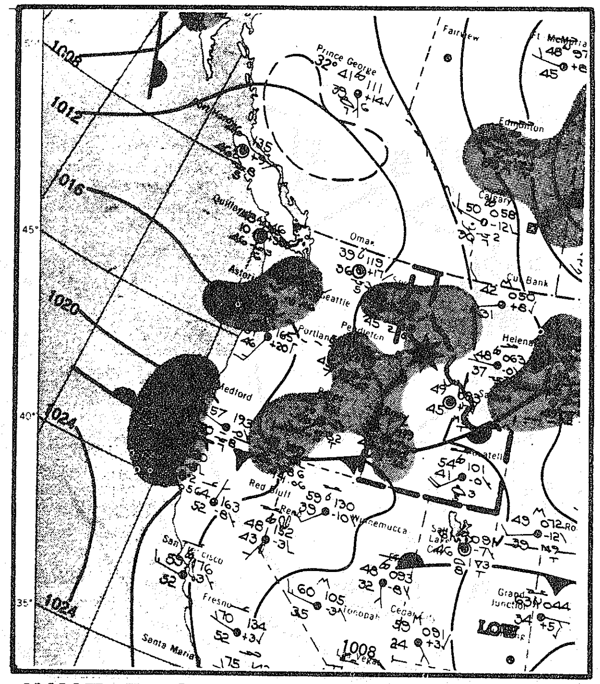
Figure 45.--Percent of MAP for storm of June 4-6, 1974.

4.3.4 June 6-8, 1964 Storm

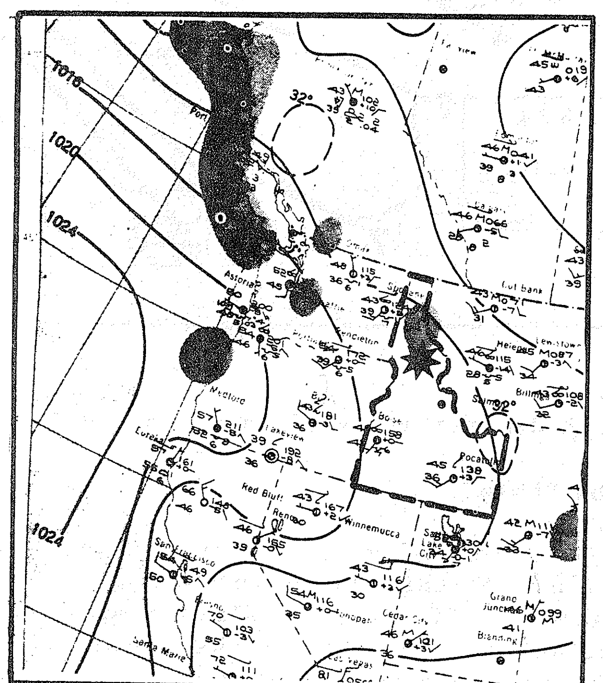
This June 6-8, 1964 storm spans the period of the more famous precipitation event centered just east of the Divide in Montana. The percent of MAP analysis for this storm is shown in Figure 51. Weather maps are shown in Figures 52 and 53. The more important rain period in the basin occurred late on June 7 into June 8 as a closed low pressure circulation aloft positioned itself over the basin (fig. 53). The percentage of MAP pattern, with highest percentages in the southwestern portion of the Clearwater basin (fig. 51), suggests that moisture from a distant Gulf of Mexico source was not a factor in the Clearwater basin precipitation, contrasting to what was the case east of the Divide in Montana.



JUNE 4, SFC MAP (1200 Z)



JUNE 5, SFC MAP (1200 Z)



JUNE 6, SFC MAP (1200 Z)

Figure 46.--Surface weather maps for June 4-6, 1974.

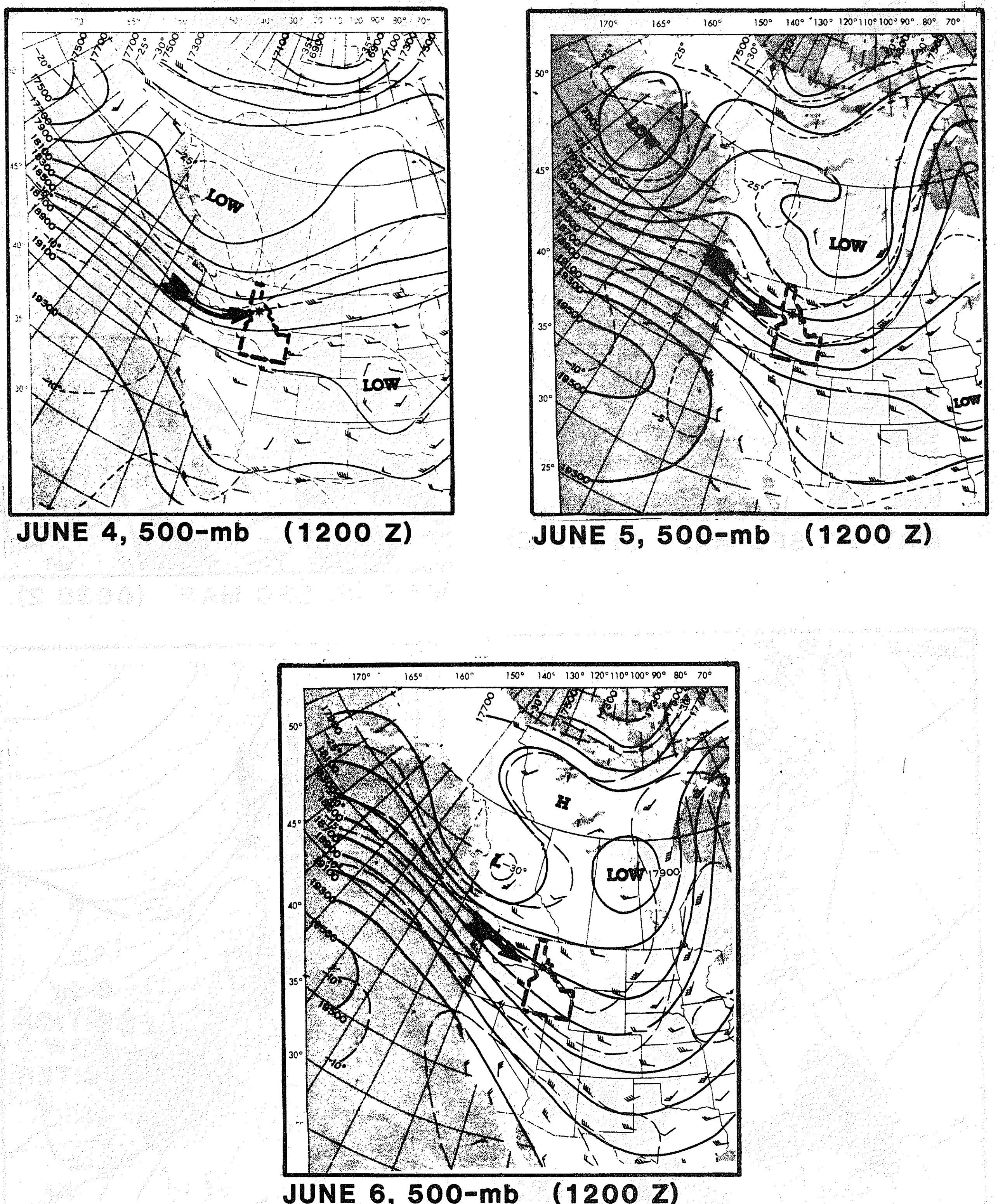
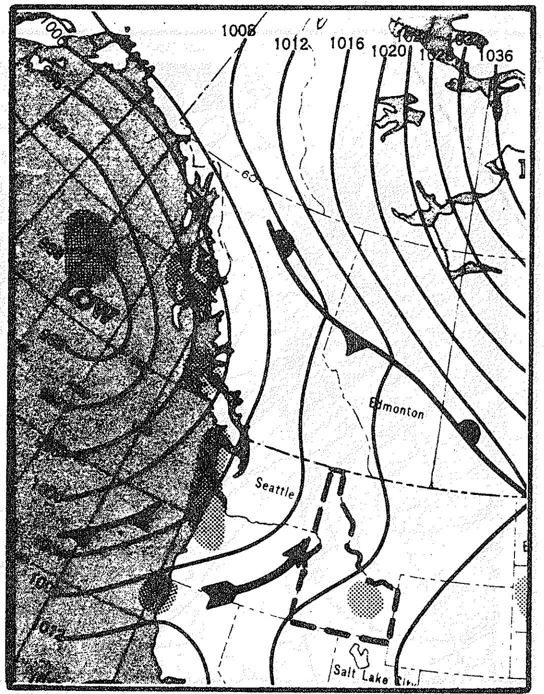
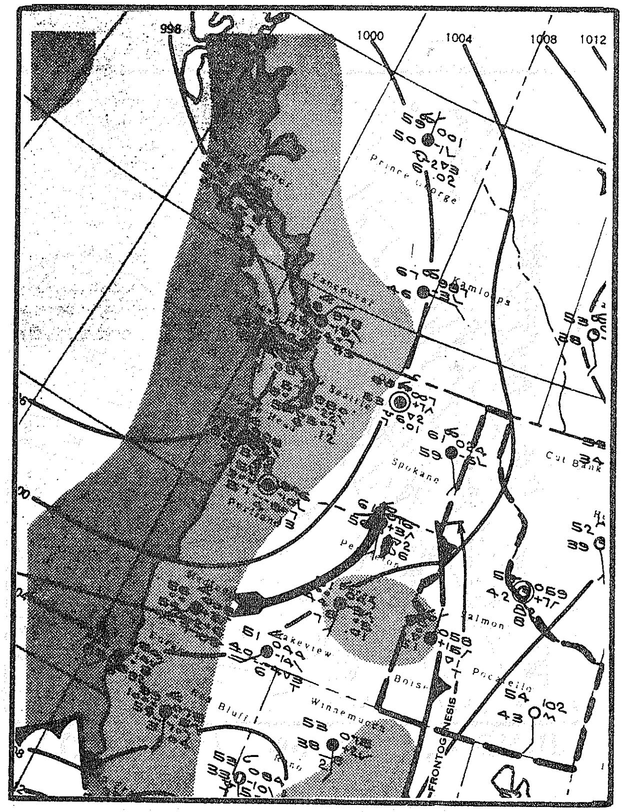


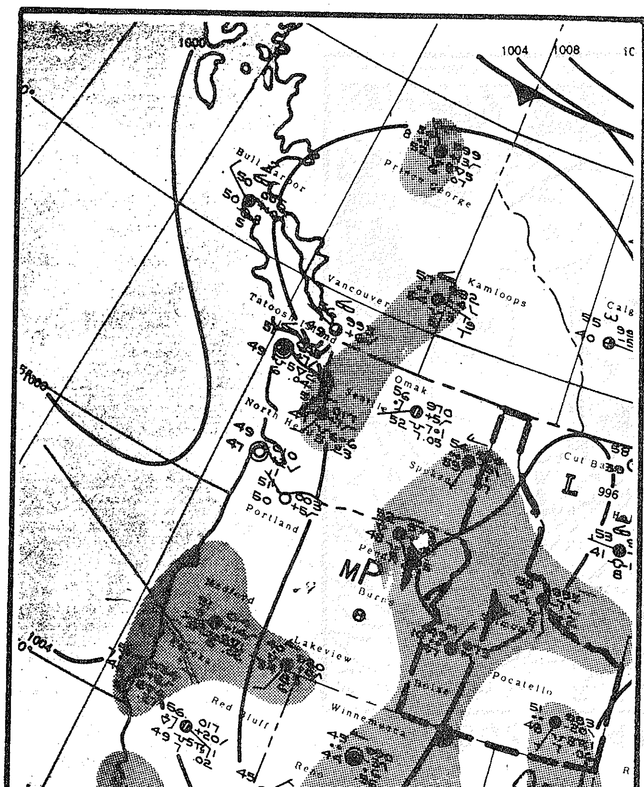
Figure 47.--500-mb charts for June 4-6, 1974.



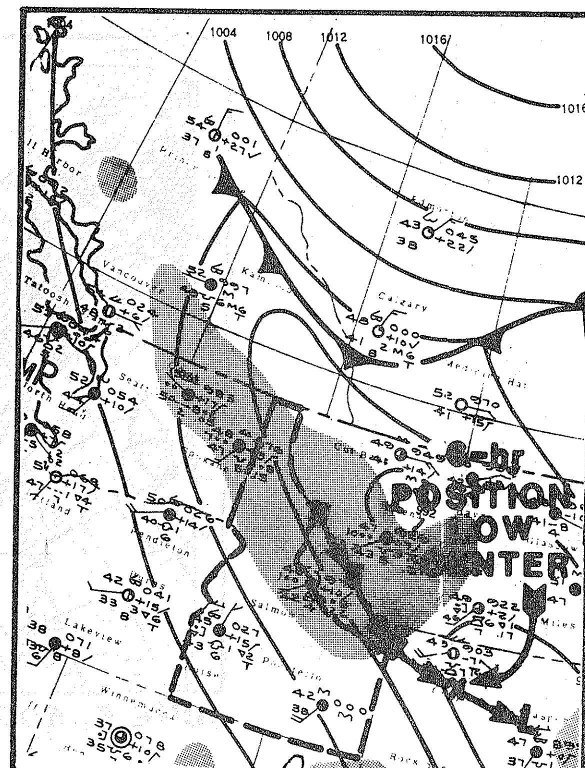
MAY 17, SFC MAP (1830 Z)



MAY 18, SFC MAP (0630 Z)

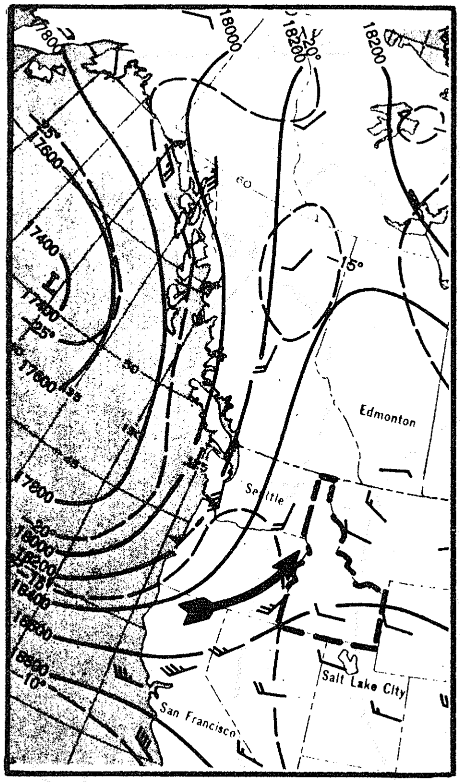


MAY 19, SFC MAP (0630 Z)

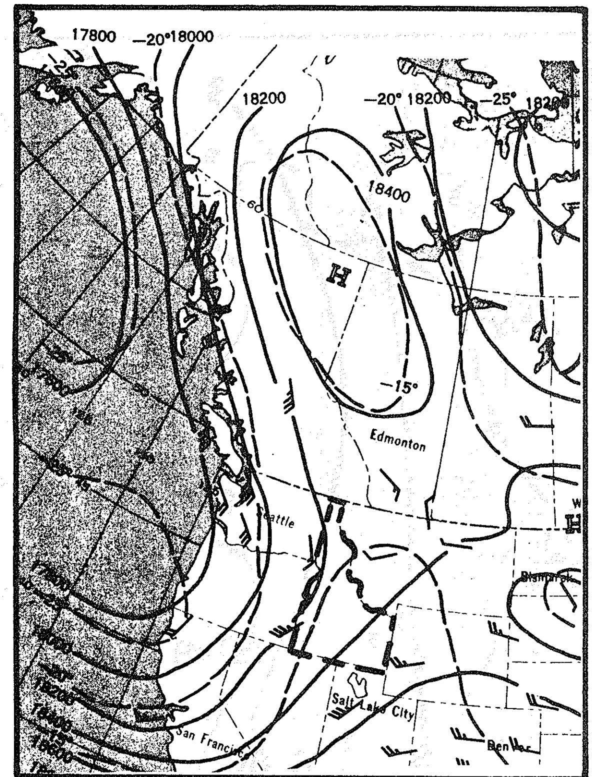


MAY 20, SFC MAP (0630 Z)

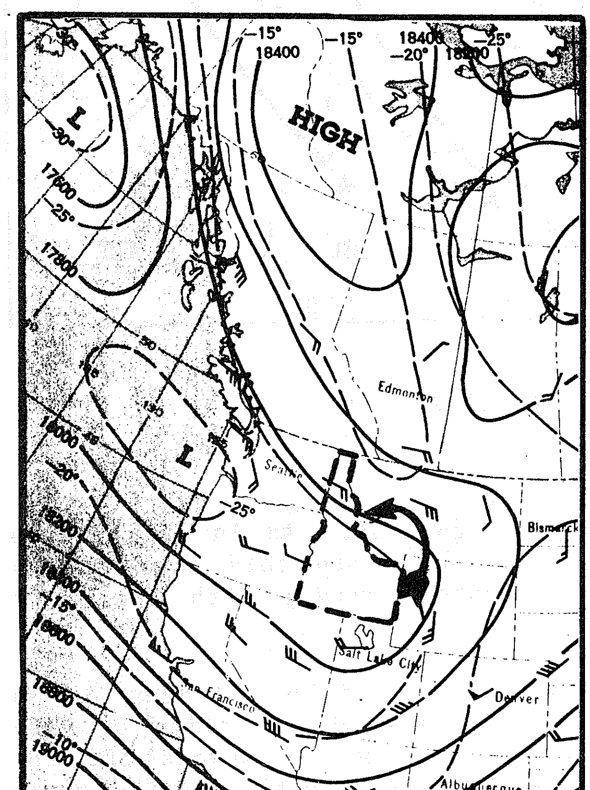
Figure 48.--Surface weather maps for May 17-20, 1957.



MAY 17, 500-mb (1830 Z)



MAY 18, 500-mb (1830 Z)



MAY 19, 500-mb (1830 Z)

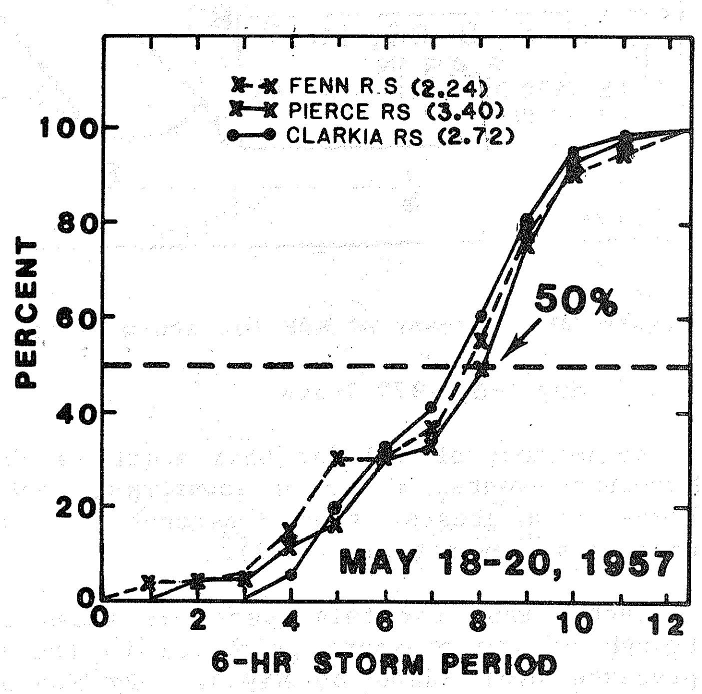


Figure 49.--500-mb charts for May 17-19, 1957, plus mass curves.

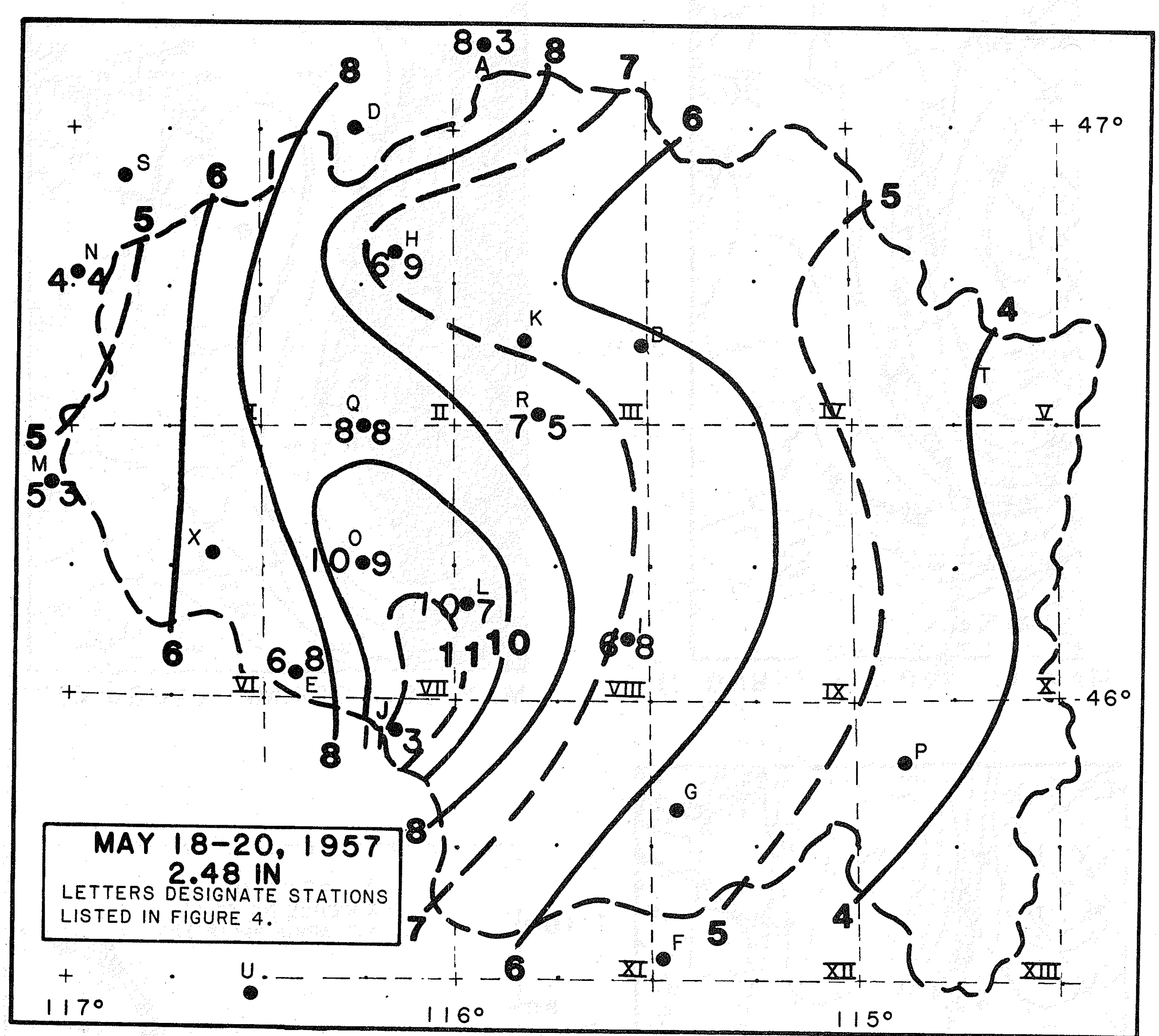


Figure 50.--Percent of MAP for storm of May 18-20, 1957.

4.3.5 May 4-6, 1979 Storm

The percent of MAP for this event is shown in Figure 54. As in many of the May-June events, a strong downstream centering occurred, in this case with a large area greater than 8 percent. This contrasts strongly with the major cool-season events (sec. 3.2).

Weather maps for this event are shown in Figures 55 and 56. A deep 500-mb trough of low pressure prevailed in the Gulf of Alaska with a ridge of high pressure over Idaho on May 4. By May 5, a 500-mb Low had formed off the Washington coast with the band of strong winds aloft moving south, causing winds aloft of Idaho to slowly back from westerly to near southwesterly. A trough aloft moving in the broadscale flow around the Gulf of Alaska Low moved across Idaho on May 6. Surface features associated with these changing conditions aloft

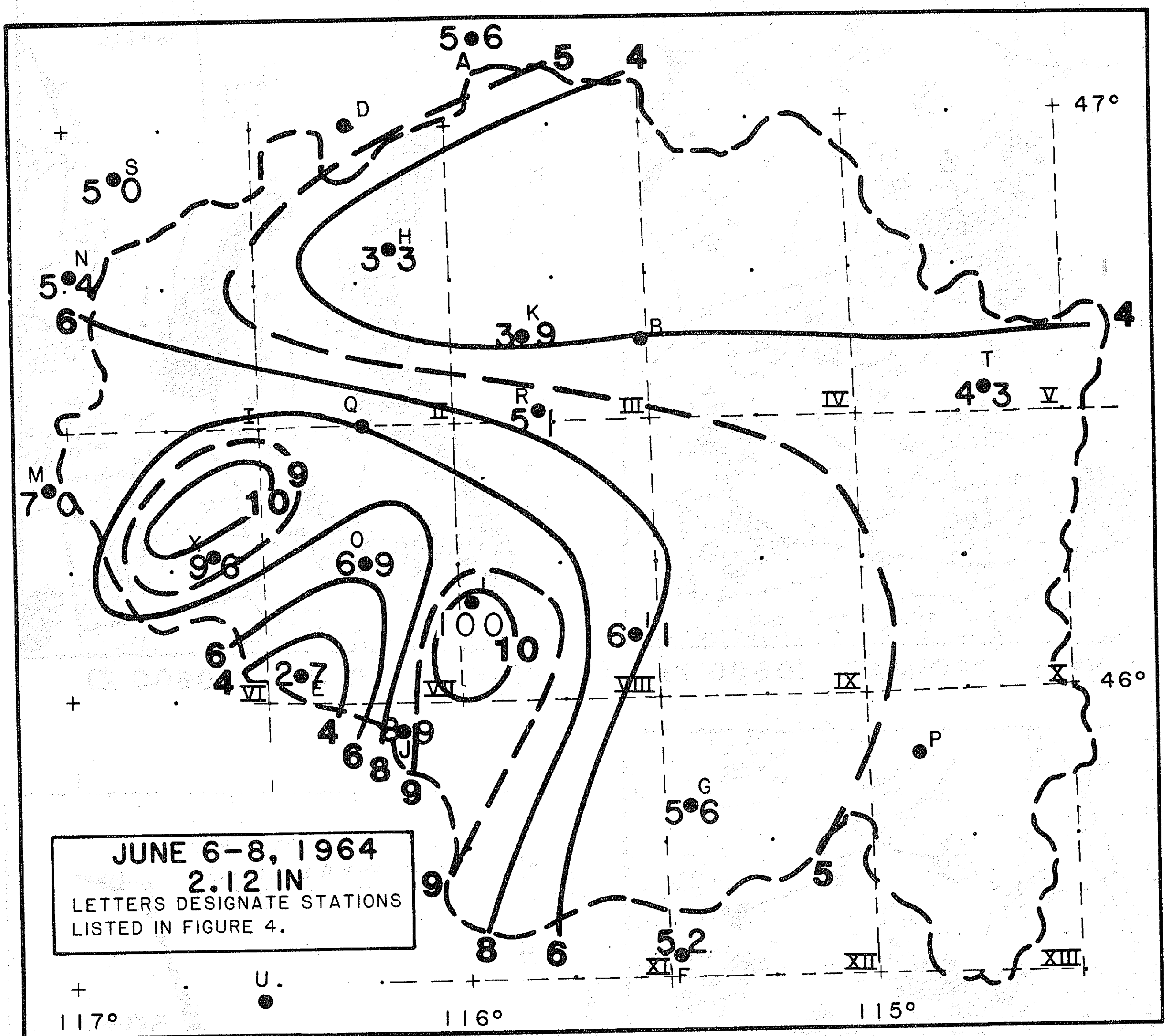


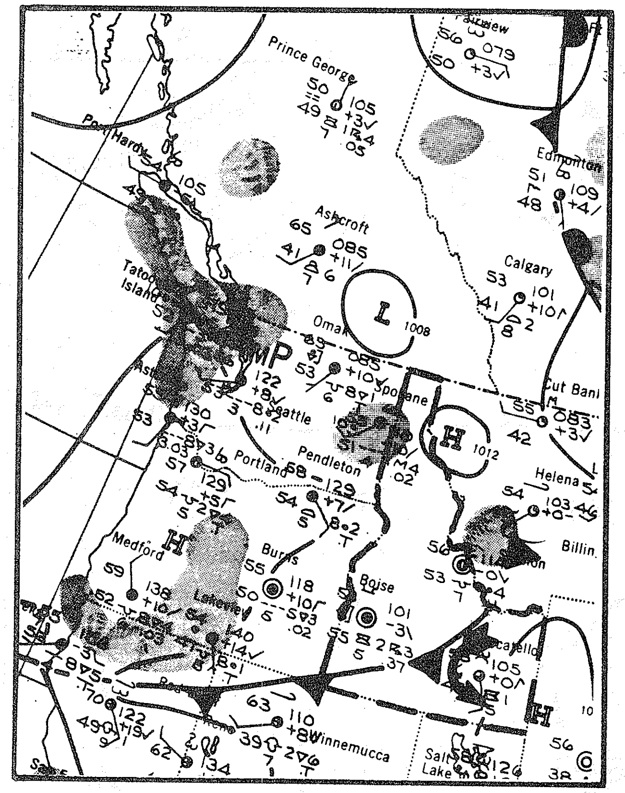
Figure 51.--Percent of MAP for June 6-8, 1964.

showed a deep offshore surface Low on May 5, followed by an "offshoot" Low and front moving eastward across Idaho on May 5 resulting in most of the precipitation on May 5 and into May 6. A characteristic (important for snowmelt temperature criteria) was the occurrence of below normal temperatures (see fig. 109), something common to most of the significant May-June 3-day events.

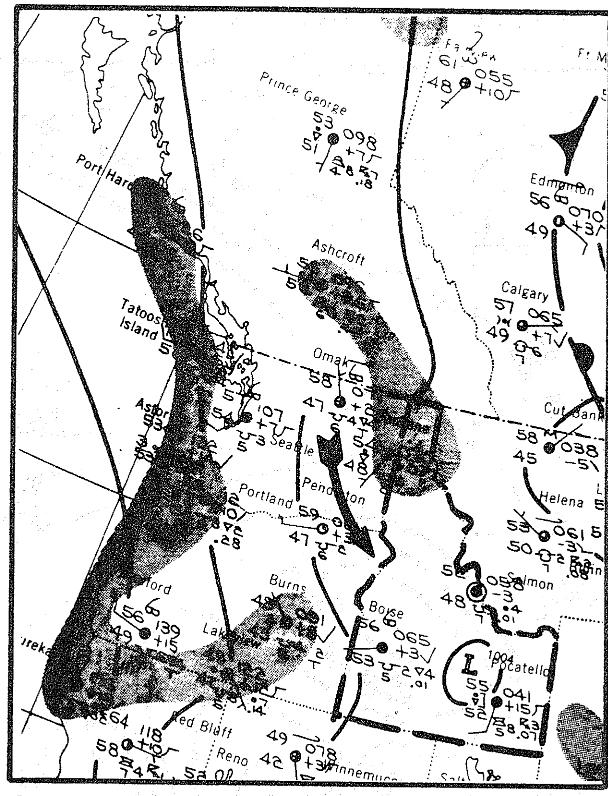
4.3.6 May 7-9, 1948 Storm

The main precipitation in this event was on May 8-9, with an important downstream concentration in percent of MAP. The percent of mean annual analysis is shown in Figure 57.

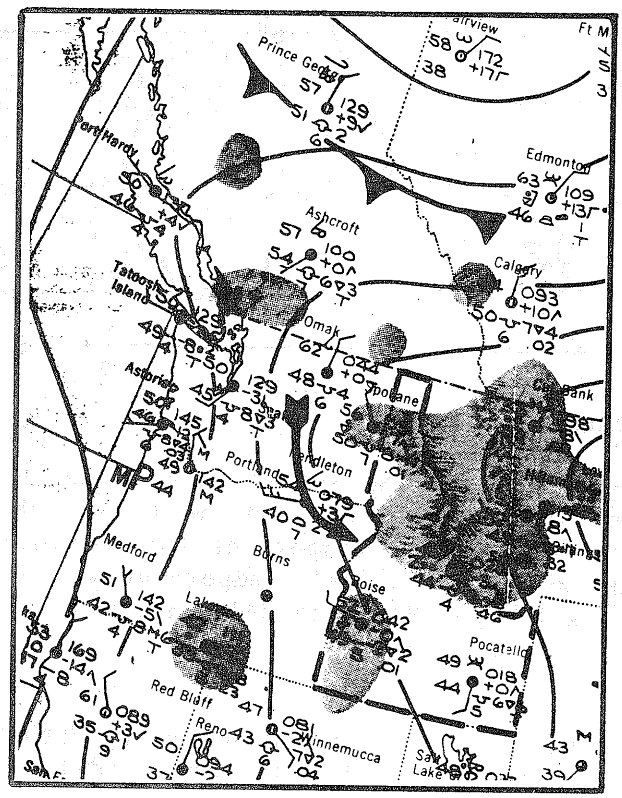
Figures 58 and 59 show the weather maps for this event. A complex surface Low over and south of the area on May 7 became better organized to the southeast with



JUNE 6, SFC MAP (0600 Z)



JUNE 7, SFC MAP (0600 Z)



JUNE 8, SFC MAP (0600 Z)

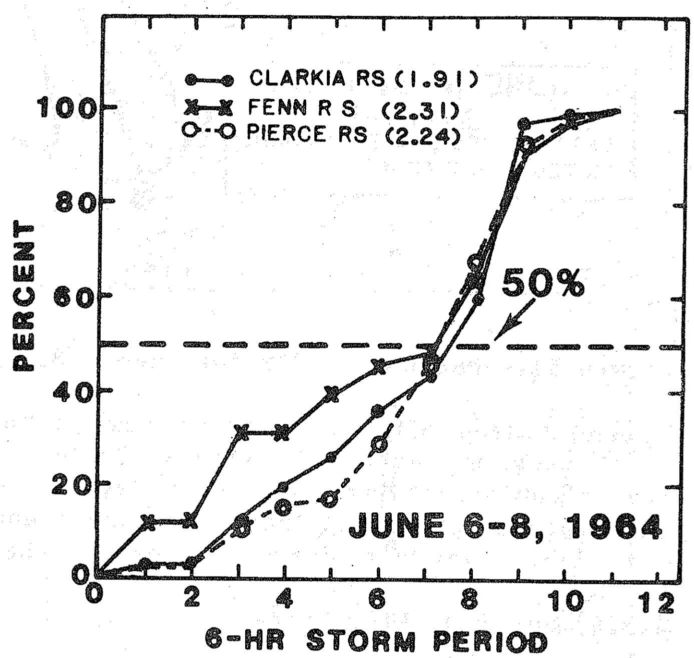
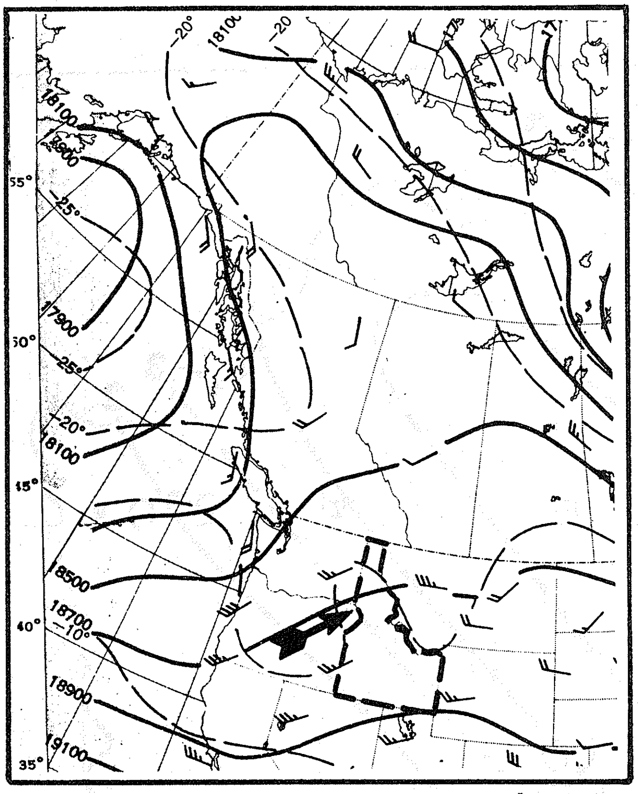
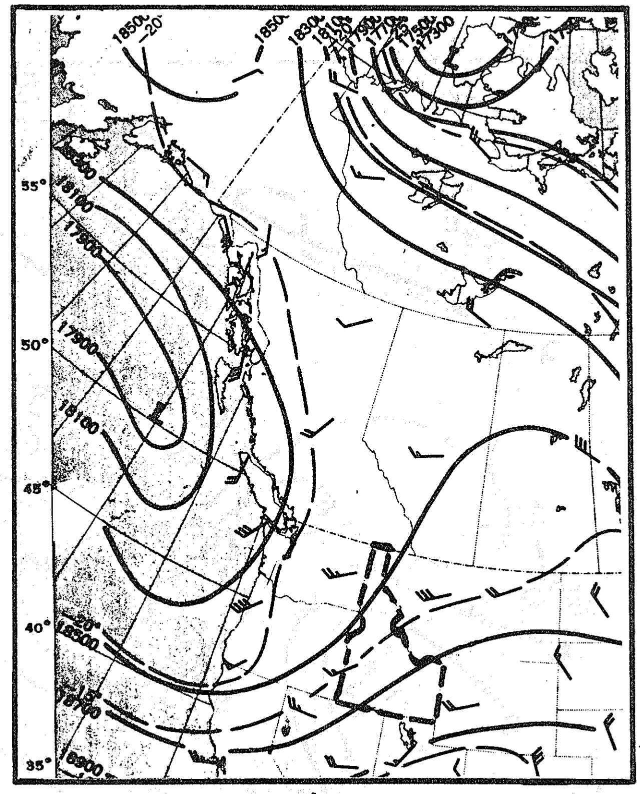


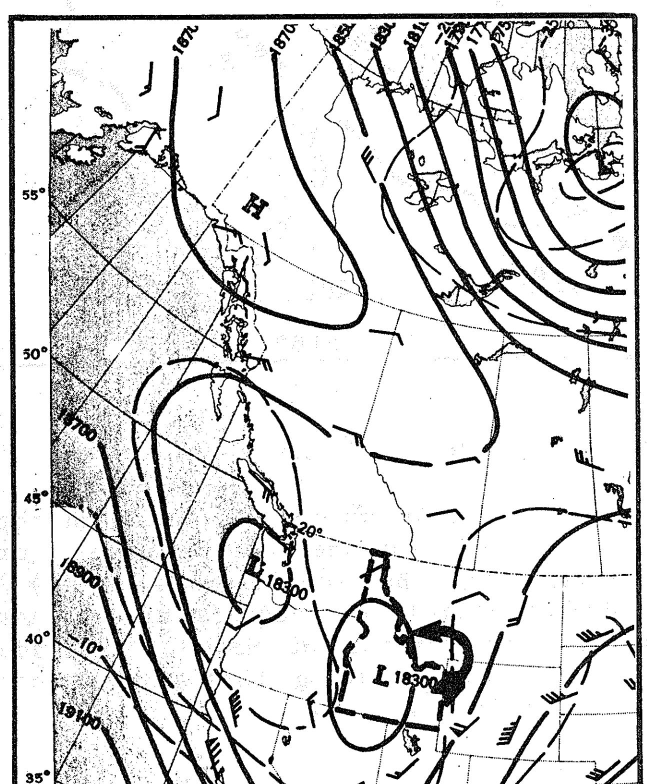
Figure 52.--Surface weather maps for June 6-8, 1964 (1:00 a.m. EST), plus mass curves.



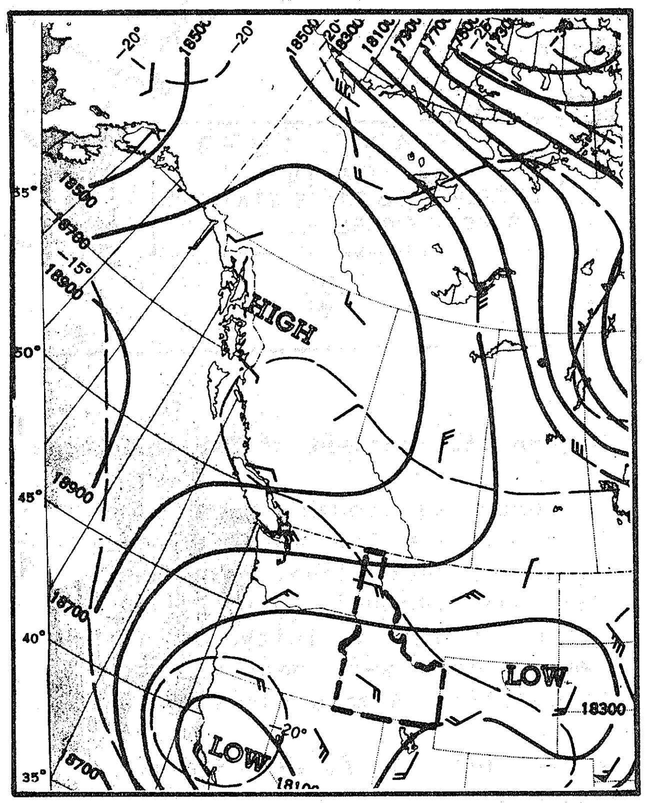
JUNE 5, 500-mb (1800 Z)



JUNE 6, 500-mb (1800 Z)



JUNE 7, 500-mb (1800 Z)



JUNE 8, 500-mb (1800 Z)

Figure 53.--500-mb charts (1:00 p.m. EST) for June 5-8, 1964.

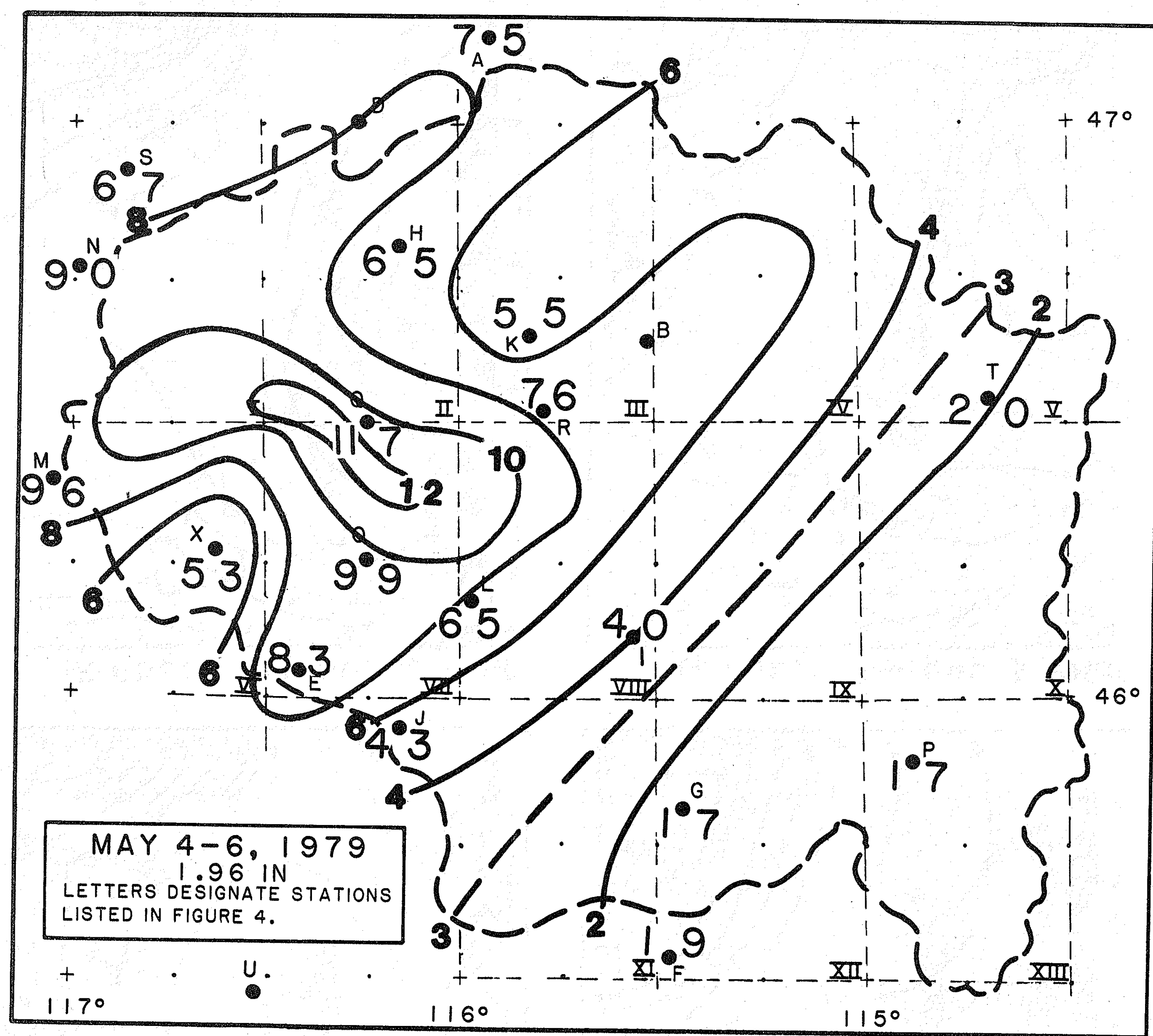
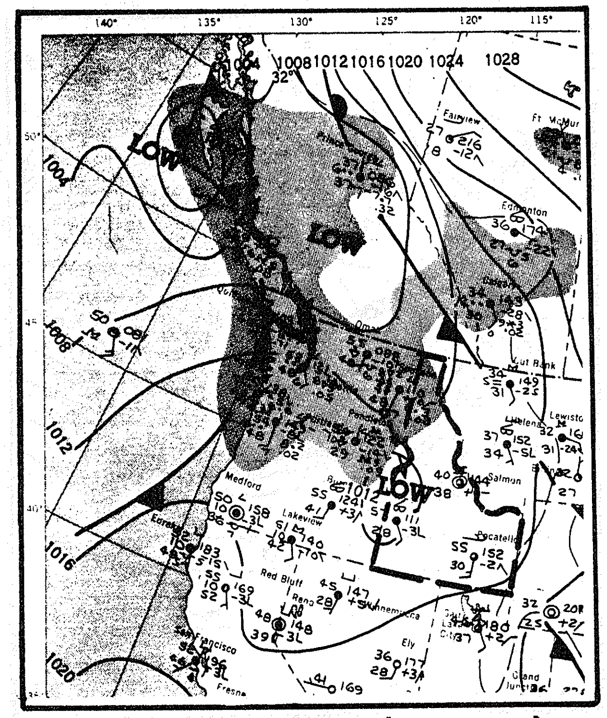


Figure 54.--Percent of MAP for storm of May 4-6, 1979.

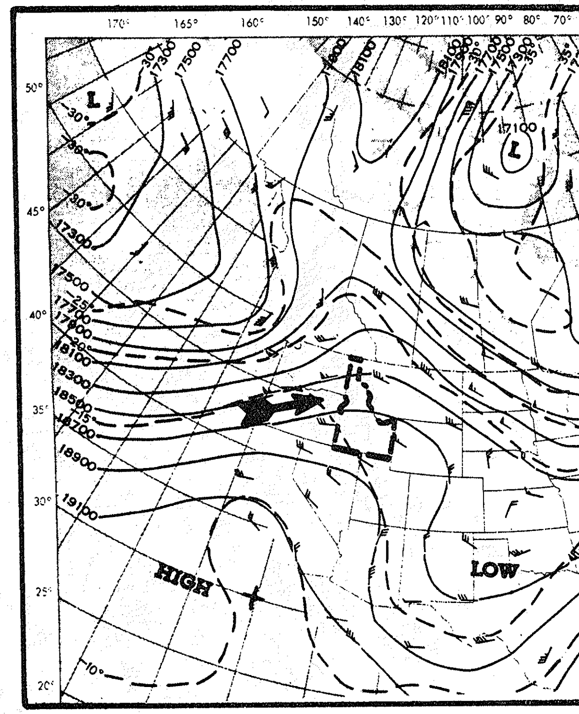
a pronounced trough extending to the northwest of Idaho on May 8. Although the main surface Low moved eastward on May 9, a weak surface Low persisted (or reformed) near Idaho. At 500-mb, a Low off Vancouver, British Columbia, on May 7 developed strongly toward the southeast with a closed low-pressure circulation aloft in the vicinity of Idaho forming by the morning of May 9. Surface temperatures were generally 8°F or more below normal during this storm event (fig. 107). A mass curve for this storm is shown in Figure 59.

4.3.7 June 15-17, 1956 Storm

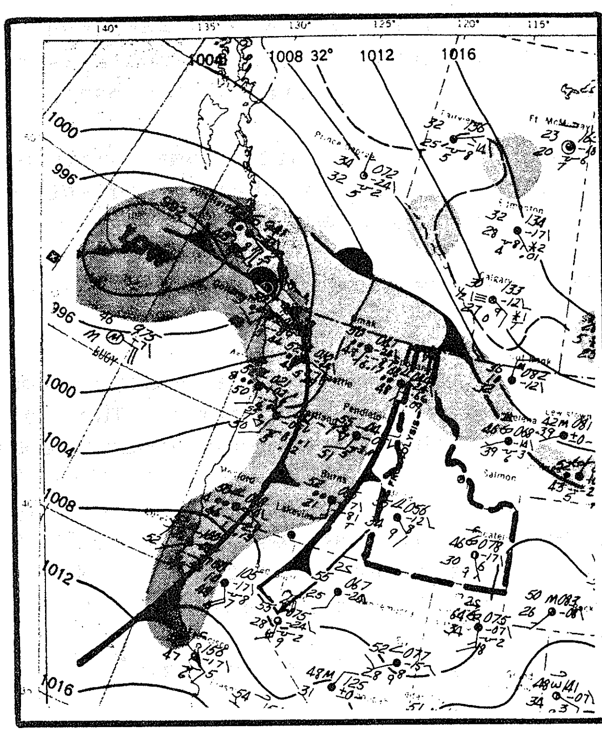
The basin-wide percent of MAP analysis for this storm is shown in Figure 60. Figures 61 and 62 show the weather maps. This event involved a closed Low that



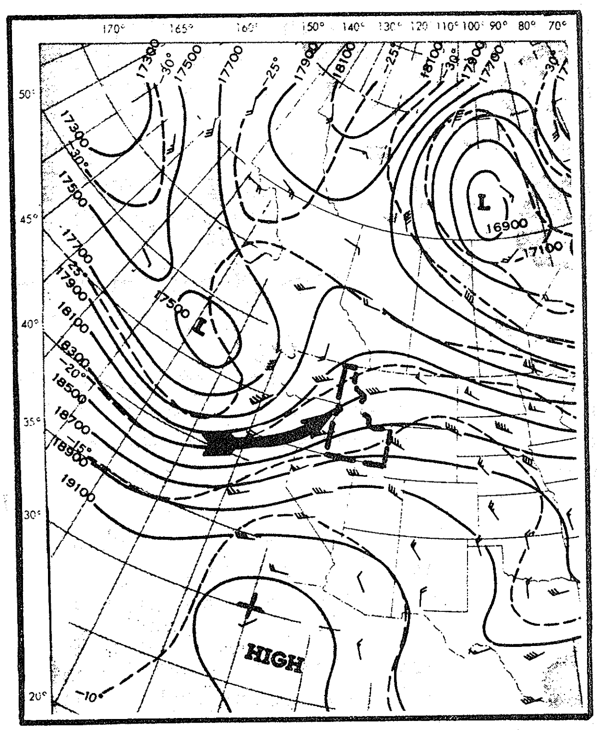
MAY 4, SFC MAP (1200 Z)



MAY 4, 500-mb (1200 Z)

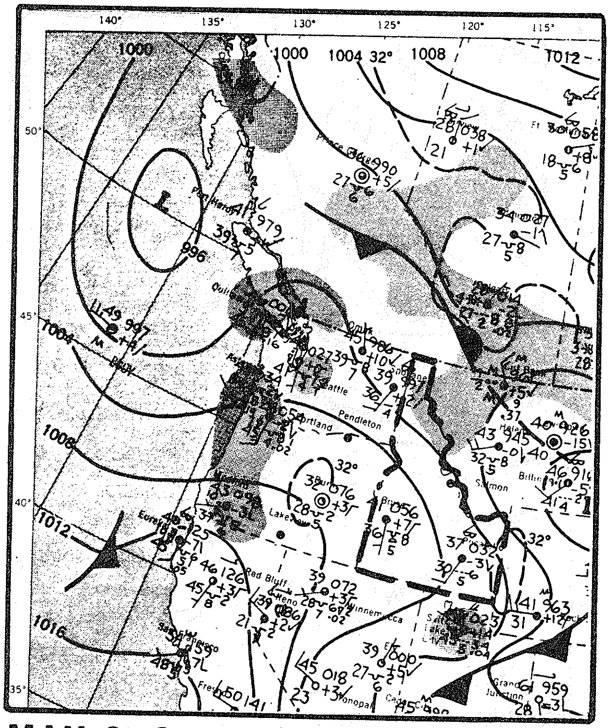


MAY 5, SFC MAP (1200 Z)

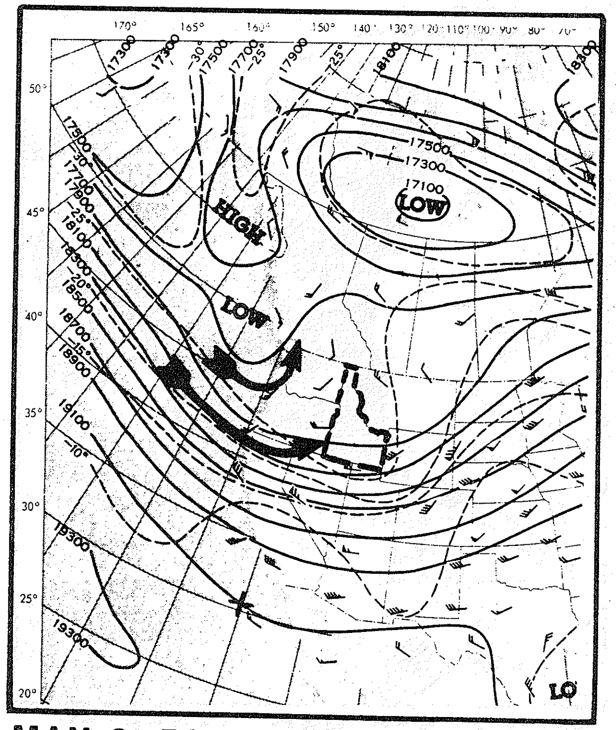


MAY 5, 500-mb (1200 Z)

Figure 55.--Surface weather maps and 500-mb charts for May 4 and 5, 1979.



MAY 6, SFC MAP (1200 Z)



MAY 6, 500-mb (1200 Z)

Figure 56.--Surface weather map and 500-mb chart for May 6, 1979.

moved across northern Idaho, but most of the precipitation concentrated on June 5, when southerly winds aloft combined with a surface Low that had a nearly northerly track across the western portion of Wyoming to the east of the basin.

The precipitation in this storm concentrated downstream with some locations receiving more than 13 percent of mean annual values. A sharp gradient of precipitation was likely indicative of the role played by instability.

4.4 Significance of Meteorological Features Shown in Major 3-Day May-June Events

Considering the meteorological features of the major May-June events, some marked contrasts with the major cool-season events were evident. The main contrasts in the May-June major events compared to the major cool-season events were:

1. There is less consistency in the meteorological features in the May-June events. In other words, a greater variety of meteorological sequences are involved in the May-June events.

2. Above normal temperatures do not typify May-June events. Rather below normal temperatures are the rule.

3. Conditions conducive to significant precipitation take longer to evolve in the May-June case.

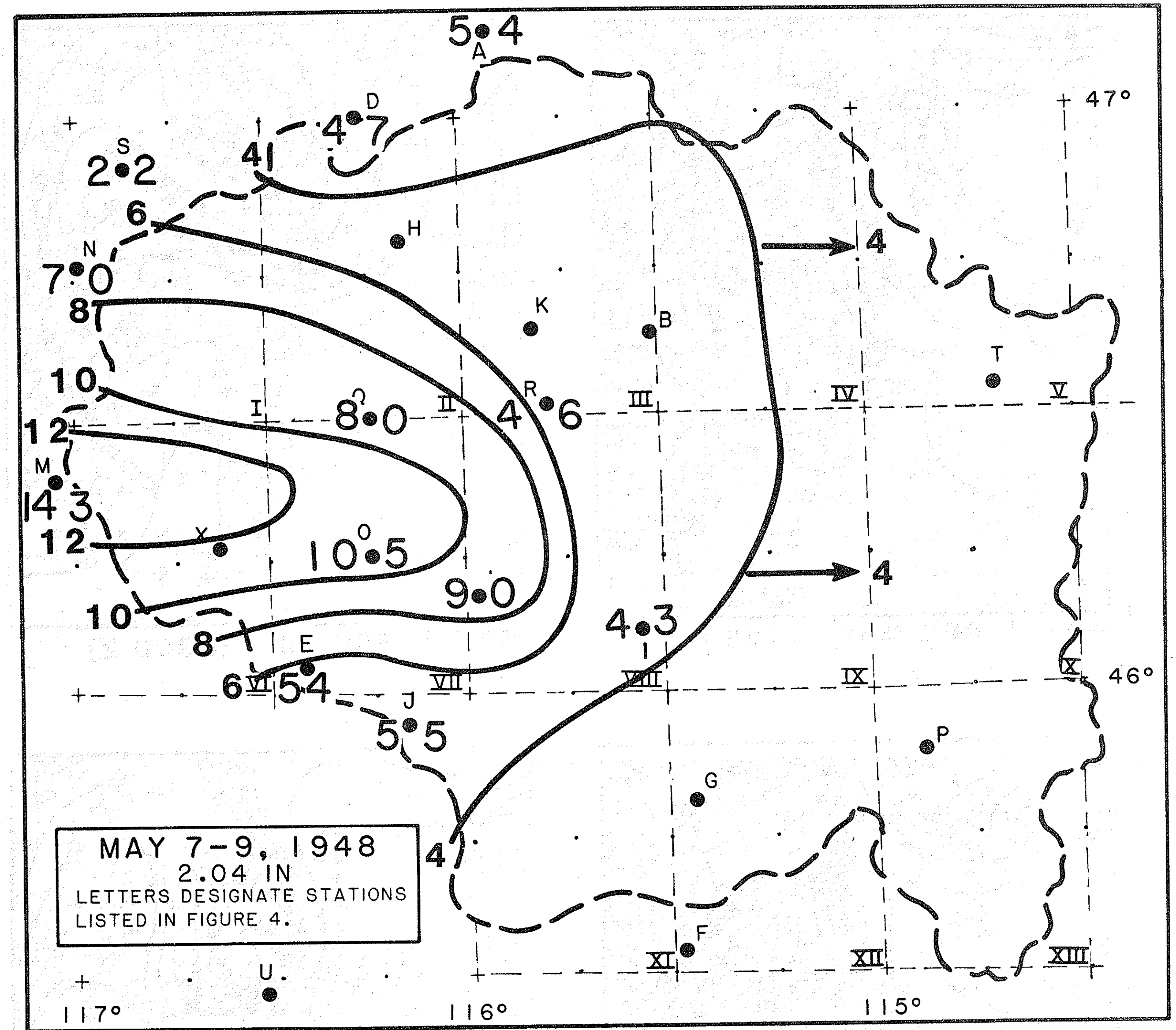


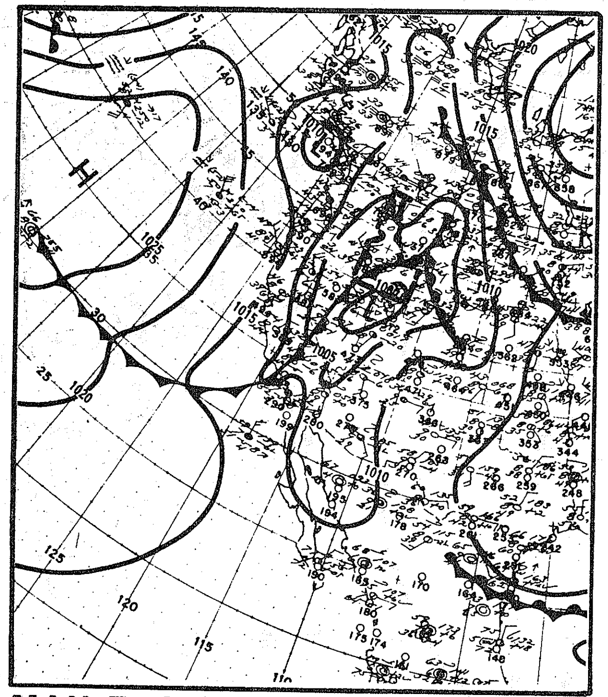
Figure 57.--Percent of MAP for storm of May 7-9, 1948.

4. The combinations of meteorological features in May-June events of consequence occur with moisture values well below maximum.

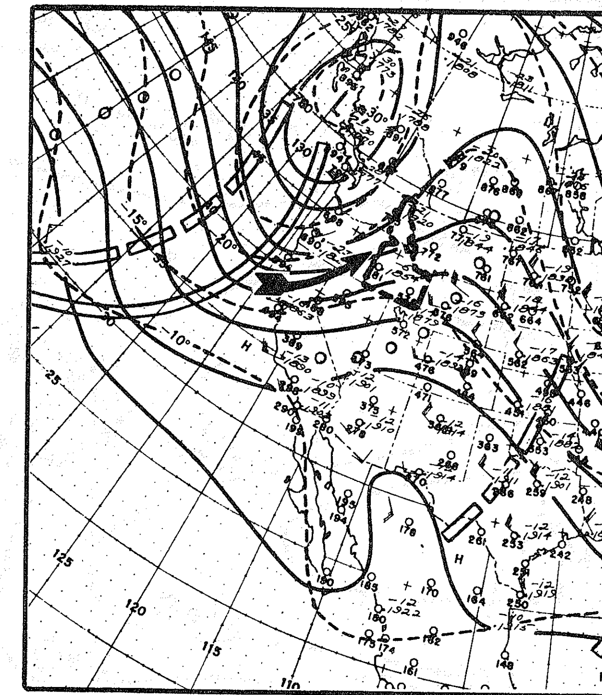
5. SPS CLEARWATER ESTIMATES BASED UPON REGIONALLY - SIGNIFICANT NORTHWEST STATES STORMS FOR DEVELOPING A "HYPO-SNAKE" 3-DAY EVENT

5.1 Introduction

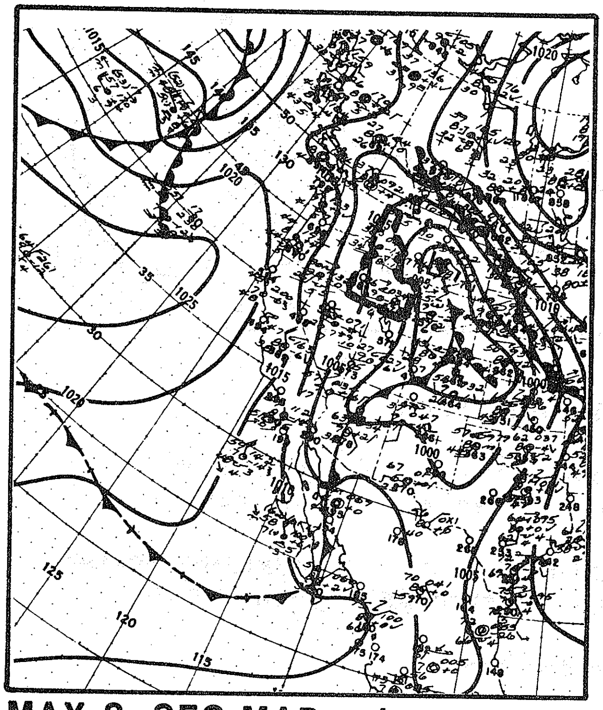
Unlike the southwest States generalized PMP study HMR No. 49 (Hansen et al. 1977), the northwest States generalized PMP study, HMR No. 43 (U.S. Weather Bureau 1966), cautions the user (for areas east of the Cascades) against extrapolation of the procedures beyond drainage area sizes of 1,000 mi^2. Among other shortcomings, seasonal variations of a complicated nature are applicable to small areas as one moves eastward toward the Continental Divide, but the large



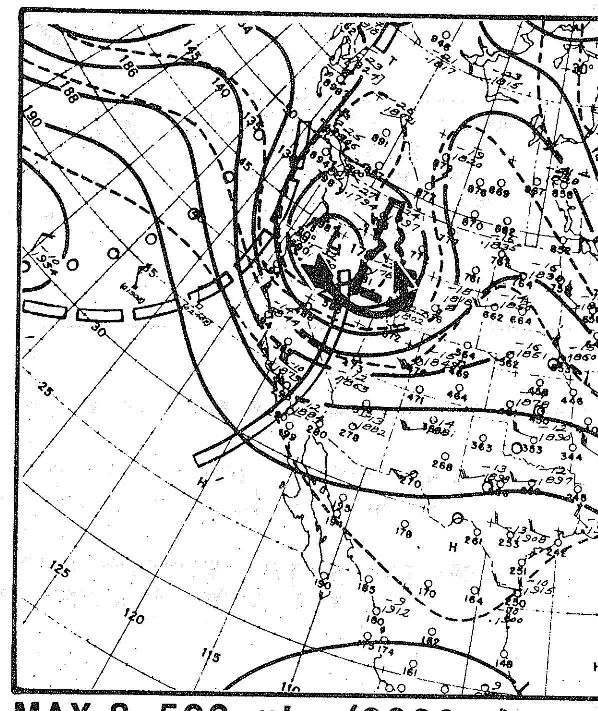
MAY 7, SFC MAP (1230 Z)



MAY 7, 500-mb (0300 Z)



MAY 8, SFC MAP (1230 Z)



MAY 8, 500-mb (0300 Z)

Figure 58.--Surface weather maps (7:30 a.m. EST) for May 7 and 8 and 500-mb charts (10:00 p.m. EST) for May 7 and 8, 1948.

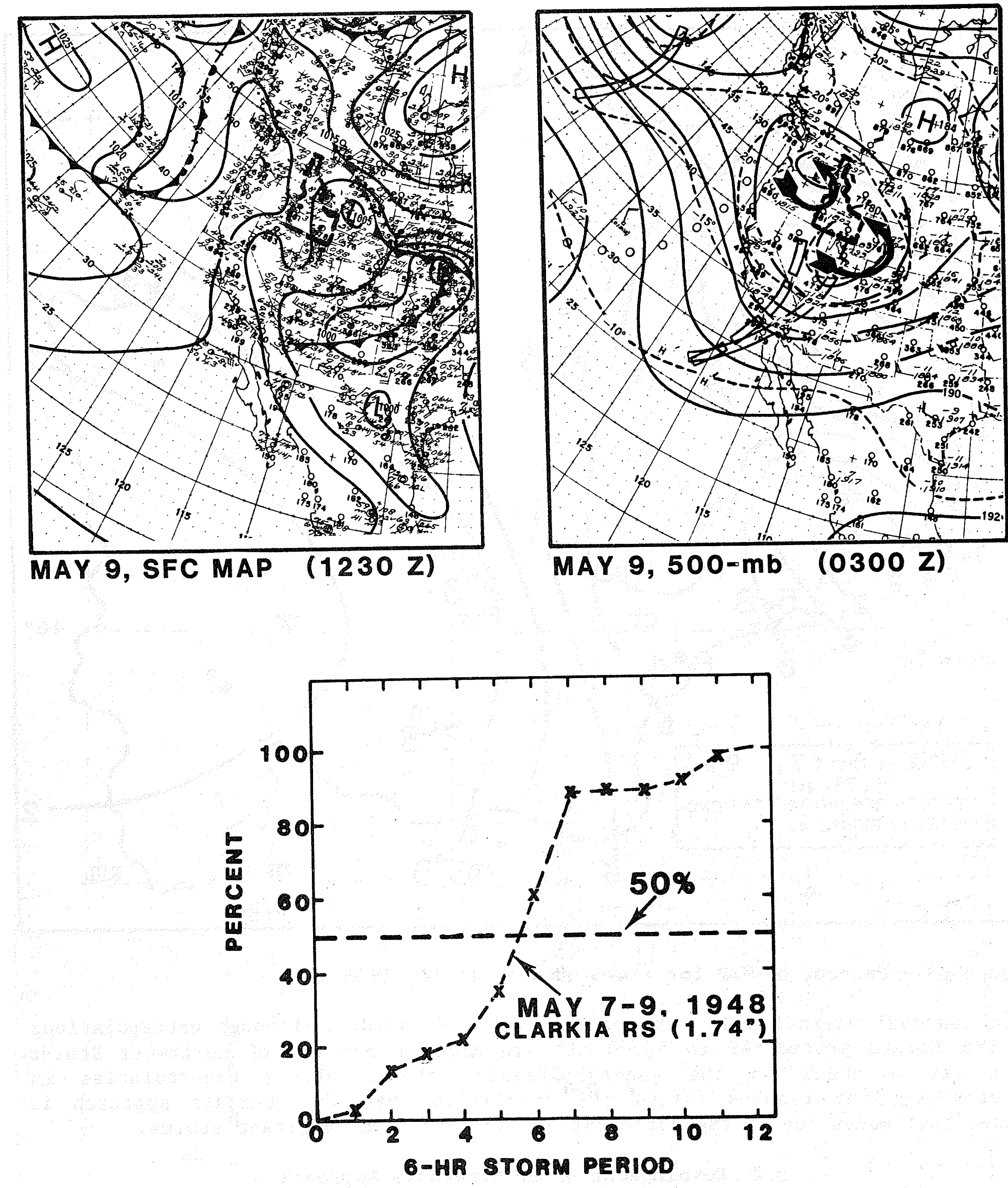


Figure 59.--Surface weather map and 500-mb chart for May 9, 1948 and mass curve of rainfall for Clarkia R.S.

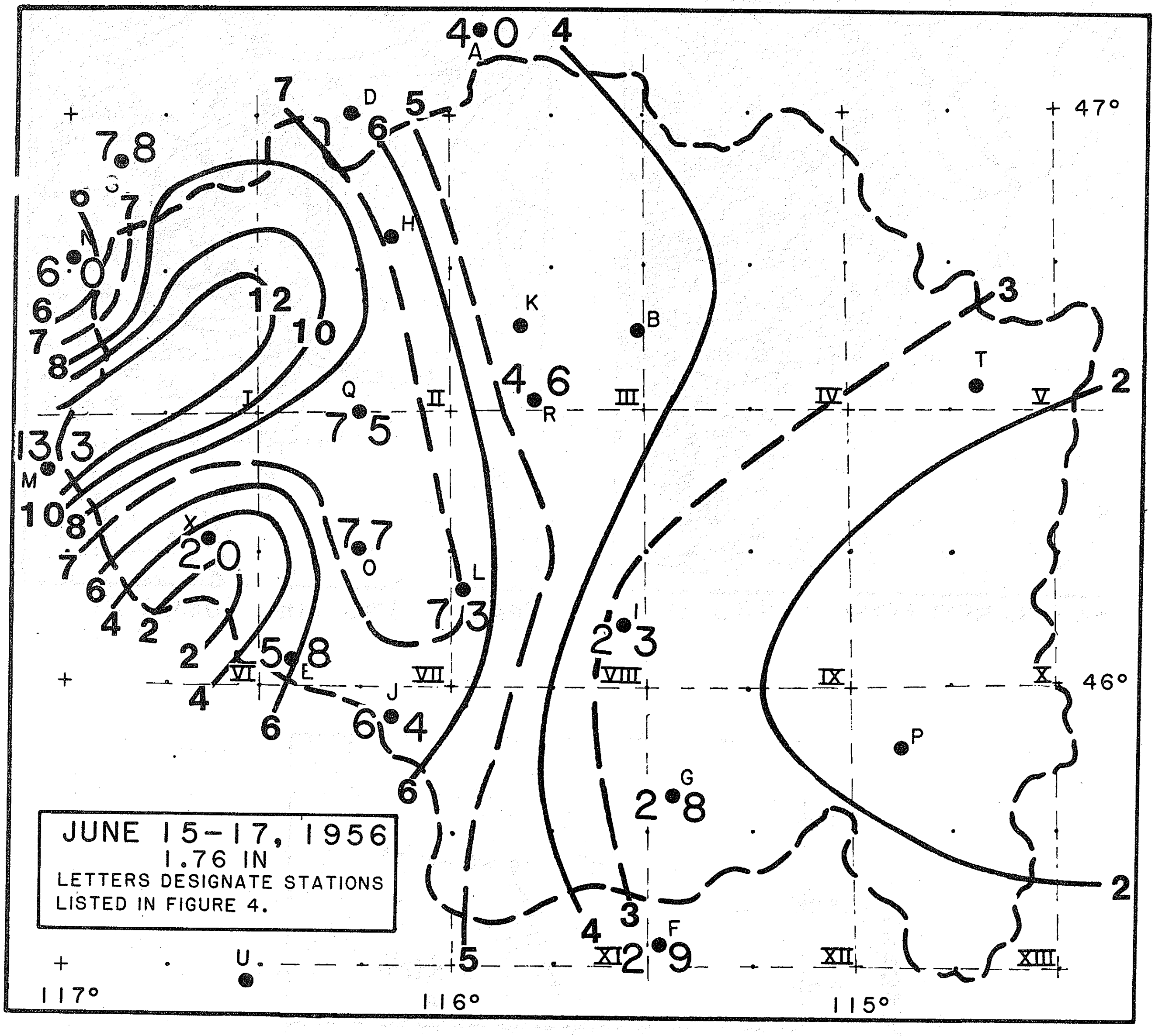
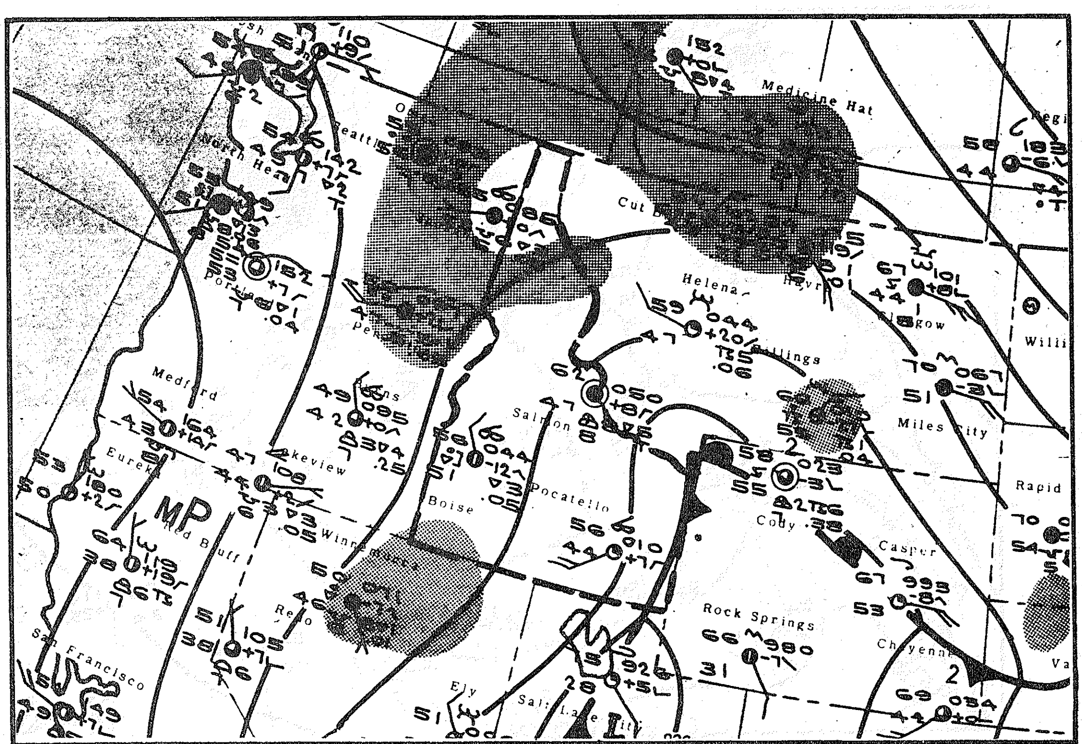


Figure 60.--Percent of MAP for storm of June 15-17, 1956.

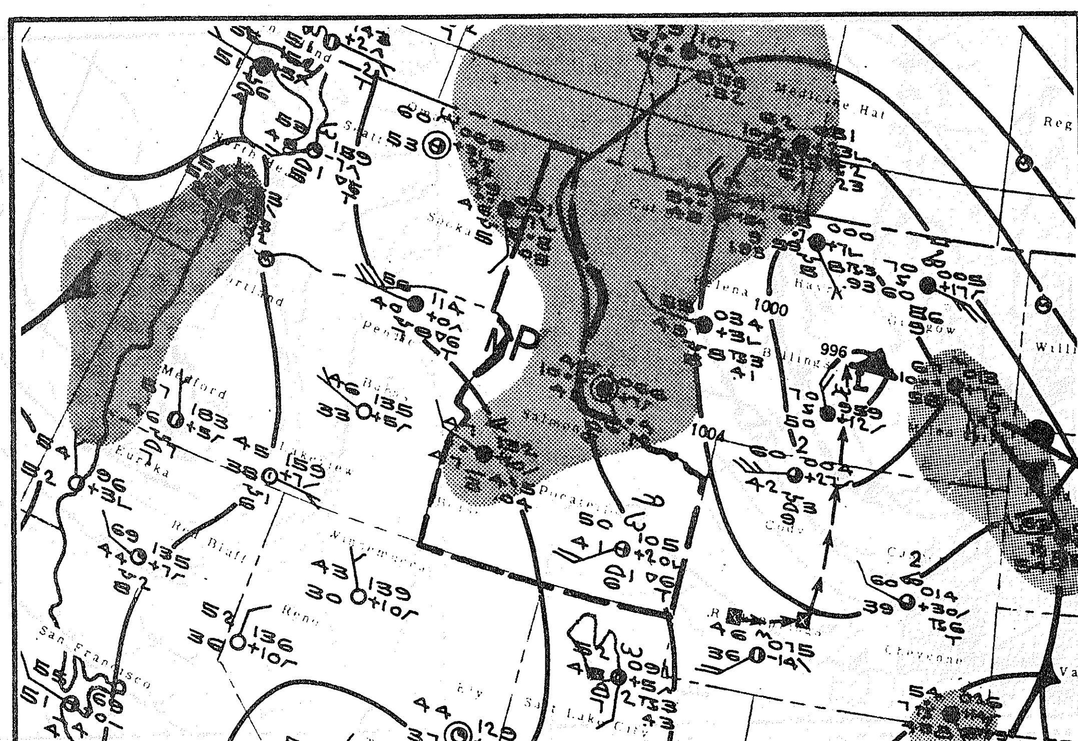
area seasonal variation is not specifically addressed. Although extrapolations of HMR No. 43 procedures to 5,000 mi^2 are made as one use of northwest States data (as a check on the general level), the resulting uncertainties in interpreting the results forces the conclusion that an alternate approach is needed that makes use of the northwest States data from important storms.

5.2 Development of an Alternate Approach

Discussions with personnel of the Walla Walla District Office of the U.S. Army Corps of Engineers at the early onset of this project resulted in emphasizing the importance of an out-of-the-ordinary downstream centered event for significant major cool-season runoff. This event should occur with a significant snowcover, especially over lower elevation downstream portions of the basin. A rainstorm, centered downstream farther than most of the major 3-day cool-season

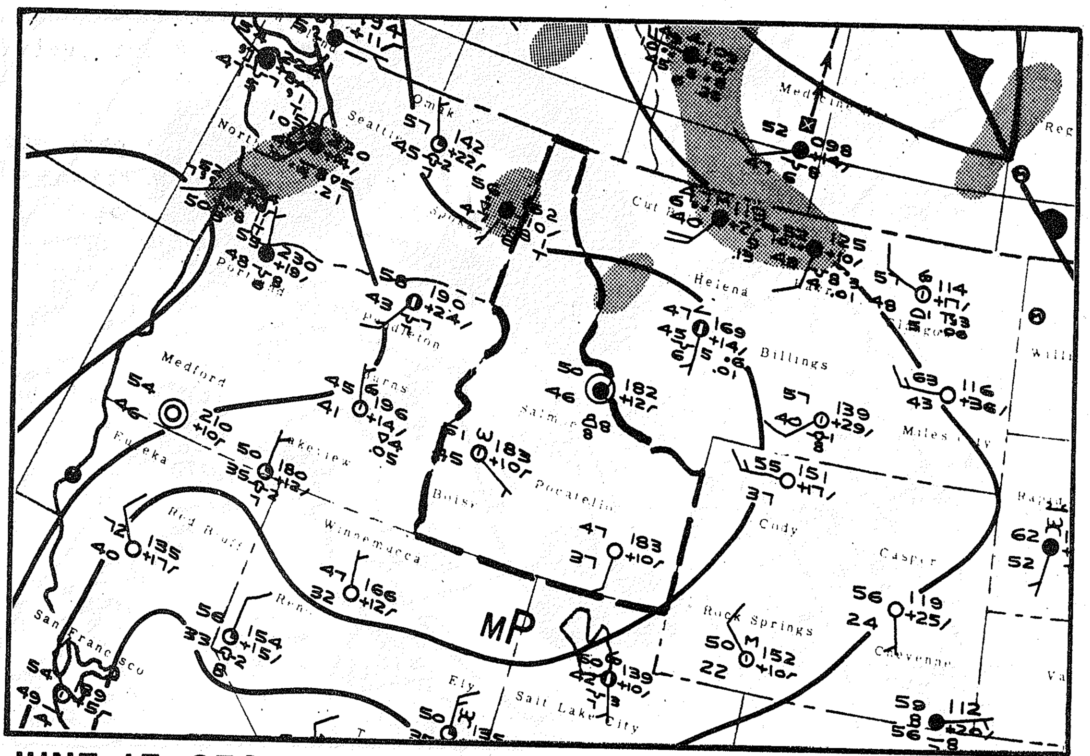


JUNE 15, SFC MAP (0630 Z)

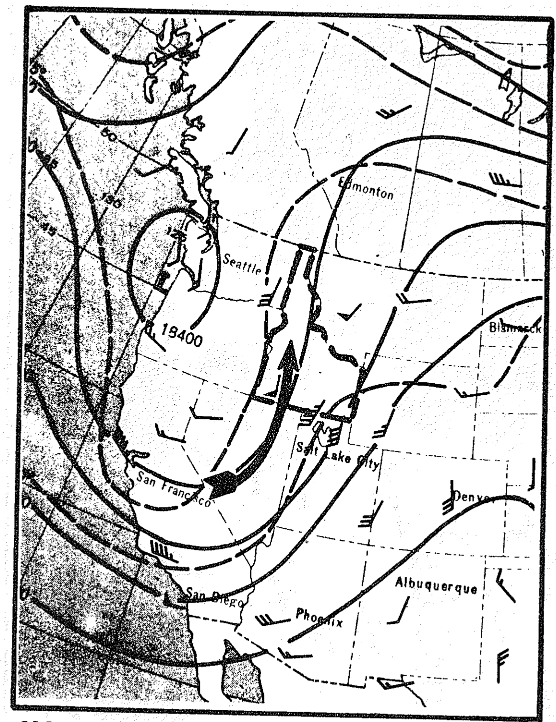


JUNE 16, SFC MAP (0630 Z)

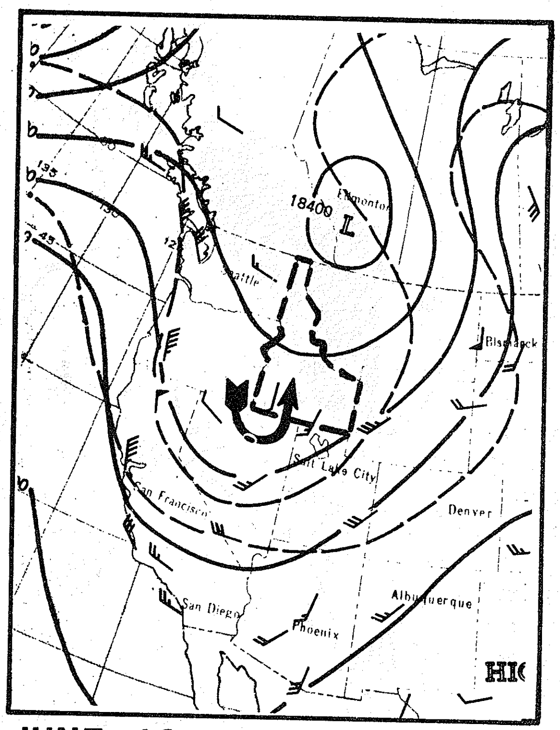
Figure 61.--Surface weather maps for June 15 and 16, 1956.



JUNE 17, SFC MAP (0630 Z)



JUNE 14, 500-mb (0300 Z)



JUNE 16, 500-mb (0300 Z)

Figure 62.--Surface weather map for June 17, 1956 and 500-mb charts for June 14 and 16, 1956.

precipitation events occurs with substantial mild, moist air influx that produces rapid snowmelt. An SPS 3-day event of this type was required for full evaluation of various hydrologic events for the basin to be determined.

This alternate method is related to northwest States storm experience and ties strongly into the regionally-characteristic extreme storm portion of the SPS definition (U.S. Army Corps of Engineers 1965). In the primary basin 3-day event direct method I, the statistical extrapolation of the surveyed record of storms that have occurred over the basin to return periods measured in hundreds of years is one way to get at the regionally characteristic portion of the definition. Here, in this alternate method, we get at the regionally characteristic idea by "zeroing-in" on significant interior northwest States storms that have occurred in other locations. These storms are selected from regions not too far distant from the basin.

Following the convention of emphasizing the percent of MAP approach of method I, the major 3-day storms of the interior northwest States region were assessed in this manner. The purpose in mind was to synthesize an idealized regionally characteristic SPS storm for downstream centering in terms of an idealized synthesized (since no single storm adequately details this event by itself) percent of mean seasonal pattern.

5.3 Storm Control

A review of large-area MAP for northwest States interior cool-season storms resulted in the selection of 3 storms based upon having large percents of MAP over various area sizes and being close enough to the Clearwater basin with orographic controls compatible with the Clearwater drainage. An idealized "Hypo-Snake" precipitation pattern resulted from a synthesis of the 3 storms, the name deriving from the important role played by the November 21-23, 1909 Rattlesnake, Idaho storm. The 3 storms are:

1. November 21-23, 1909

2. November 19-21, 1921

3. March 31 - April 2, 1931

The generalized 3-day isohyetal pattern of the 1931 storm is shown in percent of MAP as Figure 63. The analysis shows the precipitation concentrated a little to the north of the approximate 4,000-ft generalized elevation contour of the Blue Mountains. The other 2 storms that played roles in the "Hypo-Snake" pattern (November 1909 and November 1921) concentrated their rainfall in and near the Sawtooth Mountains, north and east of the Boise, Idaho area. Thus, all 3 storms were reasonably close to the Clearwater, but the main precipitation was intercepted by upwind mountainous terrain in relation to the Clearwater River drainage. The proximity and the general range of MAP at the locations of these storms put them in the realm of extreme events regionally characteristic of the Clearwater basin and environs.

The 3-day precipitation patterns of these storms, in percent of MAP, were planimetered to determine enveloping storm area control for the purpose of synthesizing a "Hypo-Snake" event.

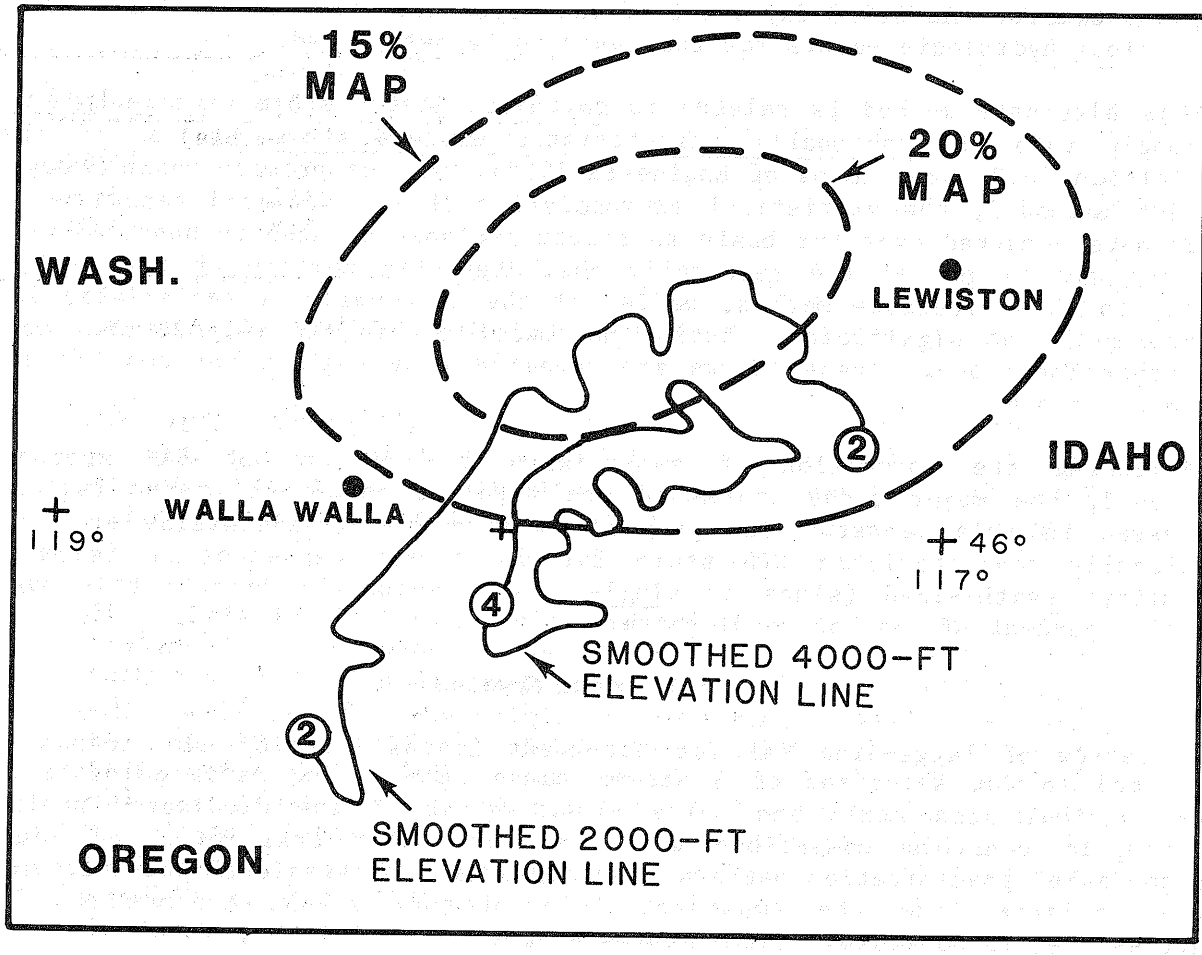


Figure 63.--Isohyetal pattern of March 31-April 2, 1931 storm as percent of MAP.

Table 2 summarizes the area (in square miles) controlled by various encompassing percent of MAP isohyetals.

5.4 Development of "Hypo-Snake" Pattern

The more important conclusions and working assumptions for development of the "Hypo-Snake" pattern are:

1. The approximate 1,000- to 2,000-mi^2 area control by the 20 percent of MAP area, typical of the regionally-characteristic storms was just slightly enveloped in the idealized pattern. This choice also is in line with downstream significant midwinter precipitation, plus a significant snowmelt contribution from the downstream area.

2. Most of the regionally characteristic large storms have had significant precipitation over rugged terrain, but near a region where upstream there is a Plains area of relatively low elevation. In these Plains areas, moisture can attain greater depth due to lack of high elevation and interference from

Table 2.--Summation of area covered by various percent of MAP isohyetals in 3 major northwest interior storms

Storm	Percent MAP 25	20	15	10
	Area (square miles)			
11/21-23/09	432	1897	5627	9872
11/19-21/21		1357	3455	2691
3/31-4/2/31		1040	7512	12074

terrain. Transposition to the Clearwater possibly represents, therefore, some slight maximization.*

3. The 72-hr 10-mi^2 precipitation in the Rattlesnake storm was 10.2 in. (U.S. Army Corps of Engineers 1945-). This is maximized somewhat in the idealized pattern based upon a smooth enveloping depth-duration curve that allows for a true 3-day event.

The slight enveloping feature requires some explanation. It was considered quite important to evolve an idealized "Hypo-Snake" pattern considered appropriate to SPS condition for maximizing downstream precipitation. To do this, the observed small 120-hr 50-percent of MAP center of the Rattlesnake storm has used as a basis for determining appropriate percent of MAP values for a 72-hr duration. (In the actual Rattlesnake storm, a substantial break in precipitation occurred after 2 days so that in the idealized version, a realistic extension of a 2-day event to a 3-day event is needed.) In addition, the point maximum percent of MAP was considered applicable (with duration adjustment to 72 hr) to areas of a few hundred square miles.

4. The November 21-23, 1909 and the November 19-21, 1921 storms represented broadscale synoptic events that also produced (with some time adjustments) important storm precipitation west of the Cascades. Thus, except for severe moisture depletion (through depth) by the Cascade Mountain range, important west of Cascades and east of Cascades cool-season storm events are not dissimilar, at least in regard to broadscale precipitation-producing and precipitation-enhancing mechanisms moving generally eastward in the mid-latitude westerly belt.

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* After providing input to the selection of appropriate SPS level of precipitation, the volume of the precipitation by placement of the "Hypo-Snake" pattern over the basin, is reduced 7 percent (see sec. 5.6)

5.5 "Hypo-Snake" Precipitation Profile

Figure 64 shows the adopted "Hypo-Snake" precipitation profile curve with supporting data. For areas larger than an area of approximately 2,000 to 2,500 mi^2, the idealized curve approximately follows the mean of the basic 3 storms, while at the 20-percent (or approximately 2,000-mi^2 area) point the main unadjusted storm data is slightly enveloped. The shaping for smaller areas is consistent with the large percent of MAP observed in the Rattlesnake storm for small areas (see previous discussion under item 3, sec. 5.4).

The adopted precipitation profile shown in Figure 64 is for an "idealized" circular precipitation pattern, appropriate and not unrealistic for a downstream centering on the Clearwater drainage.

5.6 Idealized Isohyetal Pattern

The idealized circular pattern, centered about 8-10 mi south of Orofino is shown superimposed on the Clearwater basin in figure 65. The isohyetals are in percent of MAP. The average basin precipitation resulting from this idealized "Hypo-Snake" 3-day precipitation pattern is 5.37 in, computed as in 3-day event survey using percent of MAP over 13 sub-areas of the total 9,520-mi^2 drainage. For the critical size areas at least, the March-April 1931 storm (at least by usually accepted standards) is independently equated to an approximate SPS level storm as indicated from the data on page 216 of HMR No. 43 (U.S. Weather Bureau 1966) where the 1,000-mi^2 value equals 56 percent of PMP. The 5.37 in. basin-wide "Hypo-Snake" value is compared with results of various methods presented in this report to aid in selection of an appropriate level for 3-day basin-wide SPS precipitation. The idealized pattern, in inches, applicable to November 15 is shown in Figure 66. Following the recommended adoption of an SPS 3-day basin value of 5.0 in, (chapt. 8) the original "Hypo-Snake" pattern (which gave 5.37 in.) was reduced 7 percent, so Figure 66 gives valid SPS-level November 15 values. See section 5.8 for more detailed discussion of this reduction.

5.7 Month of Applicability

Since the idealized "Hypo-Snake" storm, like its underpinning counterpart, the Rattlesnake Idaho storm of November 1909, obviously has greater than normal storm precipitation over area sizes measured in hundreds of square miles likely due to greater than normal storm low level convergence and instability, it is not reasonable to allow the occurrence of such storms throughout the cool-season without adjustment for moisture (and, likewise, instability).

Because of the likely strong paralleling of increased instability with increased low level moisture in November, the recommended adjustment is based upon the precipitable water associated with maximum mid-month 12-hr persisting dew points. Because the monthly "pairs" of January-February and December-March each have almost identical dew points (Hansen and Schwarz 1981), a single adjustment (i.e., 0.85) suffices for January and February and likewise a single adjustment (i.e., 0.80) suffices for both December and March, all based upon November being set equal to 1.00. An adjustment curve for the "Hypo-Snake" event with January-February equaled to 100 percent, is shown in the Applications Chapter (fig. 115).

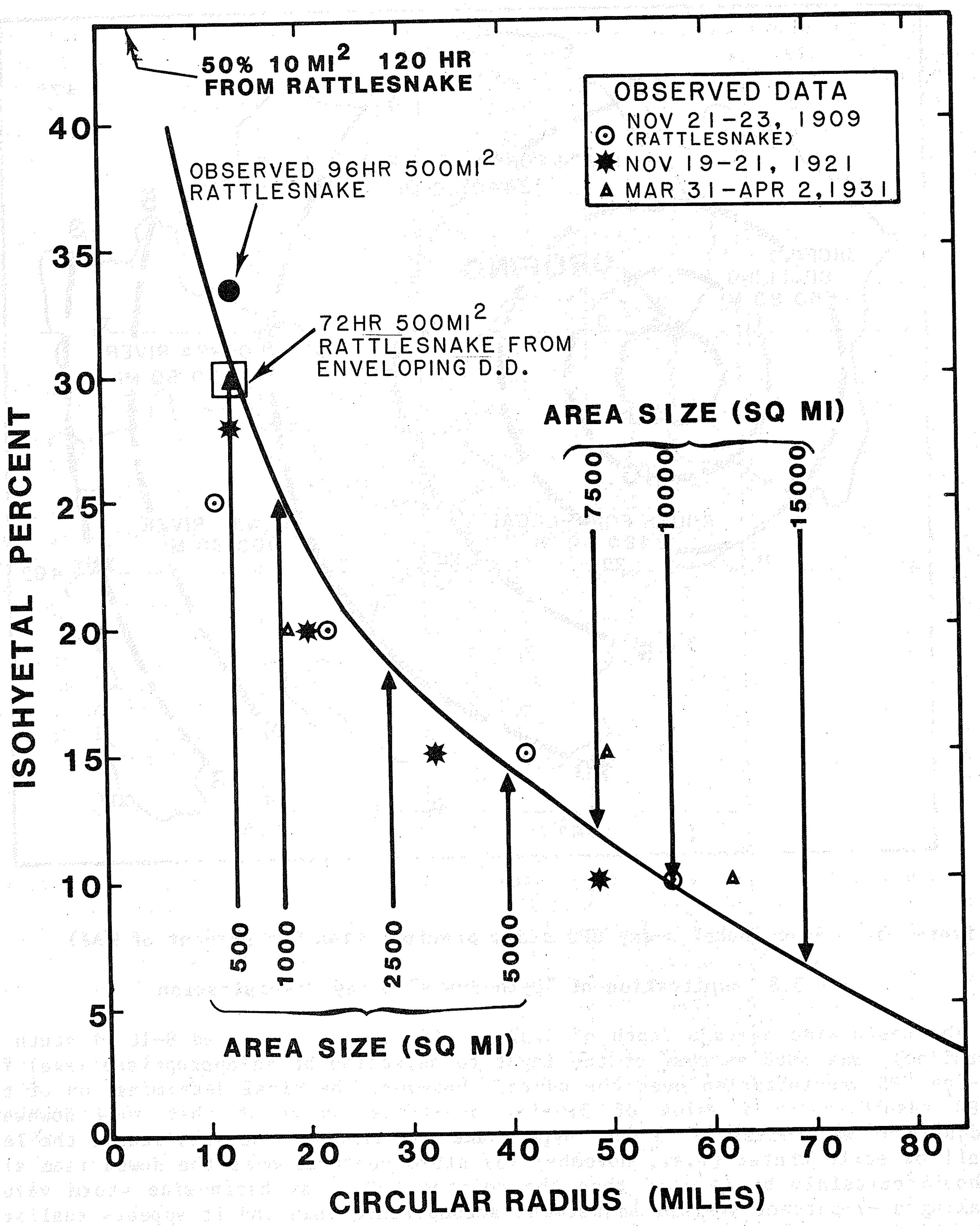

Figure 64--"Hypo-Snake" adopted 3-day precipitation profile.

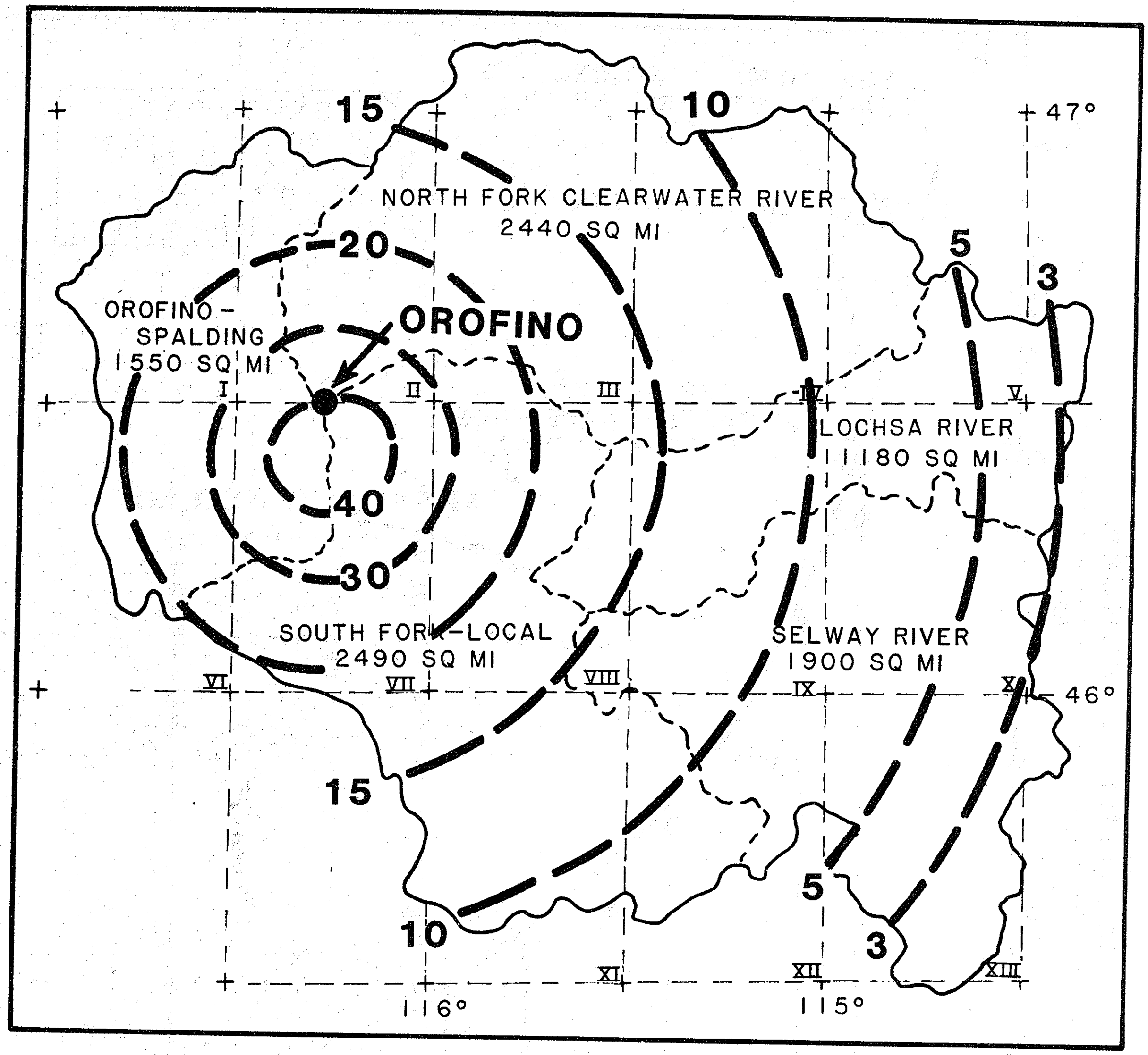

Figure 65.--"Hypo-Snake" 3-day SPS storm precipitation (in percent of MAP).

5.8 Application of "Hypo-Snake" 3-Day Precipitation

The basin-wide average depth of 5.37 in. (from fig. 65 placed 8-10 mi south of Orofino), was used as some of the input to selection of an appropriate level for 3-day SPS precipitation over the basin. However, the final determination of the SPS resulting in a value of 5.0 in. precipitation meant that some downward adjustment was necessary to the "Hypo-Snake" amount. At the very least, the late fall or early winter (i.e., November 15) storm centered over the downstream area should certainly be no more than the adopted SPS 3-day basin-wide storm value. Making a -7-percent overall adjustment accomplished this and it appears realistic by the following reasoning. Since this type of storm has decreased potential in mid-winter requiring (by maximum 12-hr dew point) a 15 percent reduction for December 15 occurrence and a 20 percent reduction for mid-January and mid-February occurrence (Environmental Data Service 1968), the average

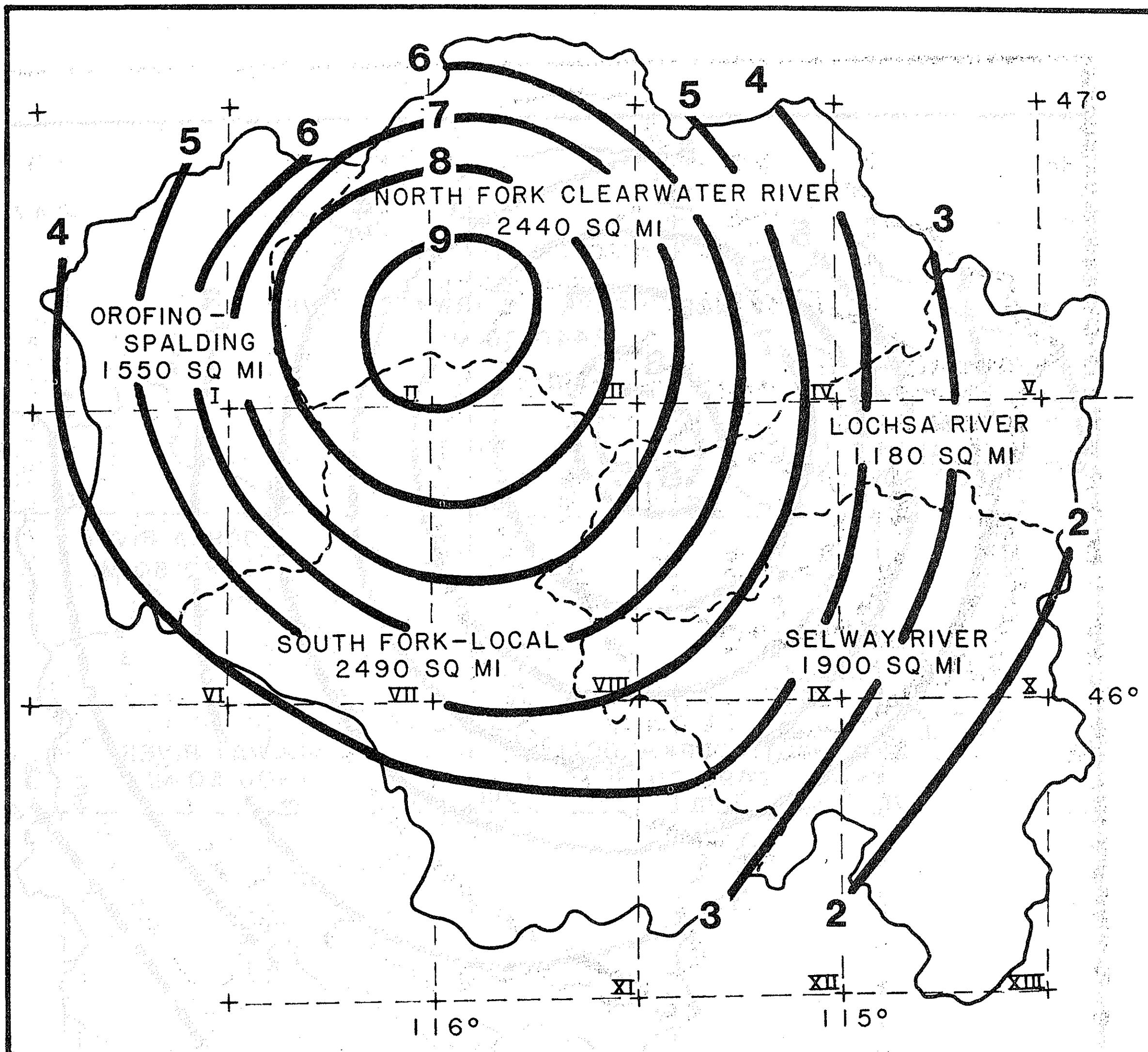

Figure 66.--"Hypo-Snake" SPS storm for November 15 (in.).

cool-season basin-wide value would, therefore, be a little over 4 1/4 in., or 86 percent of the primary upstream cool-season 3-day precipitation. The requirement of an overly prominent downstream centering of the "Hypo-Snake" storm decreases the total event probability, so that it appears reasonable that this storm should average at least 10 percent less precipitation (on a basin-wide basis) than the adopted "higher probability" 3-day cool-season storm type when the added probability-decreasing requirement of downstream centering is not applied.

A smoothed idealized isohyetal pattern, in inches, was determined for each of the months November through March. These are shown in Figures 66 through 68. These are idealized in that they are based upon average sub-area MAP values for the 13 sub-areas covering the total basin. Since sub-basin average depths are

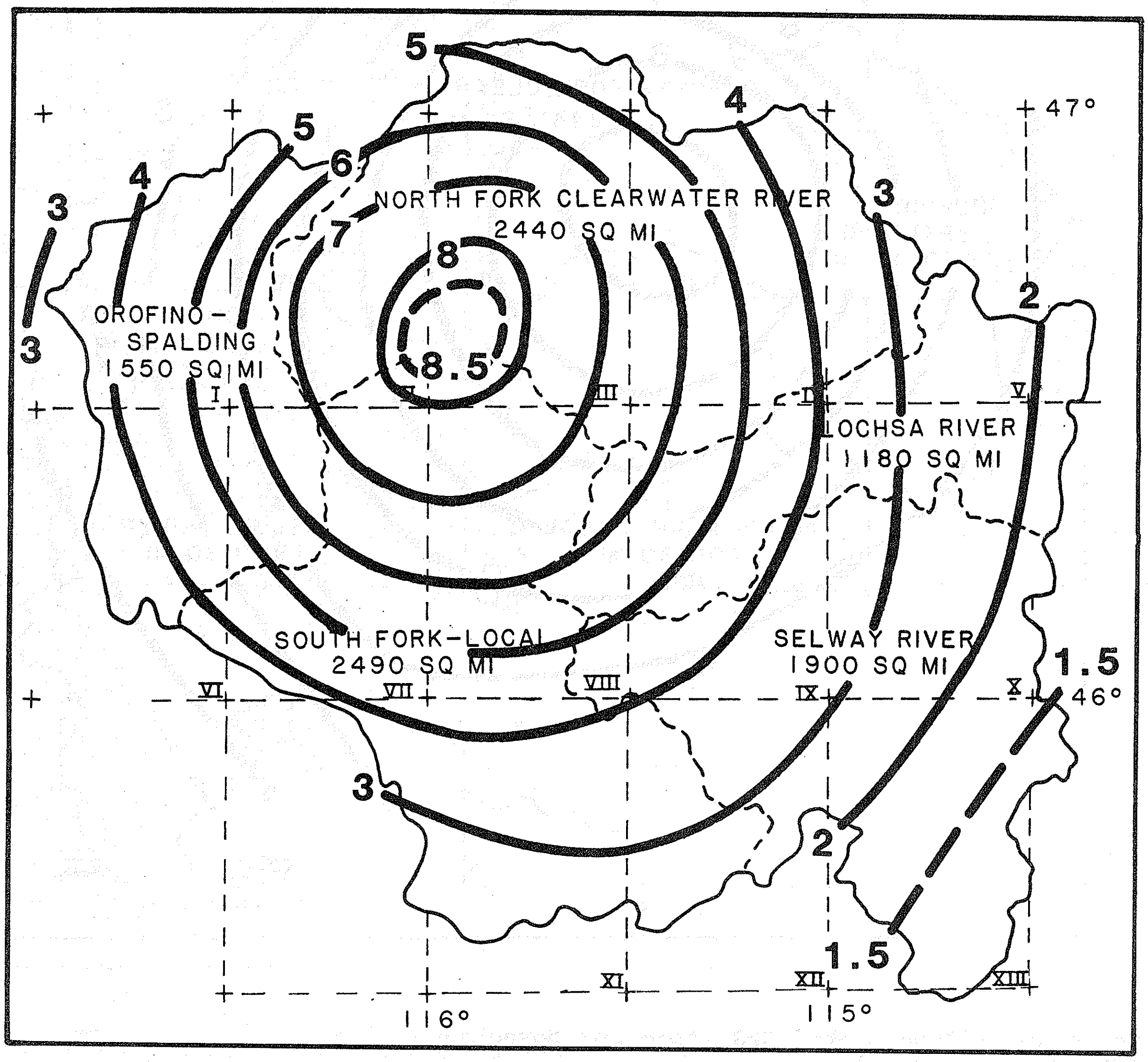

Figure 67.--"Hypo-Snake" SPS storm for December and March (in.).

being supplied,* it therefore, is not necessary to go through the timeconsuming process of working out detailed geographical features of the precipitation pattern as related to the detailed MAP pattern. Accurate sub-basin averages (required by the user) from the patterns of Figures 66 through 68 are provided for in Chapter 13.

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* Except as in the Applications Chapter (13), where the user is provided with means of using alternate placement of the "Hypo-Snake" pattern over the downstream portion of the basin.

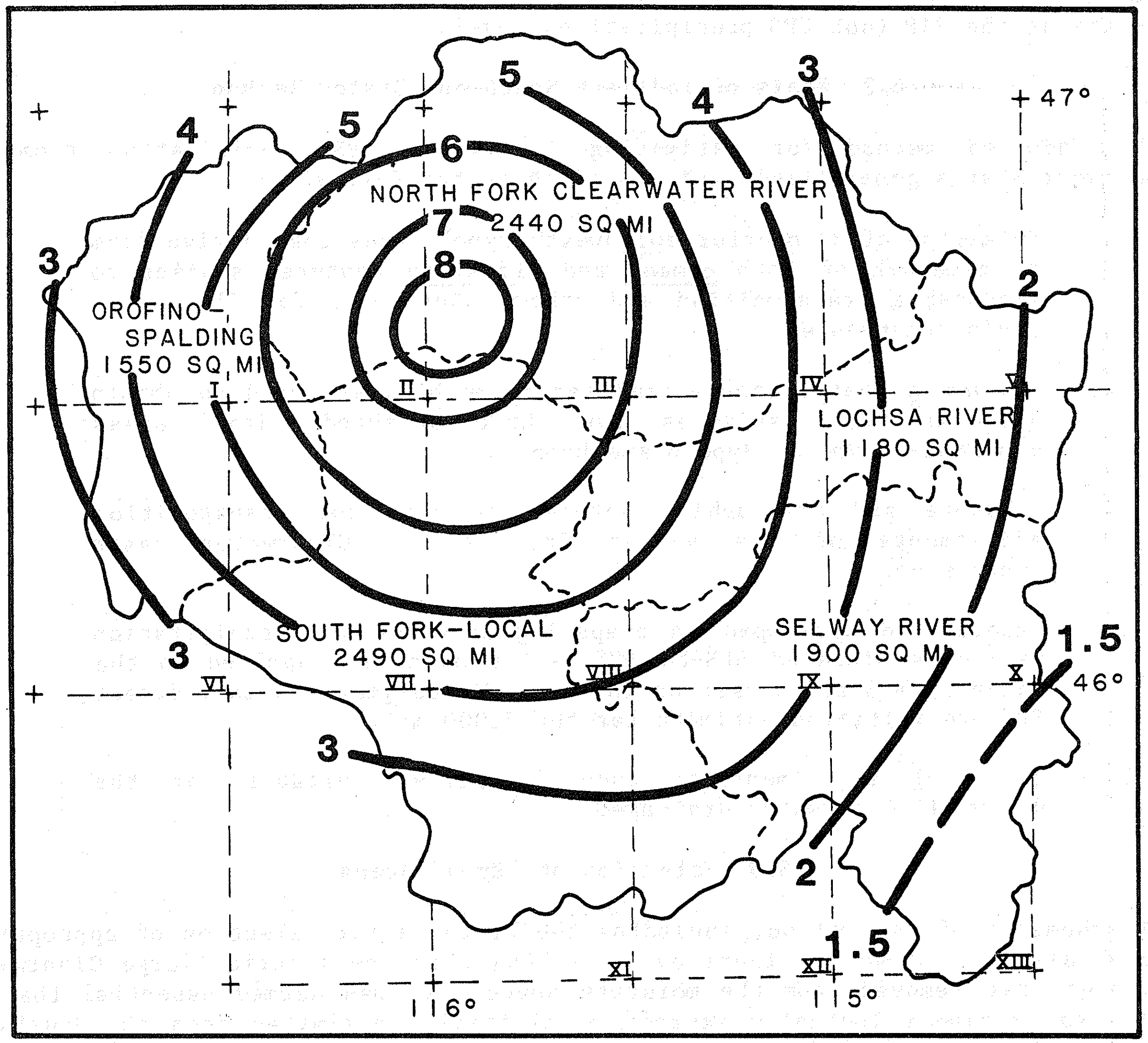

Figure 68.--"Hypo-Snake" SPS storm for January and February (in.).

6. SPS PRECIPITATION ESTIMATE BASED UPON GENERALIZED PMP PROCEDURES FOR THE SOUTHWEST STATES

6.1 Background

Generalized PMP estimates for the southwest States are available in Hydrometeorological Report No. 49 (Hansen et al. 1977). This is one of a series of reports providing such estimates for the conterminous western United States. Procedures differing from those of other western United States studies for California (U.S. Weather Bureau 1961) and the Northwest States (U.S. Weather Bureau 1966) were required, since laminar flow orographic models are generally not applicable to the complicated terrain of the southwest States. Thus, another indirect method for estimating Clearwater basin SPS precipitation involved results and procedures of the southwest States generalized PMP study. Estimates from the procedures of HMR No. 49 are limited to areas no larger than 5,000 mi^2 and are at the PMP (not SPS precipitation) level.

6.2 Basis of Indirect Southwest States Method

The adopted method for estimating Clearwater SPS precipitation from the southwest States generalized study consists of the following:

1. Selection of 3 interior southwest "Hypo" areas that derive from a framework of both common and differing features subject to acceptable transposition and other adjustments for Clearwater basin occurrence.

2. Southwest States generalized report methods are used to obtain 5,000-mi^2 PMP estimates for three selected "Hypo" areas designated Hypo A, Hypo B and Hypo C.

3. Moisture and orographic factors are used for transposition adjustments of the values from 2 for Clearwater basin occurrence.

4. Experienced developed in preparing previous SPS precipitation estimates dictated SPS-to-PMP ratios which are applied to the value from 3 to convert an indirect PMP estimate to an indirect SPS precipitation estimate for the 5,000 mi^2.

5. An areal adjustment is made (chapt. 9) suitable for the 9,570-mi^2 Clearwater drainage.

6.3 Selection of "Hypo" Areas

A schematic of the method, including the criteria for selection of appropriate "Hypo" areas is shown in Figure 69. In line with the interior large Clearwater drainage, far removed from the moisture source, it was deemed essential that in order to transpose logically extreme precipitation estimates from the southwest States, the chosen "Hypo" areas must, in common with the Clearwater, be large and located a long distance from moisture sources. In addition, again in common with the Clearwater drainage, a large variation in orographic factors needs to be present.

Contrasting features of the chosen "Hypo" areas on the other hand, include barrier differences, orographic index (i.e., mean) differences, and some location differences, within the common framework of being far from the moisture source.

The chosen "Hypo" areas are shown in Figures 70 (i.e., Hypo "A") and 71 (Hypos "B" and "C"). The location of these "Hypo" areas in relation to the Clearwater Drainage can be seen in Figure 2. As can be seen by reference to Figure 69, barriers ranged between 6,500 and 7,500 ft and orographic index values for the "Hypo" areas ranged from 2.88 in. to 3.92 in., the latter almost exactly the same as the Clearwater drainage average as computed from the basin distribution of 6-hr orographic index shown in Figure 72.

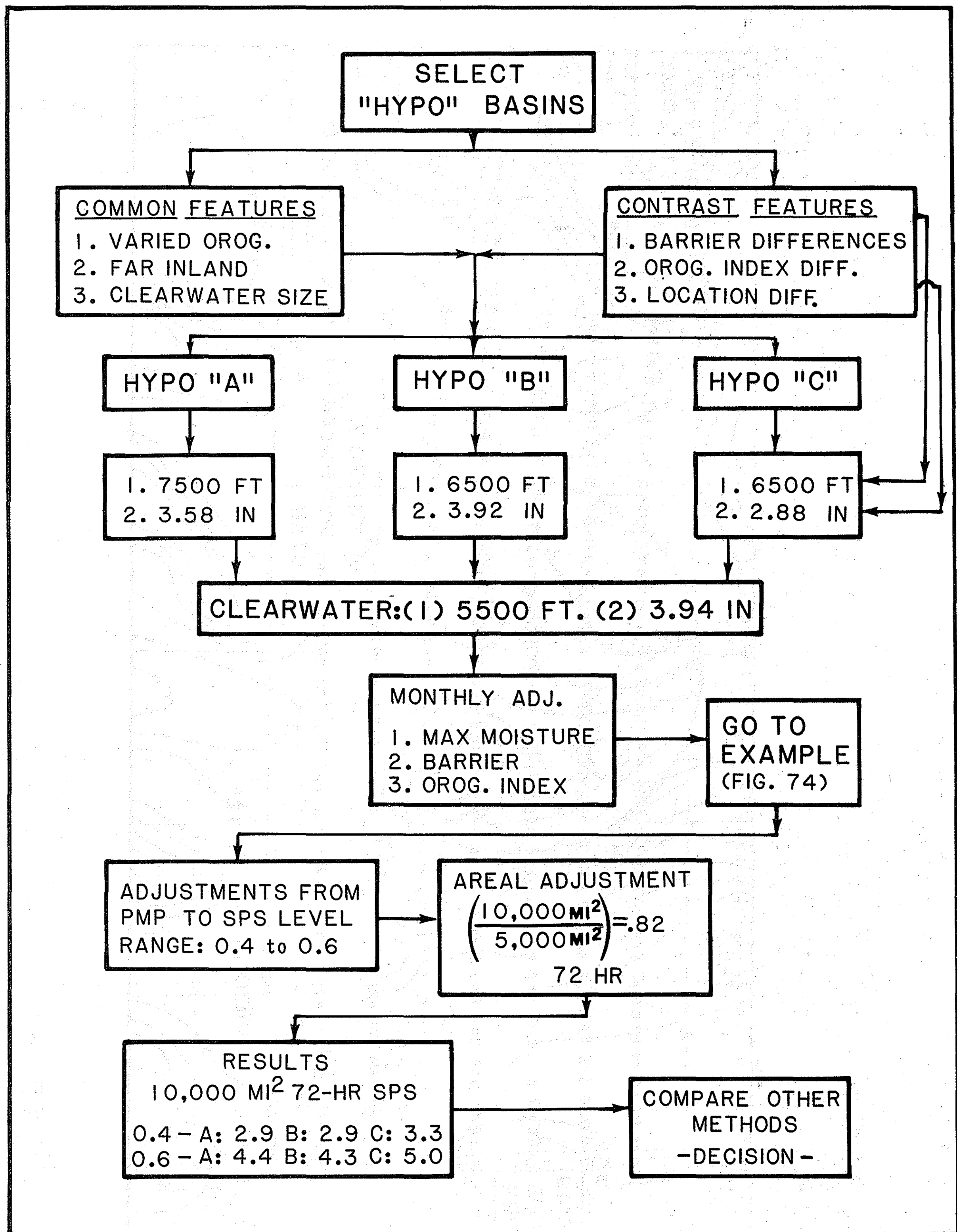

Figure 69.--Schematic Hypo-southwest method.

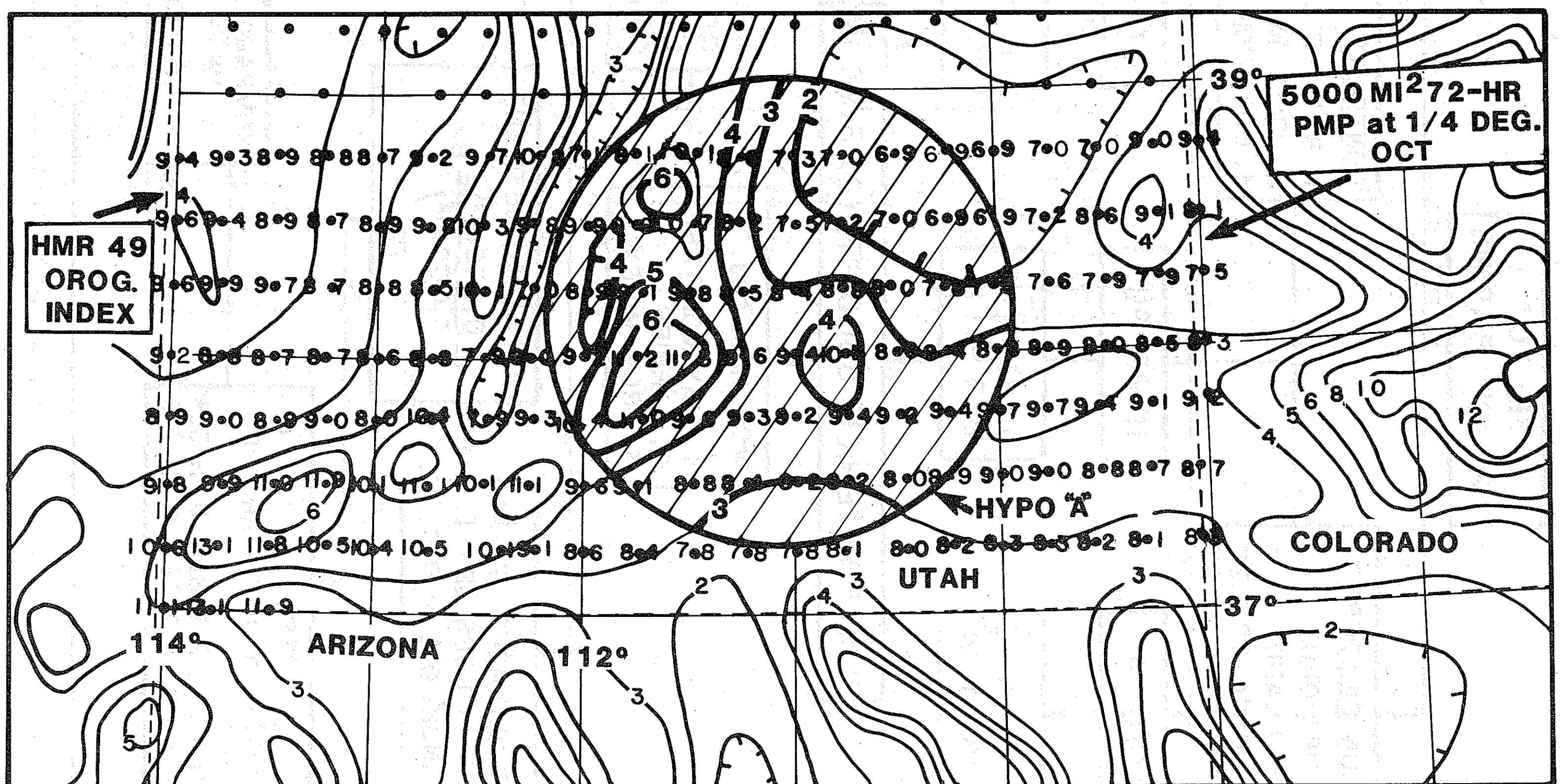

Figure 70.--Hypo-southwest area "A".

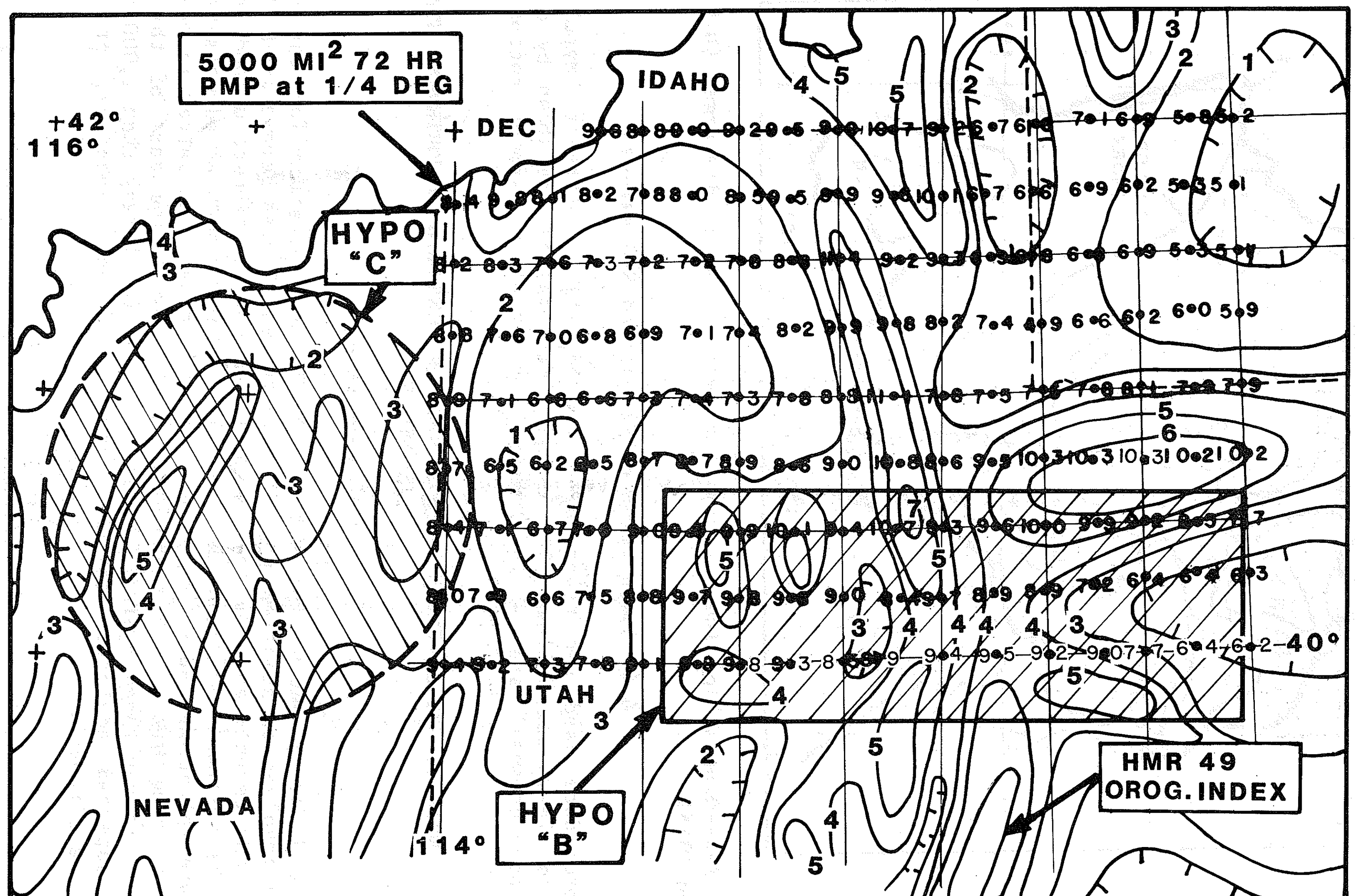

Figure 71.--Hypo-southwest areas "B" and "C".

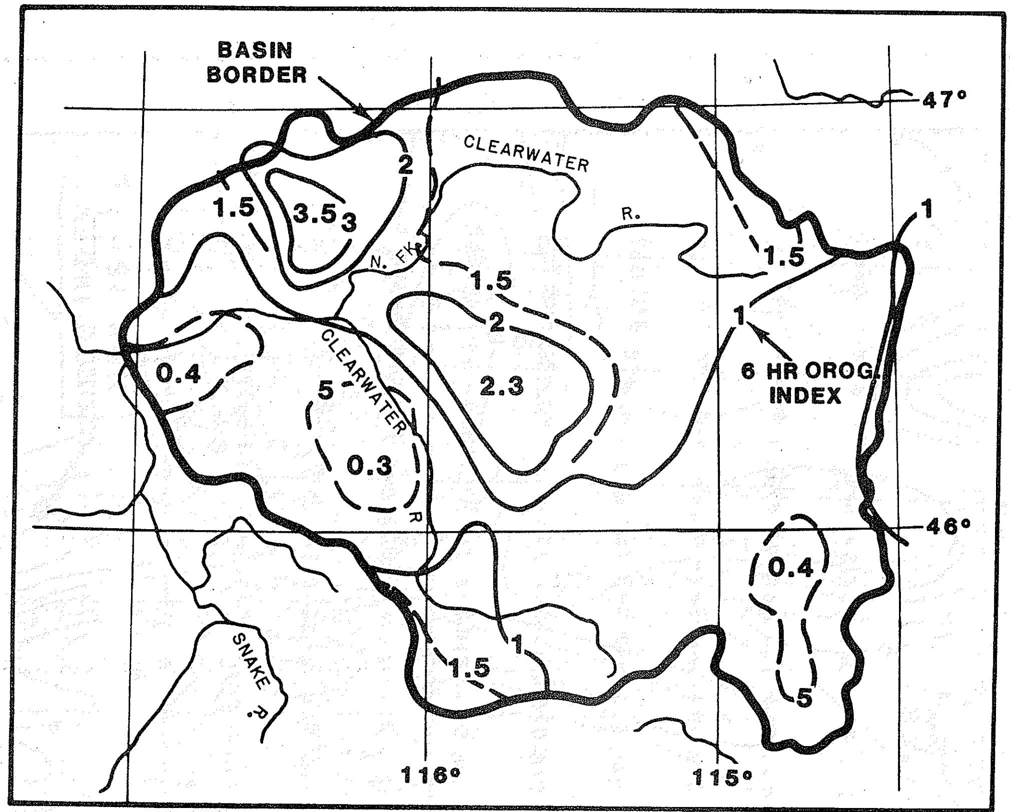

Figure 72.--Orographic index over Clearwater River drainage (U.S. Weather Bureau 1966).

6.4 Computation of Transposed SPS Values

The procedure used for transposing and adjusting southwest "Hypo" area PMP values to Clearwater drainage SPS precipitation values are shown by one example for "Hypo-southwest" area C in Figure 73. Areal adjustment ratios are from Chapter 9.

7. INDIRECT SPS ESTIMATE BY EXTENSION OF GENERALIZED NORTHWEST STATES TECHNIQUES

7.1 Background

Another indirect method for estimating SPS precipitation for the Clearwater drainage involved an adaptive use of the northwest States generalized PMP study's (HMR No. 43) techniques. As in the southwest States indirect method (chapt. 6), use of the northwest States techniques also requires both an adjustment from PMP to SPS precipitation and an adjustment for area size. The latter is even more of a problem using HMR No. 43 techniques, since for basins east of the Cascades, the user is cautioned against use of estimates for larger than 1,000 mi^2. Even so, it appeared advisable to try another indirect technique, at least for comparative purposes.

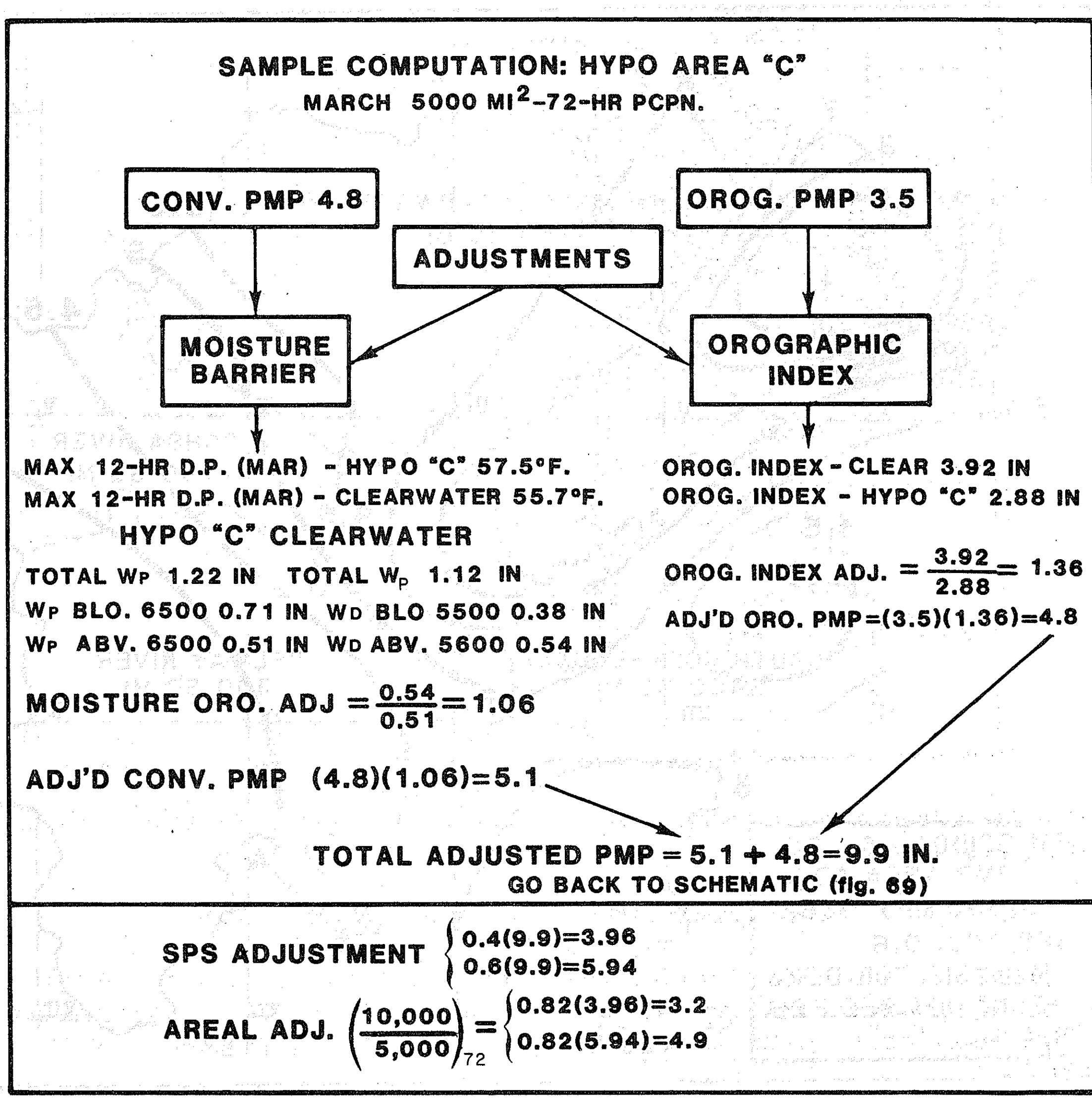

Figure 73.--Sample computation illustrating transposition and adjustment of PMP values from "Hypo-southwest" area C to Clearwater River drainage.

7.2 Method and Result

The northwest States report procedures were used, with an areal extension to 5,000 mi^2, to obtain estimates of PMP for the Clearwater basin. This was done both by a grid-point approach covering the basin and by using HMR No. 43 techniques for basin-wide PMP computations. Differences using the two techniques amounted to 4 percent or less in all cases, with a mean difference of 2 percent.

Computations were made for the months of October, December and February. Using a range of SPS to probable maximum precipitation of 0.4 to 0.6 and an areal adjustment from 5,000 mi^2 to 9,570 mi^2 of 0.82 resulted in this indirect method providing a range of average SPS precipitation of 3.6 to 5.4 in.

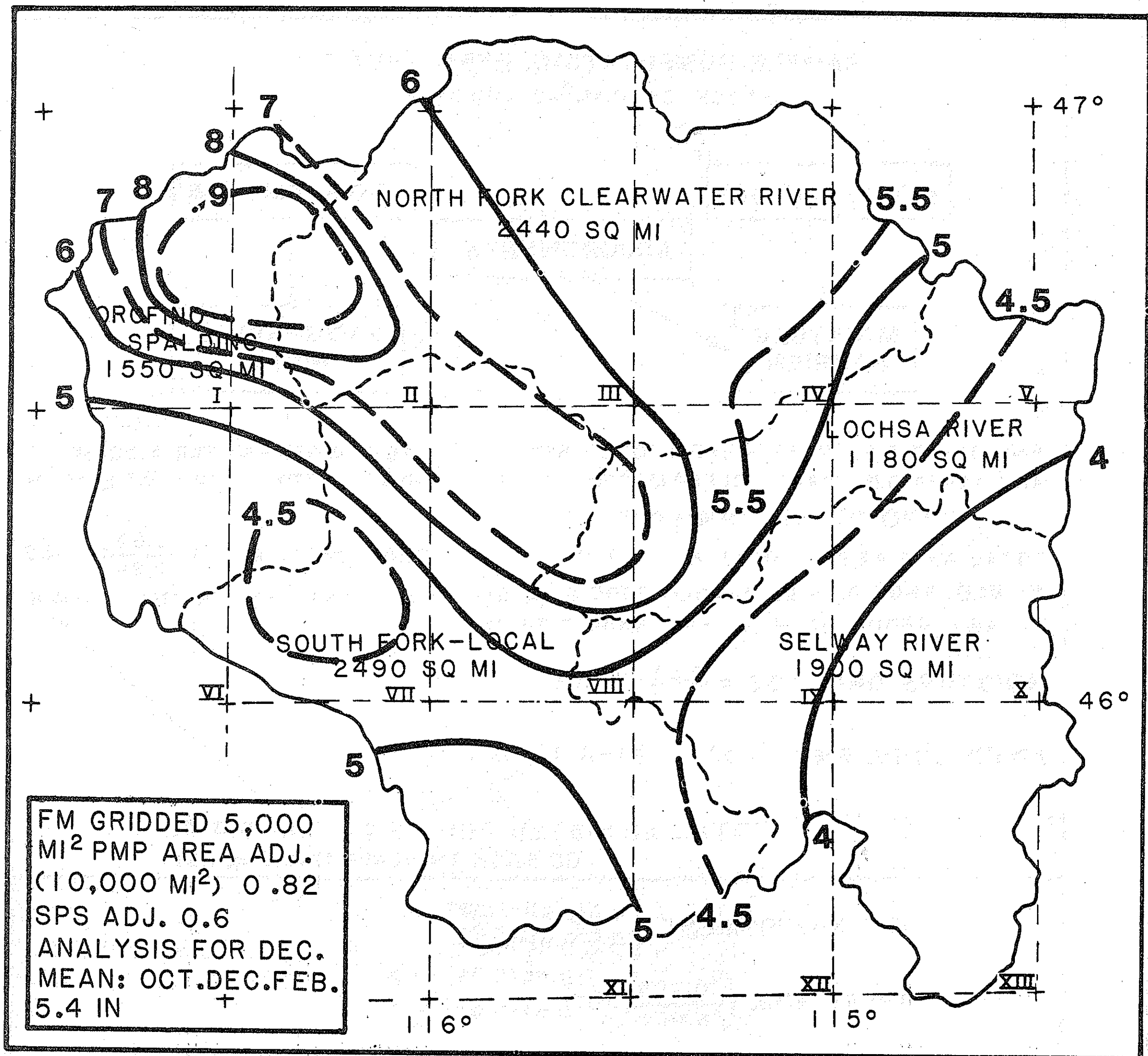

Figure 74.--Estimated 3-day December SPS precipitation (in.) from areal extension of HMR No. 43 procedures.

Figure 74 shows the analyses from the grid-point method for the month of December. The values of the isolines are those that result after adjustment of basic 5,000-mi^2 PMP values to SPS precipitation for 5,000 mi^2 using a ratio of 0.6 and then applying an areal adjustment for the Clearwater basin of 0.82.

8. ADOPTED SPS PRECIPITATION

8.1 Summary of Method, Results and Adopted SPS Value

Figure 75 is a simplified plot of the estimated basin-wide maximum cool-season 3-day SPS adopted from the methods discussed in Chapters 2 and 5 through 7. Seasonal variation of the SPS precipitation is discussed in Chapter 2. In addition, results from moisture maximized significant events resulting from direct method I (chapt. 2) are also shown. For indirect methods, where 0.4

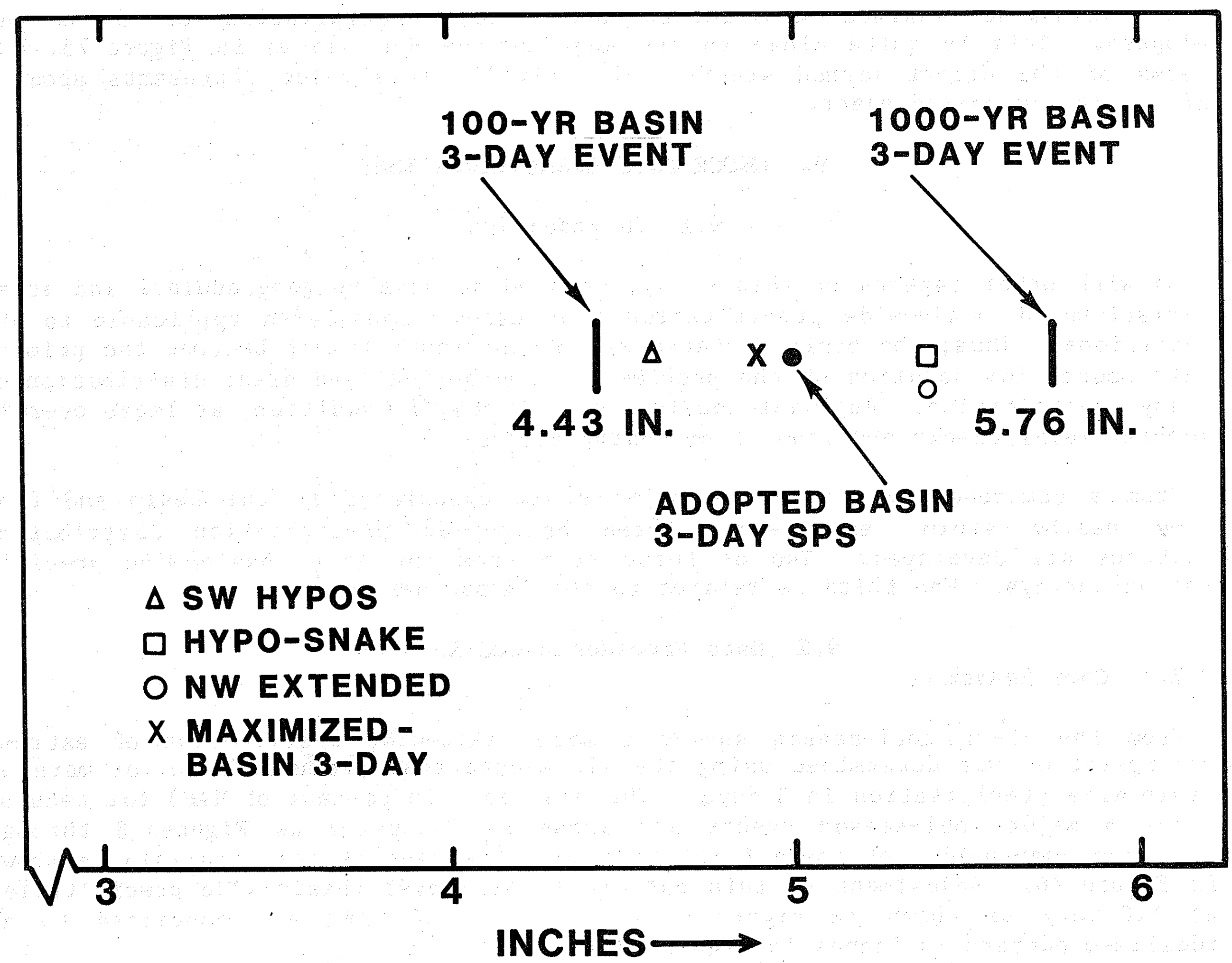

Figure 75.--Adopted basin SPS precipitation with supporting values.

SPS to probable maximum storm precipitation ratio resulted in a basin-wide value of less than 4 in., the values are not shown in Figure 75.

A range of values, embracing experience dictated SPS precipitation values in relation to return period estimates is shown in Figure 75 from the statistical analysis of direct method I. The range of return period values is from 4.43 in. (i.e., 100 yr) to 5.76 in. (1,000 yr).

The "Hypo-Snake" approach, discussed in Chapter 5, resulted in a 9,570-mi^2 basin-wide value of 5.37 in. The mean value from the 3 southwest States "hypo areas," (using an SPS precipitation to probable maximum precipitation ratio of 0.6) was 4.6 in. The northwest extended method (chapt. 7) resulted in a mean value of 5.4 in. (again for an SPS precipitation to probable maximum precipitation ratio of 0.6).

Dew points were determined for the major basin-wide events since and including 1964 and those events giving 3 in. or more precipitation basin-wide in 3 days were moisture maximized. The resulting mean moisture maximized value was 4.9 in.

A basin-wide maximum cool-season SPS 3-day precipitation of 5 in. was adopted. This is quite close to the mean of the data shown in Figure 75. In terms of the direct method statistical analysis, this value represents about a 270-yr return period event.

9. GEOGRAPHIC AREAL VARIATIONS

9.1 Introduction

As with other aspects of this study, we need to develop geographical and areal variations of basin-wide precipitation that can be considered applicable to SPS conditions. Thus, the basin dictated storm experience itself becomes the primary data source for solution of the problem of geographical and areal distribution of 3-day precipitation. Regional consistency demands, in addition, at least overall general level checks and input from nearby storms.

From a comprehensive review of major storm experience in the basin and from some nearby storm experience, three basin-wide precipitation distribution patterns are developed. Two of these stem from the 45-yr basin-wide precipitation surveys. The third is related to the "Hypo-Snake" event.

9.2 Data Procedures and Results

9.2.1 Cool Season

From the 45-yr cool-season survey a mean basin-wide distribution of extreme precipitation was determined using the six events that produced 3 in. or more of basin-wide precipitation in 3 days. The analyses (in percent of MAP) for each of these 6 major cool-season events are shown in Chapter 2 as Figures 8 through 13. The combination of these 6 into one mean (percent of MAP) analysis is shown in Figure 76. Adjustment of this pattern to SPS-level (basin-wide precipitation at 5.0 in.) is shown in Figure 77 (in percent of MAP) and converted to an idealized pattern in inches in Figure 78.

9.2.2 "Hypo-Snake" Distribution

A separate cool-season downstream pattern resulted from the "Hypo-Snake" event discussed in Chapter 5. From this "Hypo-Snake" pattern, the resulting idealized analyses for January-February is shown in Figure 79. Note the downstream concentration compared to the mean cool-season event storm in Figure 78.

9.2.3 May-June Event Distribution (Mean)

Following the cool-season distribution approach, major events resulting from the separate May-June 45-yr survey were used to obtain a mean May-June event distribution pattern of precipitation across the basin. The analyses (in percent of MAP) for these 3 major events are shown in Chapter 4, Figures 50, 51, 57. The percent of MAP analysis for three other major storms are shown in Figures 80, 81, and 82. These 6 events resulted in basin-wide 3-day precipitation of at least 2 in. The mean May-June distribution pattern that results from these 6 percent of MAP analyses is shown in Figure 83, as an idealized pattern after converting to inches.

The values of figure 83 represents the mean of the 6 major May-June events and results in a basin-wide 3-day event precipitation of 2.20 in. To adjust this mean value to SPS level, we first need a seasonal variation adjustment. From the

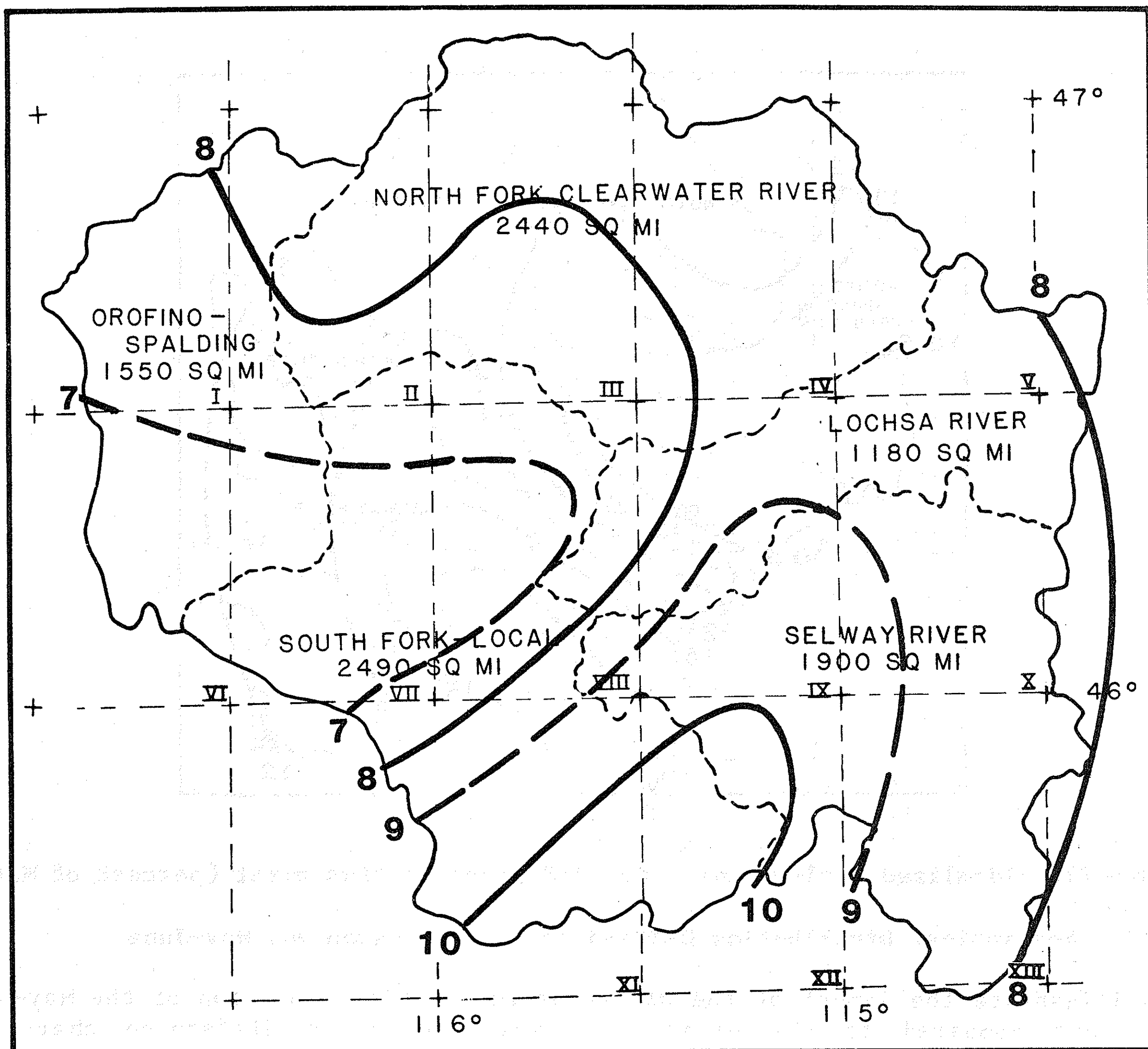

Figure 76.--Mean of 6 cool-season 3-day SPS precipitation events (percent of MAP).

9.2.3.1 Adjustment of Mean Distribution Pattern to SPS Level for a Specific Date.

seasonal variation curve (fig. 98), for May 15, we read 0.74. This is 74 percent of the adopted cool-season basin-wide SPS precipitation of 5 in., or 3.70 in. Thus, the mean basin-wide precipitation value of 2.20 in. needs to be increased 68 percent (i.e., $\frac{3.70}{2.20} = 1.68$). Increasing the 13 sub-area percents for the mean case by 68 percent results in the SPS May 15 analysis (in percent of MAP) shown in Figure 84. Figure 85 shows these percents converted to the idealized analysis* in inches.

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* The pattern is "idealized," in that there is no need to apply percentage MAP values in a detailed fashion to lines on a mean annual precipitation map. Rather, the application is in the form of mean percentages of mean annual precipitation for each of the 13 subregions.

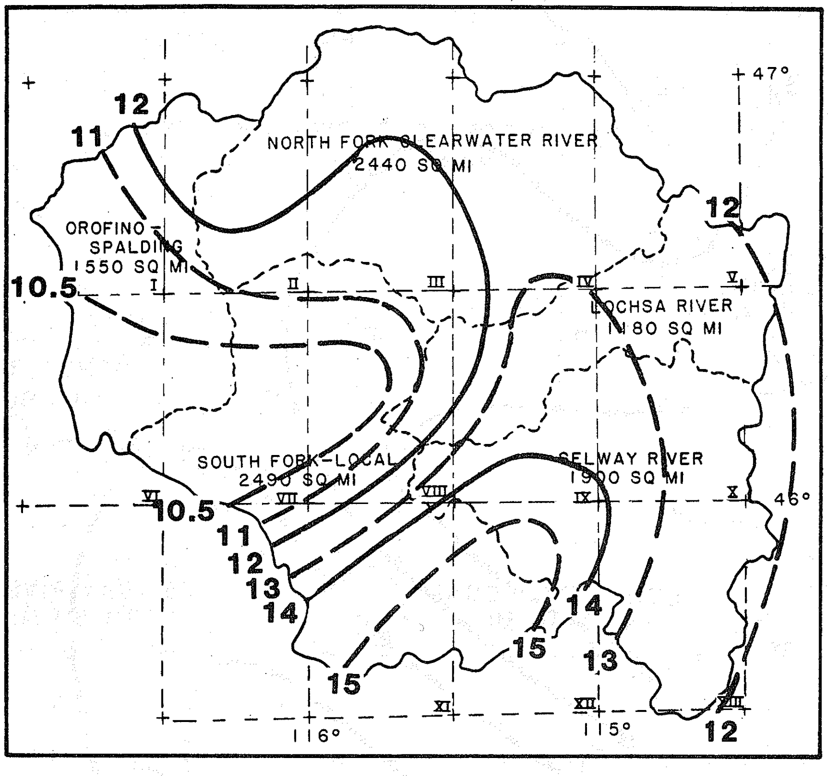

Figure 77.--Idealized cool-season 3-day SPS precipitation event (percent of MAP).

9.2.4 Geographical Distribution Difference - Cool Season vs. May-June

To illustrate the impact of the different geographical location of the May-June SPS event compared to the major cool-season event, a difference chart (in percent) was developed and is shown as Figure 86. This difference chart (fig. 86) was developed by first normalizing the values of Figure 83 to the basin average value from Figure 78 (cool-season SPS precipitation). This then removes the magnitude differences and highlights the change in precipitation patterns between the 2 seasons. The precipitation values for the May-June event have increased over the lower basin, while amounts have decreased at the higher elevations along the eastern edge of the basin.

9.3 Depth-Area Relations

9.3.1 Introduction

The adaptive indirect use of PMP methods as covered in Chapters 6 and 7 required appropriate depth-area relations to develop estimates beyond the limiting area size of the respective generalized reports (the basis of PMP estimates) to the 9,570-mi^2 Clearwater Basin area. As indicated in the earlier chapters, a total basin to 5,000-mi^2 ratio of 0.82 was adopted.

9.3.2 Data Input to Depth-Area Relation

Three basic sources of data were utilized in the adoption of an appropriate depth-area ratio. The primary data source is from the extensive 45-yr direct method survey of basin-wide 3-day events for the main cool season and for

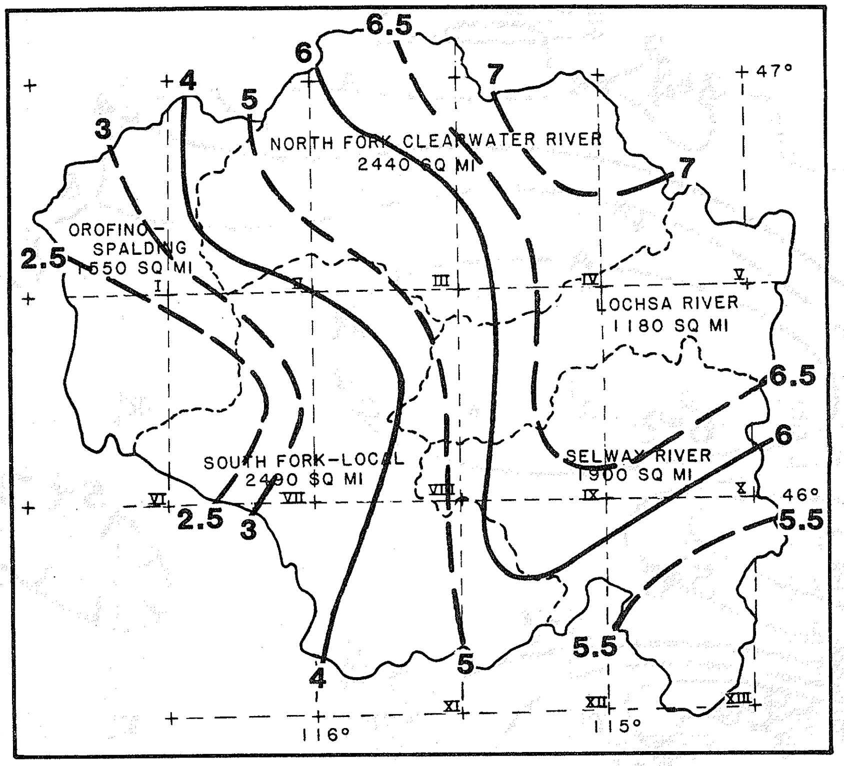

Figure 78.--Idealized cool-season 3-day SPS precipitation event (in.).

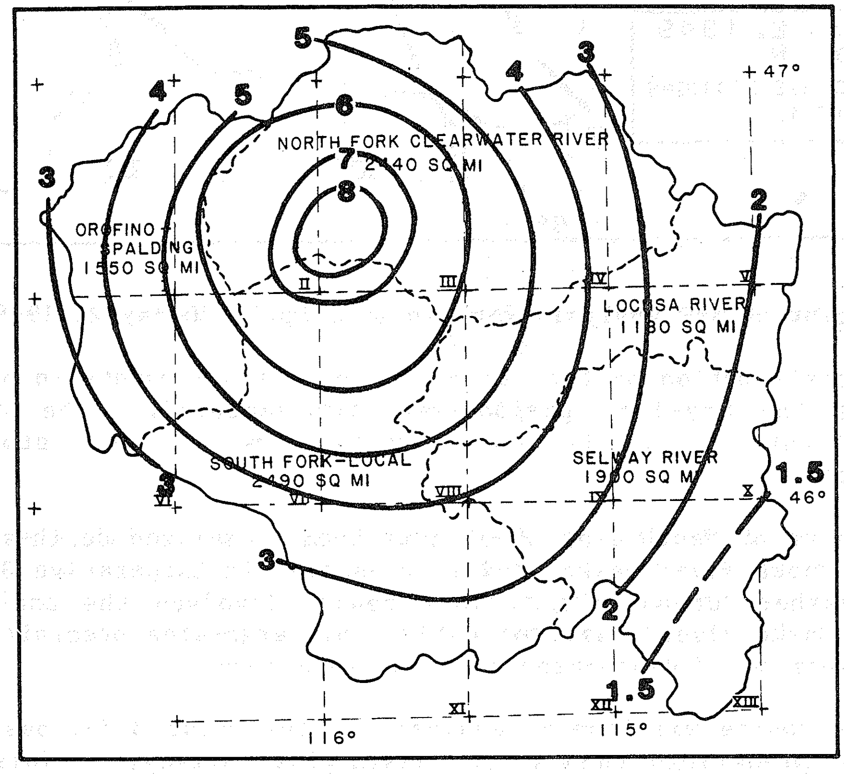

Figure 79.--"Hypo-Snake" 3-day SPS precipitation event (in.) for January and February.

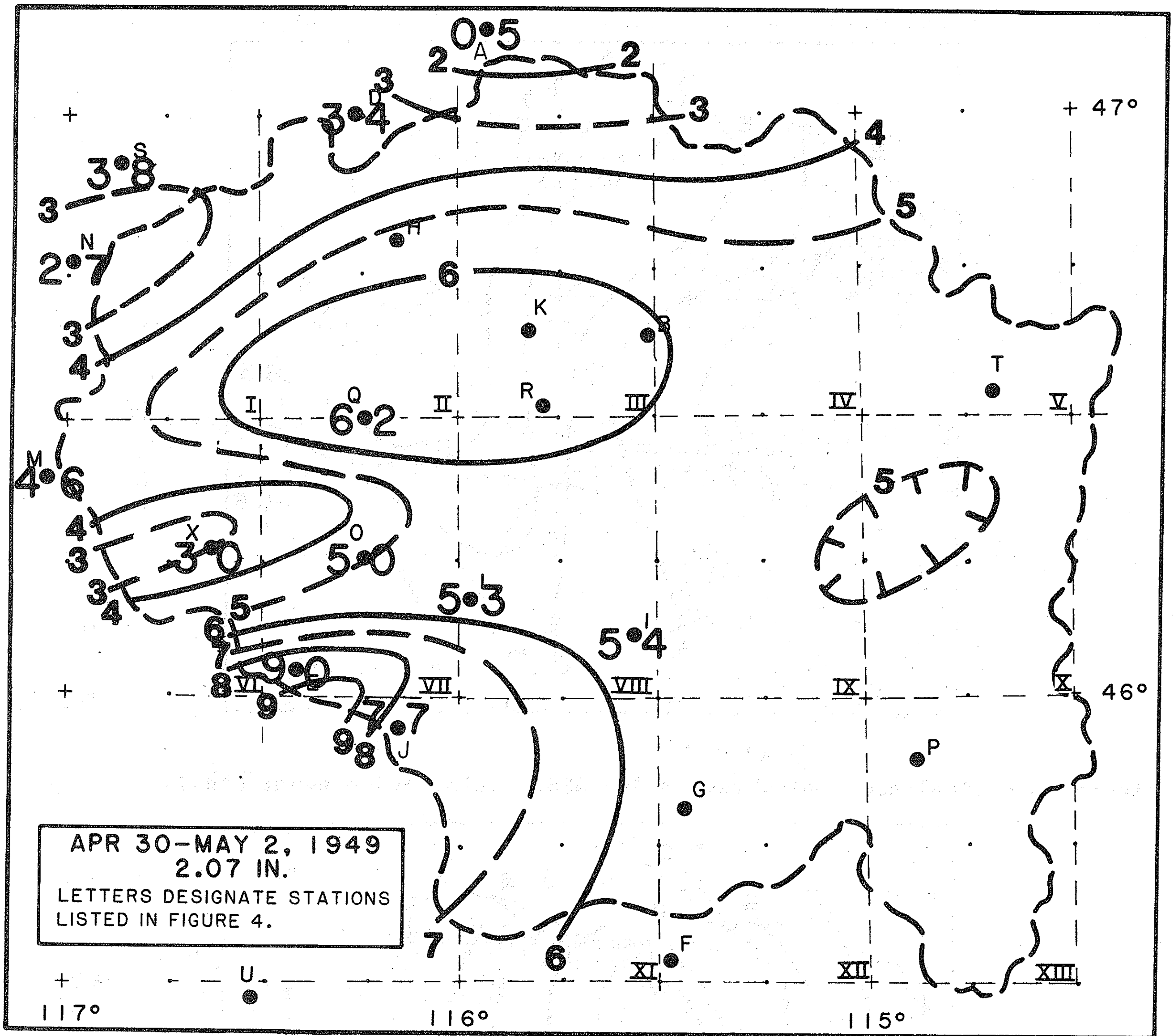

Figure 80.--Percent of MAP analysis for storm of April 30-May 2, 1949.

May-June. The distribution pattern from the top 6 storm events in both the major cool-season and the May-June period were planimetered. The result, after combining the 2 sets (i.e., 12 major events), was a basin storm-determined depth-area relation.

The second source of depth-area input came from summarized depth-area relations for the Central Snake River basin area as presented in Cooperative Studies Report No. 11 (U.S. Weather Bureau 1953). This report involved the analysis of many storms over the Snake River basin for estimating large-area precipitation amounts from resulting enveloping depth-area-duration relations.

The third data source was from an analysis of the major 3-day basin-wide storm in the period predating the 45-yr basin-wide survey. This event, in December 1933, was covered in a depth-area duration study for the period December 18-23, 1933.

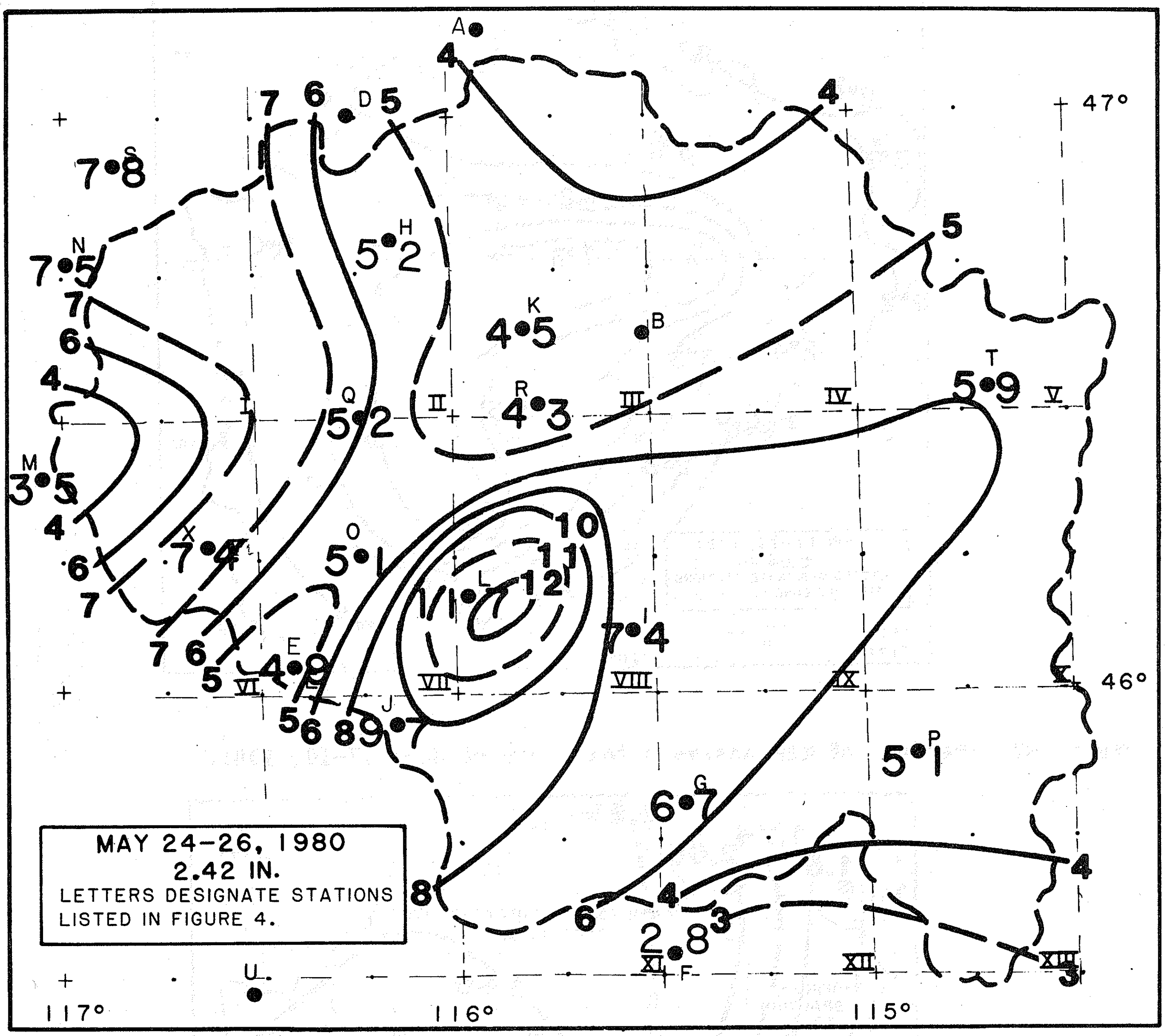

Figure 81.--Percent of MAP analysis for storm of May 24-26, 1980.

9.3.3 Results and Adopted Depth-Area Ratio

Figure 87 shows the depth-area ratios for the 3 data sources discussed in Section 9.3.2. The range is quite small. Again, as in many portions of this report since our primary concern is the adoption of values that may be considered appropriate for SPS conditions over the Clearwater River drainage, we have chosen to adopt a ratio of 0.82. This is the same value as that resulting from the mean of the major 12 basin-wide precipitation events and is considered appropriate as an SPS level depth-area ratio for adjusting 5,000-mi^2 precipitation values to the total Clearwater River drainage area of 9,570 mi^2.

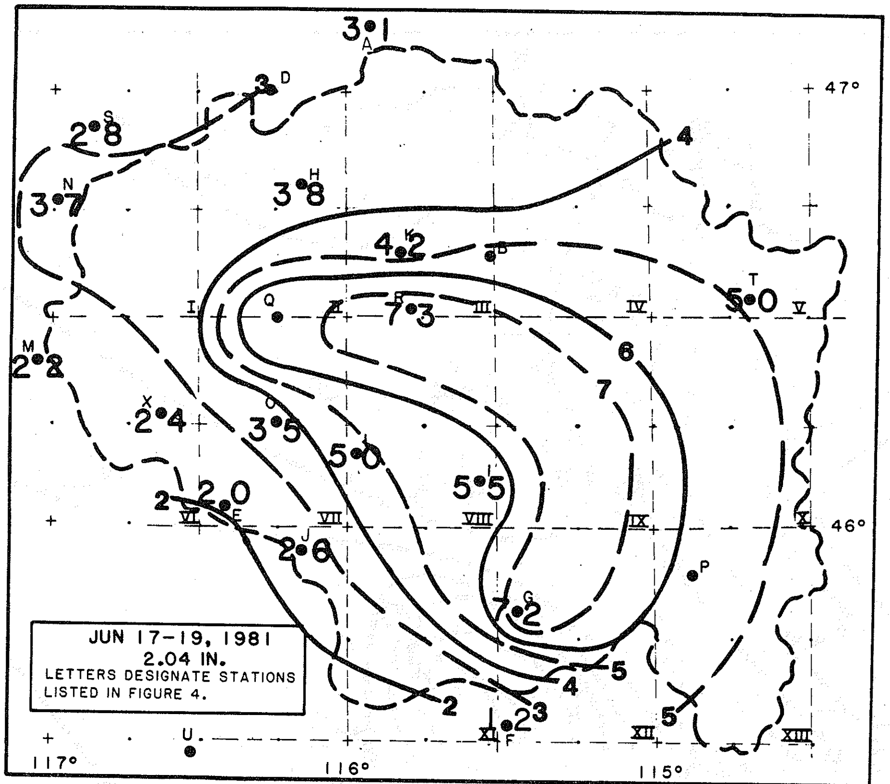

Figure 82.--Percent of MAP analysis for storm of June 17-19, 1981.

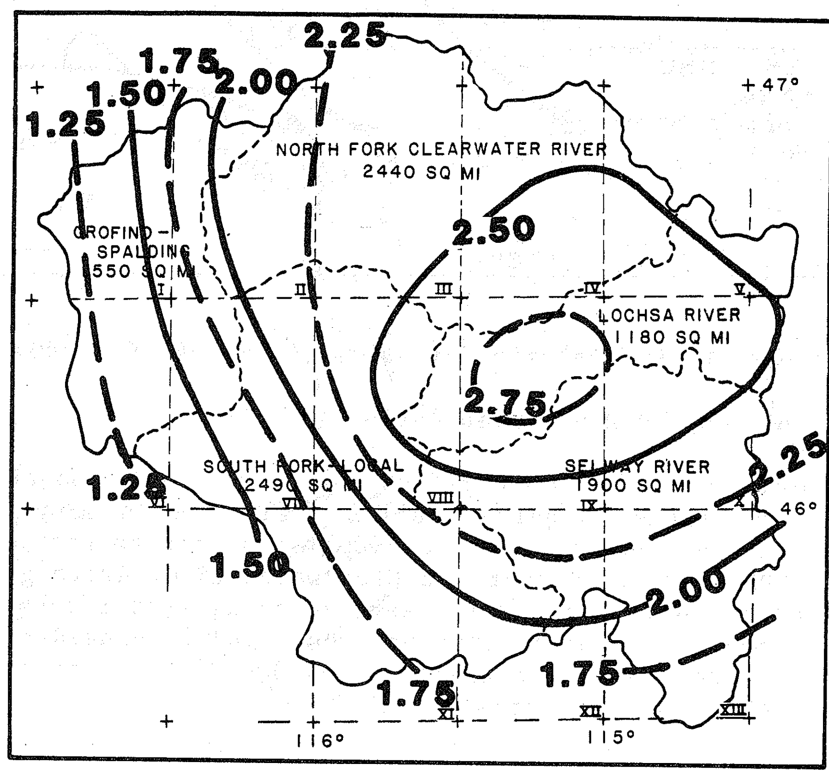

Figure 83.--Idealized May-June 3-day SPS precipitation event (in.). Based upon mean of 6 storm events.

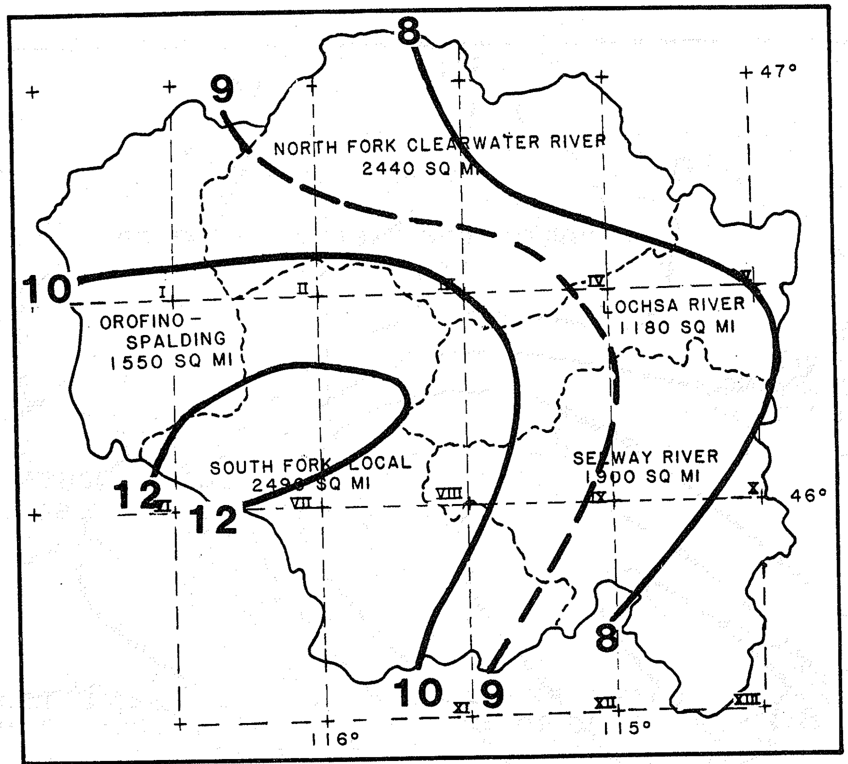

Figure 84.--Idealized 3-day SPS precipitation event for May 15 (percent of MAP).

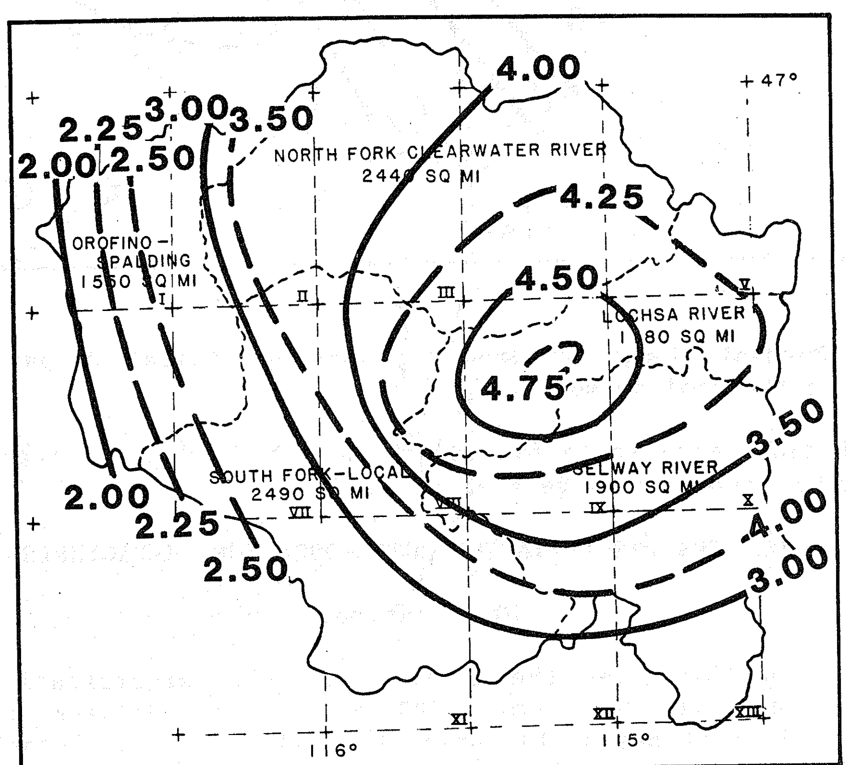

Figure 85.--Idealized basin-wide 3-day SPS precipitation event for May 15 (in.).

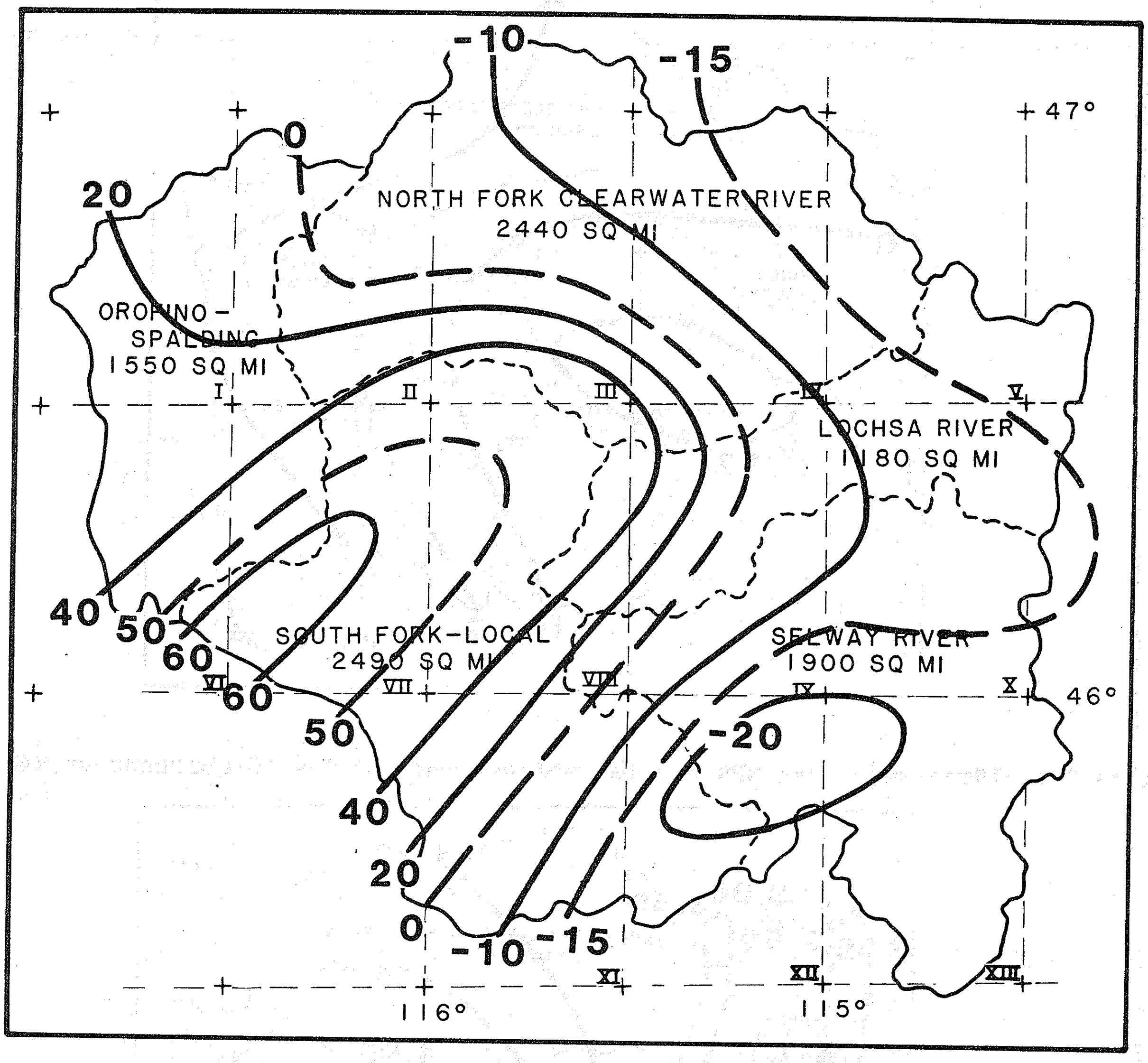

Figure 86.--Percent change between May-June precipitation pattern distribution and that for the cool season.

an SPS level depth-area ratio for adjusting 5,000-mi^2 precipitation values to the total Clearwater River drainage area of 9,570 mi^2.

10. SPS PRECIPITATION DEPTH-DURATION CHARACTERISTICS

10.1 Introduction

Since the main thrust of the basin-wide 3-day precipitation survey was to define only the 3-day basin-wide SPS event, methods are needed to develop appropriate SPS level basin-wide precipitation values for durations of less than total storm. The more significant 3-day events provide important input to the solution of this problem. Additional clues, however, especially from generalized PMP studies, are used to help the decision process.

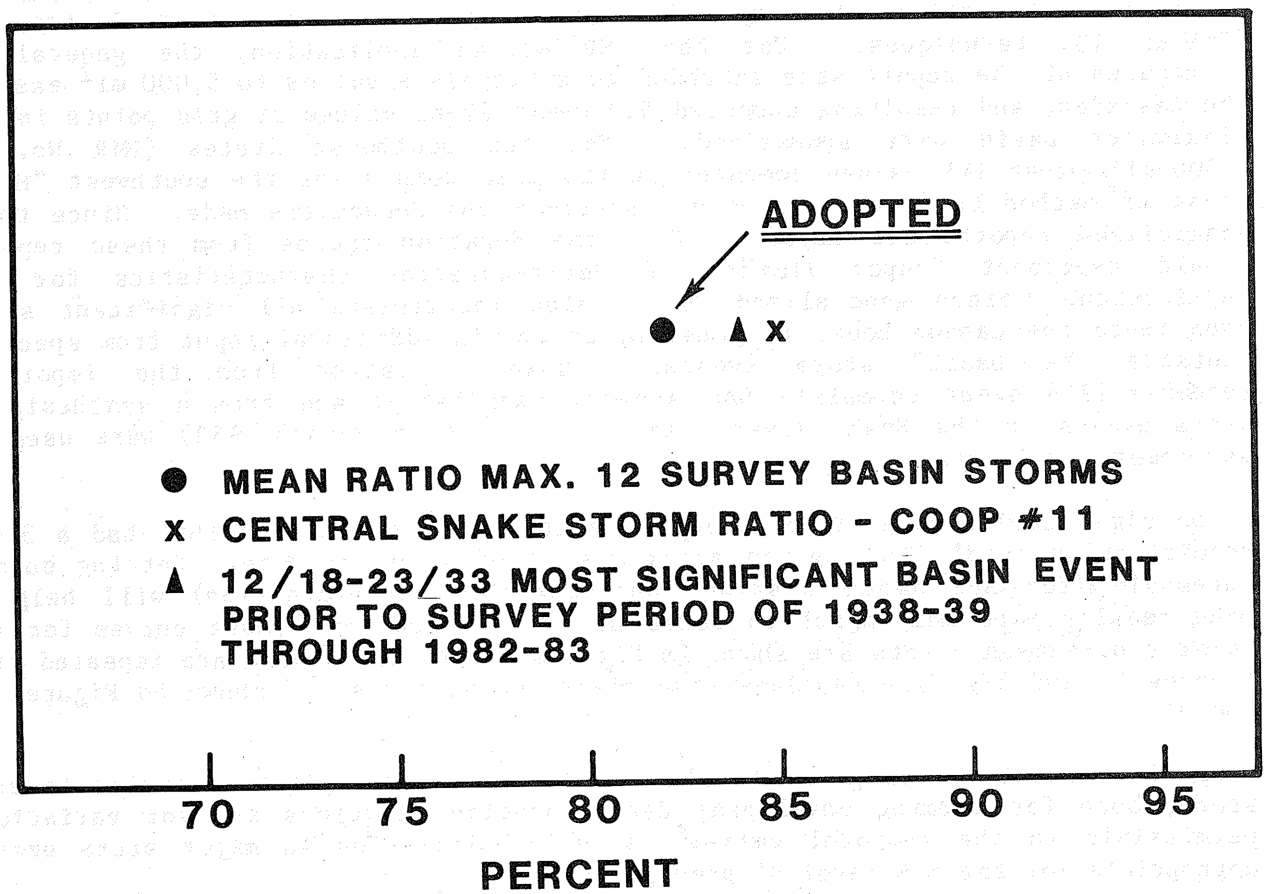

Figure 87.--Adopted 10,000- to 5,000-mi^2 ratio and data.

In addition to the depth-duration problem for each storm type, including its seasonal variations, this chapter also is concerned with temporal arrangement of the resulting 12 6-hr increments of basin-wide SPS precipitation.

10.2 Data and Techniques

From the annual maximum 3-day event survey, 8 cool-season events providing the large basin-wide precipitation amounts were analyzed and summarized. Four of these events (2/22-24/64, 2/18-20/68, 11/30-12/2/75 and 12/1-3/77) resulted in basin precipitation for 3 days in excess of 3 in. Four other cases (1/18-20/70, 1/8-10/71, 12/20-22/72 and 1/13-15/75) resulted in 3-day basin-wide precipitation of between 2 and 3 in.

A similar 45-yr survey for the months of May and June resulted in 6 significant events that were used to summarize depth-duration and temporal characteristics of big 3-day May and June events. These were May 6-8, 1948, April 30-May 2, 1949, May 18-20, 1957, June 3-5, 1963, June 6-8, 1964 and May 10-12, 1967.

Auxiliary PMP-related depth-duration data consisted of summarized characteristics for selected regions of the southwest PMP (chapt. 6), and of basin characteristics stemming from extrapolation of northwest States PMP (HMR No. 43) techniques, For the HMR No. 43 application, the generalized procedures of the report were extended to extrapolate values to 5,000 mi^2 east of the Cascades, and resulting computed 5,000-mi^2 72-hr values at grid points in the Clearwater basin were summarized. For the southwest States (HMR No. 49) 5,000-mi^2 72-hr PMP values computed at the grid points for the southwest "Hypo" areas of method II (chapt. 6) were summarized and deductions made. Since these generalized reports are keyed to PMP, the duration ratios from these reports should represent "upper limits" of depth-duration characteristics for SPS application. Since generalized PMP studies incorporate all significant storm experience one cannot hope, in general, to obtain additional input from specific "outside the basin" storm events. However, ratios from the important December 1964 event (complete DAD analysis available) and from a synthesis of storm events in the Snake River basin (U.S. Weather Bureau 1953) were used as supplementary input.

The eight cool-season storms involved a total of 34 stations that had a 3-day precipitation total (in a given storm event) of 1 in. or more. Setting such a threshold (for SPS depth-duration characteristics determination) will help to make results more meaningful in terms of SPS application. Mass curves for the major cool-season events are shown in Figures 88 and 89. These are repeated from Figures 36 and 37. The May-June time distribution plots are shown in Figures 90 and 91.

Special attention was given to the maximum 24-hr precipitation period in each storm, both for firming enveloping depth-duration relations and for variations permissible in the temporal variations of precipitation in major storm events appropriate for the SPS level of precipitation.

The simultaneity of regional precipitation across most of the basin in major events simplified the selection of the maximum 24-hr period in each event. The results of the summation of a 6-hr breakdown within the maximum 24-hr precipitation is shown, storm by storm, in Figure 92 for the cool season and in Figure 93 for the May-June period. At the top of each figure, the "all-storm" mean distribution is shown.

From the 6 outstanding May-June 3-day events from the 45-yr survey of maximum 3-day precipitation events, a few of the features of time distribution that distinguish the May-June events from the cool-season events are noteworthy.

1. The 3-day May-June event takes much longer for the precipitation to maximize within the 3-day event compared to the cool-season cases. This is important for providing guidance on the temporal arrangements permissible in the 3-day SPS event.

2. The May-June composite depth-duration curve (rearrangement of 6-hr increments) is slightly steeper than the cool-season curve. The difference in steepness closely approximates depth-duration differences from PMP reports. Hence, the rearranged May-June depth-duration curve is considered appropriate for the May-June SPS depth-duration variations.

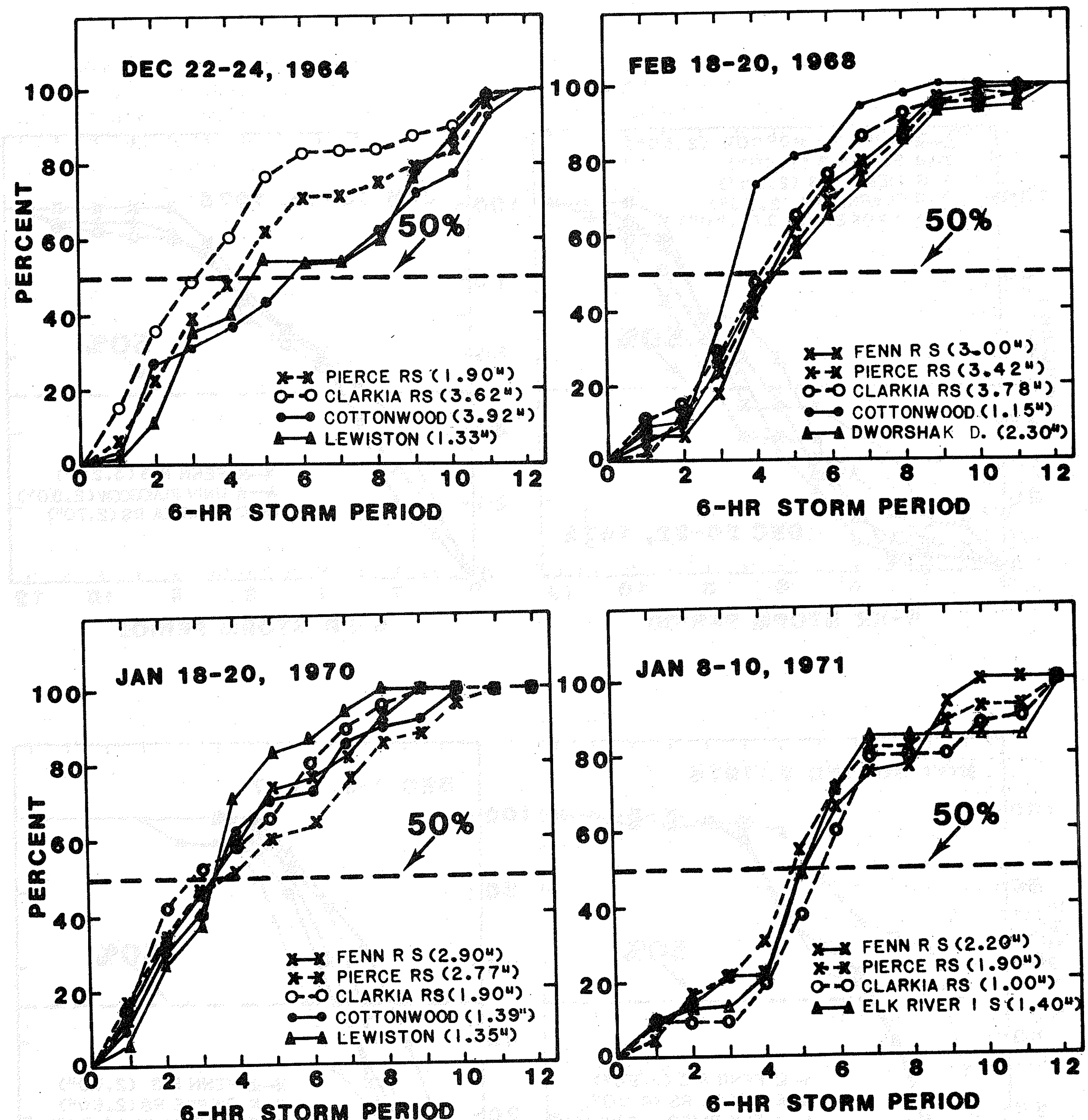

Figure 88.--Mass curves of rainfall for cool-season storms of December 22-24, 1964, February 18-20, 1968, January 18-20, 1970 and January 8-10, 1971.

The enveloping cool-season depth-duration relation is shown in Figure 94, and for May-June in Figure 95.

10.3 April as Transition Month

From a meteorological viewpoint, April is truly a transitional month. In April, at times, significant precipitation events take on the characteristics of

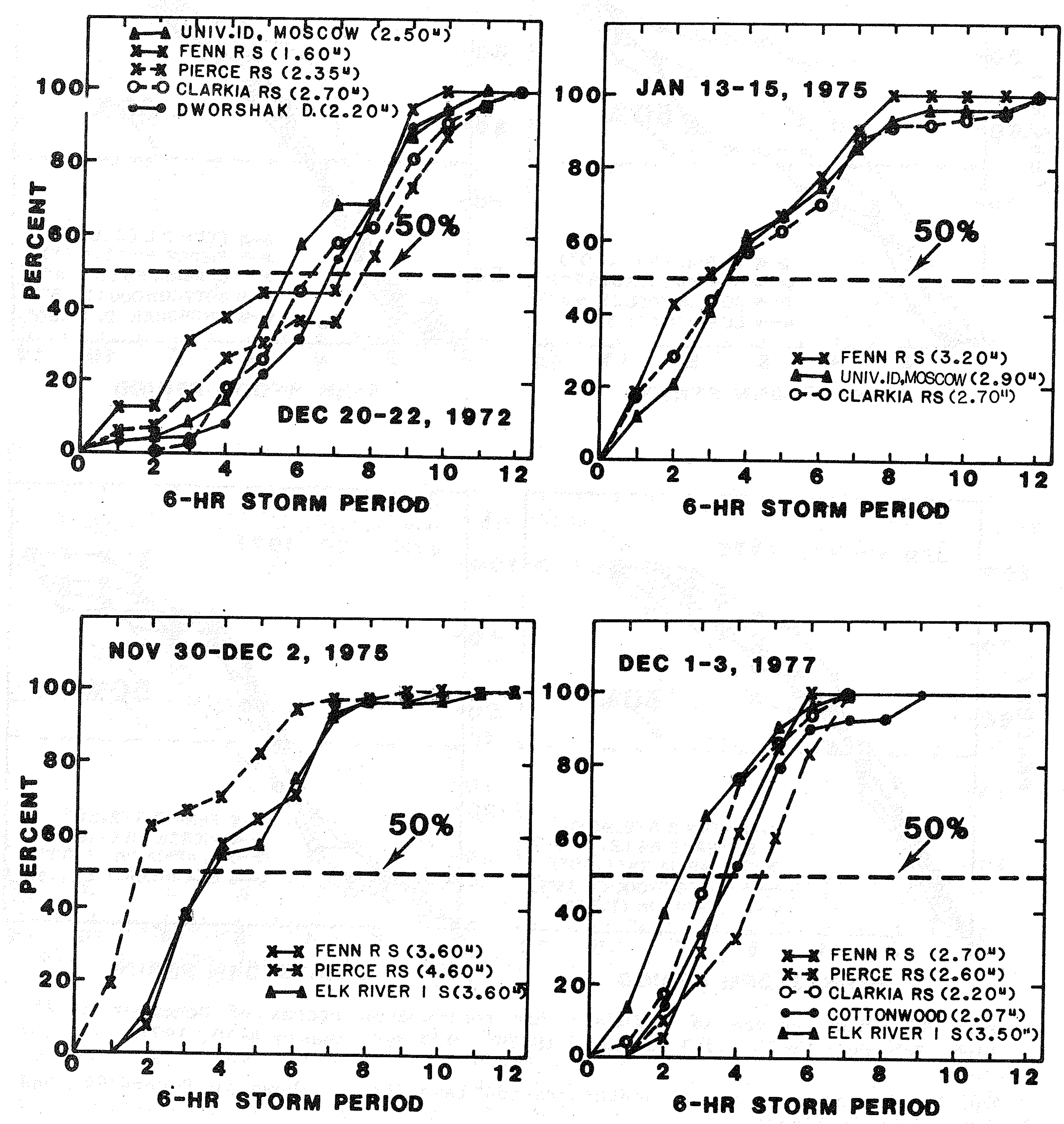

Figure 89.--Mass curves of rainfall for cool-season storms of December 20-22, 1972, January 13-15, 1972, November 30-December 2, 1975 and December 1-3, 1977.

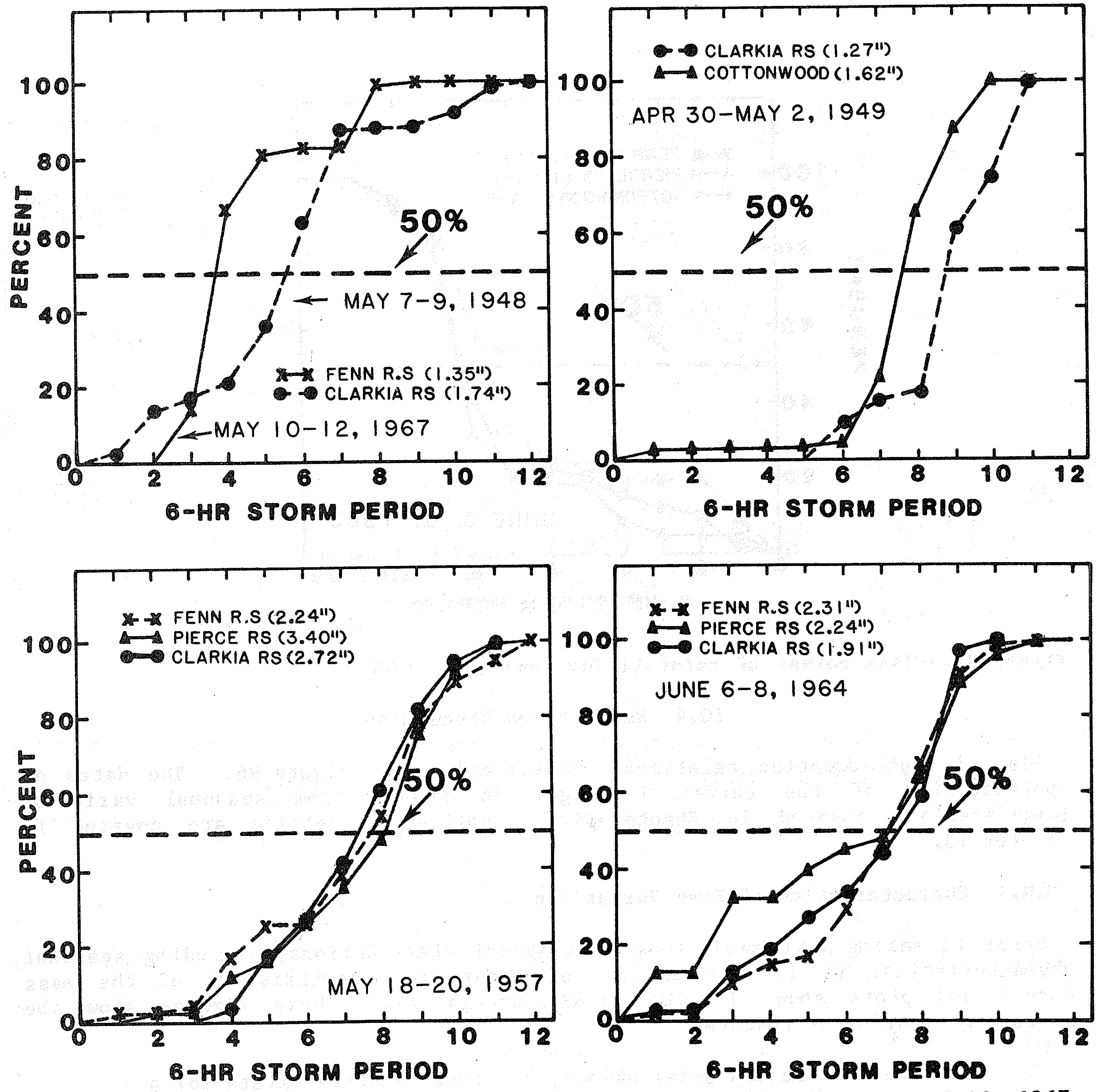

Figure 90.--Mass curves of rainfall for May-June storms of May 10-12, 1967, April 30-May 2, 1949, May 18-20, 1957 and June 6-8, 1964.

the cool-season events with moderately high moisture combining with an efficient mechanism, utilizing temperature gradients with instability contributions minimized. At other times, relatively moist, unstable air may play more of a role with the role of temperature gradient, etc., diminished. Because of this dual characteristic storm type possible in the transition month, April, varying temporal and geographical distributions of storm rainfall may take place. For this reason, the user is advised to apply both cool-season and May-June characteristics and methods (suggested in this report) for April, selecting the one which produced the most hydrologically-significant results. This recommendation is covered in Chapter 13 on applications.

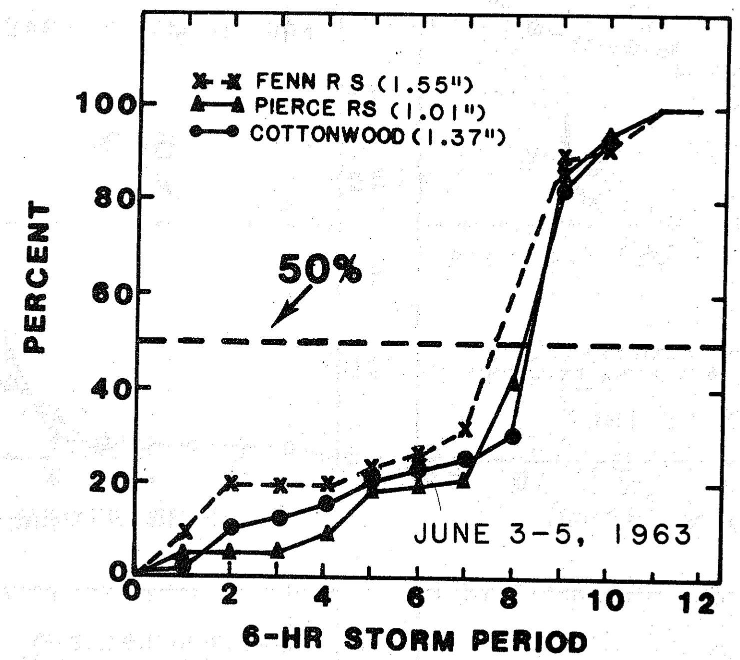

Figure 91.--Mass curves of rainfall for June 3-5, 1963.

10.4 Results and Discussion

Adopted depth-duration relations are summarized in Figure 96. The dates of applicability of the curves in Figure 96 result from seasonal variation considerations covered in Chapter 11. Application details are covered in Chapter 13.

10.4.1 Characteristics of Time Variations

Prior to making recommendations on temporal distributions, including seasonal characteristics, it is instructive to summarize characteristics of the mass curves and plots shown in Figures 88 through 95. These figures show the following significant features:

1. In the cool-season 3-day events, a strong tendency exists for a rather rapid build-up in precipitation to a rather early peak. See meteorological discussion for possible reason for this temporal distribution.

2. Contrasted to 1, the May-June important precipitation event, on the average, delays the maximum precipitation to much later portion of the storm than in the cool-season case.

3. A single period (rather than 2 or more distinctive "bursts") of maximum precipitation is characteristic of both the cool-season and May-June event. Thus, a lull followed by an important secondary burst of precipitation is not characteristic.

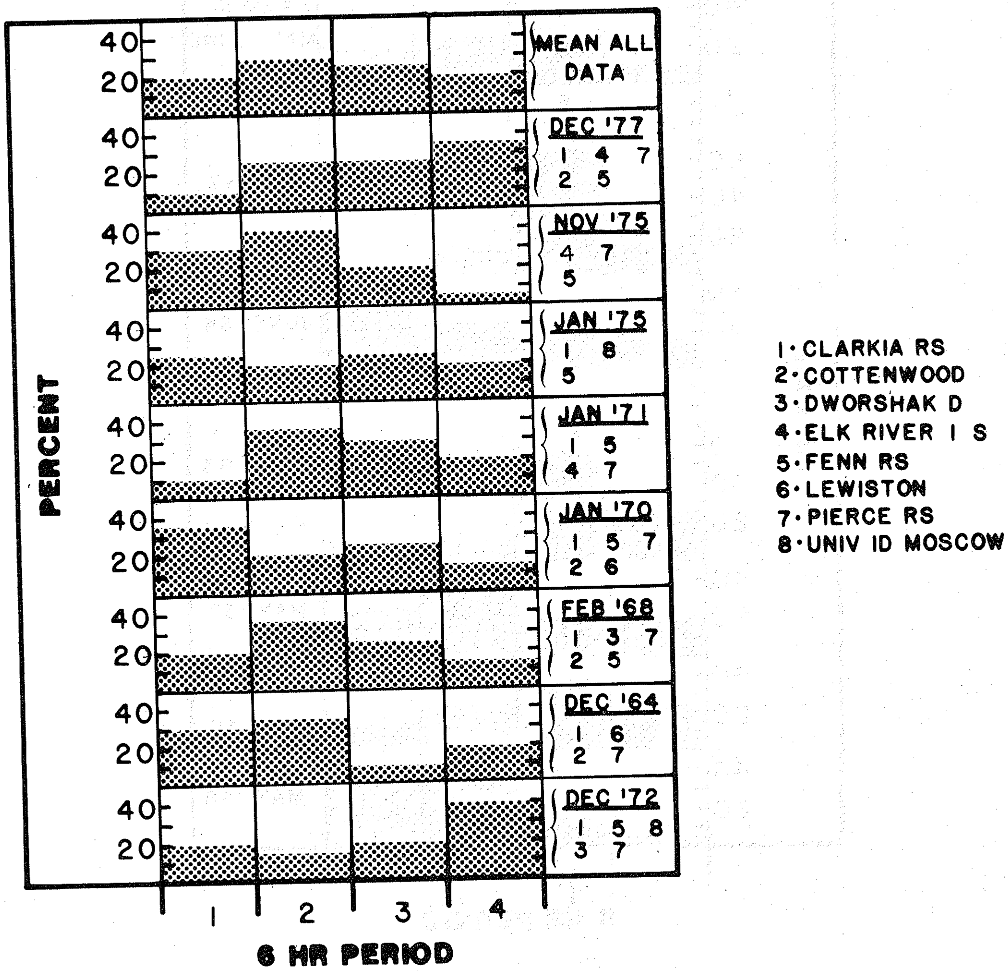

Figure 92.--Cool-season distribution (6-hr period).

4. The contrasting synoptically-supported cool-season versus May-June points to April as an important "transition" month. Hence, alternate possibilities are recommended for April with the user determining the most hydrologically-critical sequence.

5. The 6-hr distribution of precipitation in the maximum 24-hr precipitation (shown in fig. 92 for the cool-season and in fig. 93 for the May-June period) shows sufficient variability for permitting various arrangements except for not permitting the lowest 6-hr increment next to the largest increment.

6. An overall conclusion relative to the adopted depth-duration curves for basin-wide SPS precipitation is that the adopted depth-duration percentage ratios are somewhat above the basin "3-day event" storm-dictated ratios, but within the range of applicable generalized PMP procedures.

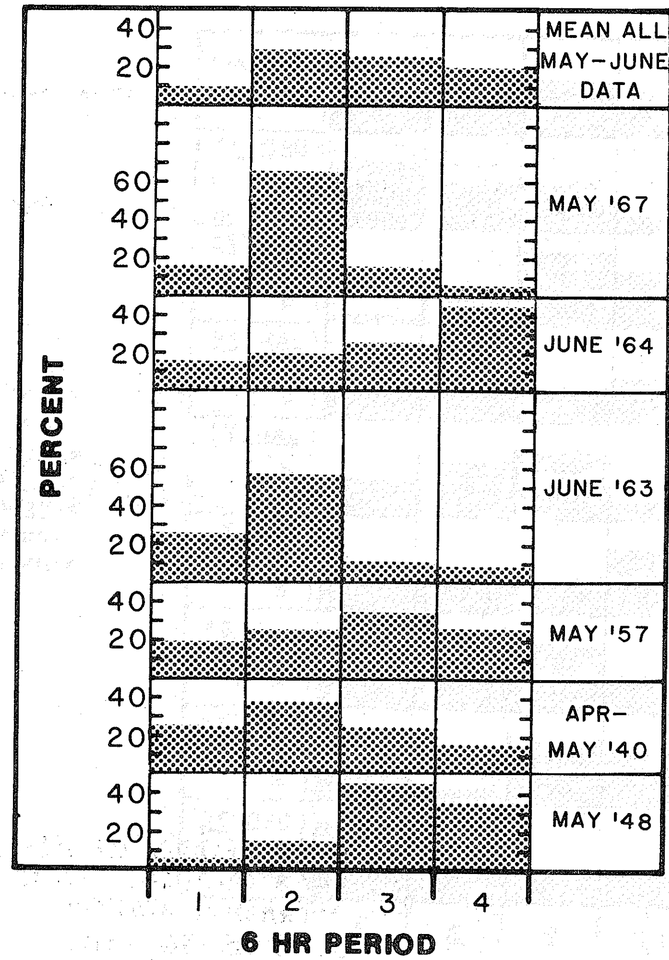

Figure 93.--May-June distribution (6-hr period).

10.4.2 Recommended Temporal Variations

The adopted depth-duration curves provide the appropriate 6-hr increments of SPS precipitation after the 72-hr SPS magnitude value is applied. The recommended temporal arrangements of 3-daily SPS increments and of the 6-hr increments within the 3-daily increments are now discussed.

10.4.2.1 Cool-Season Recommendations. The maximum 1-day SPS precipitation is preferably to be placed in the middle of the 3-day SPS sequence. The maximum may also be placed first, but not last in the 3-day sequence. With these 2 possible maximum 1-day placements, the 6-hr increments must be arranged within the following constraints: Within a 24-hr period, the 6-hr increments must be arranged so that the individual increments decrease away from the highest 6-hr increment. This means the lowest 6-hr increment must be placed at either the beginning or end of the 4 6-hr increments in a day. This is necessary, so that the phasing into the second and third day 6-hr increments will preserve the depth-duration characteristics of the adopted accumulative (ie., enveloping) depth-duration relations.

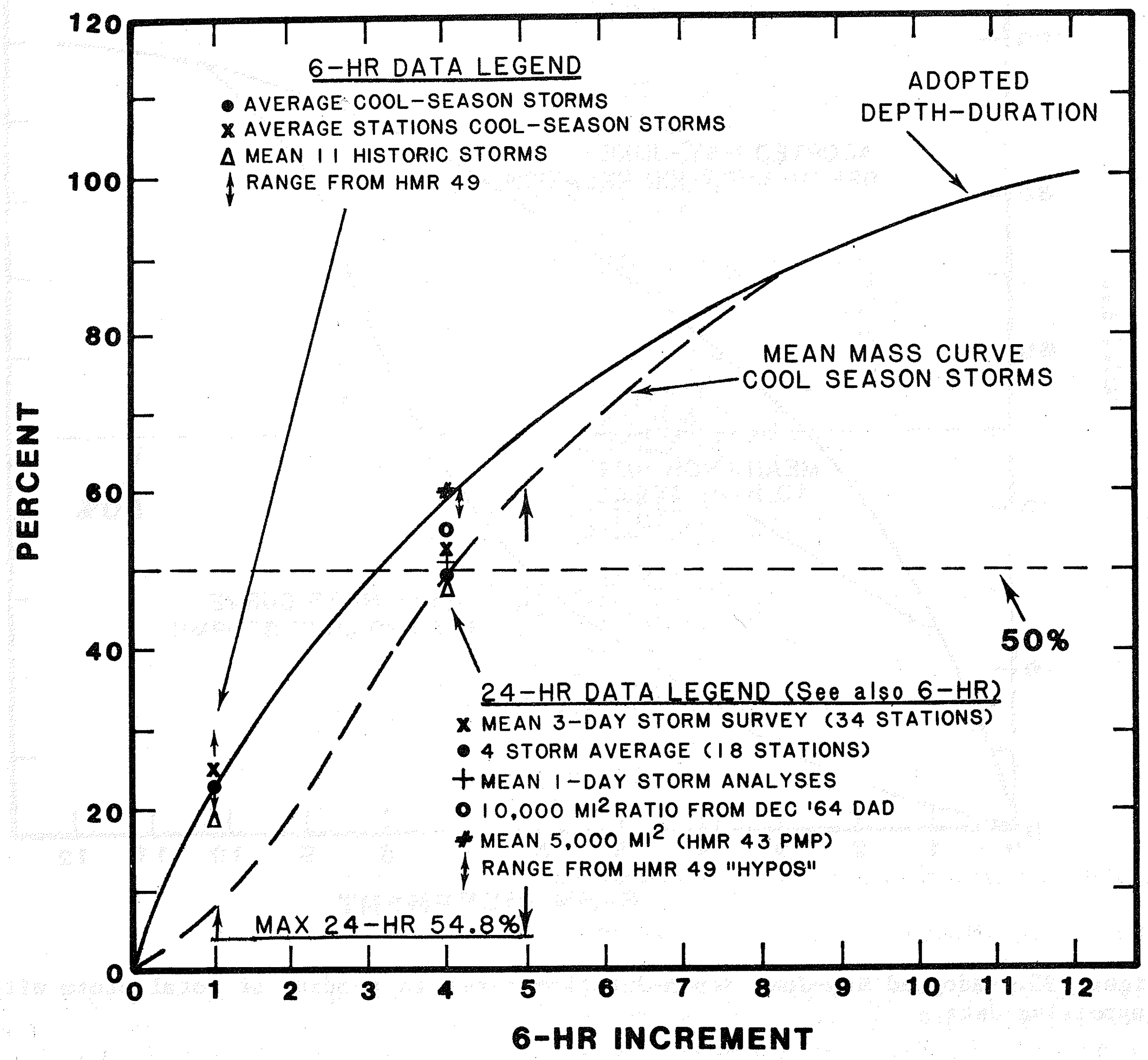

Figure 94.--Adopted percent cool-season depth-duration curve in percent of total storm supporting data.

As an example of application of temporal placements within these constraints, the following array of possibilities exist for the preferred positioning of the maximum 1-day in the middle ("1" means maximum 6-hr increment, "2" means second highest 6-hr increment, etc.).

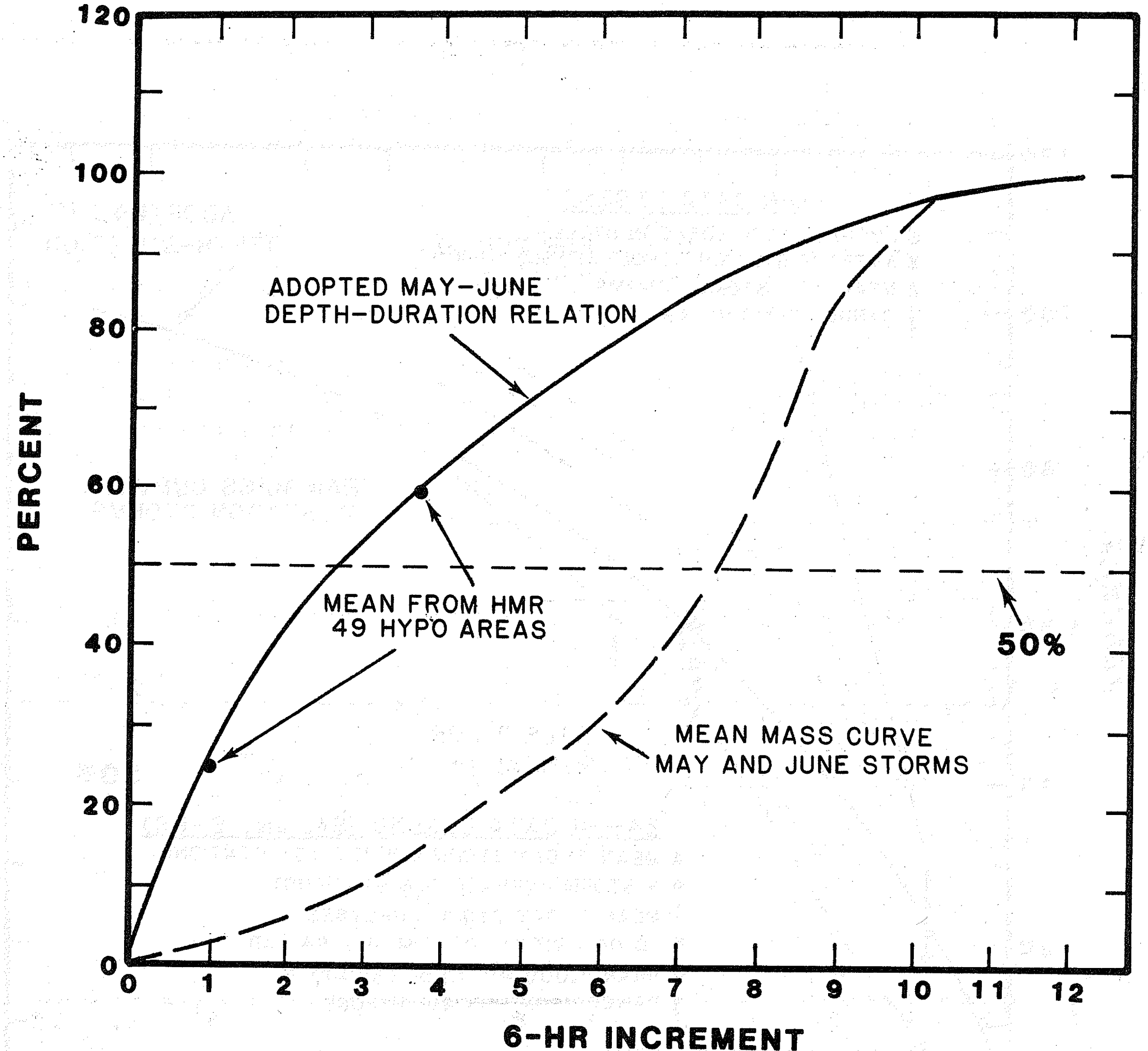

Figure 95.--Adopted May-June depth-duration curve in percent of total storm with supporting data.

Preferred placement of maximum 24-hr period with possible temporal arrangements of remaining 6-hr increments

Second highest day	Max. 1-day in middle	Third highest day
8,7,6,5	1,2,3,4	9,10,11,12
	2,1,3,4	
	3,1,2,4	
	3,2,1,4	
	4,3,2,1	
	4,2,1,3	
	4,1,2,3	

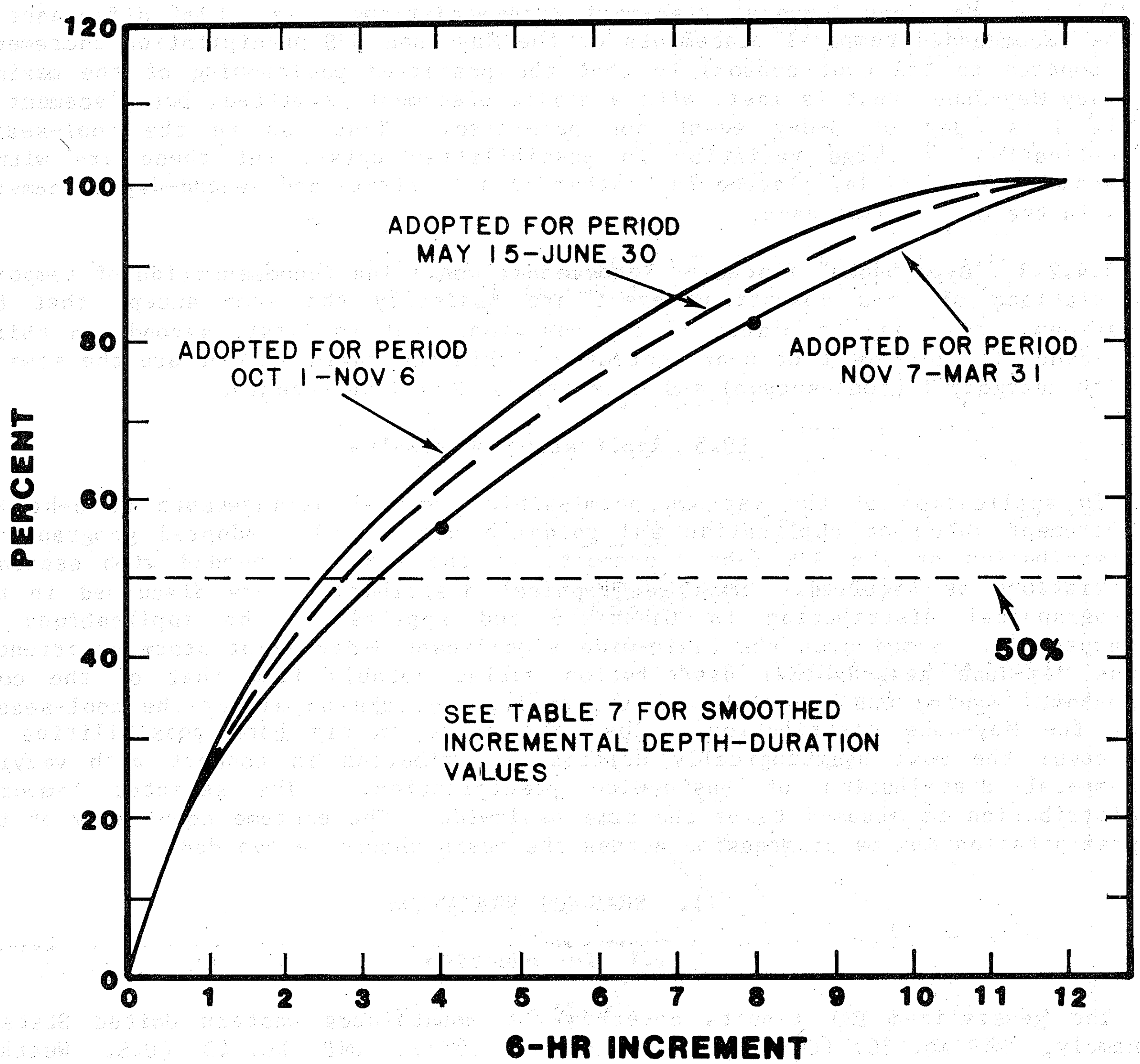

Figure 96.--Adopted depth-duration curves (percent of total storm).

With the above maximum 1-day in the middle placement all 8 variations may be repeated with the following switching (and reordering) of the first and third day.

Third highest day	Max. 1-day in middle	Second highest day
12,11,10,9	Repeat 8 variants on page 104	5,6,7,8

Note that with a switching of second and third highest 1-day events, the ordering must be changed in order to preserve all SPS increments.

10.4.2.2 May-June Temporal Placement Recommendations. The chief difference in the recommended temporal placements of the May-June SPS precipitation increments (compared to the cool season) is that the preferred positioning of the maximum 1-day May-June event is last, with a middle placement permitted, but placement as the first day of 3-day event not permitted. Thus, as in the cool-season application, a large variation in possibilities exist, but these are within second- and third-day placements, rather than in first- and second-day placements as in the cool-season case.

10.4.2.3 "Hypo-Snake" Placement Recommendations. The recommendation of temporal variations of this downstream event are basically the same except that the maximum 1-day may be placed in any position, that is first, second and third. Guidance for placement of 6-hr increment within the maximum 24 hr are the same as with category I (cool-season) and category II (May-June) events.

10.5 Application of Results

In application of the various permissible temporal arrangements of 6-hr SPS increment rules of application and guidance are needed. Adopted geographical distribution of the SPS 6-hr increments in the basin is needed with seasonal variations as required. Such geographical distributions are discussed in the geographical distribution in Chapter 9 and applied in the applications of Chapter 13. Based upon the basin-wide significant 3-day event storm experience, the May-June geographical distribution varies notably from that of the cool season. Again, the transition month, April, may take on either the cool-season or the May-June distribution. The user needs to try both possibilities to uncover the most hydrologically critical distribution in concert with varying temporal distribution of basin-wide precipitation. The selected temporal distribution is assumed to be the same basinwide. The extreme complexity of the precipitation maxima progressing across the basin should be avoided.

11. SEASONAL VARIATION

11.1 Introduction

The generalized PMP reports covering the mountainous western United States, namely; HMR No. 36 (U.S. Weather Bureau 1961), HMR No. 43 (U.S. Weather Bureau 1966), and HMR No. 49 (Hansen et al. 1977), do not specifically address the problem of seasonal variations for areas as large as the 9,570-mi^2 Clearwater drainage above Spaulding, Idaho. Some older studies for example, Cooperative Studies Report No. 11 (U.S. Weather Bureau 1953) did address the problem of large area seasonal variation, in this case for the Snake River.

Because of the overall lack of definitive studies of large area seasonal variation in the mountainous western United States, it was deemed important to provide some direct input to the solution of the seasonal variation problem in this report. The direct input in this report came from a comparison of major cool-season and May-June SPS precipitation resulting from the respective 45-yr survey of maximum 3-day basin-wide events. Additional input came from adoptive use of prior work in the west on seasonal variation.

11.2 Data and Procedures

The data used for the seasonal variation evaluation consisted of the following:

1. 45-yr basin-wide 3-day precipitation survey results.

2. Central Snake River seasonal variation results from Cooperative Studies Report No. 11 (U.S. Weather Bureau 1953).

3. A 6-station mean of greatest weekly precipitation in the Clearwater basin, (Meteorological Committee, Pacific Northwest River Basins Commission, 1969).

4. Normal monthly precipitation (Environmental Data Services, 1973a), plus 3 standard deviations of this monthly precipitation for the central mountain region of the Clearwater drainage.

5. Adaptive use of HMR No. 43 (U.S. Weather Bureau, 1966) seasonal variation results based upon Pacific Ocean influences.

The basin-wide survey data for May-June was statistically analyzed in the same manner as the cool-season survey data (chapt. 2). After adoption of an appropriate cool-season basin-wide SPS precipitation value based on meteorological considerations, the implied return period value (i.e., 270 yr) was then used to obtain an "equal probability" value for May-June (fig. 97).

The Snake River seasonal variation values (U.S. Weather Bureau, 1953) were simply adopted from that report as a general-level check.

Weekly precipitation data for stations within those stations considered unaffected by moisture seepage from the southeast were examined. The greatest weekly precipitation at 8 stations was averaged for the November through January period and then compared to similarly chosen data for the May-June period.

Normal monthly precipitation plus 3 standard deviations (to obtain reasonably "rare" events) for the central mountain region in the cool season was compared to similarly determined May-June values.

11.3 Results and Adopted Seasonal Variation

The meteorological evaluation of the major cool-season events (chapt. 3) and the major May-June events (chapt. 4) showed the Pacific Ocean the source of the weather features and moisture contributing to significant Clearwater basin precipitation throughout the entire October through June season. With this as background, the seasonal variation of zones A and B of HMR No. 43 was additional input to the seasonal variation problem. This seasonal variation (from HMR No. 43) was adjusted slightly for consistency in the length of the basic major "cool season" adopted for the Clearwater drainage.

A plot of the data used and the adopted seasonal variation curve for the 9,570-mi^2 Clearwater drainage above Spaulding, Idaho is shown in Figure 98. The adopted curve is somewhat above the mean of the various methods for May-June and slightly below the adopted and ajusted HMR No. 43 seasonal variation.

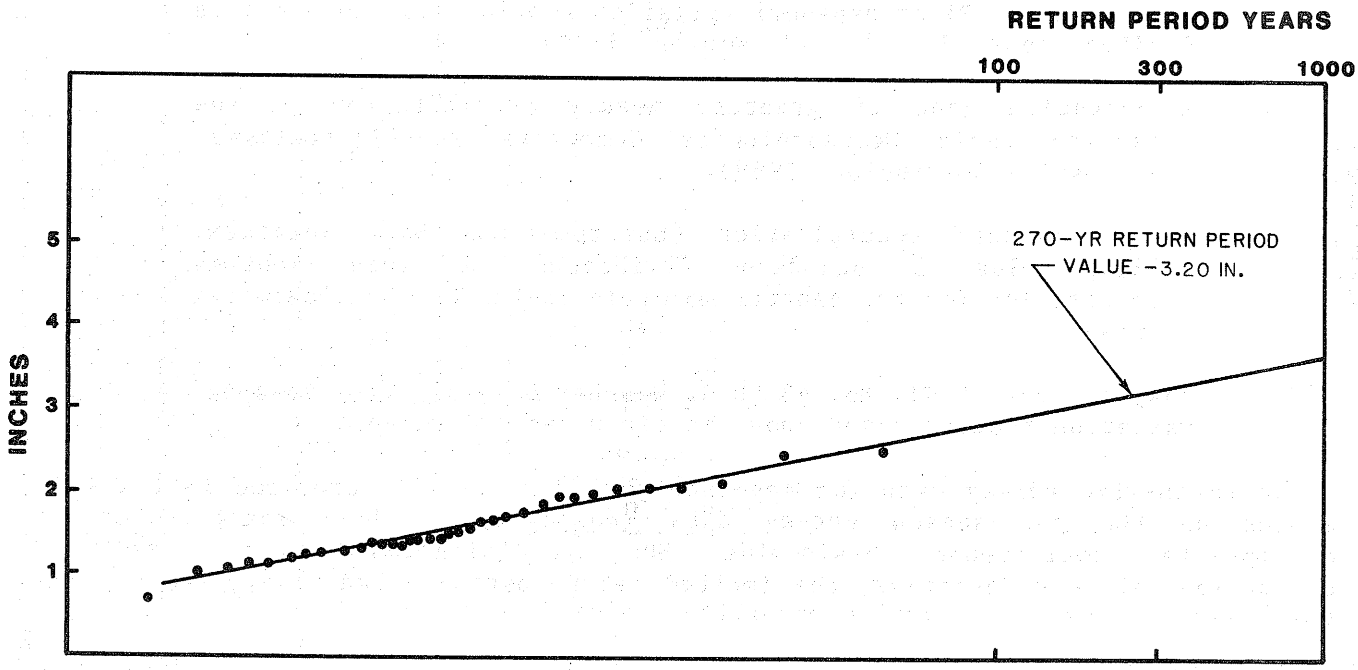

Figure 97.--Statistical analysis of 3-day May-June basin precipitation.

12. SPS SNOWMELT TEMPERATURE CRITERIA

12.1 Introduction

Consultation with potential users of this study indicated a need for specifying snowmelt temperature criteria covering the months of November through June. Results were preferred in a form allowing ready determination of index station values, with a lapse rate provided for elevation variation, and a daily temperature range for obtaining maximum and minimum departures for 12-hr application to snowmelt. All of this is to be done for both the 3-day period of SPS precipitation and for the 3 antecedent days of snowmelt prior to the occurrence of the SPS event. Criteria developed are considered appropriate for SPS precipitation conditions; more extreme snowmelt temperatures could prevail under PMP conditions (U.S. Army Crops of Engineers, 1960).

12.2 Data

Various data sources were reviewed for obtaining reliable SPS snowmelt temperature criteria. In broad terms these data included, climatological temperature data including normals, extremes, standard deviations, temperature probability levels, etc. Part of this background data package included the

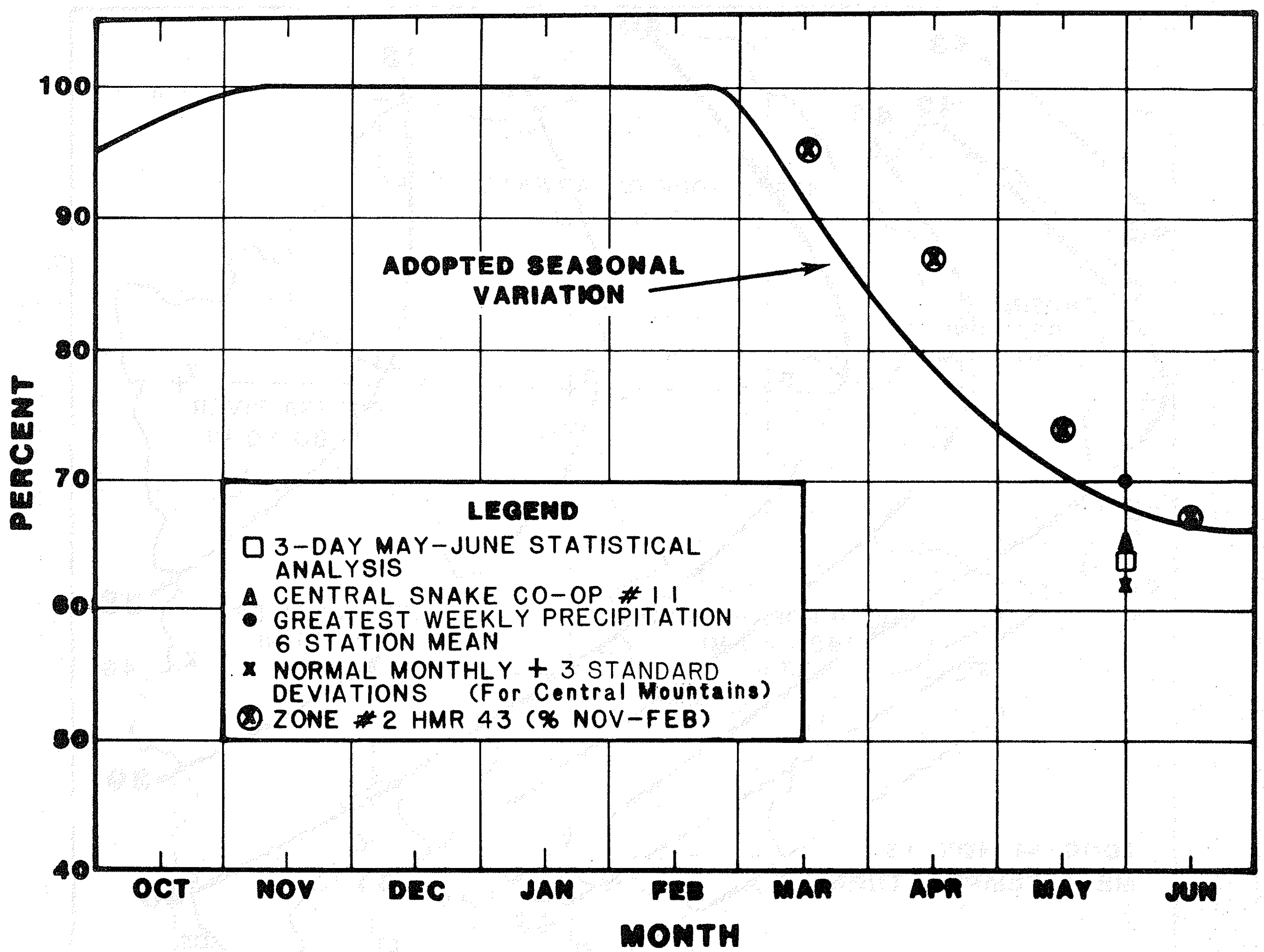

Figure 98.--Adopted seasonal variation - Clearwater River drainage.

Columbia River basin reports (Meteorological Committee, Pacific Northwest River Basins Commission 1968 and 1969), and Weekly Weather and Crop Bulletins (National Weather Service 1913-1983). In addition, prior work in the snowmelt temperature field (Riedel et al., 1969) was considered.

Since the objective was to provide temperature criteria appropriate to SPS conditions, the most important body of data consisted of prevailing temperature extremes during the more significant basin-wide 3-day precipitation events resulting from the 45-yr survey for both the cool season and for the May-June spring period.

12.3 Basic Normal Temperature Charts

The provision of mid-month temperature charts for some standard elevation assures consistency in temperature criteria. Therefore, as an underpinning for the snowmelt temperature criteria such a midmonth normal charts were developed, with values appropriate to a standard 1,000-ft elevation.

Normal temperatures for the stations in the basin were part of the data base needed for development of a set of normal charts (Environmental Data and

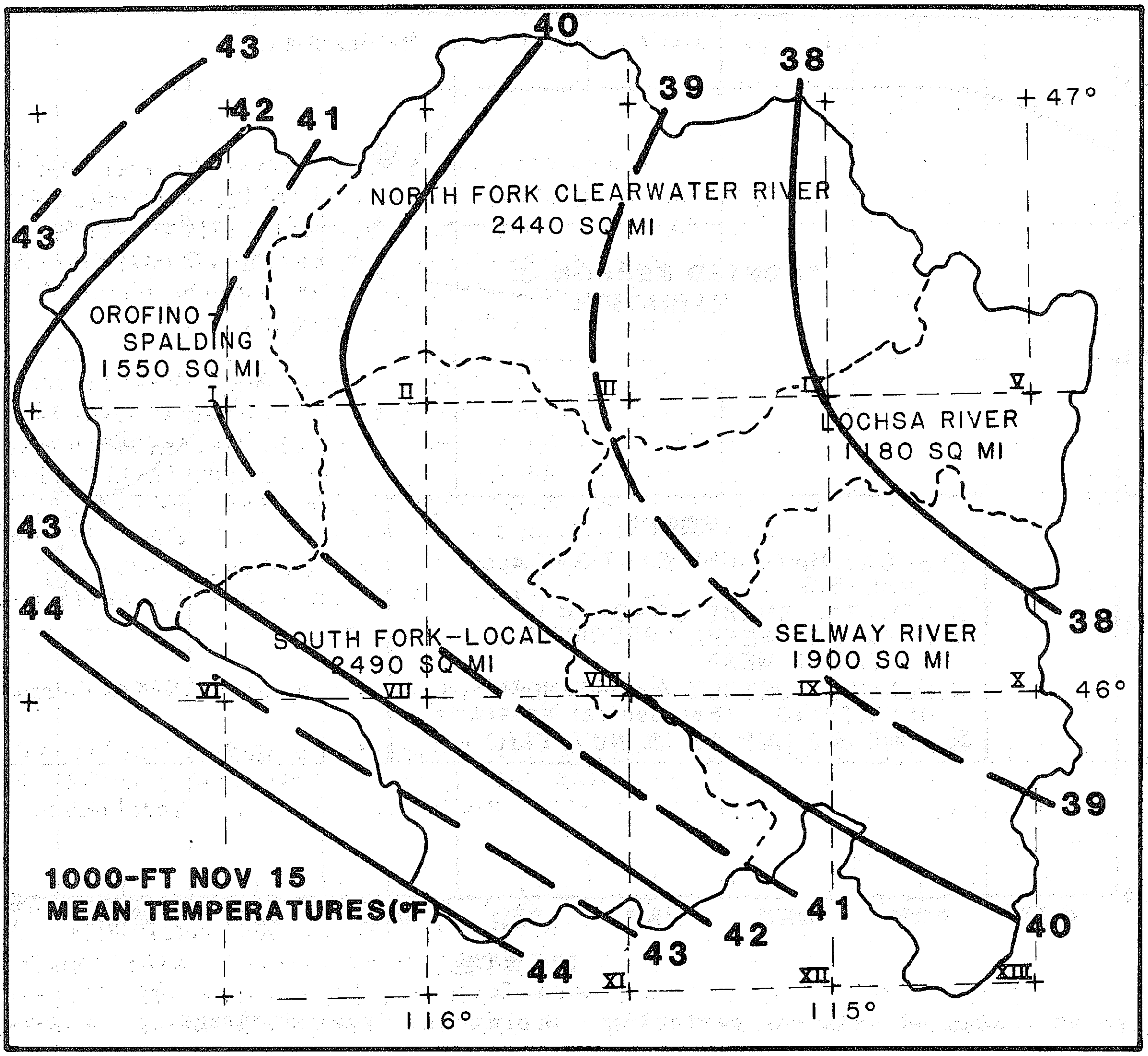

Figure 99.--November 15 mean 1,000-ft temperatures.

Information Service 1973a and 1973b). Station normal temperature values were adjusted to the 1,000-ft elevation by application of 3.5°F/1,000-ft elevation temperature variation. Such a lapse rate was found to be the mean value from comparison of station-to-station variations in many observed cases and thus, confirmed earlier work with lapse rates during significant precipitation events. The resulting midmonth normal 1,000 ft temperature charts are shown in Figures 99 through 104* for the months of November through April. For the months of May and June flat maps (i.e., no temperature gradient) appear the most reasonable. Hence, for May a mean for the 15th of 59.5°F applies throughout, while the June 15 basin-wide adopted value is 65.0°F.

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* This set of 1,000-ft mean temperature charts are repeated in the Applications Chapter 13 for ease of use.

12.4 Cool-Season Temperature Departures

12.4.1 Introduction

Many sources for estimations of temperature departures were utilized including large positive monthly (American Meteorological Society 1974-83, National Weather Service 1913-1973) and weekly (National Weather Service 1913-1983) departures, but of paramount importance was a detailed study of the temperatures prior to and during the more important basin-wide 3-day precipitation events, both for the cool season of November through March and the May-June periods.

A specific use of the warm-month and warm-week data was, in concert with synoptic considerations as to whether the more extreme departures were consistent with the greatest 3-day precipitation events and also, whether certain extreme positive temperature events were so rare as to be beyond an SPS-level event. A good example of the latter is the warm January 1953 situation. The unusualness of this month (for warmth) was first obvious in reference to its exceeding of the next warmest month. No other month was such an outstanding "outlier." The extremely unusual event represented by January 1953 is shown by reference to Figure 105.

12.4.2 Cool-Season Survey of Temperature Departures During 3-Day Storm Event

A preliminary investigation of large weekly temperature departures in winter, but especially investigation of departures during significant 3-day events in the basin indicated no particular basin distribution of departures was characteristic.

A detailed investigation and summation of the prevailing temperature regions during and prior to the major 3-day precipitation events was undertaken. Where not readily available from the literature, daily normal curves were constructed for some stations (National Climatic Data Center 1938) so that the departures could be determined in a manner that would be representative of basin-wide departures.

In order not to overlook important temperature departure trends, especially in connection with the synoptics of significant 3-day precipitation episodes in the basin (chapt. 3), departures were investigated for a full 6-day antecedent period leading up to the 3-day event, even though only 3 antecedent days need to be specified.

A total of 8 major cool-season events were evaluated for determining appropriate temperature departures during cool-season SPS precipitation and for 3 antecedent days. An across-basin average mean temperature departure was used in each case. Figure 106 shows plots of these individual event mean departures for the desired 6 days.

The day-by-day regionally averaged departures for these 8 cases were ranked both individually and as a summed (3-day total) departure and the upper quartile value adopted as an appropriate SPS-level temperature departure based upon the following points stemming from conclusions in relation to the meteorological features of the major cool-season events (sec. 3.3).

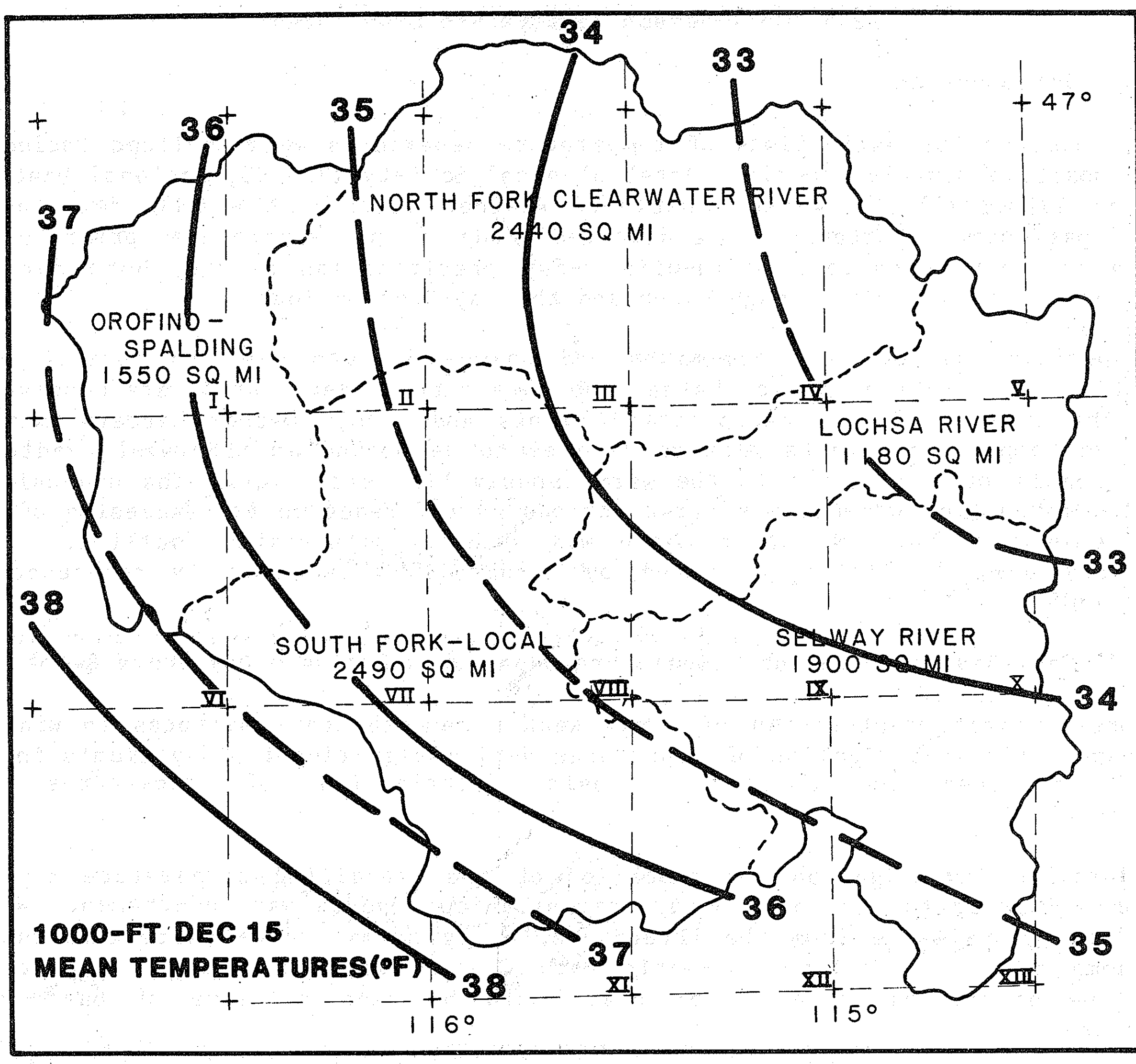


Figure 100.--December 15 mean 1,000-ft temperatures.

1. The choice of less severe design criteria of temperature departures (such as mean values) emphasize the severity requirements of too much prior cold air to be characteristic of the SPS event.

2. The choice of a more severe design criteria, like a 10-percentile value, would emphasize the "outlier" unusually warm situation too much to be characteristic of the SPS situation.

The basis for the development of a middle-of-the-cool-season 3-day sequence is illustrated best by a summation of the 8 cool-season cases. This is done in Table 3.

The positioning of the maximum 1-day departure within the 3-day storm for the 9 3-day events showed the maximum 1-day occurring twice on day 1, 4 times on day

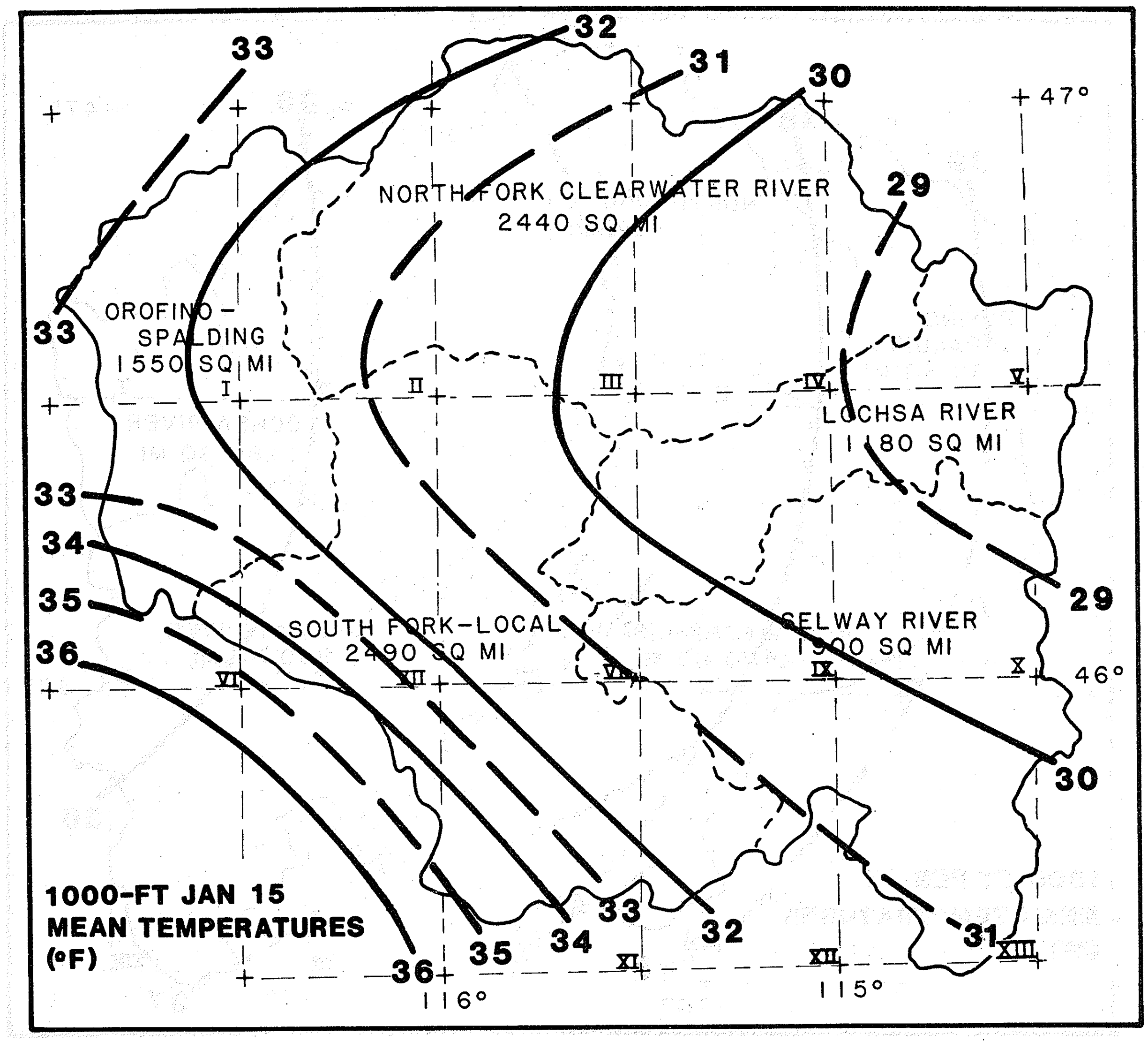


Figure 101.--January 15 mean 1,000-ft temperatures.

2 and 6 times on day 3. As can be seen from the listing in Table 3, 2 storms had equal departures on 2 of the 3 days. This means for the 3 days of the data shown in Table 3 are 15°F, 12°F and 9°F, giving the mean accumulative 3-day departure of 36°F. The storms producing the departures shown in Table 3 stretched from November through February.

From the above and from additional evaluation of detail of the departures, the adopted 3-day cool-season event departure sequence was 10°F, 17°F and 14°F above normal (i.e., 3-day accumulations departure of 41°F). These values are considered appropriate for occurrence for the middle of the cool season (i.e., January 15).

Later (sec. 12.5), a seasonal trend in departures is adopted so as to phase into the somewhat below normal (i.e., negative departures) characteristic of the May-June period (sec. 12.5).

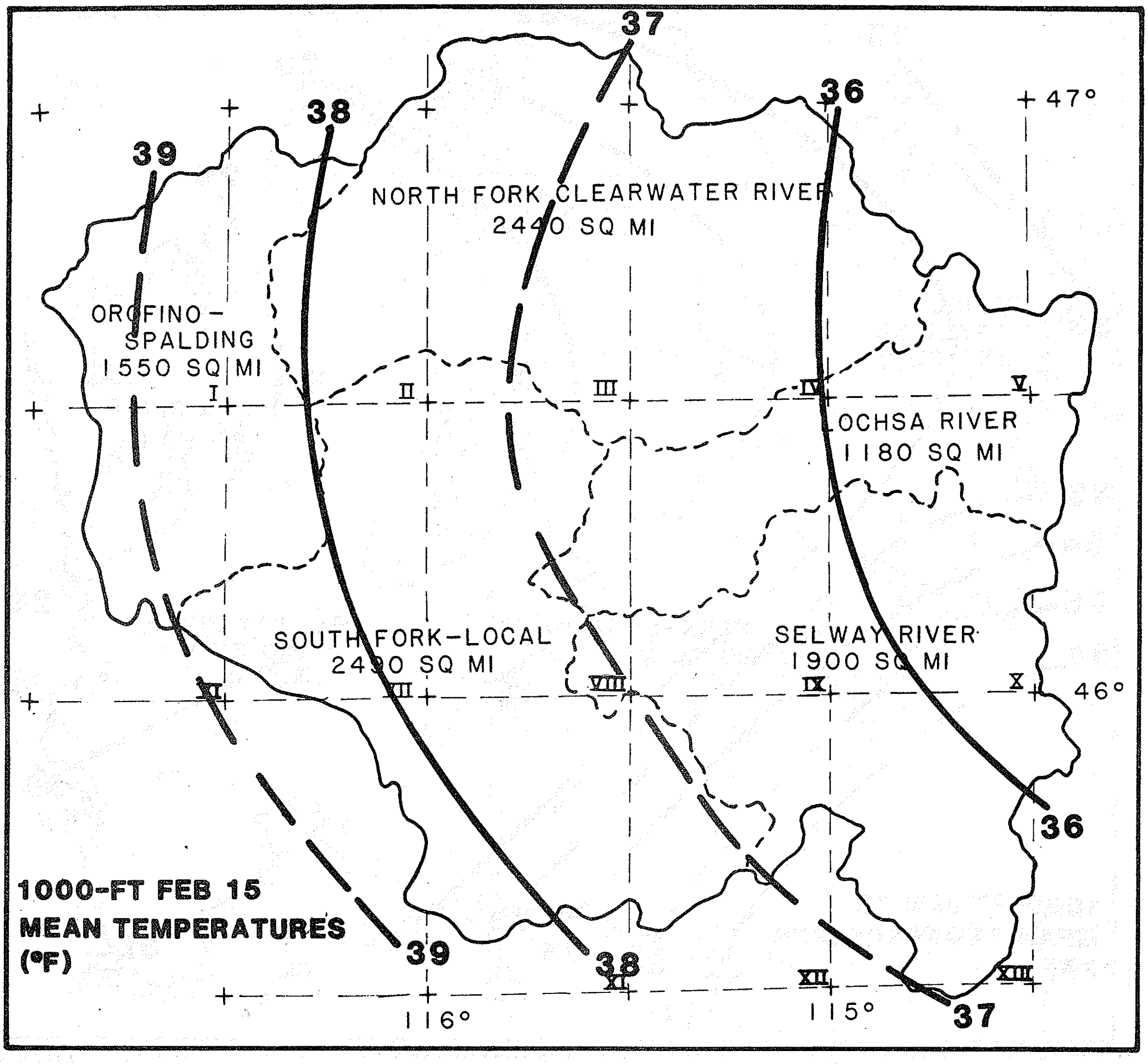


Figure 102.--February 15 mean 1,000-ft temperatures.

12.5 May-June Temperature Departures

Five major May-June 3-day basin-wide precipitation events in recent years were summarized as in the cool-season cases, in order to establish appropriate SPS level temperature departures for snowmelt during the May-June season. These 5 cases with the accompanying basin-wide 3-day precipitation amounts were:

1. June 6-8, 1964, 2.12 in.

2. June 4-6, 1974, 1.92 in.

3. May 4-6, 1979, 1.96 in.

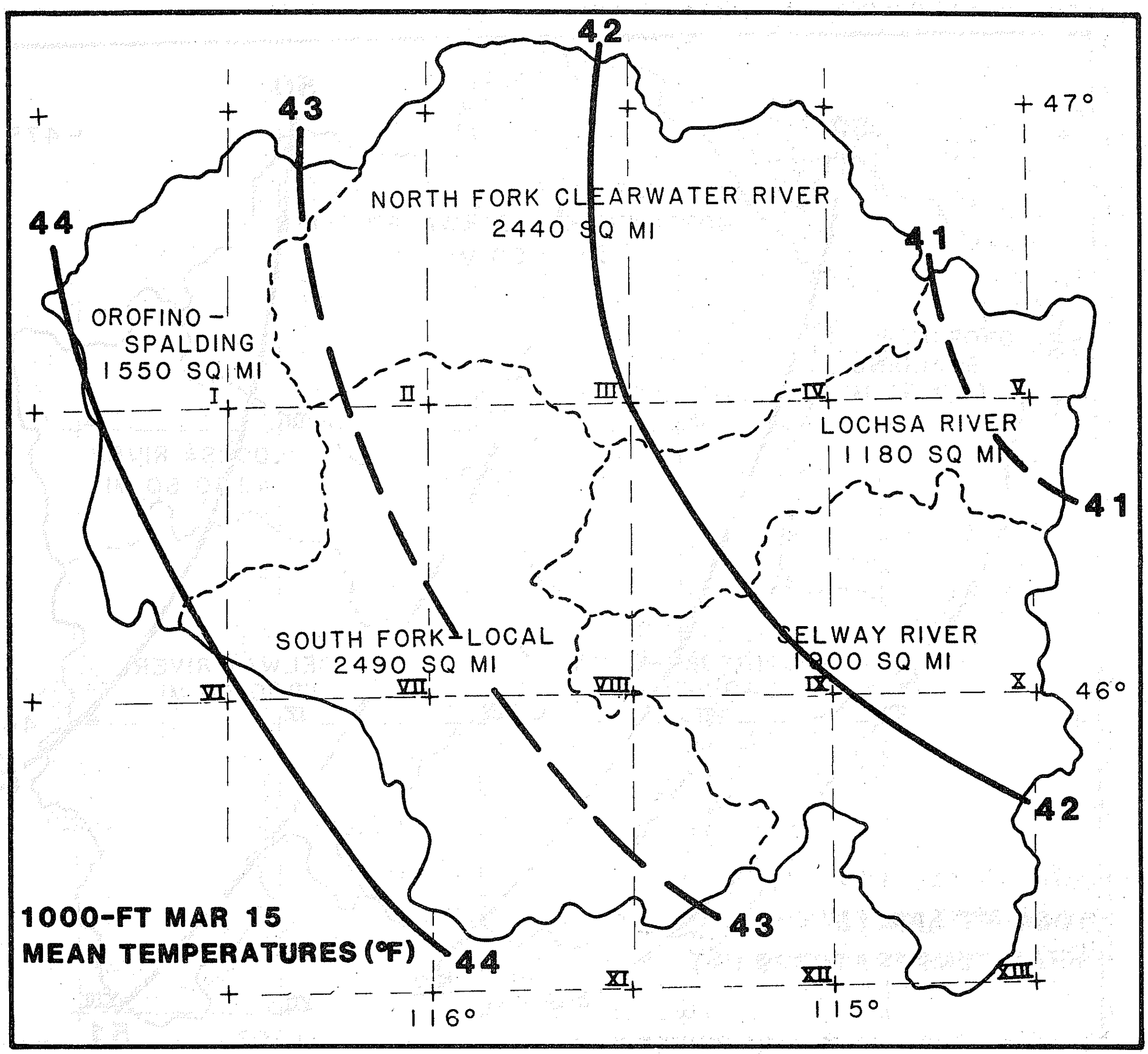


Figure 103.--March 15 mean 1,000-ft temperatures.

4. May 24-26, 1980, 2.42 in.

5. June 17-19, 1981, 2.04 in.

The basin mean station temperature departures for these 5 3-day events and for the older significant storms of May 7-9, 1948 are shown in Figure 107. Departure for three antecedent days are also shown in this figure. More detailed basin-wide analyzed temperature departures were done for the middle day of the 5 recent events listed above. These are shown in Figures 108 through 110. To accomplish this, normal mid-May and June 1,000-ft basin temperatures, a lapse rate, and daily temperature data for all within-basin stations, and a few close-to-basin stations were used. A consideration of much storm related station-to-station (with differing elevations) temperature data were summarized for determining an appropriate lapse rate. These data indicated the

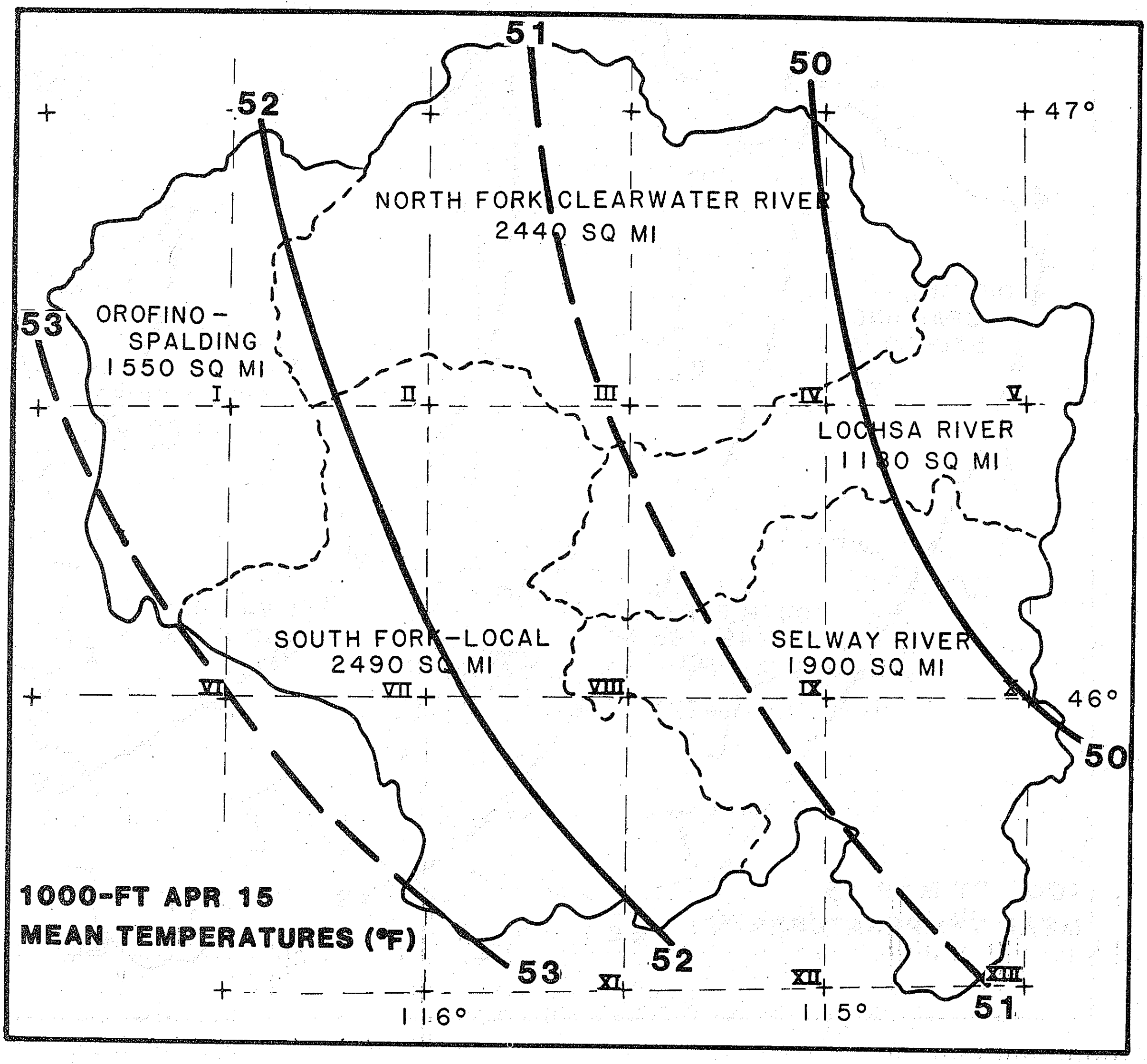


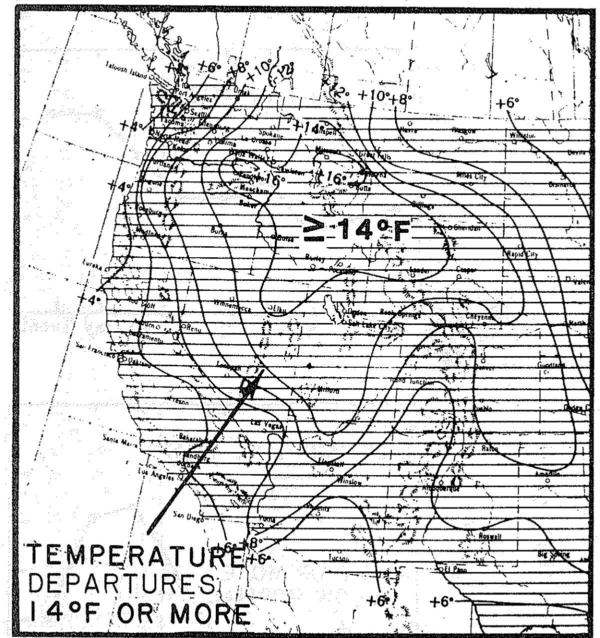
Figure 104.--April 15 mean 1,000-ft temperatures.

3.5°F/1,000 ft lapse rate adopted for the cool season was also applicable to storm situations in the months of May and June.

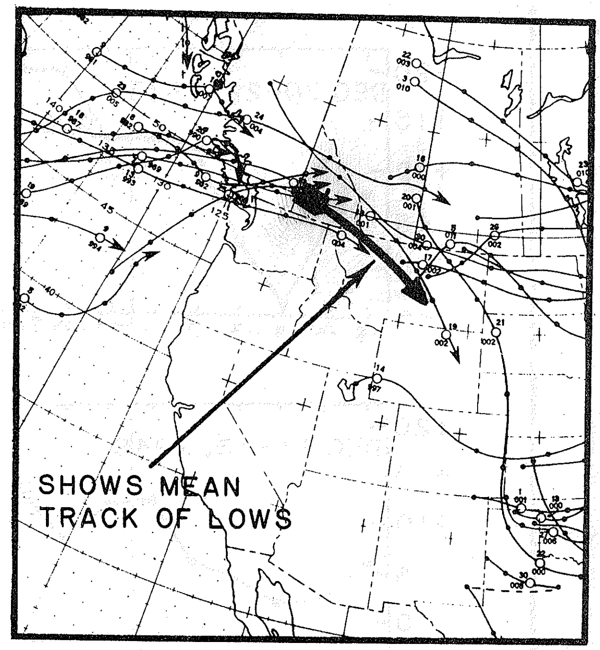
From a smooth seasonal normal curve drawn through mid-month data for November through April and a flat 59.5°F for May 15 and a flat 65°F for June 15, normal temperatures were determined for each storm date. All station daily means for the storm dates were then related to the appropriate normals by use of the 3.5°F/1,000 ft. The resulting full basin analyses in terms of departures from normal (fig. 108 through 110) were planimetered to give the following basin-wide average departures from normal temperature:

1. June 6, 1964, -1°F

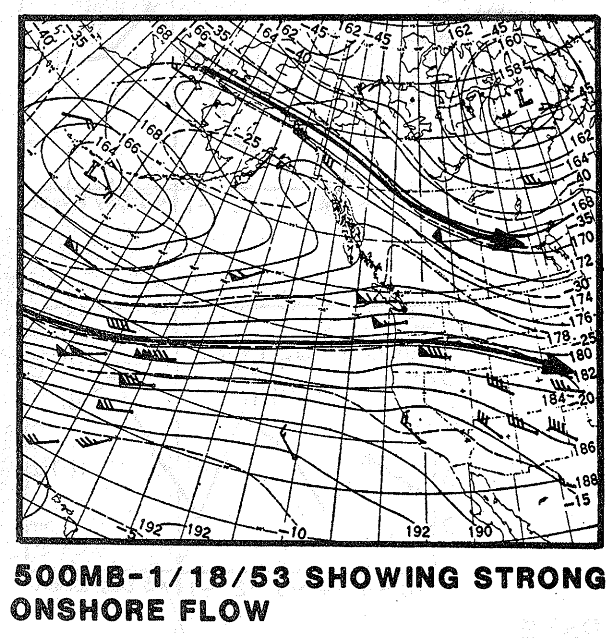
2. June 7, 1974, -6°F



JAN 1953 MONTHLY TEMPERATURE DEPARTURE



1230 Z POSITION OF SFC LOWS



500MB-1/18/53 SHOWING STRONG ONSHORE FLOW

POINTS IN REFERENCE TO CLEARWATER SPS EVENT:

(1) HEAVY RAINS—COAST RANGE DUE TO:
(a) STRONG ONSHORE FLOW UPSLOPE
(b) MOIST AND UNSTABLE AIR

(2) PARTIALLY SHELTERED BASIN LIKE CLEARWATER NEEDS ATMOSPHERIC DISTURBANCES WITH MORE COLD AIR CONTROL (OTRW LIMITS ON PCPN)

REF.=MONTHLY WEATHER REVIEW (1953)

Figure 105.--Unusual temperature regime - January 1953.

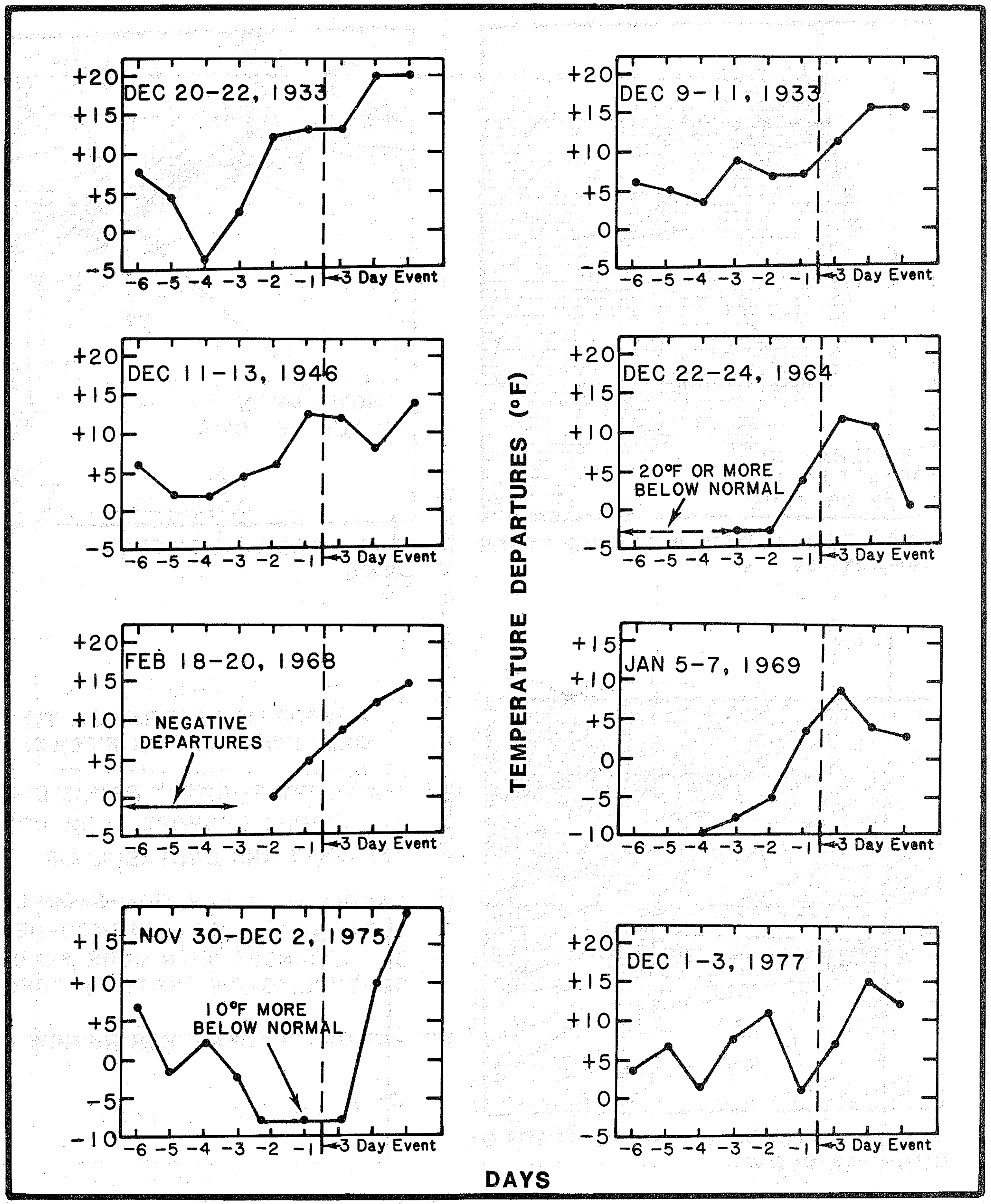


Figure 106.--Temperature departures prior to and during cool-season 3-day event.

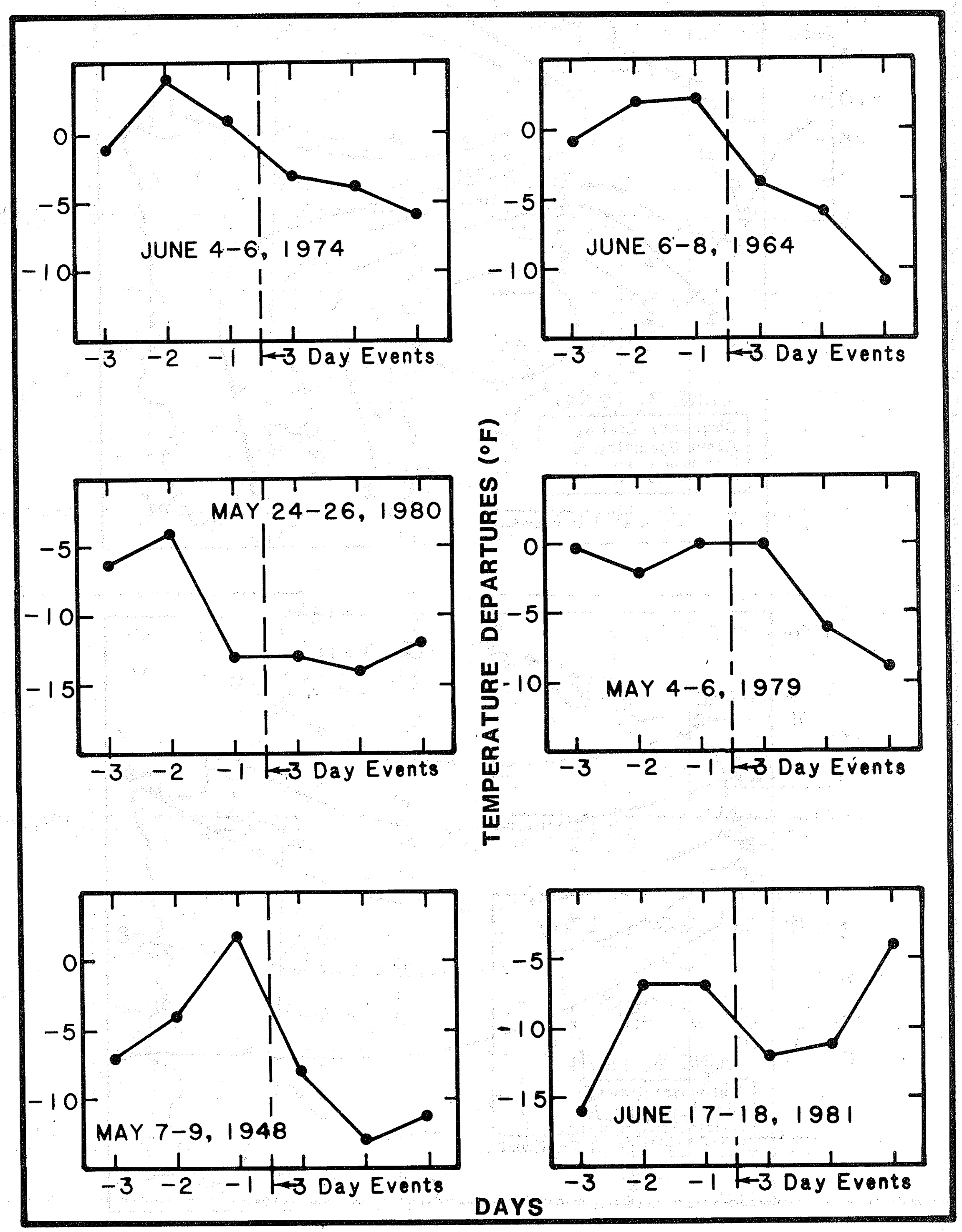


Figure 107.--Temperature departures prior to and during May-June 3-day event.

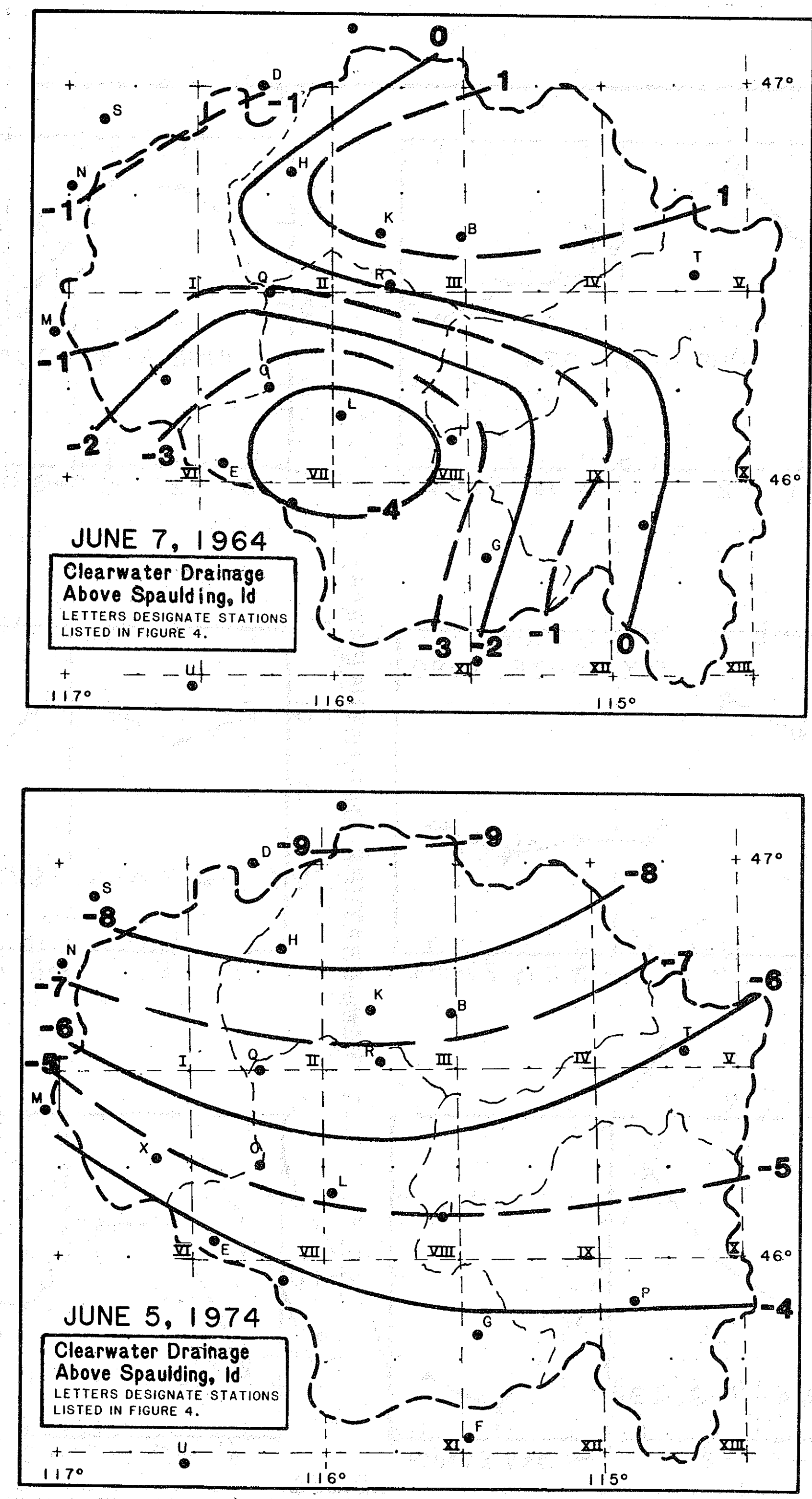


Figure 108.--Basin-wide temperature departures - June 7, 1964 and June 5, 1974.

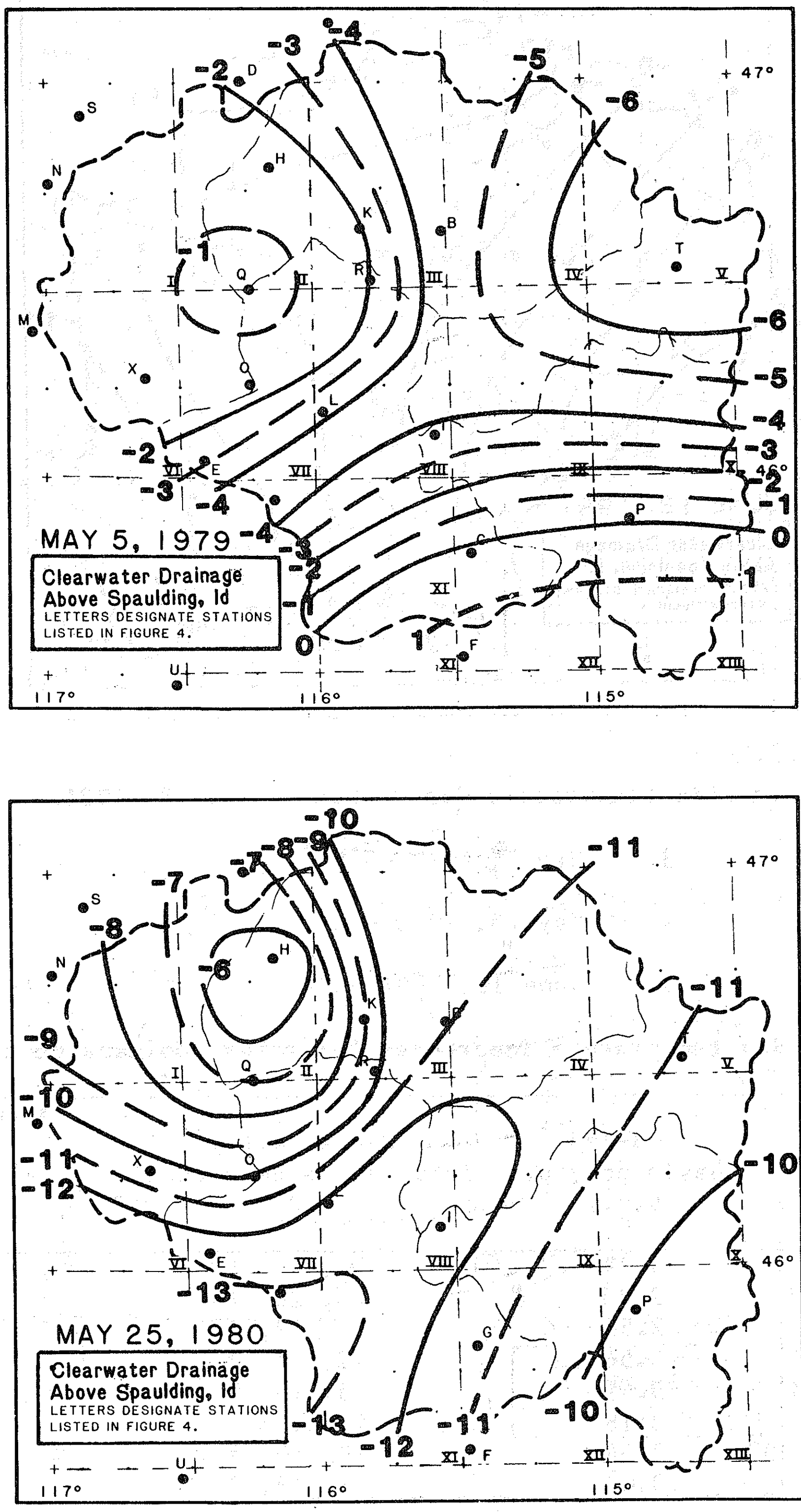


Figure 109.--Basin-wide temperature departures - May 5, 1979 and May 25, 1980.

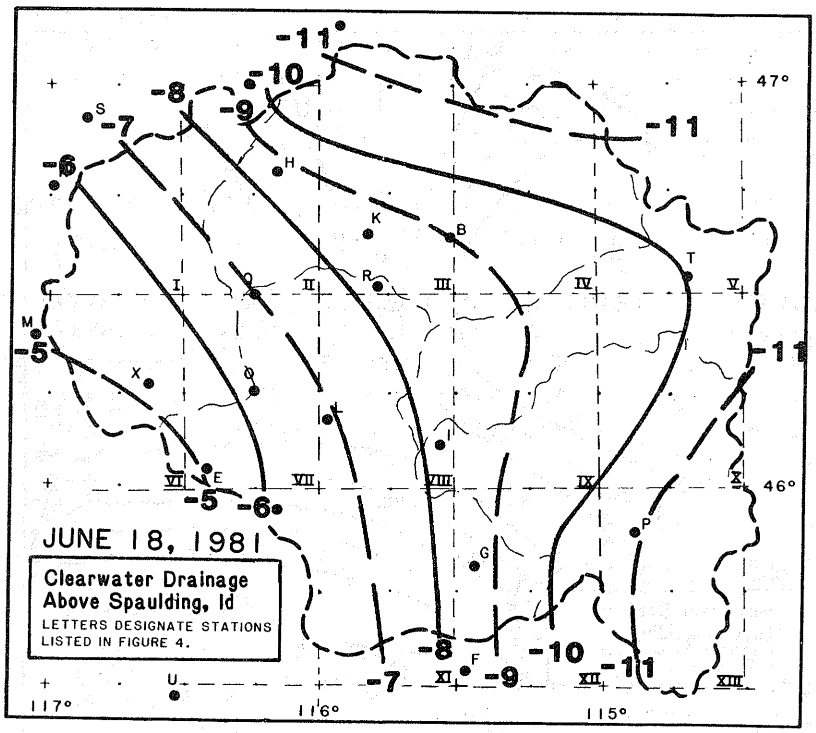


Figure 110.--Basin-wide temperature departures - June 18, 1981.

3. May 5, 1979 -3°F

4. May 25, 1980 -10°F

5. June 18, 1981 -6°F

Table 3.--Three-day temperature departures for major cool-season storms

Storm date	3-day basin precip. (in.)	Ranked daily Temperature departures °F	Accumulative 3-day temperature departures °F
Dec. 9-11, 1933	3.32	16, 16, 11	+42
Dec. 20-22, 1933	2.95	20, 20, 13	+53
Dec. 11-3, 1946	2.58	14, 12, 8	+34
Dec. 22-24, 1964	3.56	12, 11, *	(+24)*
Feb. 18-20, 1968	3.41	15, 13, 9	+37
Jan. 5-7, 1969	3.18	9, 4, 3	+16
Nov. 20-Dec. 2, 1975	3.54	19, 10, *	(+29)*
Dec. 1-3, 1977	3.04	16, 13, 7	+35

* One day zero or negative

** Note that adopted 3-day sequence (i.e., 10°, 17°, 14°) is 5° above mean

From these cases, a mean basin-wide negative departure of around 5°F resulted. An influx of at least slightly warmer air for SPS-level conditions - compared to these major events - suggests a slight decrease in the absolute magnitude of the May-June departures is in order. This is done as discussed in Section 12.6 on seasonal variation of departures.

12.6 Seasonal Trend in Temperature Departures During the SPS 3-Day Precipitation Event

There are insufficient major 3-day storm events on a monthly basis, to define the seasonal variation solely on this type of data. A number of other indices were investigated to aid in shaping a seasonal variation of temperature departure curve with mid-January and May-June data supported points as "anchors." These indices are judged to approximate "equal-probability" type indices. These auxiliary indices are:

1. Maximum persisting 12-hr dew-point values (Environmental Data Service 1968).

2. Weekly trend in upper decile values of maximum temperature for Lewiston, Idaho (Meteorological Committee, Pacific Northwest River Basin Commission, 1968).

3. Mean monthly temperature plus 3 standard deviations from the mean monthly temperatures for the Central Mountain region of Idaho (Environmental Data and Information Service, 1973a).

The mean monthly plus 3 standard deviations index providing reasonably consistent smoothing except at the edges of the season. It is likely that many high temperature non-precipitating days bias this index near the edges. The upper decile of weekly maximum temperatures at Lewiston appeared to be a better index than the monthly plus 3 standard deviations index. Superior - at least relative to smoothness - to the previous 2 indices was the seasonal curve of maximum 12-hr persisting dew point.

Since all indices had approximately the same overall trend, but with the 12-hr dew-point curve the most consistently smooth, the 12-hr dew point curve was given the most weight in establishing a seasonal variation for temperature departures. This judgment is supported separately by the fact that it is the 12-hr maximum persisting dew point curve that determines the limiting temperature departures during PMP conditions (Riedel et al., 1969). The adopted monthly temperature departures during the 3-day SPS precipitation storm are given in table 4.

12.7 Antecedent Temperature Departures - Cool Season

Based upon summations of temperature departures for the 3 days antecedent to major cool-season events, the adopted departures in mid-January are 9°F, 9°F and 3°F. The adopted criteria are higher than the primary cold intrusion cases giving 3°F, 4°F and 3°F, but at the same time are below the means for the antecedent days prior to the 3 primary days "warm" cases of the 9 major cool-season events used. These 3 warmest cases were January 16-18, 1953,

Table 4.--Departures from normal for the adopted temperature variation during the 3-day SPS event

	Temperature departure (°F)		
Month	Day 1	Day 2	Day 3
Nov.	9	14	12
Dec.	9	14	12
Jan.	10	17	14
Feb.	8	13	11
Mar.	5	9	8
Apr.	0	4	3
May	-2	-2	-2
Jun.	-2	-2	-2

December 9-11, 1933 and December 20-22, 1933. The adopted sequence for mid-January allows for as much snow melting capability as is deemed to be appropriate prior to the 3-day SPS, but at the same time allowing some cold air intrusion to aid the efficiency of the 3-day cool-season precipitation event. This is in accordance with the conclusions reached regarding meteorological features of the cool-season event, summarized in Chapter 3.

12.8 Antecedent Temperature Departures for May-June

Above normal temperatures prior to May-June 3-day events are characteristic, unlike the below normal departures prevailing during the 3-day event itself. Departures of +10°F were adopted for all 3 antecedent days for both May and June. These data supported departures compare to somewhat higher departures characteristically adopted in connection with conditions prior to the more severe PMP conditions.

12.9 Seasonal Temperature Departures Antecedent to the SPS Event

The seasonal antecedent trend for the cool season (i.e., November through February) approximately parallels that of the SPS event itself with the following constraints or modifications.

1. For the middle of the cool season, the data supported level of approximately one-half the SPS departures are adopted.

2. Beyond February the seasonal trend is constrained to tie-in the data-support approximate +10°F departures for May and June antecedent days. This sharply contrasts with the continued downward trend during the SPS required for tying into negative departures for May and June.

3. The meteorological support requiring some relatively cold air prior to the 3-day event requires that for the cool season the largest positive departures must be displaced to the second and third antecedent days, rather than the 1st day prior to SPS.

Table 5.--Departures from normal for the adopted temperature variation for 3 days antecedent to the SPS event

Month	Temperature departures (°F) 3rd day	2nd day	1st day
Nov.	6	6	3
Dec.	8	8	5
Jan.	8	8	5
Feb.	7	7	5
Mar.	7	7	5
Apr.	7	7	5
May	10	10	10
Jun.	10	10	10

The adopted monthly temperature departures for the 3 antecedent days are given in Table 5.

12.10 Temperature Range Evaluation

Basin average cool-season and May-June temperature ranges for the 3-day SPS-type precipitation event and for the antecedent 3 days were evaluated for the major storm events. This resulted in daily means as follows for the 3 antecedent days and the 3 SPS days: 14°F, 13°F, 12°F, 16°F, 13°F and 13°F. An analysis of basin-wide temperature range over the 3-day December 22-24, 1964 is shown in Figure 111.

For the May-June cases, 5 major May-June event cases were summarized: June 4-6, 1974, May 4-6, 1979, May 24-26, 1980, June 17-19, 1981 and May 7-9, 1948. The resulting mean ranges were quite similar to those for the cool season for the 3-day event. However, for the 3 antecedent days the ranges were about twice as large as the cool-season antecedent case.

An evaluation of ranges in reference to intensity and duration of precipitation indicated the overall mean values of temperature range were biased on the high side by too many periods with little or no precipitation. Hence, the means listed above for the 3-day SPS event were modified for the more intense and prolonged character of SPS precipitation compared to largest observed 3-day events. The adopted ranges are as follows:

1. During 3-day event (all months) - a range of 8°F (±4°F).

2. 3-day antecedent to cool-season 3-day event - a range of 12°F (±6°F).

3. 3-day antecedent to the spring snowmelt event - a range of 24°F (±12°F).

12.11 Example of Use of Adopted Criteria and Comparisons

Figure 112 is an example showing the use of the adopted data with comparisons. The data on the figure are for a specific location, 43°30'N 116°W. The data are for the maximum 1 day of the 3-day SPS. The hatched areas show the temperature departures (difference in temperature between bordering curves).

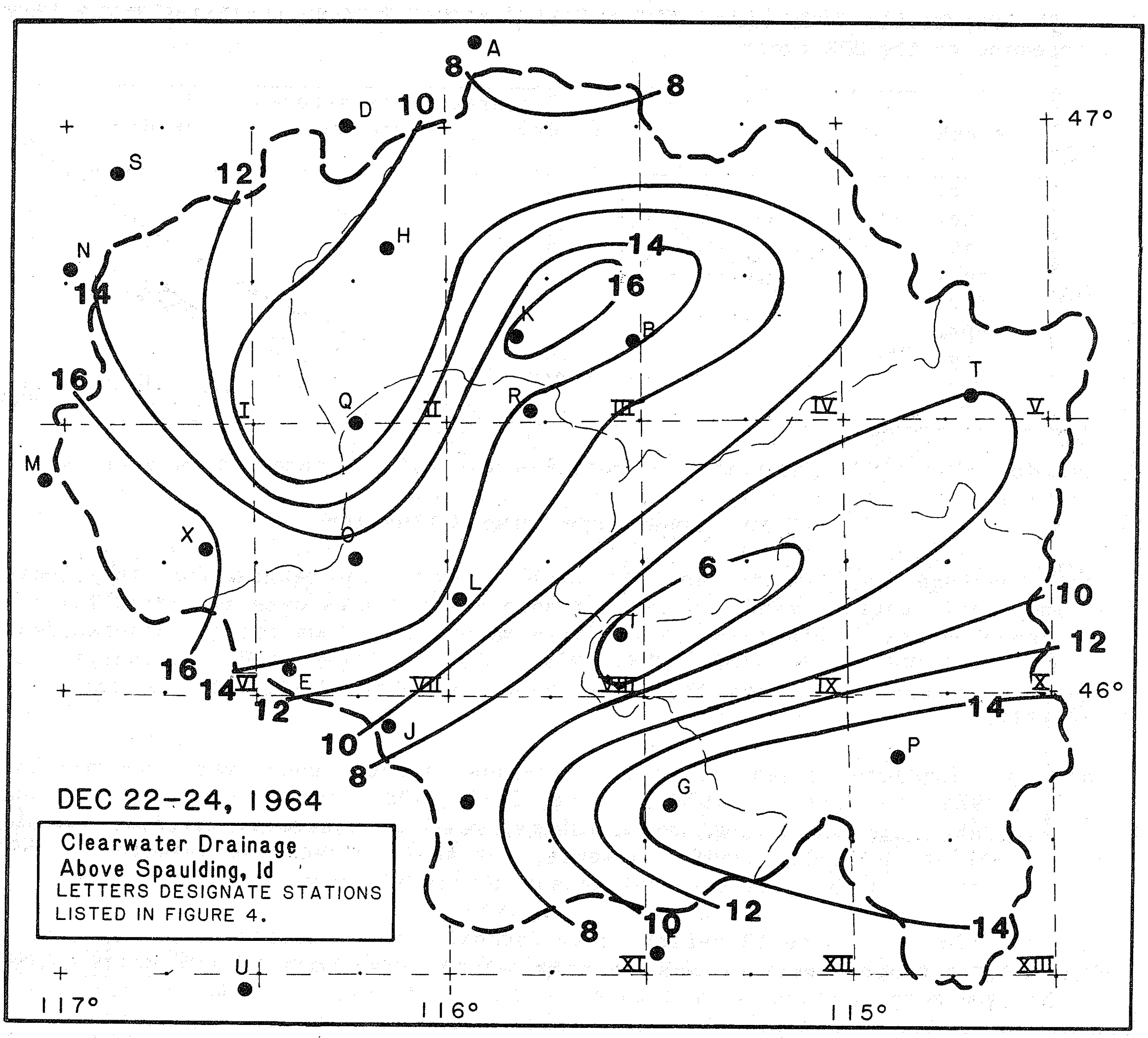


Figure 111.--Mean basin-wide temperature range for December 22-24, 1964.

12.12 Summation of Snowmelt Temperature Criteria

Figure 113 summarizes the use of snowmelt temperature criteria developed in this chapter. The data is shown in the figure in the form of a synopsis of the procedure for applying the data. More detailed explanation of the use of the snowmelt temperature criteria may be found in Chapter 13, Applications.

13. APPLICATIONS OF CLEARWATER RIVER BASIN PROJECT SPS PRECIPITATION AND SNOWMELT TEMPERATURE CRITERIA

13.1 Introduction

This chapter develops final values of SPS basin-wide precipitation with required time and geographical variations. These precipitation criteria involve

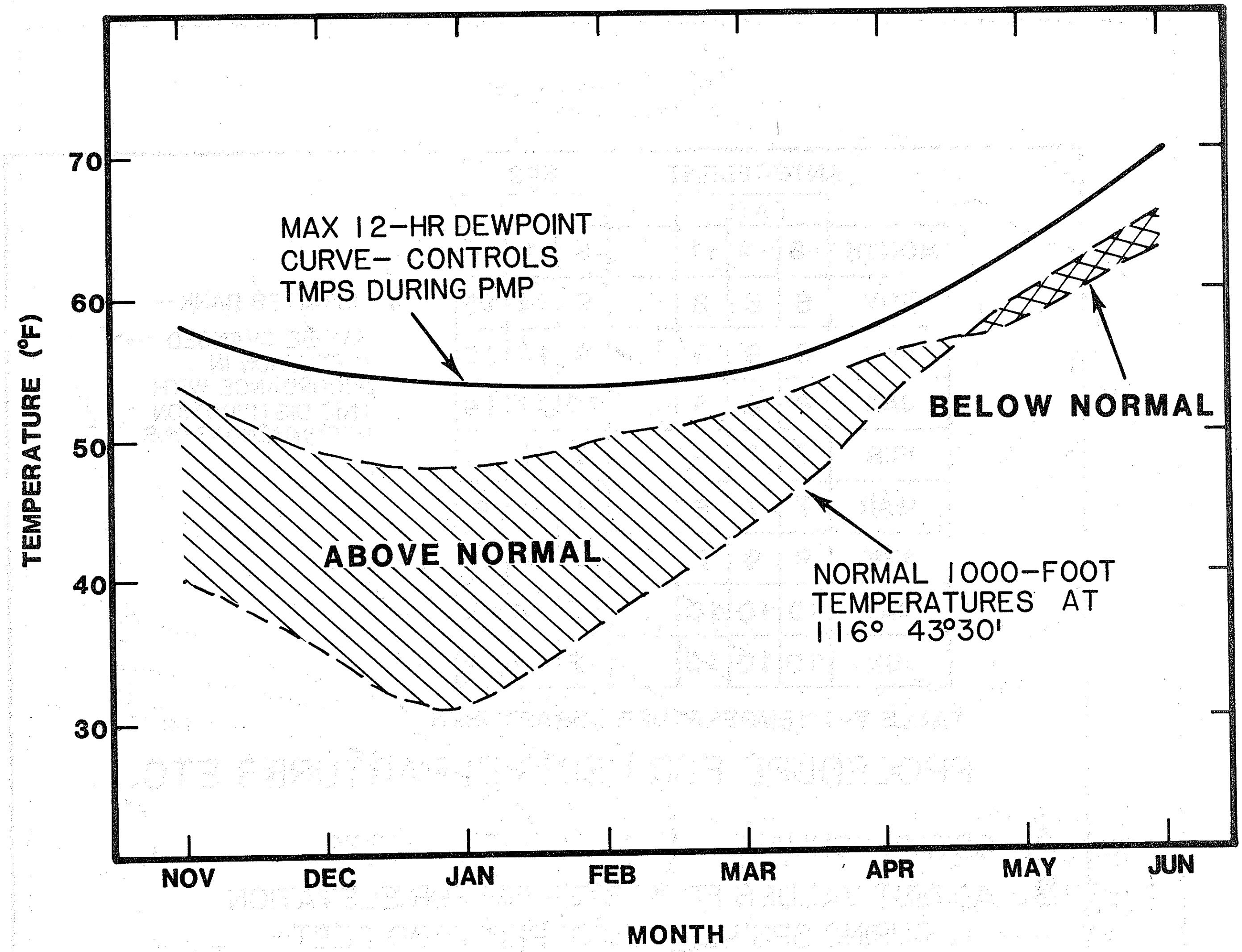


Figure 112.--Adopted maximum SPS day temperature departures - 43°30'N 116°W, with comparisons.

3-basin SPS storm events. Snowmelt temperature criteria are also provided. All criteria are presented in a form that provides adjustments for occurrences at any date both during the main cool season and through the main snowmelt season. Figures from previous chapters that are used in the procedure are repeated in this chapter.

13.2 SPS Precipitation Criteria

SPS precipitation criteria are presented for 3 "event" categories:

I. Main cool-season event

II. May-June event

III. Downstream cool-season event

	ANTECEDENT DAYS				SPS DAYS		
MONTH	-3	-2	-1		3	1	2*
NOV	6	6	3		9	14	12
DEC	8	8	5		9	14	12
JAN	8	8	5		10	17	14
FEB	7	7	5		8	13	11
MAR	7	7	5		5	9	8
APR	9	9	7		0	4	3
MAY	10	10	10		-2	-2	-2
JUN	10	10	10		-2	-2	-2

TABLE T-1 TEMPERATURE DEPARTURES

* INDICATES RANK — MAY BE CHANGED IN POSITION IN ACCORDANCE WITH TIME DISTRIBUTION RECOMMENDATIONS

PROCEDURE FOR USING DEPARTURES ETC.

A. OBTAIN NORMALS FROM 1000-FT CHARTS

B. ADJUST VALUES FROM STEP "A" FOR ELEVATION

1. DURING SPS USE −3.5°F PER 1000 FEET
2. FOR ANTECEDENT DAYS USE −3.7°F / 1000 FT

C. TO VALUES FROM STEP "B" APPLY TABLE T-1 DEPARTURES

D. TO CHANGE THE ADJUSTMENT MEAN TEMPERATURES OF STEPS "C" TO DAILY HIGH AND LOW TEMPERATURES, APPLY THE FOLLOWING PLUS AND MINUS DEPARTURES:

1. NOV–JUN ±4°F DURING 3-DAY SPS
2. NOV–MAR ±6°F ANTECEDENT DAYS
3. APRIL ±8°F ANTECEDENT DAYS
4. MAY–JUN ±12°F ANTECEDENT DAYS

Figure 113.--Use of snowmelt temperature criteria.

The basin SPS-precipitation values are presented as sub-basin total storm values for 4 designated drainages of the total 9,570 mi^2 Clearwater drainage above Spaulding, Idaho. For this example, the Selway and Lochsa sub-basins have been combined. Values for the 3 categories for specific designated dates or periods (as discussed later) for these sub-basins are shown in Table 6.

The season of applicability (without adjustment) and adjustments for other times of occurrence are now covered:

Category I

The values in Table 6 for the Category I event are valid values (with no need of adjustment) for the period from November 7 through February 20. The full season of applicability of Event I is from October 1 through April 30. Adjustments for occurrence, prior to November 7 and after February 20 come directly from a seasonal variation curve (fig. 114).

Category II

The values in Table 6 for the Category II event are valid values (with no need of adjustment) for May 15 only. The full season of applicability of Event II is from April 1 through June 30. Adjustments for occurrence prior to and after May 15, as with category I events, come from the seasonal variation curve (fig. 114).

Category III

The values in Table 6 for the Category III event are valid values (with no need of adjustment) for the period January 15 to February 15. Adjustments for occurrence prior to January 15 and later than February 15 come from a special adjustment curve for season. This adjustment curve is labeled, "Seasonal Adjustment Type III SPS Event" (fig. 115).

13.3 Geographic and Time Distribution for April

April is a month of transition that may involve a geographic distribution that mimics either the main cool season or the May-June period. Thus, for SPS-storm Categories I and II (the only 2 involving an April occurrence) the geographic distribution of both I and II (as given by the relations of sub-basin values of

Table 6.--Sub-basin average total 3-day storm precipitation for 3 SPS precipitation "event" categories

Basin	Area square miles	SPS storm event category I	II	III
North Fork	2440	6.08	3.89	5.25
S. Fork Local	2490	3.80	3.30	4.39
Oro-Spaulding	1550	3.06	2.47	4.25
Selway-Lochsa	3090	6.08	3.92	2.62
Total Basin	9570	5.00	3.53	4.00

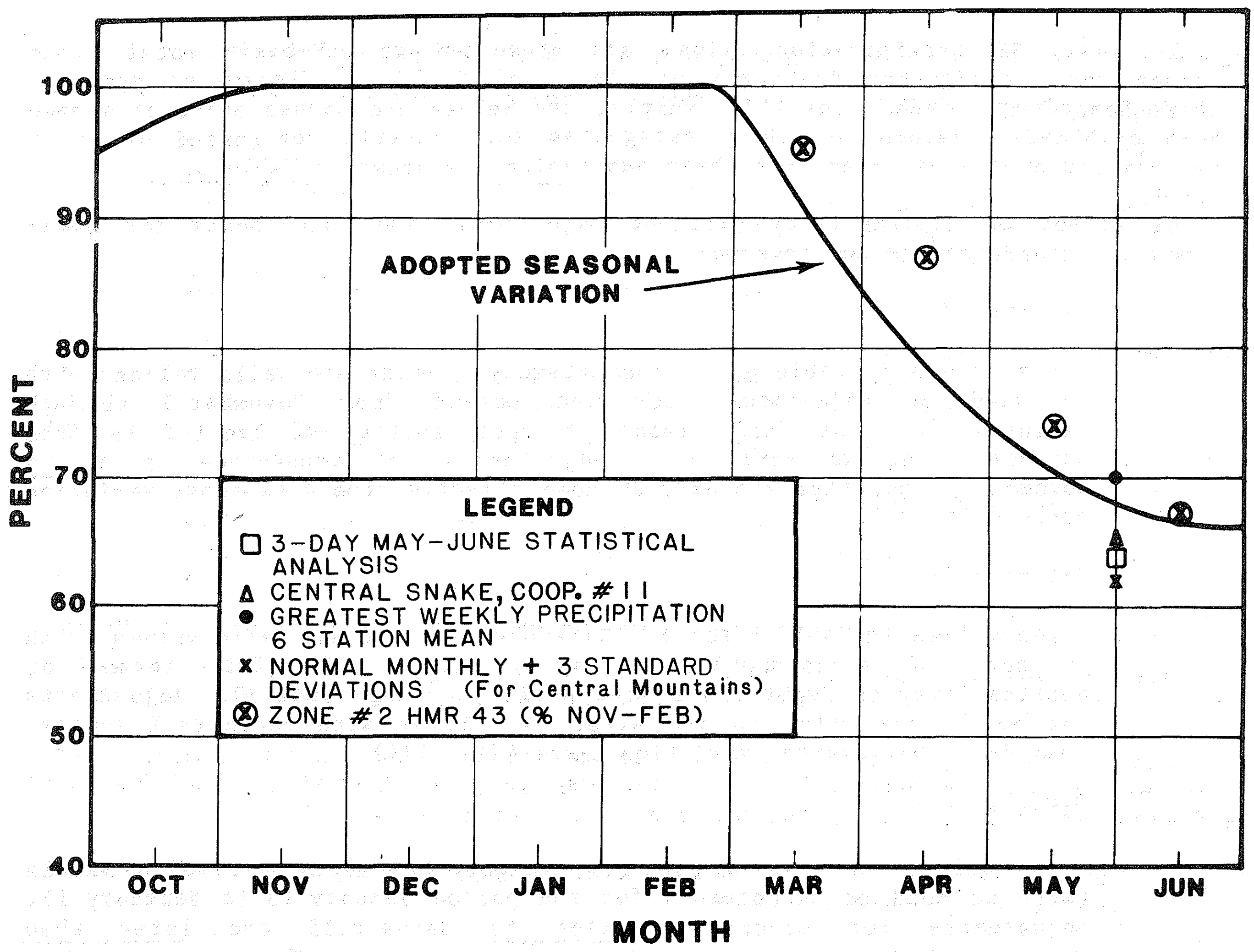


Figure 114.--Seasonal variation - Clearwater River drainage.

table 6) are to be tried for hydrologic criticality. In other words, the total 3-day basin-wide average derived from application of a seasonal adjustment is apportioned according to the sub-basin ratios of Table 6 for both Categories I and II for April.

As with the geographic distribution, time distributions appropriate to both the cool-season and the May-June season should be tried by the user to determine and use that which proves to be most hydrologically critical.

13.4 Time Distribution

So far, we have been concerned with total basin 3-day SPS precipitation only. Now, we move to the problem of time distribution - or the breakdown of the total 3-day storm values (by sub-drainages) into 12 6-hr increments. Table 7 gives twelve 6-hr increment percentages (to tenths of a percent) for three seasonal periods within the total season of applicability from October 1 through June 30. Where a particular event category is used for some date not specifically covered in Table 7, simple interpolation may be used with the one caution that the total of the 12 resulting incremental percents should total 100.0 percent.

Table 7.--Incremental 6-hr percentages of the 72-hr SPS precipitation event

Season Interval							
Nov. 7-Mar. 31	6-hr period	1	2	3	4	5	6
	percent	25.2	12.3	10.0	8.9	7.2	6.6
	6-hr period	7	8	9	10	11	12
	percent	6.0	5.5	5.1	4.7	4.4	4.1
Oct. 1-Nov. 6	6-hr period	1	2	3	4	5	6
	percent	26.0	14.5	10.5	9.0	7.5	7.0
	6-hr period	7	8	9	10	11	12
	percent	6.0	5.5	4.5	3.8	2.9	2.8
May 16-June 30	6-hr period	1	2	3	4	5	6
	percent	27.0	16.0	11.5	9.5	7.5	7.3
	6-hr period	7	8	9	10	11	12
	percent	6.0	5.5	4.5	2.4	1.5	1.3

A most reasonable time sequencing of the 12 6-hr increments of the 72-hr SPS for each of the 3 event categories is shown in Table 8.

Although the sequences of Table 8 are reasonable, many other sequences are "meteorologically-reasonable." The user may use the following guidelines in selecting various sequencing for hydrological criticalness.

(A) Placement of daily increments (i.e., highest 1-day, 2-day and 3-day of the 3-day sequence).

1. Category I. The maximum 1-day of the 3-day SPS may be placed first or second, but not last in the 3-day sequence.

2. Category II. The maximum 1-day of the 3-day SPS may be placed in the second or third position, but not first in the 3-day sequence.

3. Category III. The maximum 1-day of the 3-day SPS may be placed in any of the 3 possible positions in the 3-day sequence.

Table 8.--Chronological arrangement of 6-hr SPS precipitation increments

Category Type	Chronological arrangement
I	6, 5, 4, 3, 2, 1, 7, 8, 9, 10, 11, 12
II	12, 11, 10, 9, 8, 7, 6, 5, 2, 1, 3, 4
III	either of Type I and Type II sequences

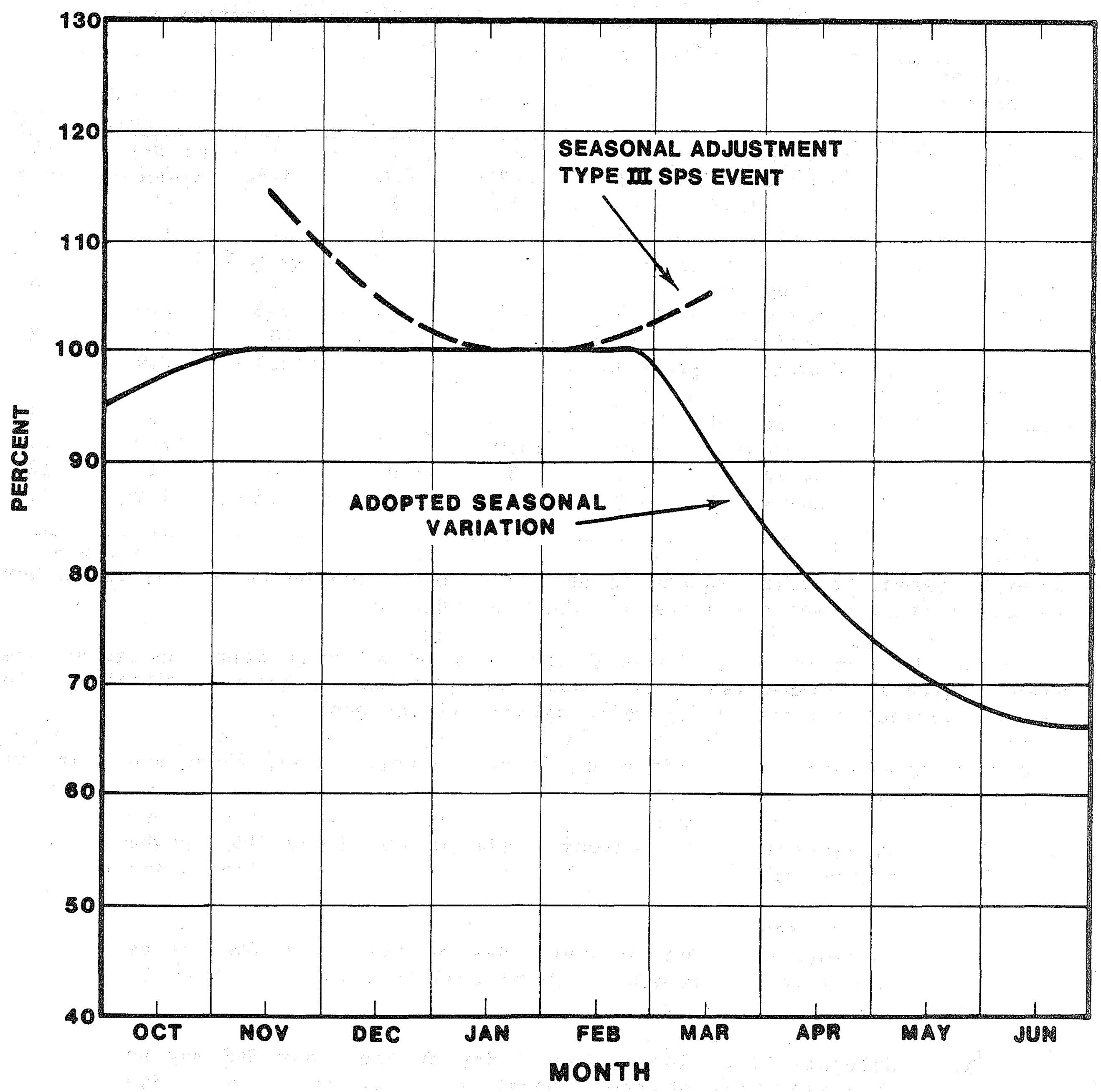


Figure 115.--Seasonal adjustment Type III SPS event.

(B) The rules for the sequences of the 4 6-hr increments within a given 24-hr period are the same for all 3 SPS-storm categories (i.e., I, II and III).

1. Within a 24-hr period, the 6-hr increments must be arranged so that the individual increments decrease away from the maximum 6-hr increment. This means the lowest 6-hr increment must be placed at either the beginning or end of the 4 increments (6 hr) in a day so that the phasing into the second and/or third day 6-hr increments

will preserve the depth-area-duration characteristics of the adopted accumulative depth-duration relations.

Numerous arrangements of the 12 6-hr increments are possible within the rules above. The category differences have been used so that constraints suggested by the actual storm experience are adequately applied. The user is to try as many allowable sequences as deemed necessary to uncover the most hydrologically critical sequence to fit the purposes of the study.

13.5 Alternate Centerings of "Hypo Snake" Category III

The Category III sub-basin averages of Table 6 are appropriate for an occurrence of this SPS storm event between January 15 and February 15. Also, these averages derive from centering a percentage of the MAP pattern near 46°25'N 116°15'W and (just south of Orofino). Seasonal adjustment of the sub-basin values of Table 6 are obtained by reference to Figure 115.

As a result of a suggestion eminating from the December 8, 1983 presentation of project results at the Corps of Engineers North Pacific Division Office in Portland, Oregon, a provision is added for alternate centerings of this "Hypo-Snake" SPS storm. Figure 116 shows the percentage SPS pattern centered in accordance with the numbers (in inches) of Table 6 (Category III). Figure 117 shows a cross hatched area within which the center of the isohyetal pattern (in percent of MAP) may be placed.

13.6 Sub-basin Averages for Alternate Centerings

If the user desires to shift the pattern of Figure 116 to some other position within the cross-hatched area of Figure 117, the percentage of MAP values of Figure 116 must be applied to appropriate MAP values. For purposes of consistency and to avoid discrepancies, it is suggested that the user make use of previously determined sub-area (i.e., numbers I through XIII of fig. 116) MAP values. These are as follows:

Sub-area	MAP (in.)
I	25.0
II	38.6
III	47.6
IV	54.6
V	53.9
VI	20.2
VII	22.2
VIII	37.7
IX	48.4
X	52.5
XI	29.9
XII	38.8
XIII	43.2

For alternate centerings of the Category III (i.e., "Hypo-Snake" event), the user must determine the resulting total storm sub-basin averages in inches. Application of the percentages of MAP for each of the 13 sub-areas shown, with a given placement of the pattern of Figure 116, will give the average depth over each sub-area for that placement. It remains to equate the sub-area (I through XIII) averages to averages over the specified 4 sub-basins of the total Clearwater. To do this, the sub-areas (within the four basin sub-drainages) summarized in Table 9 are needed. This table shows for each of the 4 sub-drainages the area contributed by each of the 13 sub-areas involved in that sub-drainage.

As an example of the use of the Table 9 areas to compute the average total SPS storm precipitation over, say the Orofino-Spaulding area with percents of MAP from an overlay placed over desired location as follows: Sub-area I, 10 percent, sub-area II, 12 percent, sub-area VI, 7 percent and sub-area VIII, 4 percent. Therefore,:

$$
\begin{aligned}
(.10) \times (25) \times (511) &= 1278 \text{ in. mi2} \\
(.12) \times (38.6) \times (268) &= 1241 \text{ in. mi2} \\
(.07) \times (20.2) \times (535) &= 825 \text{ in. mi2} \\
(.04) \times (37.7) \times (236) &= \underline{356 \text{ in.}} \text{ mi2} \\
& 3700
\end{aligned}
$$

or,

$$\frac{3700 \text{ in. mi}^2}{1550 \text{ mi}^2} = 2.39 \text{ in.}$$

13.7 Temperature Criteria for Snowmelt

Figure 118 summarizes the 6 days of snowmelt temperature departures and the procedure for applying these. A few explanatory notes will help clarify the abbreviated procedural steps, listed in that figure. The 1,000-ft normal temperature charts* are used to determine a sequence of 6 days of mean 1,000-ft temperatures at a desired "index station" location. For times other than mid-month, simple linear interpolation is suggested. If the user desires even more accuracy, he/she may plot a smooth seasonal temperature curve from the mid-month maps and read the desired temperatures directly from this smooth curve.

To avoid minor discontinuities, for example in a 6-day sequence of temperatures that involve more than 1 month, the user may wish to use a smoothing interpolation technique. For example, in step "D" where plus and minus departures are presented to convert a mean daily temperature into a maximum and minimum temperature (each applying for 12 hr) in a 6-day sequence extending from April 27 to May 3, the user may wish to apply a plus and minus 10°F, rather than the tabular values of 8°F for April and 12°F for May.

The stepwise procedure of Figure 118 is a reasonable one timewise. However, the user need not adhere rigidly to such a stipulated ordering of steps. For example, steps B and C may be reversed in order if such an altered sequence better suits the users requirements.

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*Analyzed maps are provided from November 15 (fig. 119) through April 15 (fig. 124). For May 15 a smooth across-basin value of 59.5°F applies, while for June 15 a smooth across-basin value of 65°F applies.

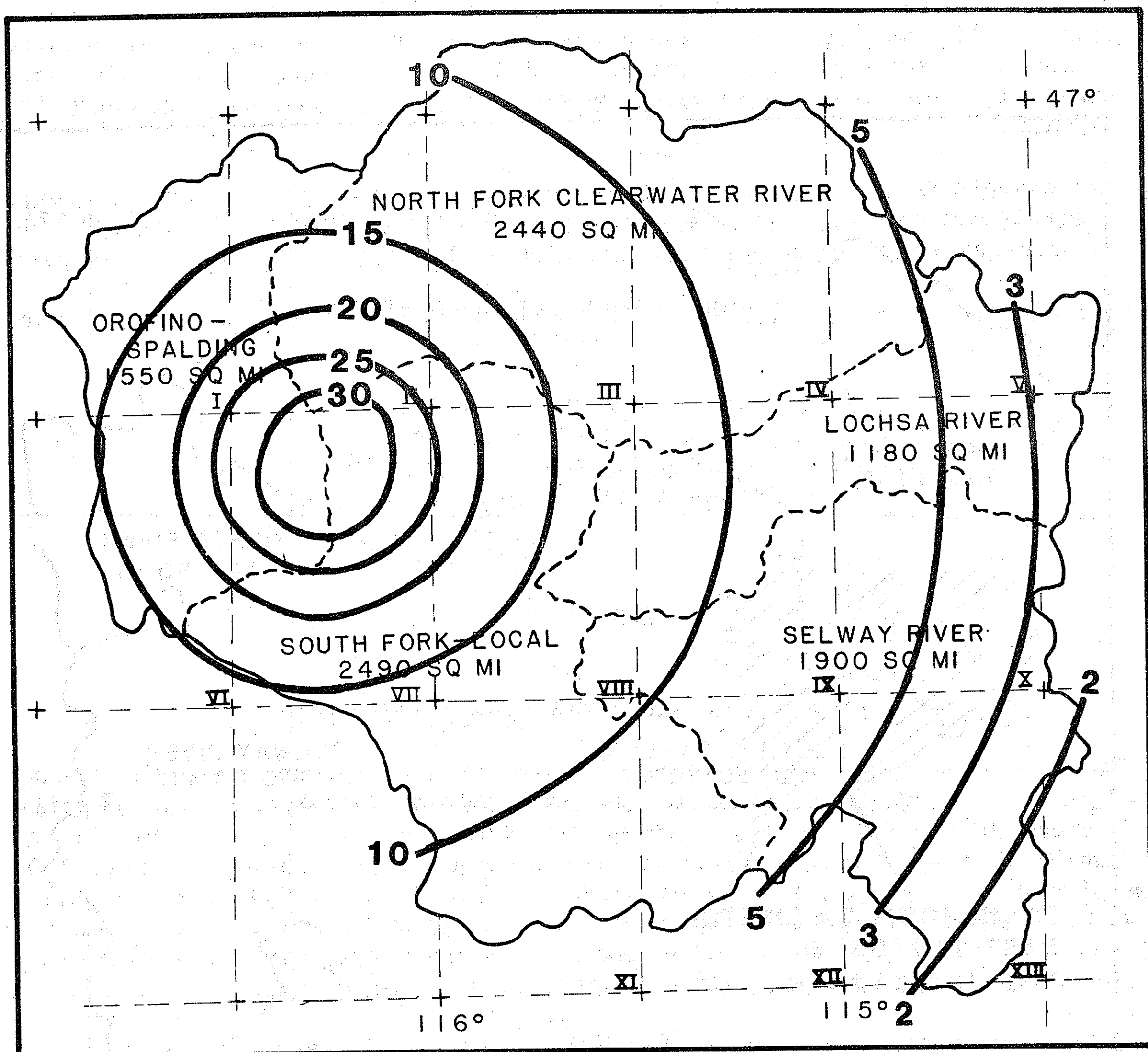

Figure 116.--SPS precipitation as a percent of MAP adjusted to January-February occurrence.

Table 9.--Sub-area contributions (in square mi) to each of four sub-drainages

Sub-drainage	Sub-areas (mi^2)													(mi ^{2})
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	Total area
N. Fork		454	868	816	196			31	75					2,440
S. Fork		55	62			44	714	643			689	283		2,490
Oro-Spaulding	511	268				535		236						1,550
Lochsa-Selway					293		202		751	878		253	713	3,090

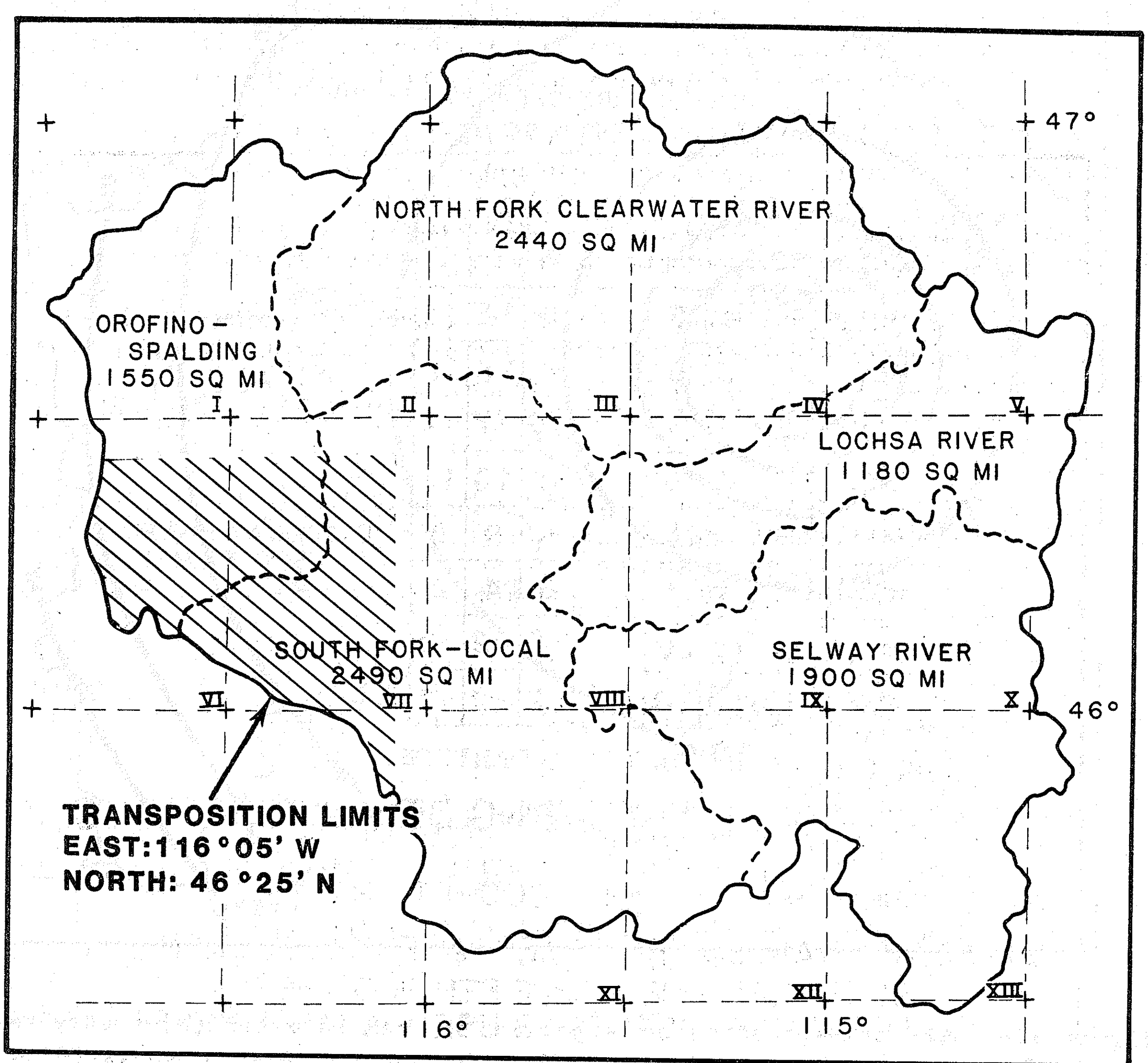

Figure 117.--Limits of transposition for the "Hypo-Snake" SPS-precipitation event.

	ANTECEDENT				SPS		
	DAYS				DAYS		
MONTH	-3	-2	-1		3	1	2*
NOV	6	6	3		9	14	12
DEC	8	8	5		9	14	12
JAN	8	8	5		10	17	14
FEB	7	7	5		8	13	11
MAR	7	7	5		5	9	8
APR	9	9	7		0	4	3
MAY	10	10	10		-2	-2	-2
JUN	10	10	10		-2	-2	-2

* INDICATES RANK – MAY BE CHANGED IN POSITION IN ACCORDANCE WITH TIME DISTRIBUTION RECOMMENDATIONS

TABLE T-1 TEMPERATURE DEPARTURES

PROCEDURE FOR USING DEPARTURES ETC.

A. OBTAIN NORMALS FROM 1000-FT CHARTS

B. ADJUST VALUES FROM STEP "A" FOR ELEVATION
   1. DURING SPS USE −3.5°F PER 1000 FEET
   2. FOR ANTECEDENT DAYS USE −3.7°F / 1000 FT

C. TO VALUES FROM STEP "B" APPLY TABLE T-1 DEPARTURES

D. TO CHANGE THE ADJUSTMENT MEAN TEMPERATURES OF STEPS "C" TO DAILY HIGH AND LOW TEMPERATURES, APPLY THE FOLLOWING PLUS AND MINUS DEPARTURES:
   1. NOV–JUN ±4°F DURING 3-DAY SPS
   2. NOV–MAR ±6°F ANTECEDENT DAYS
   3. APRIL ±8°F ANTECEDENT DAYS
   4. MAY–JUN ±12°F ANTECEDENT DAYS

Figure 118.--Use of snowmelt temperature criteria.

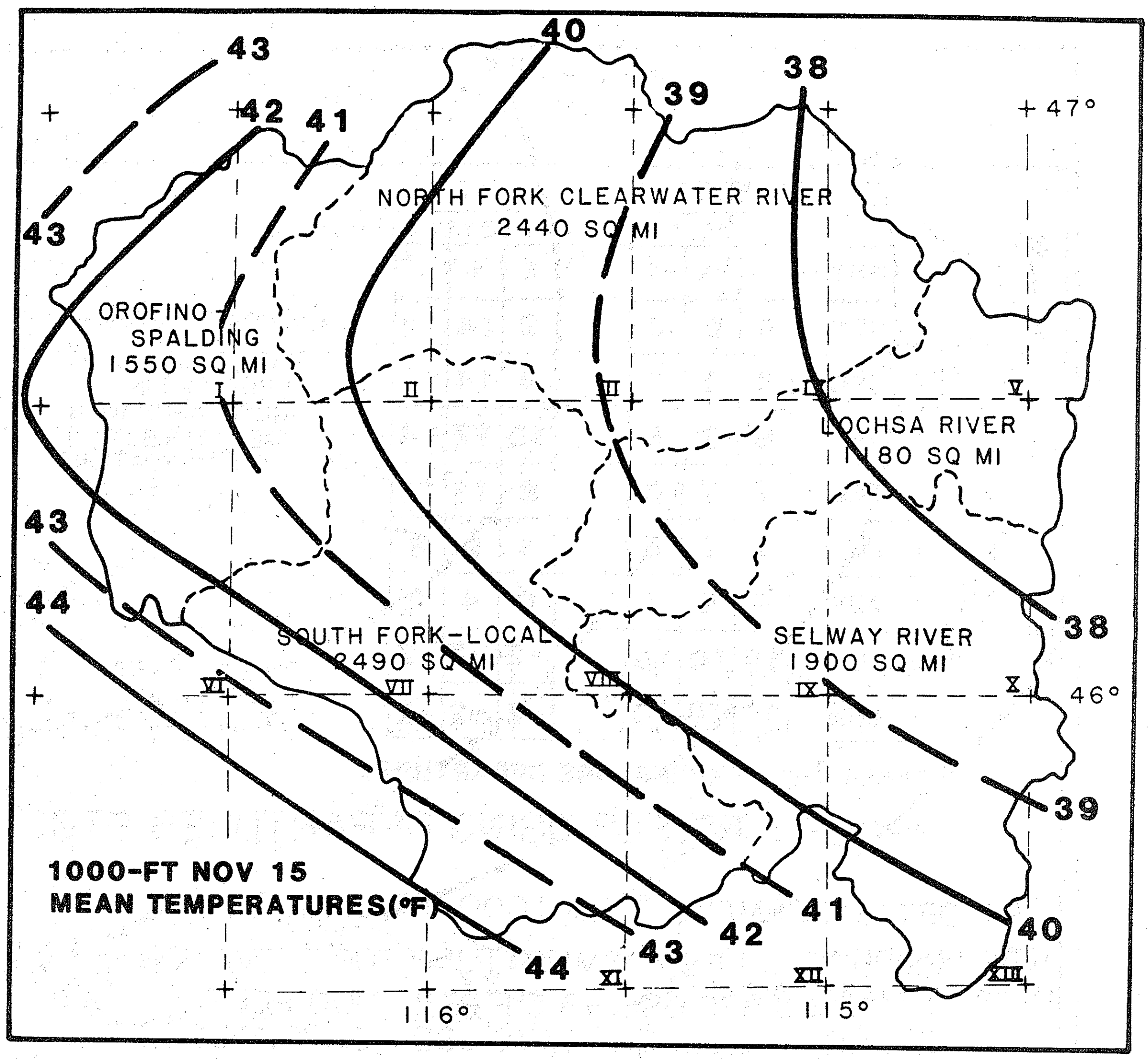

Figure 119.—November 15 mean 1,000-ft temperatures.

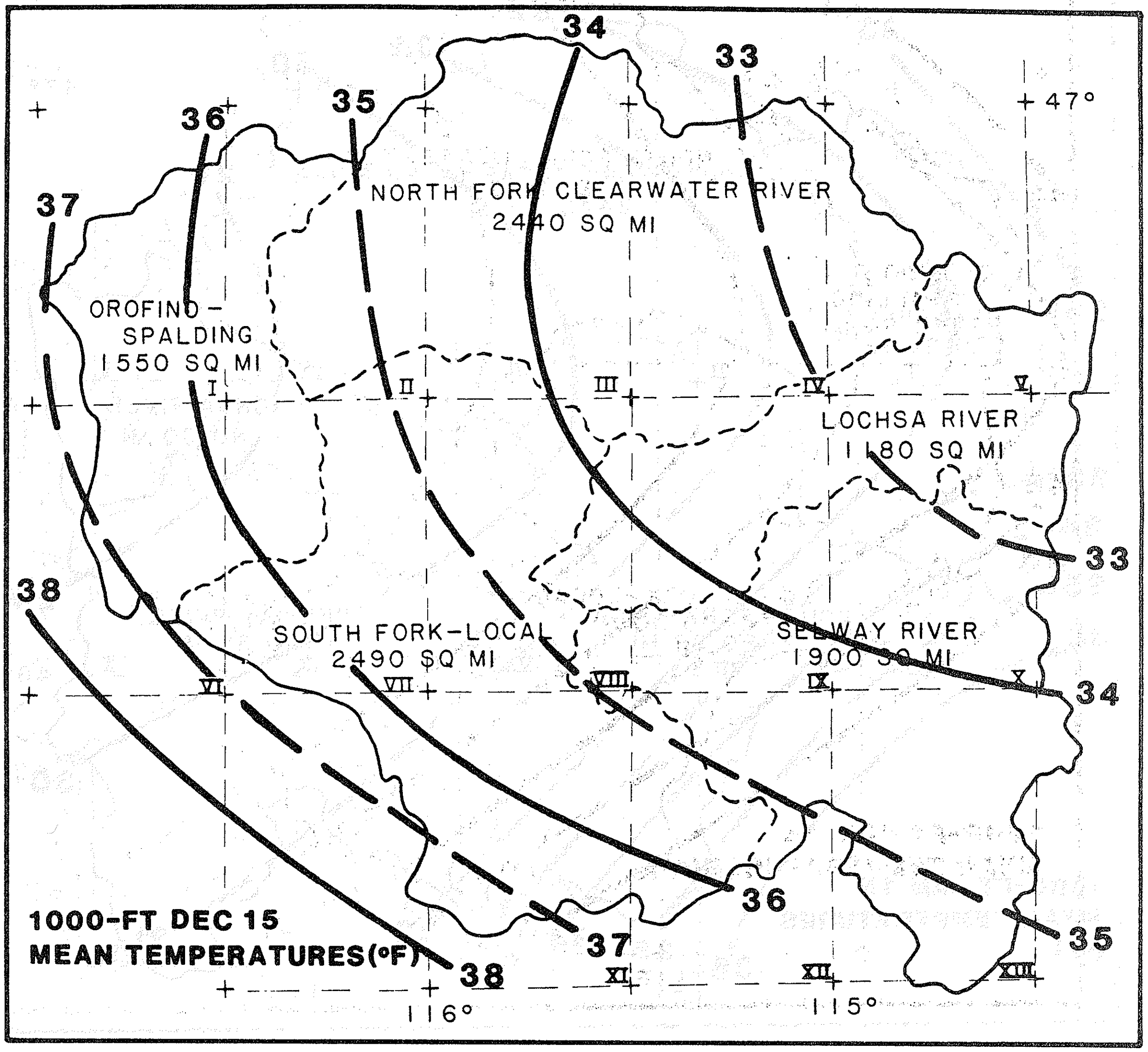

Figure 120.--December 15 mean 1,000-ft temperatures.

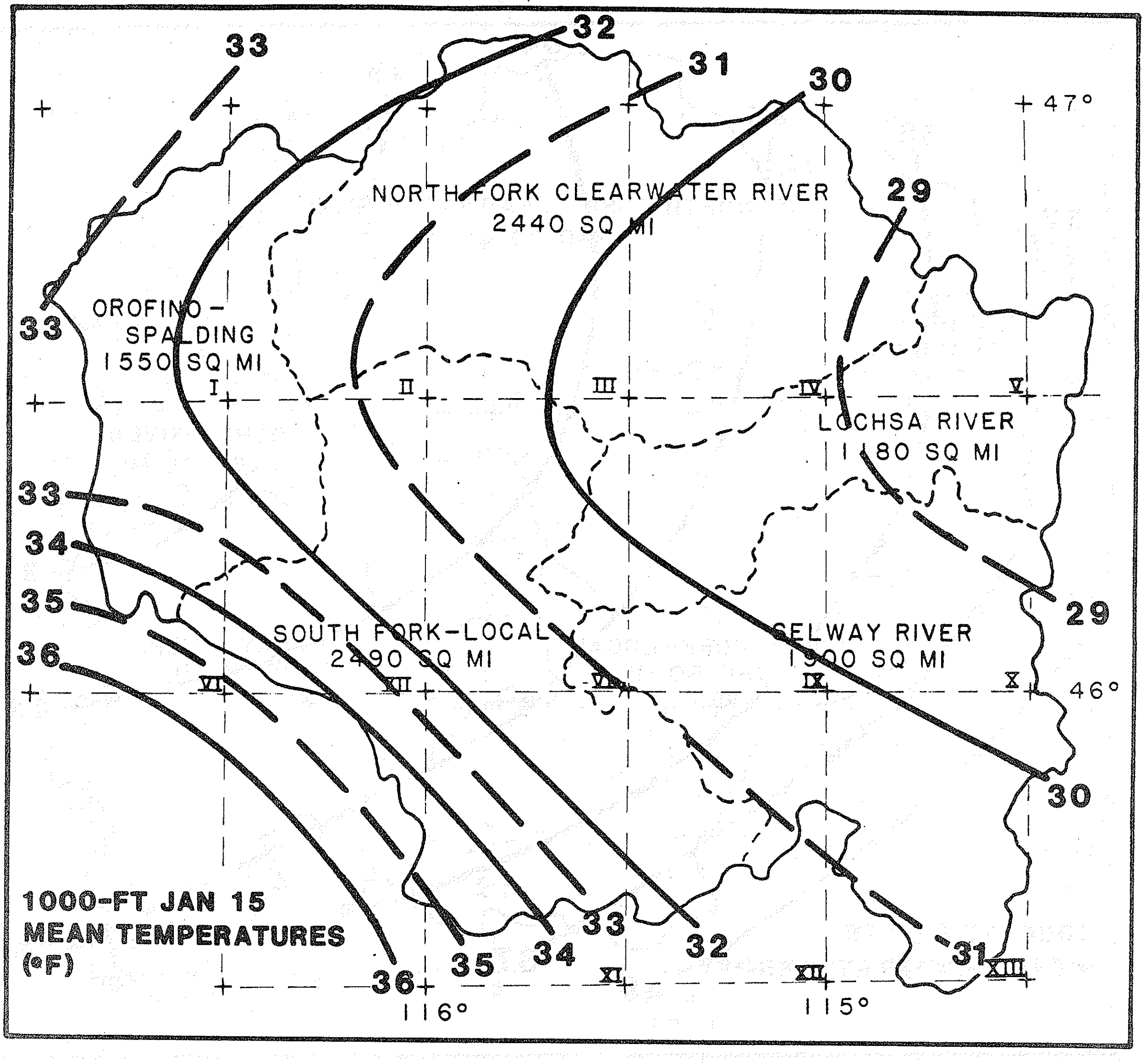

Figure 121.—January 15 mean 1,000-ft temperatures.

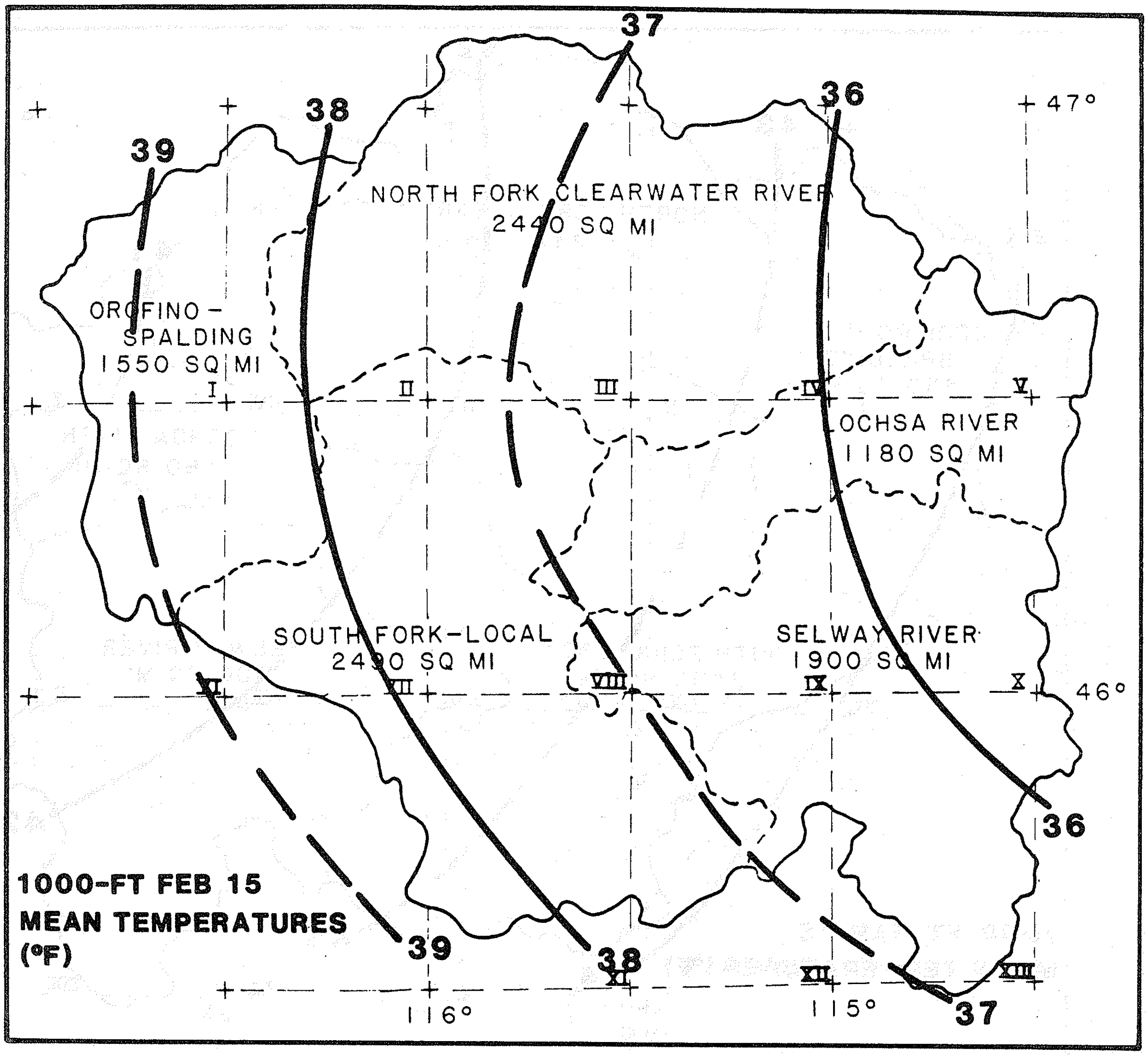

Figure 122.--February 15 mean 1,000-ft temperatures.

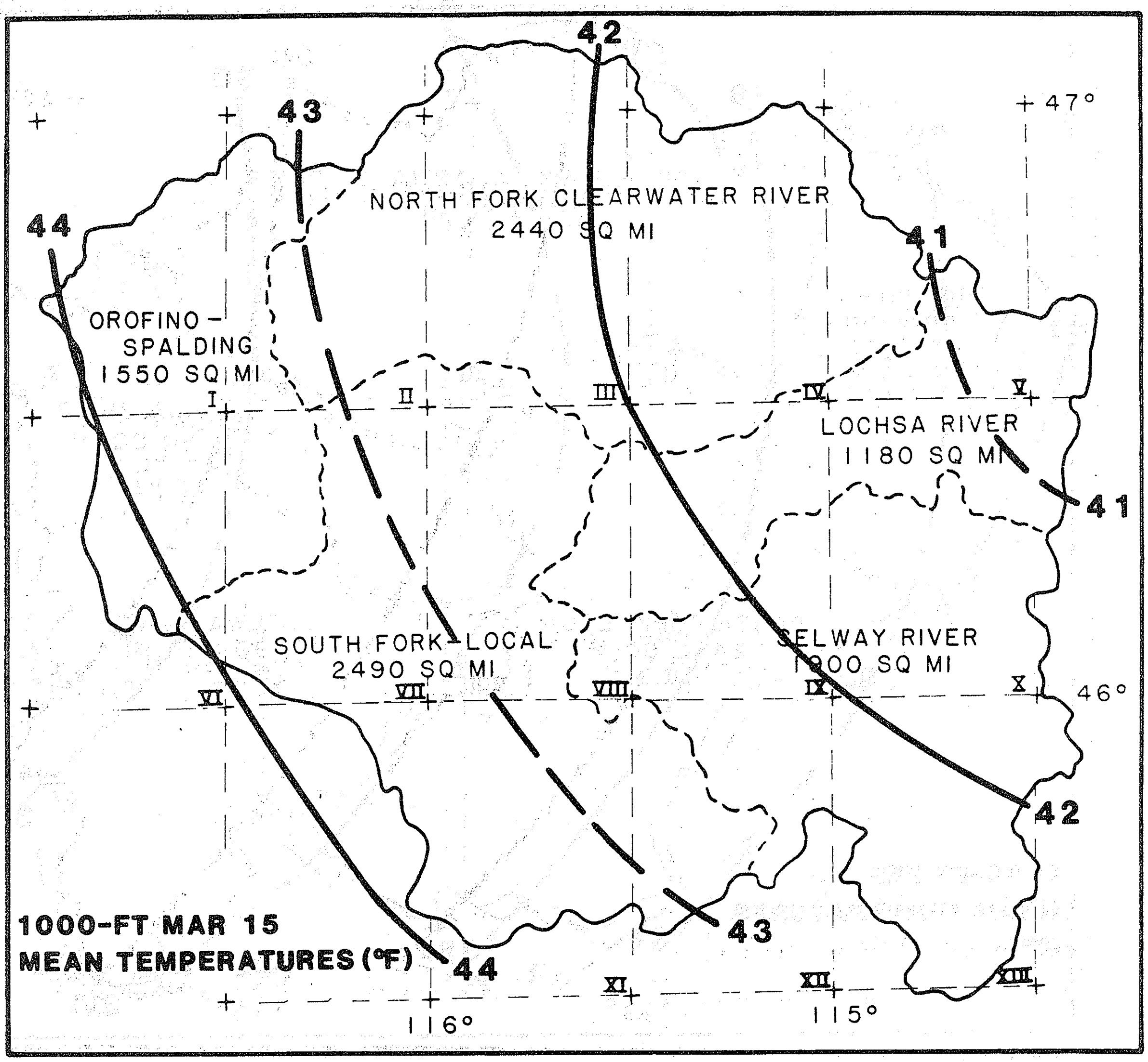

Figure 123.--March 15 mean 1,000-ft temperatures.

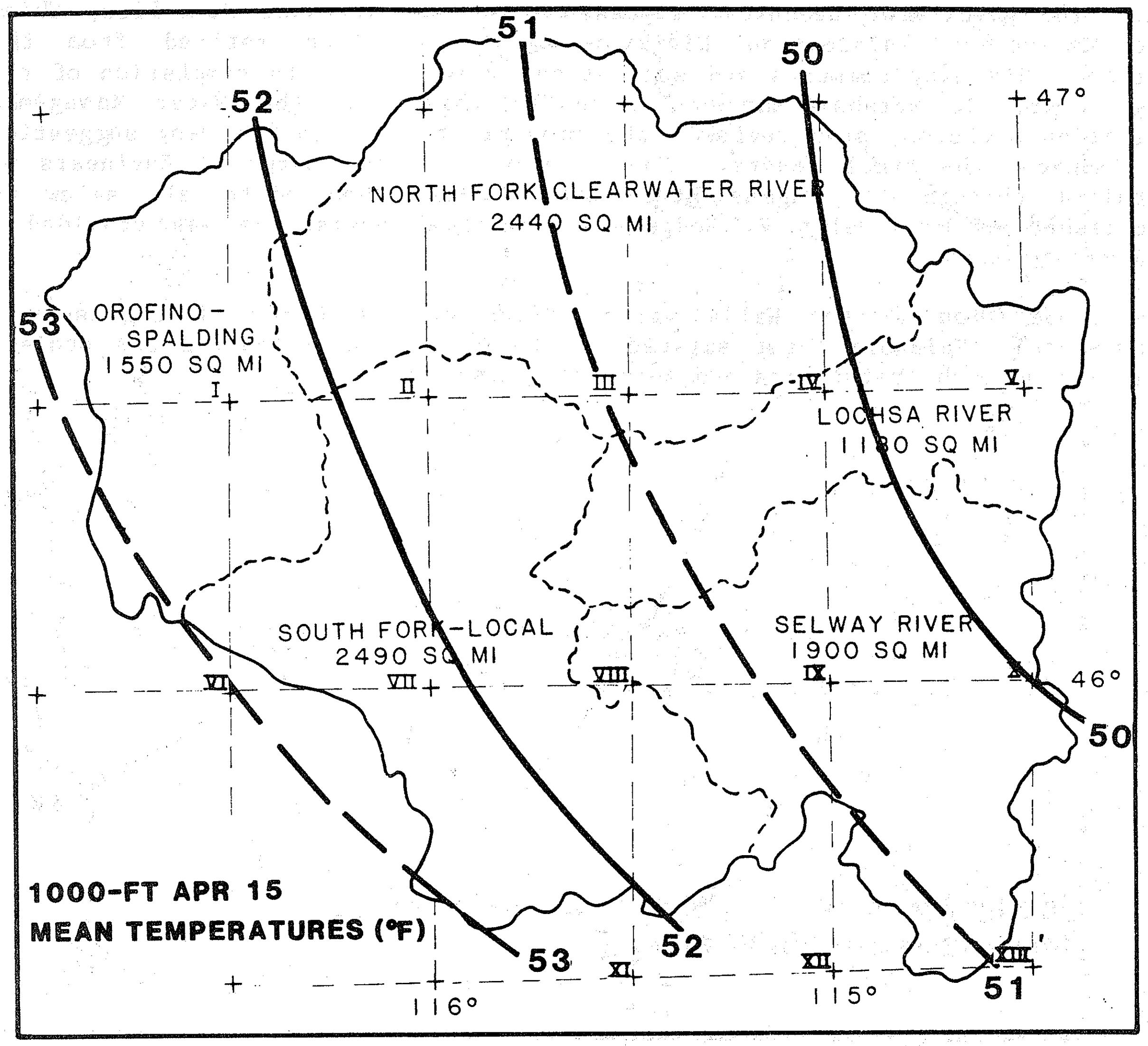

Figure 124.--April 15 normal 1,000-ft temperatures.

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