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"K" Chart Application to Thunderstorm Forecasts Over the Western United States

by

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A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

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Western Region Technical Memorandum No. 23, May 1967

"K" CHART APPLICATION TO THUNDERSTORM FORECASTS OVER THE WESTERN UNITED STATES

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"K" CHART APPLICATION TO THUNDERSTORM FORECASTS OVER THE WESTERN UNITED STATES

I - ABSTRACT

The purpose of this study is to show that George's 1/ "K" Chart, a thunderstorm forecasting scheme developed for southeastern United States, is also applicable to other geographical locations. In particular, the adaptation of the "K" Chart to thunderstorm probability forecasts during the fire-weather season over the mountainous West is also discussed.

II - INTRODUCTION

Due to the growing needs of protection agencies, the Fire-Weather Service underwent an expansion beginning about 1960, and the Reno Fire-Weather District was established for the season beginning 1964. The district initially encompassed the state of Nevada (Figure 1). In 1965 the additional area from near Lake Tahoe northward to the Oregon border, and from the Sierra Nevada-Cascade crest eastward to the Nevada border--for simplicity, the "California east side"--was added to the district.

Thunderstorms provide most of Nevada's summer precipitation, but the associated lightning constitutes the main hazard to range and timber lands. Grass and scrub juniper abound in the more fertile areas, while sage grows rampant in less suitable soils. Abundant timber is to be found in the mountains of the central and northern portion of the state, as well as the Sierra-Cascades in California.

A considerable number of the thunderstorms are predominantly dry in most years, owing to Nevada's distance from the Gulf of Mexico and Gulf of California moisture on the south, and the shielding effect of the high Sierra on the west with regard to moisture from the Pacific. However, southwestern United States, during the summer monsoon, receives the major portion of its annual precipitation from thunderstorm activity. In the Pacific Northwest, cold lows will frequently bring an outbreak of thunderstorm activity. Due to the areal extent of the Reno Fire-Weather District, it is quite evident that a single station raob or a two-station scheme, for a simple YES or NO thunderstorm forecast would be unlikely to achieve success. To compound the problem, protection agencies desire--and understandably so--that thunderstorm forecasts be issued in the form of percentage probability of occurrence. In this respect, the probability forecasts will better enable protection agencies to utilize their planning programs in personnel and equipment distribution to handle potential lightning strikes in timber and range lands. The "K" Chart appears to be the best tool to assist in fulfilling the pressing need of thunderstorm probability forecasts.

III - DATA AND PROCEDURE

The raw data is obtained from the preliminary morning raob transmission, consisting of the mandatory levels, taken at 1200Z and transmitted on the national teletype circuit as UXUS at 1450Z. A work sheet (Figure 2) is used to record the initial values. These values include: 1) 850-mb minus 500-mb temperatures (an air mass stability factor); 2) 850-mb dew point (a low level moisture parameter); and 3) 700-mb temperature-dew point spread (an intermediate level moisture value). To compute 850-mb data at stations above this level (i.e., GJT, ELY, LND, DEN, ABQ), temperatures are reduced adiabatically from the top of the surface inversion to the 850-mb level and dew points reduced to the 850-mb level along a representative mixing ratio line. To fill a critical gap in the raob network along the Sierra Nevada crest, which is a favored area for convective development as indicated by Sacramento WSR-57 radar 2/, 7 a.m. observations from four lookouts (8-9000 ft. elev.) are integrated into the scheme as supplementary data. These observations sample the Sierra Nevada region, where the mountain snow pack normally remains well into the summer. This vast snow field serves as a local moisture source, which is undetected by our raob network.

The combination of parameters described above results in a final "K" value containing criteria conducive to thunderstorm development; namely, a stability factor and a measure of available moisture. In order to indicate flow patterns on the "K" chart, the 850-mb and 700-mb heights are added arithmetically and contours drawn for these values at intervals of 200 meters. The winds at 700 mb are also plotted. The "K" chart thus prepared combines into one single map, portions of information appearing on five National Facsimile maps (Severe Weather Outlook, 850-, 700-, and 500-mb maps, Stability Chart). These maps are not all available for full consideration, due to the morning forecast deadline. The "K" value itself is not available on any FAX chart.

The "K" chart is analyzed from the Western Plains westward to the Pacific Coast, and will usually indicate a gradation of thunderstorm potential over the Western United States. "K" value isopleths are drawn at five unit increments; and, instead of George's adjective probability rating, a percentage probability for thunderstorm occurrence is ascribed, with "K" value assignments as follows: 15 or less, 0%; 15 - 20, less than 20%; 21 - 25, 20 - 40%; 26 - 30, 40 - 60%; 31 - 35, 60 - 80%; 36 - 40, greater than 80%; 41 - 45, near 100%. The height contours indicate areas of confluent and difluent flow, cyclonic and anticyclonic curvature, and indicated advection of "K" values.

The initial analysis will provide an objective thunderstorm forecast scheme. Essentially, the forecaster can use the probability values as a starting point. Further consideration of the synoptic situation then leads to subjectively increasing or decreasing the thunderstorm threat. Naturally, the 1200Z "K" chart analysis provides the basis for thunderstorm forecasts for the remainder of the day. Subsequent synoptic changes by afternoon, in conjunction with later prognostic information, will lead to the adaptation of the "K" chart for use in the 24-hour afternoon forecasts for the next day.

Verification of the "K" chart and forecasts has been accomplished by noting the time of occurrence of thunderstorms on hourly sequence observations on teletype Service A, for all stations from the Rockies to the West Coast, and Canada to the Mexican border. Additional reports, from within the district, are gleaned from the 10-day observation forms submitted by fire-weather stations and lookouts of the various agencies.

Figure 3 shows some of the verifying points in the Reno area of responsibility. Note the paucity of such points in Nevada; however, a dense network covers the California east side.

Table 1 is a table of forecasts and verifications for the 1965 thunderstorm season June to September inclusive, and 1966 May to September. The 1965 season was the more active, with 359 thunderstorms reported during a four-month period, while the 1966 season consisted of a five-month thunderstorm period with only 228 thunderstorms reported. The probability forecasts were verified by means of Briers Modified P-score 3/. The Modified P-score ranges from a perfect score of zero (0) to a poor score of unity (1). Forecasts issued at 1530 PDST for a 24-hour period were verified. However, for the shorter term forecast revisions, issued in the morning at 0830PDST, and using the latest 1200Z "K" chart, an improvement in forecast accuracy was indicated. For example, revisions were issued for 80 of the 137 cases that had a thunderstorm occurrence with an initial afternoon 24-hour forecast probability of less than 10%. Even so, the Modified P-score for the 24-hour period forecasts was 0.18; the morning revisions would reduce this value to about 0.14. Using the climatology of thunderstorm occurrences (27%) as a forecast gave a Modified P-score of 0.39. The 24-hour forecasts, therefore, showed a 55 percent improvement over climatology (Table 1).

Figure 4 is a "K" chart analysis, with thunderstorm occurrences entered. Solid lines are "K" value isopleths. Dotted lines are isopleths of sum of 850-mb and 700-mb heights. These values are entered to the right of station, "K" values to left. Winds are at the 700-mb level. Times of observed thunderstorms are also entered.

IV - OTHER APPLICATIONS

The "K" chart lends itself to the forecasting of other elements as well as thunderstorms, for example: 1) the height term combined with the change in height can be used to indicate the temperature trend; 2) the height gradient or packing will indicate wind speed, especially speeds at mountain peak levels; and 3) the 15 "K" value isopleth in many cases will depict the ensuing 24-hour precipitation envelope or pattern of early winter storms.

V - CONCLUSION

The "K" chart has been an invaluable tool for thunderstorm forecasts in the fire-weather program at Reno. Modification by the forecaster increases the accuracy of the forecasts, and the forecast aid is applicable throughout the mountainous West.

VI - ACKNOWLEDGMENT

Acknowledgement is due Mr. J. B. Smith, Fruit-Frost Meteorologist, Pomona, California, for assistance in the use and application of the "K" chart during the 1964, 1965, and 1966 Fire-Weather Seasons.

Appreciation is also due Scientific Services Division for the help in getting the manuscript into final form.

VII - REFERENCES

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2/ H. P. Benner, R. E. Hambidge, L. B. Overaas, D. B. Smith, J. Youngbert, October 1962, MWR, "Summer Convective Cell Radar Patterns Over Northern and Central California", pp 425-430.

3/ G. W. Brier, January 1950, MWR, "Verification of Forecasts Expressed in Terms of Probability", pp 1-3.

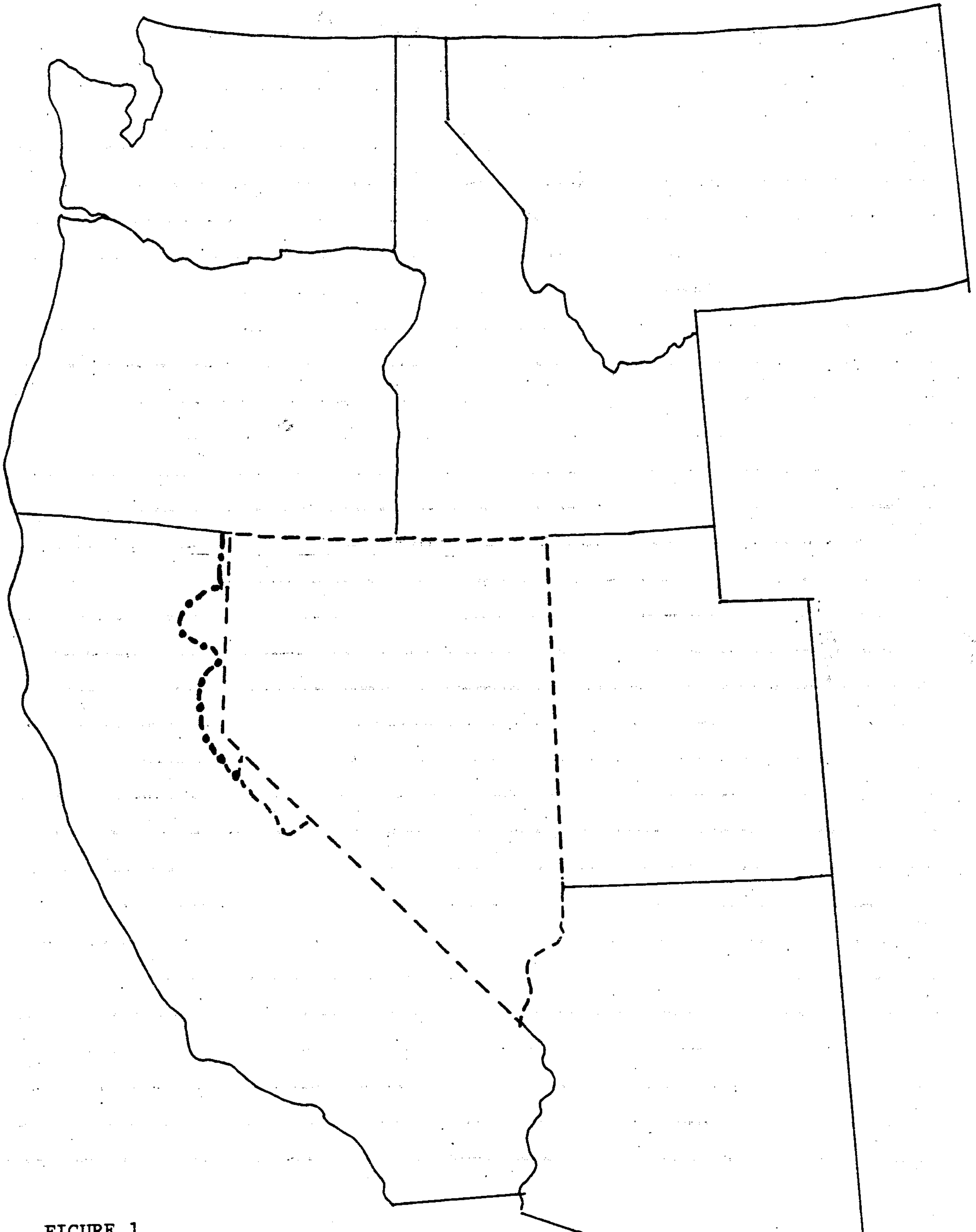

FIGURE 1

Reno District 1964 - - - - - -
Added Area 1965 —•—•—•-

DATE________________

Formula: K= (850mb 'temp - 500mb temp) + (850mb dewpt) - (700mb depres)

STATION	850-500mb TEMP.	850mb DEWPT.	700mb DEPRESS	"K"	850+700 mb HHH	700mb WIND	
YUM							
4JA							
LAX							
SLC							
OAK							
WMC							
INW							
ELY							
GJT							
VBG							
LAS							
ABQ							
SAN							
TUS							
ELP							
GEG							
GTF							
GGW							
BIS							
SLE							
LND							
MFR							
BOI							
TTI							
DEN							
AMA							
MXCN 225							
256							

FIGURE 2

Thunderstorm "K" Chart Data Computation Sheet

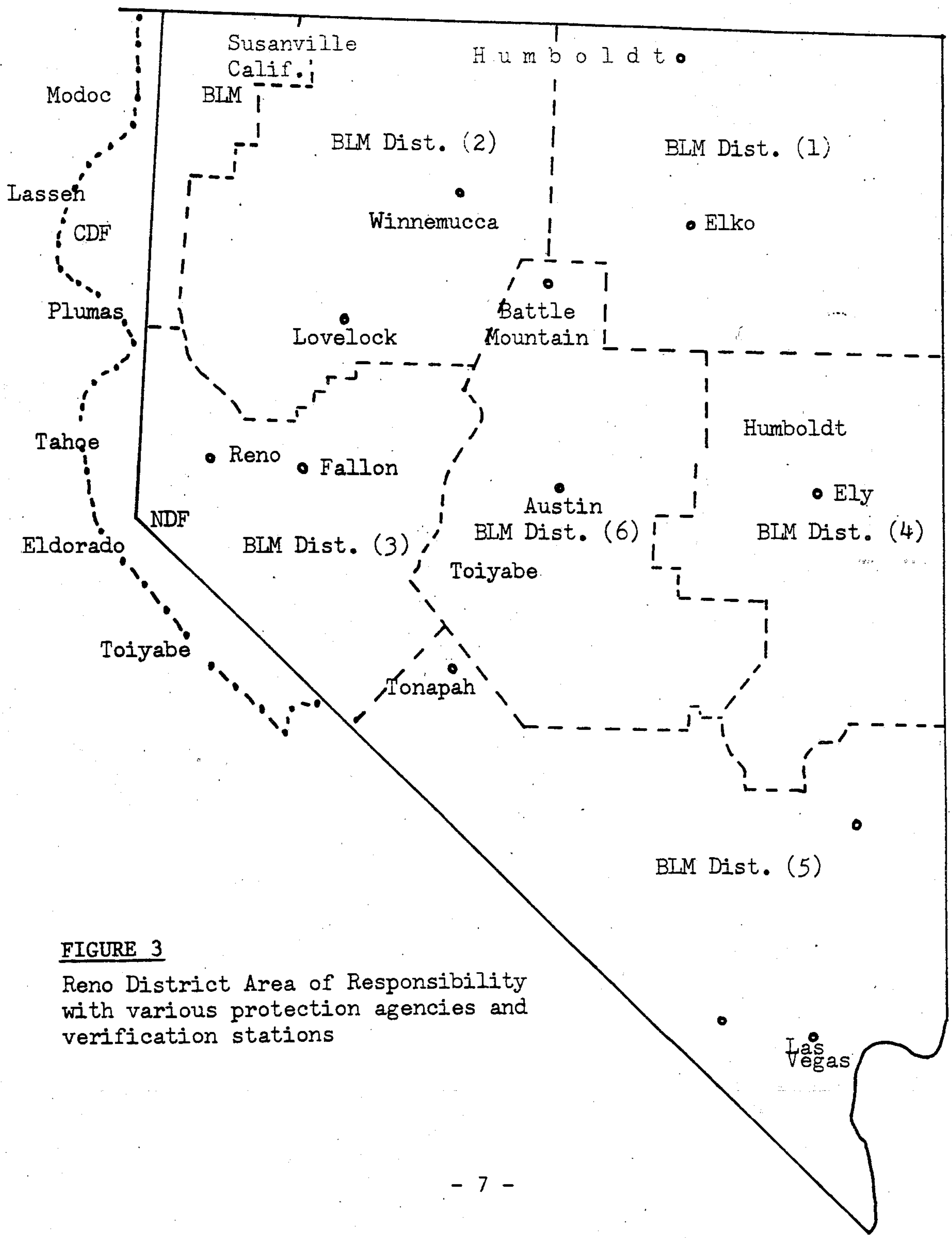

FIGURE 3

Reno District Area of Responsibility with various protection agencies and verification stations

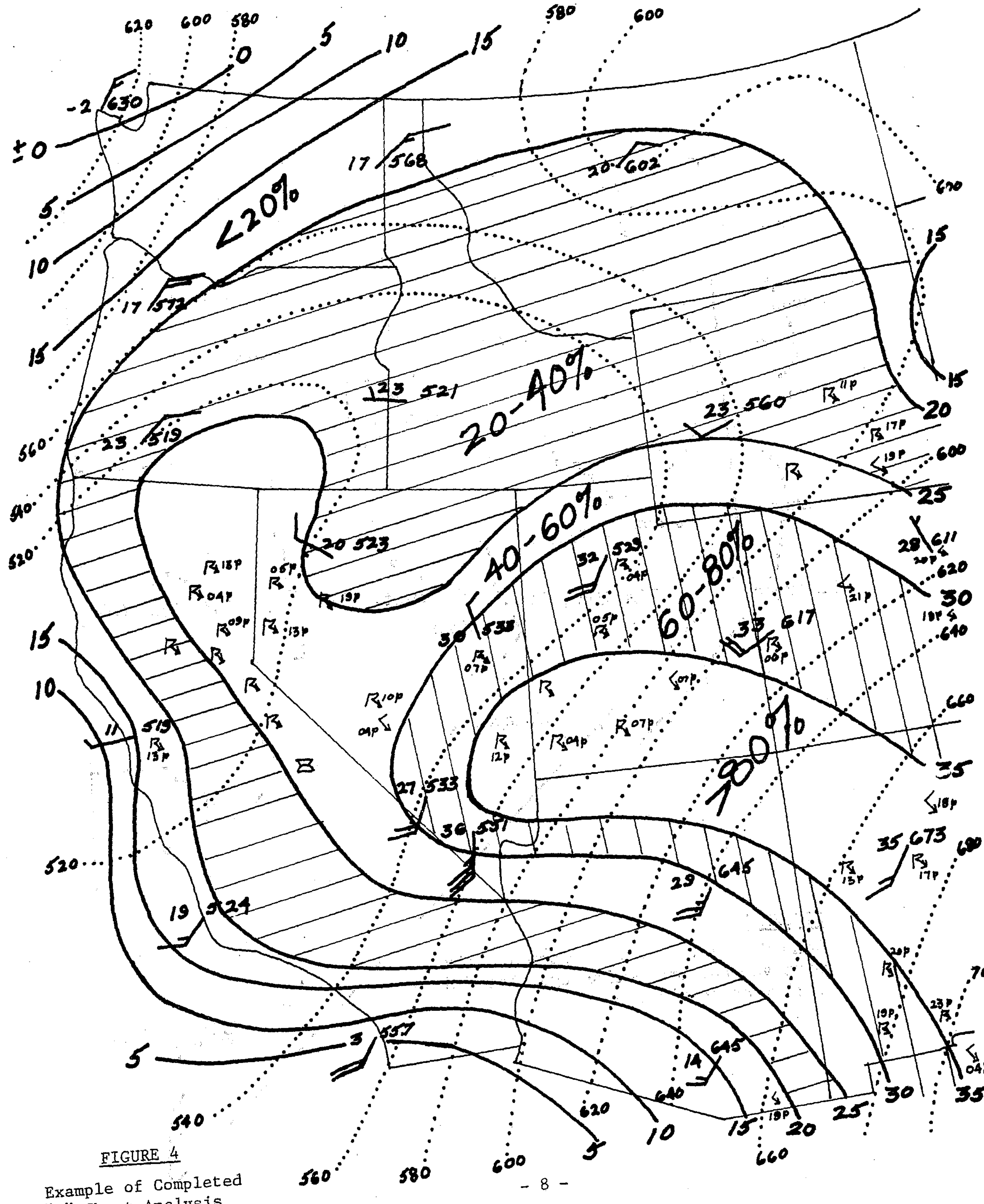

FIGURE 4

Example of Completed "K" Chart Analysis 1200Z Sept. 6, 1965

<u>TABLE 1</u>

THUNDERSTORM FORECASTS AND VERIFICATION
June-September 1965
May-September 1966

		Less than 10%	20%	30%	40%	50%	60%	70%	80%	90% to 100%	
DISTRICT I	Fcst.	157	2	26	26	14	11	25	9	4	
	Obs.	25	0	4	13	3	8	19	8	2	
DISTRICT II	Fcst.	180	5	25	14	11	17	9	12	2	
	Obs.	17	0	9	1	4	5	5	10	2	
DISTRICT III	Fcst.	170	4	15	20	20	19	9	11	7	
	Obs.	22	1	6	12	13	10	6	10	7	
DISTRICT IV	Fcst.	139	2	29	36	12	10	21	17	8	
	Obs.	18	1	10	15	6	6	16	14	8	
DISTRICT V	Fcst.	131	3	25	29	13	27	16	18	12	
	Obs.	13	0	7	9	4	11	10	13	12	
DISTRICT VI	Fcst.	169	3	21	21	10	17	15	11	5	
	Obs.	16	1	6	11	5	11	11	9	5	
SUSANVILLE NORTH	Fcst.	177	4	26	17	14	12	11	7	6	
	Obs.	22	1	12	3	5	5	6	5	5	
SUSANVILLE SOUTH	Fcst.	172	6	19	21	17	15	12	9	6	
	Obs.	24	2	5	7	10	4	10	7	4	
TOTALS	Fcst.	1295	29	186	184	111	128	118	94	50	2195
	Obs.	137	6	59	71	50	60	83	76	45	587
OBSERVED FREQUENCY		11%	21%	32%	39%	45%	47%	70%	81%	90%	

Modified P-score - 0.18
Climatology for this period - 0.27 or 27%
Climatology P-score - 0.39
Improvement over Climatology - 55%