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THE GREAT BASIN CLIMATE STUDY FOR RANGE FIRE MANAGEMENT

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and
Joel E. Fletcher

A study

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ABSTRACT

The BLM (Bureau of Land Management) fire management personnel routinely use a fire danger computer program to estimate the effects of recent weather upon the fire hazard on the BLM rangeland sites. The program used for this purpose is the National Fire Danger Rating System (NFDRS) which was developed by the National Forest Service (Deeming, 1978). The NFDRS was used in conjunction with fire weather stations in the Great Basin for the dual purposes of evaluating the ability of NFDRS to predict fire danger and of determining the effectiveness of the present fire station network in detecting fire weather on the Great Basin rangelands.

Seasonal fire frequency and real time fire occurrence were examined with respect to climatic and weather variables to determine the meteorological parameters which are most closely related to fire occurrence. These parameters were then used to delineate zones within the Great Basin of approximately equal fire climate. The climate relationships are also discussed with regard to the possible development of pre-season fire projection models.

ACKNOWLEDGMENTS

Recognition is made of the many people involved in furnishing data for use in this study. Appreciation is expressed to John K. Westbrook for the use of upper air climatological maps which he developed during his graduate study at Utah State University.

Acknowledgment is made of E. Arlo Richardson, Utah State Climatologist, for his efforts to furnish climatological data and materials. The manuscript was typed by Barbara South, Kathy Hobbs, and Debbie Rickert.

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One possible solution to this question of representativeness would be to keep two sets of fire danger indices during precipitation events. One set of fire danger indices would reflect the situation on the wetted surfaces and the other would be indicative of the areas not receiving precipitation. Other model inputs would be identical for both calculations. The only change would be to hold precipitation constant at zero for one fire danger calculation. The sectors represented by the wet and non-wet fire danger indices could be determined by the radar patterns over the area during the precipitation event. After a series of dry days the calculations using actual precipitation and the calculations using zero precipitation, would (by nature of the model) begin to converge toward the same status of fire danger.

Even with the improved lightning detection techniques, the importance of treating precipitation with other than point measurements has been identified as an important area of concern.

III. ZONING STUDY

A. Overview of Zoning Techniques

There are many techniques available for climatic zoning. Each has been developed for a specific purpose. Some proposed methods emphasize the homogeneity of: 1) Air Mass; 2) Vegetation; 3) Potential Evapotranspiration (PE); 4) Human Comfort; 5) Weathering or Erosion, and 6) Major World Climatic Divisions.

For the purpose of delineating fire climate zones within the Great Basin, the typical classification systems must be rejected. The air mass treatment would not differentiate zones due to the dominating continental affect during summer on Polar (cP) or Tropical (cT) air masses. The vegetative approach could be aimed at defining the type of vegetation which exists as a step in choosing a proper fuel model, but the approach is not satisfactory for addressing the fire danger in that region. PE classification has advantages, but the data needed to accurately estimate PE are limited. The PE approach would require also that the vegetative characteristics with respect to PE be well known for range plants. For instance, some range plants can extract moisture from very dry soil but these plants have not been studied to determine what the actual crop coefficients are. The remaining classification systems can be rejected on the basis that their intended purpose is not compatible with the goals of this study.

After reviewing the zoning techniques available, it was clear that a technique was needed which deals directly with fire danger concepts. The fire danger philosophy has been indicated in Deeming et al. (1978). This philosophy treats the worst case of fire danger rather than the average or some other statistical measurement. To date classifications delineating zones of equal fire danger have been few in number (Searby, 1975).

B. Fire Danger Zoning in the Great Basin

In this section the general approach developed for zoning the Great Basin will be presented. This discussion will give the background for the specific results indicated in following sections.

1. Seasonal Distribution of Fire Frequency

Boundaries for the BLM districts discussed below are shown on the maps in Appendix E. The fire information for various districts throughout the U.S. is archived through a joint effort by the various agencies. The information from the Normal Fire Year Profile proved valuable in determining the seasonal distribution of fires in each district as will be seen in the following discussion.

Daily fires were totaled to obtain 10 year monthly totals for each fire district within the Great Basin. The histograms prepared to display these values are shown in Appendix A. It was found that relatively few fires occur before May or after October. The highest fire totals occurred in July for most fire districts, while the second highest total number of fires was usually found to occur in August. This is reversed in a few situations, notably for the Oregon Fire Districts examined (see Lakeview, Burns, Vale, and Prineville in Figures A-7 through A-10).

The two districts of highest fire occurrence as determined by the 10 years of fire data are Carson City in Nevada and Prineville in Oregon. Both districts have months which average nearly 40 fires per month. Areas of low fire occurrence are all the districts in Utah plus the Burns and Vale districts in Oregon, and the Idaho Falls district in Idaho.

relationship to a mean humidity map. Similarly, the maximum temperature would indicate the minimum humidity and the minimum temperature would determine the maximum humidity.

Locally water surfaces could modify this relationship between relative humidity and temperature. Where more moisture is available near a water surface the relative humidity would be somewhat higher. This affect diminishes quite rapidly as the distance from the body of water increases and is usually of most importance downwind from the water surface rather than upwind or to the sides of the prevailing wind direction.

3. Precipitation Frequency and Amounts

The examination of precipitation and fire data shows a definite tendency for fires to occur with increased frequency at the beginning of a precipitation episode. In this publication episode refers to a group of one or more consecutive days during which precipitation was observed on all days in the group. The tendency for fire frequency to increase is evident in Figure 1 where the accumulated fires and the accumulated precipitation days have both been indicated. It was also concluded from this comparative analysis that fire frequency is inversely proportional to the length of the precipitation event. Therefore, long precipitation events bring about an overall reduction in fire danger. The most significant increases in fire occurrence are observed at the beginning of an episode.

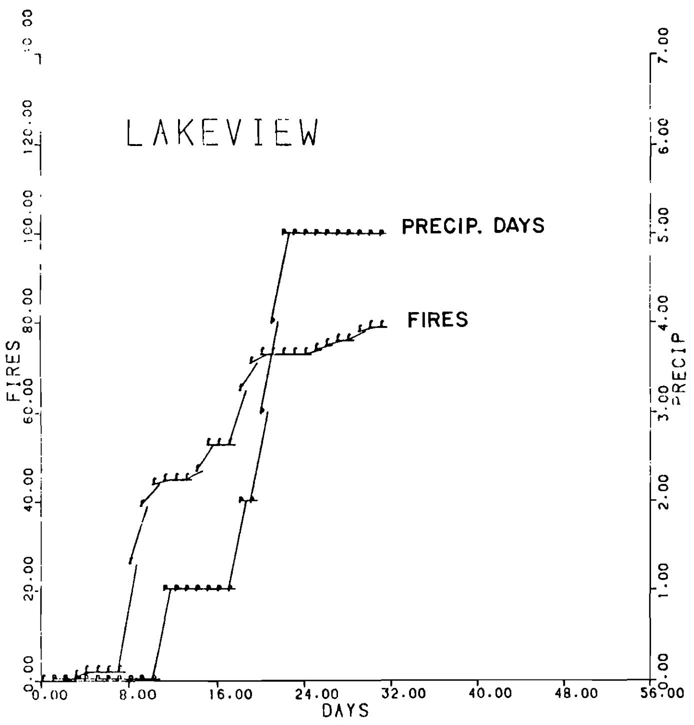


Figure 1. Simultaneous curves of accumulated fire occurrence and accumulated precipitation days for the Lakeview Fire District in August of 1972.

These two findings are supported by a conceptual model which is based upon the supposed surface wetness of the surface fire fuels. First of all, a precipitation episode which lasts only one day is likely the result of convective cloud formation. The associated lightning activity causes a marked increase in the number of fire outbreaks. The fire danger in this situation is a function of the fire fuel condition, the cloud to ground lightning frequency, and the number of convective clouds in the area. Of course, one lightning producing cloud in a vast region would limit the lightning threat to only a small area, while many such clouds would probably produce adequate surface wetting to reduce the fire danger over the region. In between these two limits is where the greatest potential fire hazard exists.

In contrast to the one day convective type precipitation, we find some episodes of fire season rain last for several days in succession. These events are the result of a relatively moist air mass moving through the Great Basin. The widespread shower activity can wet the surface to the point where fuel moisture precludes fire outbreaks. The longer episode is pointed out in Figure 2. Several long episodes begin at about day 4 of the month. The fire increase is seen at the beginning of the rain episode, while the fire occurrence levels off dramatically as the precipitation continues for several days. After several consecutive dry days the occurrence of precipitation again causes an increase in fires reported as can be seen at about day 21 of Figure 2.

One of the most important considerations for determining fire zones within the Great Basin is the precipitation characteristics in relation to not only the probability of precipitation, but also the amount, duration, areal coverage, and type of cloud formation. Within the limits of the present study, consideration was given to the probability of certain amounts of precipitation and the duration of precipitation at locations throughout the Great Basin. As was mentioned earlier, in a climatological sense the duration is an indicator of the type of cloud present and, therefore, to some extent the areal coverage of precipitation.

a. Selected Probabilities. Probabilities were taken from a previous study by Gifford et al. (1967). The probabilities were plotted at the appropriate stations resulting in the maps shown in Appendix D. When the contours are examined, it can be seen that they are displaced to the northwest as the fire season progresses. The push of Gulf moisture from the southeast quadrant is the likely cause of the northwestward movement of these contours. A probability by itself does not disclose the average fire danger but must

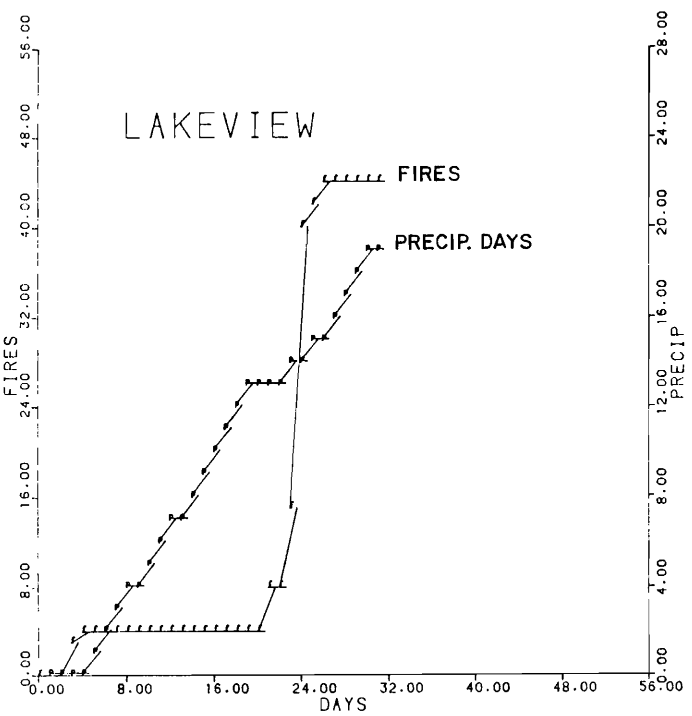


Figure 2. Simultaneous curves of accumulated fire occurrence and accumulated precipitation days for the Lakeview Fire District in June of 1970.

be considered with regard to when the probability occurs during the fire season.

b. Length of Rain Episodes. In the discussion at the beginning of this section, it was indicated that the number of consecutive days on which measurable precipitation occurs is an index of the type of storm and its coverage. An examination of this parameter for short and long duration episodes was completed to determine temporal precipitation features upon which the Great Basin fire climate zones could be based.

Map D-4 in Appendix D indicates the average number of July precipitation episodes which last at least one day. It is apparent that topography plays a role in this frequency. The highest frequency occurs along the Wasatch Mountains and again in the vicinity of Nevada's higher elevation nearest to the Gulf flow.

4. Potential Evapotranspiration

Methods are available to determine potential evapotranspiration (PE) from temperature data (Oliver, 1973). The PE when combined with a moisture index can be used to delineate vegetation potential at a given site because PE is related to production and curing of rangeland plants. The usefulness of this technique was shown by Mather and Yoshioka (1968). For the present study, vegetation types were determined directly from vegetation maps of the Great Basin area. The results of the vegetative analysis will be discussed in the following section.

D. Vegetation Map of the Great Basin

1. Background

Vegetation contributes to fire danger both from the type of consumable material and the quantity of that material available to burn. Futhermore, even rainfall intensity and frequency were related to vegetative zones in the Great Basin by Farmer and Fletcher (1971) and Martin and Fletcher (1943). Hales (1973) showed that the grass-producing summer monsoonal rains for the southwestern United States originate in the Gulf of California and the southern Pacific Ocean thus serving as a near source of summer moisture.

A vegetational map was prepared drawing upon previous maps published by Kuchler (1975) and Smith (1970) and upon personal inspection.

Base maps used were USGS 1:250,000 topographic maps on which the 5,000 foot contour was traced as a heavy line to serve as the upper boundary for vegetation classification.

2. Vegetation Map

The natural vegetation types were classified and entered on the base map. A number was assigned each type on the map. Each number, called a map number, and its fire classification are tabulated in the remainder of this section. Some of the numbers designate vegetation above the 5,000 foot contour simply because the mapping was begun before the 5,000 foot limitation was imposed. As the map is drafted these areas can be deleted or others added as seems desirable.

Map Number 4. Fir-Hemlock Forest.

This complex is dominated by subalpine fir (Tsuga lasiocarpa) and mountain hemlock (Tsuga mertensiana). The vegetation in this type belongs to Fire Group G.

Map Number 5. Mixed Conifer.

This complex is principally composed of white fir (Abies concolor), incense cedar, sugar pine, ponderosa pine and douglas fire. The vegetation in this type belongs to Fire Group G.

Map Number 10. Ponderosa Shrub Forest.

This complex is dominated by western yellow pine (Pinus ponderosa) with an understory of a variety of grasses and small shrubs. The vegetation in this type belongs to Fire Group G.

Map Number 11. Western Ponderosa Forest.

This complex is dominated by western yellow pine (Pinus ponderosa) with an inderstory of mixed grasses, sedges and forbes particularly varieties of Lupinus. The vegetation in this type belongs to Fire Group G.

Map Number 14. Grand Fir--Douglas Fir Forest.

This group is essentially composed of the two species grand fir (Abies grandis) and douglas fir (Pseudotsuga mengiesii). Other species are very scattered. The vegetation in this type belongs to Fire Group G.

Map Number 23. Juniper--Pinyon Woodland.

This woodland is dominated by four tree species--single seeded juniper (Juniprus monosperna) juniper (Juniprus osteosperma) pinyon pine (Pinus edulis), pine (Pinus monophylla) with minor concentrations of grasses and sage. The vegetation in this type belongs to Fire Group G.

Map Number 24. Juniper Steppe Woodland.

This woodland has scattered western juniper (Juniperus occidentalis) with well developed blue bunch wheat grass (Agropyron spicatum) mixed with beg sagebrush (Artemesia tridentata). Other sages and grasses are minor components. The vegetation in this type belongs to Fire Group C.

Map Number 38. Great Basin Sagebrush.

This brushland is strongly dominated by big sagebrush (Artemesia tridentata) with minor components of forbes and miscellaneous grasses. The vegetation in this type belongs to Fire Group F.

Map Number 40. Saltbush--Greasewood.

This shrubland is dominated by shadscale (Atriplex convertifolia) and greasewood (Sarcobatus vermiculatus) with minor concentrations of other salt loving plants. The vegetation in this type belongs to Fire Group F.

Map Number 46. Desert.

In this area little or no obvious vegetation is present. Therefore, it belongs to No Fire Group.

Map Number 49. Tule Marshes.

This complex is dominated by common tule (Sirpus acutus), cattail (Typha latifolia) and other less common tules. The vegetation in this type belongs to Fire Group A.

Map Number 50. Fescue--Wheatgrass.

This grassland is dominated by Idaho fescue (Festuca idahoensis) and blue bunch wheatgrass (Agropyron specatum) with minor components of other grasses and forbes. This grassland belongs to Fire Group A.

Map Number 51. Wheatgrass--Bluegrass.

This grassland is dominated by blue bunch wheatgrass (Agropyron specatum), sandberg bluegrass (Poa secunda) and Idaho fescue (Festuca idahoensis) mixed with minor concentrations of forbes and other grasses. This grassland belongs to Fire Group A.

Map Number 55. Sagebrush Steppe.

The steppe has scattered big sagebrush (Artemesia tridentata) with the interspaces dominated by blue bunch wheatgrass (Agropyron specatum). The vegetation in this type belongs to Fire Group C.

E. Great Basin Fire Climate Zones

Using the information developed in this study, certain fire climate characteristics will be outlined as they relate to the Great Basin region. First, by calling attention to the individual districts a basis will be shown for understanding the zoning system to be used below.

Within the Battle Mountain Fire District, one can find from Figure A-6 that the fire occurrence is relatively low for each month. This low fire occurrence is in agreement with the medium number of events of one or more days duration (Figure D-4) and the relatively large number of events longer than three and four days in length (Figures D-5 and D-6). This is a good combination for producing low fire danger.

Now consider the Carson City Fire District. As indicated in Figure A-3, Carson City has a high number of fires relative to the other districts. From Figure D-4 we find that the Carson City District also has an average number of events lasting at least one day (averages two to three events in July). This is in combination, however, with a very small number of events which last three, four, or more days in length. Most of the Carson City District is typified by less than one of these long duration episodes during July in a 10-year period, compared to some areas which average one of these longer precipitation episodes per year. This was the case for the Battle Mountain District discussed above.

It is then a combination of factors which determine the average worst fire climate for areas within the Great Basin. District boundaries intersect the isolines drawn on Figures D-4 through D-6 so that not all districts will be as easily discussed as the one mentioned above. The zoning concepts are listed in Table 2 for further clarification according to the combinations which produce fire climate classifications.

Table 2. The relative fire danger for fire climate zoning as determined by the frequency of short and long duration precipitation episodes. The numbers in each box are the numeric code for the fire danger which will be used to denote the zones on later maps.

		Number of Short Duration Days		
		Low	Medium	High
Number of Long Duration Days	Low	Medium (3)	High (4)	Highest (3)
	Medium	Low (2)	High (4)	High (4)
	High	Lowest (1)	Low (2)	Medium (3)

These concepts were also discussed in Section C.3. The classifications were applied to the maps in Figures D-4 and D-6 to yield the zones indicated in Figure D-7. When the district boundaries are overlayed on this final map, the agreement between the 10-year fire totals and the areas delineated by this zoning procedure is good.

F. Location and Operation of a Fire Danger Observation System

Adequate instrumentation in the proper location is a vital part of any detection system. As pointed out in Section I, a network which detects the surface precipitation (or any other quantity) for every point in a x, y, t system is impossible to construct. However, understanding how much of the area is represented by a single measurement can be of great benefit. In analyzing convective systems, radar is a valuable tool to determine the location and spacing of thundershowers. Adequately detecting the moisture at the surface would require a special relationship between the backscattered radar signal and the rain rate at the precipitation gage for each region in the Great Basin. This relationship could be deduced by calibration using rain gages located on the ground and recalibration would be necessary as the weather conditions change.

If such a system is ever to be operated in the Great Basin, the precipitation gages would need to be weighing type gages rather than the type which must be read out manually by the observer. This feature is necessary in determining the rate of precipitation accumulation at the surface. When the rate is integrated over time, the total precipitation results.

Of course until this system can be implemented, an estimation of the area being affected by rain would be much more beneficial in determining the location of fire danger than the present practice of entering only point measurements. Additional rain gages in the data sparse Great Basin region are essential to determining the coverage of precipitation. Summertime convective activity can be locally quite intense. In frontal precipitation, this is not so often the case due to the wide-spread cloudiness and the stratus clouds usually present. Convective clouds are potentially a greater fire hazard than are stratus clouds due to the concurrent lightning activity and the limited coverage of convective clouds. Additional rain gages would provide important information not now available to the fire management personnel.

Until new precipitation equipment can be installed, it is recommended that several sets of fire danger indices be maintained for each fire weather station. To ascertain the upper limit on fire danger, one set of indices should be calculated by entering zero precipitation or a reduced precipitation (Trace).

Fire weather stations should be located according to the zones shown in Maps D-7 of Appendix D. Available resources should be heavily concentrated in Zone 4 with less emphasis on Zones 2 and 3. These zones indicate areas of equal climatic potential for fire occurrence. There are 10 separate zones of which Zone 4 is by far the largest. In addition to potential fire occurrence, the vegetation in each zone must be considered. This consideration is necessary to estimate actual rather than potential fire occurrence.

Vegetative characteristics were studied and the results have been presented in Section II.D. Considerable effort was made to identify the prominent native vegetation. This study will be useful in determining the appropriate fuel model to use for a given weather station. The fuel model, of course, determines the relationships to be used in determining fire danger indices from weather inputs.

Climate, to a large extent, determines the boundaries for each vegetative type (Mather and Yoshioka, 1968). Since potential fire occurrence is related to climatic factors in a different way, it follows that a certain vegetation in one locality may present a higher fire danger than the same vegetation in another area. This means that overlapping of potential vegetative zones and potential fire occurrence zones can make a complicated picture with many more zones than indicated on Map D-7. The fact that so many fire danger zones result from overlapping the potential fire occurrence and the vegetative boundaries does not, however, mean that a fire weather station is required for each zone.

The procedure recommended is to establish fire weather stations in the major zones of potential fire occurrence in sufficient number to adequately determine fire weather conditions on the zone itself. By concentrating on detecting fire weather conditions, the worst case of fire danger can be assessed.

Location of the fire weather stations, in regard to vegetative boundaries, should be a further consideration. It is recommended that a weather station be located within the boundaries of the major vegetation variety present in each potential fire occurrence zone. In addition, a fire weather station should be located within the boundaries of the vegetation variety known to present the greatest fire hazard.. Funding to establish fire weather stations with this density should be made available. A density of station sites higher than suggested above, is probably impractical considering the availability of such area sensors as the WSR-57 radar and the Great Basin Lightning Detection network.

Data from already established radars could be supplemented where needed by locating a portable radar unit in the field. The National Weather Service utilizes data from FAA radars, as well as the data collected from NWS units. Currently, data are available from several FAA radars in or near the Great Basin boundaries including: Salt Lake City and St. George, Utah; Elko and Las Vegas, Nevada; and Boise, Idaho. The National Weather Service Office in Sacramento, California, operates a WSR-57 radar, however, the Sierras would likely block from view all but very high altitudes over the Great Basin. Utilizing radar data in conjunction with precipitation measurements at the ground is one way of determining in detail what the precipitation patterns are.

IV. PROJECTION MODELS

A. Seasonal

The average fire activity has shown a marked seasonal relationship, with a maximum activity in July or August. This seasonal tendency is definitely linked to the seasonal temperature in the long-term. Figure 3 shows that individual districts have a different relationship between temperature and fire activity, but that a curve can be fit to the data of any particular district. When the average temperature is 60 F, it can be seen that the 10 year fire totals are 5, 25, and 250 for the Las Vegas, Salt Lake, and Boise districts respectively.

The reason that data from these different districts do not fall along a single curve, is that precipitation and vegetation are important factors within the respective districts. While precipitation patterns within these districts vary considerably from one year to the next, the type of vegetation growing there remains relatively constant (in location not fuel volume). The vegetative volume for any year can be viewed as a transform of both the precipitation which occurs in the area and the temperature for that year. Nevertheless, average temperature and fire frequency are related within the districts examined. The physical reason for this is the fact that heat is required to bring fire fuels to a dry state and temperature is a good index of heat. The affect of heat upon drying is definitely a function of vegetative type and moisture present, therefore, each vegetative region should have its own reaction curve to environmental inputs.

Standard regression techniques did not yield significant relationships between meteorological parameters, such as temperature and precipitation, to fire occurrence on a month by month basis. This situation did not improve when lag variables were considered. Perhaps, on the basis of the conclusions drawn from Figure 3, one would expect rather poor results from a simple statistical treatment. More likely to yield an improved result would be the use of a physical model with emphasis on the input of meteorological measurements. The specified vegetative algorithms would then transform the basic measurements into effective heat and effective moisture with regard to the basic vegetation present.

More time would be needed to develop a physical projection model with update capabilities. This would be a worthwhile objective for further study. Insight into the structure of such a model could be gained by concurrent examination of the vegetation zones already under study and analysis of fires with respect to their location.

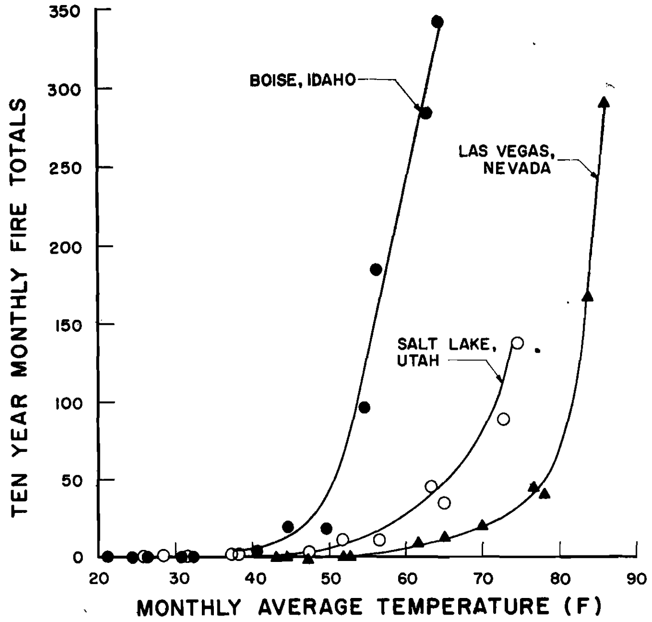


Figure 3. The climatic relationship between temperature and fire occurrence on the districts shown. Average monthly temperature was determined for 30 year normals on climatic divisions. Where fire district boundaries passed through more than one climate division, a weighting technique was applied to obtain the temperatures.

B. Medium Range Fire Projection

A medium range forecast for weather purposes is by definition a forecast made two days to one week in advance of the forecasted event. This type of forecast or projection capability would be quite valuable in planning the actual operations and especially for determining the weekend work force requirements.

It has been determined from the work reported here, that the best indication of fire occurrence on a day-by-day basis is the presence or absence of precipitation in the area. The presence of precipitation indicates the possibility of lightning. Of course, large amounts of moisture will wet the area enough to reduce fire activity, but this is not the usual product of fire season convective clouds.

The logical tool for projecting work force requirements is then the medium range precipitation forecast released by the National Weather Service. It is important to know the type of cloud system which will be associated with any forecasted moisture for the purpose of determining the areal coverage of moisture and the lightning potential.

This is an area which needs further study and with the implementation of the lightning detection system in the Great Basin, there will be a data base from which to study the climatology of precipitation, lightning, and the likelihood of both occurring in various parts of the Great Basin.

V. CONCLUSIONS AND RECOMMENDATIONS

It was found that precipitation has a profound impact on the indices of the NFDRS. It was found that the NFDRS did not simulate the effects of precipitation. The fire danger indices are essentially affected by a great reduction in value. The form of precipitation during summer in the Great Basin is essentially discrete convective cells. These cells are the spawning ground for severe electrical activity and as such, should be viewed in terms of the lightning and precipitation present. Since lightning can and does hit outside of the precipitation area, it is recommended that:

1) Two sets of fire indices should be kept for each fire weather station. The first should be determined by following the instructions for the 1978 NFDRS, while the second should be determined by inputting zero precipitation even though the station might have received moisture. This is in keeping with determining the worse case of fire danger.

2) Real time radar data should be collected and analyzed to determine which indices apply to given locations.

3) Weighing type precipitation gages should be operated in the Great Basin to provide a ground truth for determining precipitation amounts from the radar data taken. This would provide the fire management officer with not only the precipitation at each fire weather station, but also an estimate of the precipitation for any location covered by the radar.

It was also found that precipitation frequency and duration are equally as important as precipitation amount. Lower fire occurrence was observed to correspond with longer duration events while higher fire occurrence was observed to occur with shorter duration precipitation events. On this basis, the Great Basin was zoned into classes of fire occurrence potential. This decision has a strong physical basis, because convective thunderstorms have a typical duration of one hour, while air mass stratus precipitaion may last for days. Of course, the former covers less with rain and is generally associated with greater electrical activity. It is recommended that:

4) Available resources should be concentrated in the zones of highest fire occurrence potential.

5) Sufficient analyses are made to determine the optimum density of precipitation gages to be used in conjunction with the radar equipment suggested above.

In regard to projecting fire danger on a seasonal basis, several problems were encountered. It was found that data concerning fuel volumes were lacking and this represented a major obstacle. A model which projects fire load might be possible with the addition of such data. With this information, one could build a model which projects fuel volume. When the fuel volume and fuel condition are projected, one could hope to estimate the fire occurrence and behavior. But without reliable information in this regard, it is difficult or impossible to determine what climatic indicators are important. It is recommended that:

6) A study be made of fuel volume and fuel moisture on selected sites within the Great Basin. It is important that these sites be relatively free from other impacts (grazing, recent fires, etc.). Further, these sites should be near to the fire weather stations.

VI. SUMMARY OF RESULTS

It has been found that the best climatic measure of fire occurrence is rain. In the summer, the Great Basin receives large amounts of heat at the earth's surface. some of this heat is used in generating upward moving wind currents and these updrafts act to carry the available moisture from the lower layers to the upper atmosphere. When the moisture condenses into tiny droplets, it scatters the light and the process forms a visable image which we call a cloud. There are many complex processes which occur inside clouds, some of them are not well understood. Clouds often carry an opposite electrical charge than the earth's surface and when this electrical difference reaches a certain limit, a discharge occurs in the form of lightning. This is quite similar to touching opposite poles of a battery and causing a spark which momentarily reduces the charge difference between the two poles. Sometimes the rain falling from these clouds will wet the surface sufficiently to keep fire fuels from burning when hit by a lighning stroke. The lightning does not always follow a simple path to the earth's surface and the parameters affecting the trajectory of a raindrop (gravity, wind direction, wind speed) do not determine the path taken by lighning. This increases the fire danger because lightning can strike outside the wetted area. When the clouds are high and the atmosphere is very dry, the rain may become virga, evaporating before it hits the earth's surface.

This work clearly shows that the onset of rain usually means an increase in the number of fires reported. It was found that when rain occurs on more than one day in succession, the fire danger begins to decrease and beyond the fourth consecutive day of rain, fires are seldom reported. This provided a straight forward method of determining fire weather zones. The zones indicated in this study should be considered potential fire occurrence zones. Inside these zones, vegetative boundaries determine a further delineation of actual fire occurrence zones. Since the objective of this work is to determine the impact of weather on fire occurrence and behavior, it is appropriate to consider placement of fire weather stations according to the potential fire occurrence zones where measurements will be rather homogeneous with respect to fire weather.

Because the number of weather stations needed to indicate the boundaries between rain wetted and nonwetted surfaces would be astronomical, it was concluded that several sets of fire danger indices should be kept for each station. A set to indicate the precipitation conditions at the station location and additional sets to represent the precipitation at nearby locations. The additional sets could reflect individually more and less precipitation than received at the fire weather station. This would give the fire management officer an improved idea of how the fire danger indices vary over his management area. With judicious use of radar data, the areas of concern could be better represented and an estimate of the fuel condition at points between fire weather stations could be obtained.

Further understanding is needed to determine the climatic influence on vegetative growth and conditions. This can be accomplished by further study of specific sites in the Great Basin. The ability to project fire occurrence and behavior on rangelands is dependent upon further investigation of vegetative reactions to environmental conditions.

APPENDIX B

AVAILABLE CLIMATIC DATA

Table B-1 indicates the fire weather stations in the Great Basin areas while Table B-2 lists the stations which are maintained by the National Weather Service for the purpose of providing basic data.

Table B-1. Fire Weather Stations in the Great Basin Area.

Station	Latitude (deg)	Longitude (deg)	Elevation (ft)
CALIFORNIA			
Adin RS	41.20	121.00	4200
Blue Mt. LO	41.80	120.90	5740
Canby RS	41.40	120.90	4312
Happy Camp LO	41.40	121.10	6329
Sugar Hill LO	41.80	120.30	7267
Timber Mt. LO	41.60	121.30	5140
Blacks Ridge LO	40.80	121.20	6037
Bogard RS	40.60	121.10	5680
Laufman RS	40.10	120.40	4858
Observation Mt.	41.80	120.10	7964
Ravendale	41.80	120.30	5298
Dry Creek	41.20	120.50	5484
Beckwourth GS	39.80	120.40	4900
Boulder Creek GS	40.20	120.60	5000
Camel Peak LO	39.70	121.10	5760
Chester RS	40.30	121.20	4530
Greenville RS	40.10	121.00	3580
Mohawk GS	39.80	120.60	4400
Quincy HQ	39.90	121.00	3408
Smith Peak LO	39.90	120.50	7679
Chilcoot	39.80	120.20	5000
Dog Valley	39.60	120.10	5880
Saddleback LO	39.60	120.90	6690
White Cloud	39.30	120.80	4320
Duncan Peak GS	39.20	120.50	7128
Forest Hill FS	39.00	120.80	3365
Stateline LO	39.20	120.00	8900
Armstrong Hill LO	38.60	120.40	5740
Angora Ridge LO	38.90	120.10	7300
Bald Mt. LO	38.90	120.70	4613
Georgetown RS	38.90	120.80	3000
Meyers RS	38.80	120.00	6337
Leviathan LO	38.70	119.60	8985
Markleeville	38.70	119.80	5501
Blad Mt.	37.80	118.90	8500

Table B-1. Continued.

Station	Latitude (deg)	Longitude (deg)	Elevation (ft)
Bridgeport RS	38.30	119.20	6560
Lee Vining	37.90	119.10	7200
Mammoth RS	37.60	119.00	7800
Topaz	38.60	119.30	5025
Bald Mt. LO	37.40	118.40	9046
Walker	38.60	119.50	5860
IDAHO			
Squaw Butte LO	44.00	116.20	5960
Garden Vly. RS	44.00	115.50	3134
Idaho City RS	43.50	115.50	3950
Jackson Peak LO	44.00	115.20	8133
Lowman RS	44.00	115.30	3900
Shafer Butte LO	43.40	116.00	7591
Cottonwood RS	43.38	115.50	3450
Big S Butte LO	43.20	113.00	7550
Bennett Mt. LO	43.15	115.26	7438
Dutch Creek RS	43.50	115.20	4400
Lester Creek RS	43.20	115.20	4825
Shake Creek RS	43.30	115.10	4773
Iron Mt. LO	43.30	115.00	9714
Bell Mt. LO	43.20	114.00	7850
Swan Vly. RS	43.20	111.20	5260
South Mt. LO	42.40	116.50	7850
Grasmere	42.23	115.53	5100
Notch Butte LO	42.50	114.20	4240
Kimama Butte LO	42.40	113.50	5000
Crystal Caves	42.70	113.30	5160
Bannock RS	42.40	112.20	5142
Chinks Peak LO	42.50	112.20	6790
Rock Creek GS	42.10	114.10	6700
Malta RS	42.20	113.20	4543
Mt. Harrison	42.19	113.39	9265
Montpelier	42.30	111.20	5743

Table B-1. Continued.

Station	Latitude (deg)	Longitude (deg)	Elevation (ft)
NEVADA			
Peavine	39.36	119.51	5260
Bowers	39.16	119.50	5040
Anderson	39.37	119.55	5300
Empire	40.35	119.26	4000
Winnemucca AP	40.54	117.48	4200
Mt. City RS	41.47	115.59	5650
Austin RS	39.29	117.04	6700
Clear Creek	39.00	119.48	5850
Kyle RS	36.17	115.37	7200
OREGON			
Antelope Mt.	44.00	118.40	6500
Bone Point	45.00	119.00	4527
Crane Prairie	44.20	118.50	5373
Desolation Med.	44.80	118.60	5480
Dry Soda	44.20	118.90	5854
Monument LO	44.80	119.40	3876
Tamarack	44.90	119.70	4979
Crockett Knob LO	44.70	118.70	4760
John Day HQ	44.42	118.95	3125
Rocky Flat	44.92	119.67	4400
Spring Flat DI	44.88	118.90	4600
Crane Flat	44.80	118.40	5675
Durkee	44.60	117.50	2700
Halfway RS	44.90	117.10	2558
Huckleberry	44.70	118.20	5790
Lookout Mt.	44.60	117.30	7120
Russell Mt.	45.10	117.10	7487
Summit Point	45.00	117.20	7006
Unity RS	44.40	118.20	4000
Baker	44.50	117.80	3373
Round Mt. LO	43.45	121.43	5900
Sisters RS	44.18	121.33	3182
Trout Creek Butte	44.15	121.40	5500
Tumulo Butte	44.06	121.22	3885
Cold Springs GS	44.40	120.10	4695
Foley Butte LO	44.50	120.80	5450
Rager RS	44.20	119.70	4000
Tower Point	44.10	120.30	6086
Prineville HQ	44.30	120.80	2865
Cabin Lake GS	43.29	121.03	4545

Table B-1. Continued.

Station	Latitude (deg)	Longitude (deg)	Elevation (ft)
Dog Mt. LO	42.07	120.43	6936
Fort Rock	43.26	120.51	4450
Silver Lake RS	43.08	121.04	4380
Sycan Butte LO	42.52	121.01	6347
Brim Well GS	43.09	120.10	5000
Lantern Flat	42.40	120.70	6390
Allison GS	43.90	119.60	5320
Burns Butte	44.33	119.13	5297
Riddle Mt.	46.06	118.30	6450
Wagontirf	43.15	119.53	4726
Joaquin Miller	43.82	118.93	5200
Jordan Valley	42.59	117.05	4300
Monument Peak	43.38	117.54	5760
Juntura	43.45	118.05	2970
Castle Rock	44.30	118.20	5820
Blue Mt.	42.30	117.85	4860
Crowley	43.20	117.95	4080
Burns Junction	42.80	117.85	3950
Whitehorse	42.30	118.25	4390
UTAH			
Golden Spike	41.63	112.55	5000
Card RS	41.80	111.70	5200
Monte Cristo GS	41.50	111.50	9100
Beus Canyon	41.20	111.90	5100
Dugway	40.20	112.90	4339
Guardsman HQ	40.70	111.80	4600
Pleasant Grove RS	40.40	111.80	5400
Moark	40.08	111.60	4820
Ephraim ES	39.30	111.60	5650
Delta	39.40	112.50	4755
Chalk Creek	39.00	112.30	5700
Fishlake RS	38.60	111.70	8900
Richfield HQ	38.80	112.10	5303
Bryce Canyon HQ	37.70	112.20	7920
Panguitch RS	37.80	112.40	6625
Boulder	37.80	111.42	6700
Lava Point LO	37.40	113.00	7890
Zion HQ	37.20	113.00	4000
Enterprise	37.60	113.70	5340
Kanab HQ	37.00	112.50	4925

Table B-2. Great Basin NWS Stations.

Station	Latitude (deg,min)	Longitude (deg,min)	Elevation (ft)
CALIFORNIA			
Boca	39 23	120 06	5575
Cedarville	41 32	120 10	4670
Ft. Bidwell	41 51	120 08	4498
Hat Creek PH	40 56	121 33	3015
Sonora RS	37 59	120 23	1749
Susanville AP	40 23	120 34	4148
Tahoe City	39 10	120 08	6230
Truckee RS	39 20	120 11	5995
Twin Lakes	38 42	120 02	7829
Woodford	38 47	119 49	5671
IDAHO			
Aberdeen	42 57	112 50	4405
American Falls	42 47	112 52	4318
Anderson Dam	43 21	115 28	3882
Arrowrock	43 36	115 55	3275
Ashton	44 04	111 27	5220
Bliss	42 56	114 57	3265
Boise WSO	43 34	116 13	2838
Burley FAA	42 32	113 46	4146
Caldwell	43 40	116 41	2370
Cambridge	44 34	116 41	2650
Cascade	44 32	116 03	4896
Council	44 44	116 26	2950
Deer Flat	43 35	116 45	2510
Dubois Expt.	44 15	112 12	5452
Emmett 2 E	43 52	116 28	2500
Ft. Hall Ind.	43 02	112 26	4460
Glenns Ferry	42 57	115 18	2570
Grand View	43 00	116 08	2400
Hailey RS	43 31	114 18	5328
Hazelton	42 36	114 08	4060
Hill City	43 18	115 03	5000
Hollister	42 21	114 34	4525
Idaho Falls FA	43 31	112 04	4730
Idaho Falls 46 W	43 32	112 57	4938
Island Park Dam	44 25	111 24	6300
Jerome	42 44	114 31	3740
Kuna 2 NNE	43 31	116 24	2685
Lowman 3E N2	44 05	115 34	3980
Malad	42 12	112 15	4600
McCall	44 54	116 07	5025
Mt. Home	43 09	115 43	3185
New Meadows	44 58	116 17	3870
Oakley	42 15	113 53	4600
Parma Expt.	43 48	116 57	2215
Paul 1 ENE	42 37	113 45	4210
Payette	44 05	116 56	2150
Pocatello WSO	42 55	112 36	4454
Richfield	43 04	114 09	4306
St. Anthony	43 58	111 43	4950
Shoshone 1 WNW	42 58	114 26	3950

Table B-2. Continued.

Station	Latitude (deg,min)	Longitude (deg,min)	Elevation (ft)
Strevell	42 01	113 17	5290
Sugar	43 53	111 45	4890
Swan Falls PH	43 15	116 23	2325
Three Creek	42 05	115 09	5410
Twin Falls 2N	42 35	114 28	3690
Twin Falls 3S	42 32	114 25	3765
Weiser 2 SE	44 14	116 57	2120
NEVADA			
Adaven	38 07	115 35	6250
Austin	39 30	117 05	6605
Battle Mt. AP	40 37	116 52	4530
Caliente	37 37	114 31	4402
Carson City	39 09	119 46	4651
Elko	40 50	115 47	5075
Ely	39 17	114 51	6253
Fallon Expt. St.	39 27	118 47	3965
Imlay	40 39	118 09	4260
Lahontan Dam	39 28	119 04	4158
Lamoille PH	40 41	115 28	6290
Lehman Caves	39 00	114 13	6825
Lovelock	40 11	118 28	3975
Lovelock FAA	40 04	118 33	3900
McGill	39 24	114 46	6340
Mina	38 23	118 06	4552
Minden	38 57	119 46	4720
Montello	41 16	114 12	4877
Owyhee	41 57	116 06	5396
Pioche	37 56	114 27	6165
Reno WSO	39 30	119 47	4404
Ruby Lake	40 12	115 30	6012
Rye Patch Dam	40 28	118 18	4135
Sheldon	41 51	119 38	6500
Wells	41 07	114 58	5650
Winnemucca	40 54	117 48	4301
Yerington	38 59	119 10	4375
OREGON			
Adrian	43 44	117 04	2231
Bend	44 04	121 19	3599
Buelah	43 55	118 10	3277
Burns	43 35	119 03	4140
Danner	42 56	117 20	4397
Dayville	44 28	119 32	2364
Hart Mt. Ref.	42 33	119 39	5616
Lakeview	42 11	120 21	4774
Malheur Expt.	43 59	117 01	2240
Malheur Ref.	43 17	118 50	4109
Nyssa	43 52	117 00	2185
Ochoco RS	44 24	120 26	3975
Owyhee Dam	43 39	117 15	2400
Paisley	42 42	120 32	4360
Prineville	44 21	120 54	2840

Table B-2. Continued.

Station	Latitude (deg,min)	Longitude (deg,min)	Elevation (ft)
Redmond FAA	44 16	121 09	3075
Squaw Butte	43 29	119 41	4675
Vale	43 59	117 15	2240
UTAH			
Bingham Canyon	40 32	112 09	6095
Bear River Ref.	41 28	112 16	4208
Beaver	38 17	112 38	4920
Brigham City	41 29	112 02	4335
Cedar City	37 42	113 06	5601
Corinne	41 33	112 07	4230
Deseret	39 17	112 39	4585
Farmington USU	41 01	111 54	4340
Fillmore	38 51	112 19	5160
Lewiston	41 58	111 50	4480

Table B-2. Continued.

Station	Latitude (deg,min)	Longitude (deg,min)	Elevation (ft)
Milford	38 26	113 01	5028
Modena	37 48	113 55	5460
Oak City	39 23	112 20	5075
Ogden Pioneer	41 15	111 57	4350
Ogden Sugar Fac.	41 14	112 02	4280
Park Valley	41 49	113 19	5520
Parowan	37 51	112 50	5975
Riverdale PH	41 09	112 00	4390
St. George	37 07	113 34	2760
Salt Lake City	40 46	111 58	4222
Santaquin	39 58	111 47	5120
Scipio	39 15	112 06	5306
Silver Lake Bri.	40 36	111 35	8740
Tooele	40 32	112 18	4820
Utah Lake Lehi	40 22	111 54	4497

APPENDIX C

CLIMATIC RELATIONSHIPS

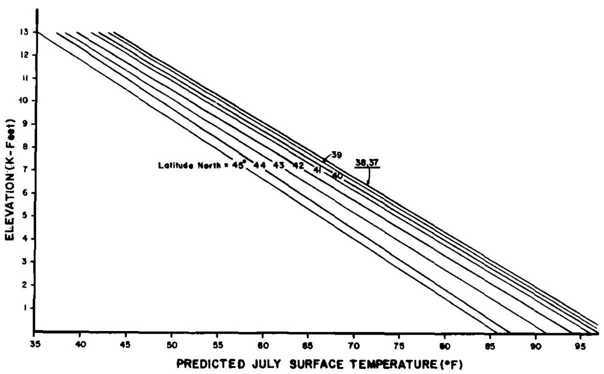


Figure C-1. The predicted averge surface temperature, T_p, as a function of elevation and latitude for the Great Basin region during the month of July.

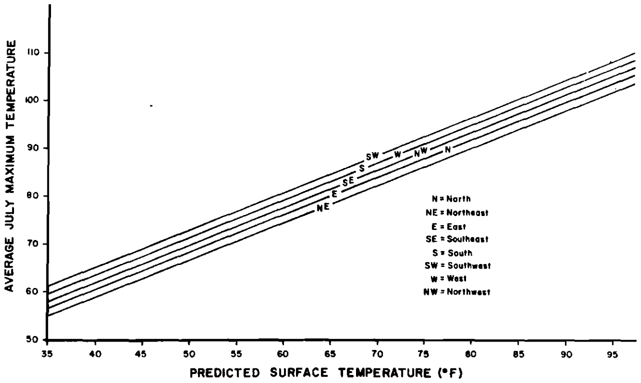


Figure C-3. The relationship between average maximum temperature during July and the predicted surface temperature (T_p from C-1) as a function of aspect in the Great Basin.

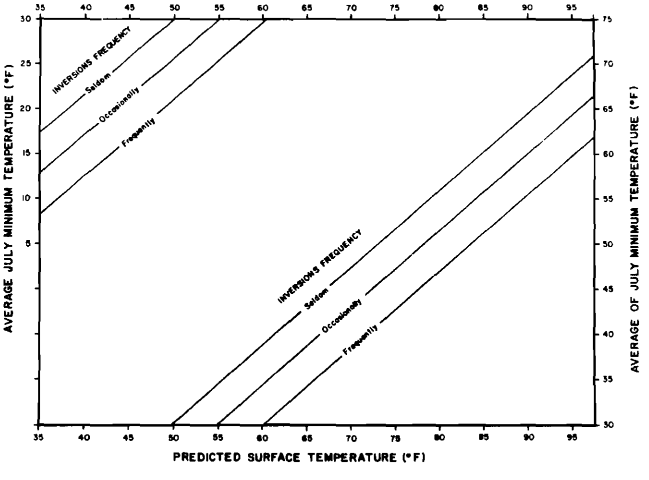


Figure C-2. The relationship between average maximum temperature during July and the predicted surface temperature (T_p from C-1) as a function of inverse frequency.

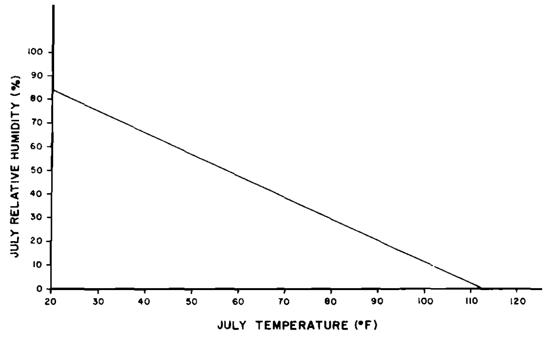
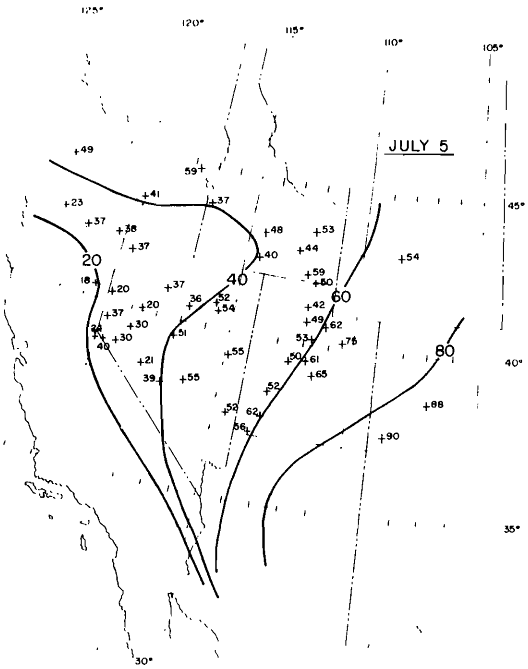


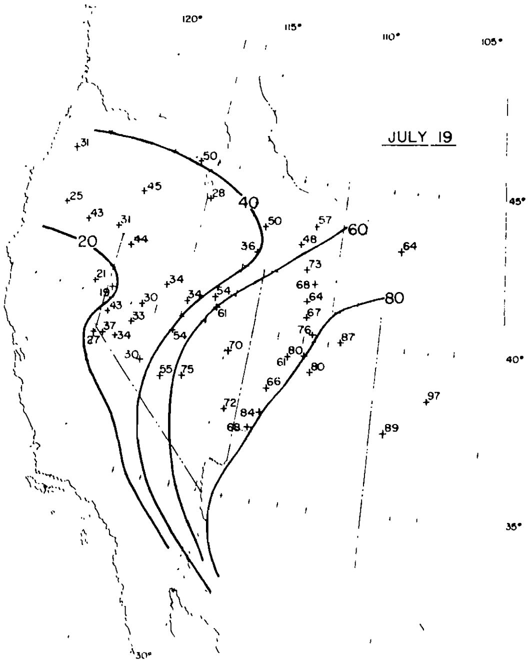
Figure C-4. The relationship used to predict relative humidity from temperature data for the month of July in the Great Basin region.

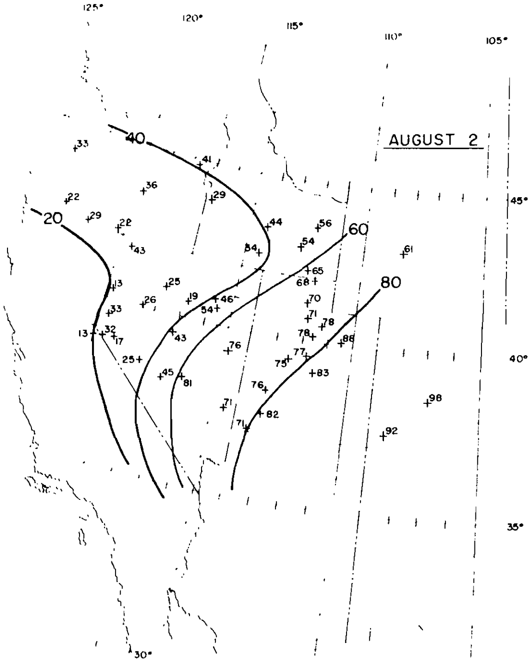
APPENDIX D

PRECIPITATION DURATION AND PROBABILITY



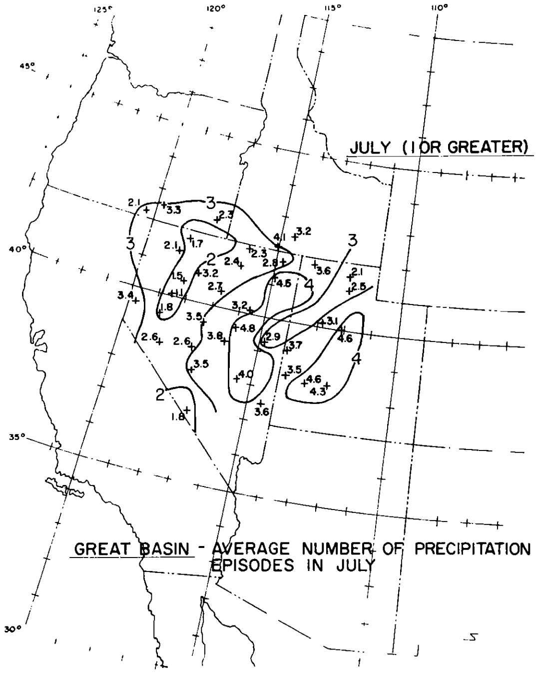
Map D-1. The precipitation probability expressed in frequency units for the two week period beginning July 5.



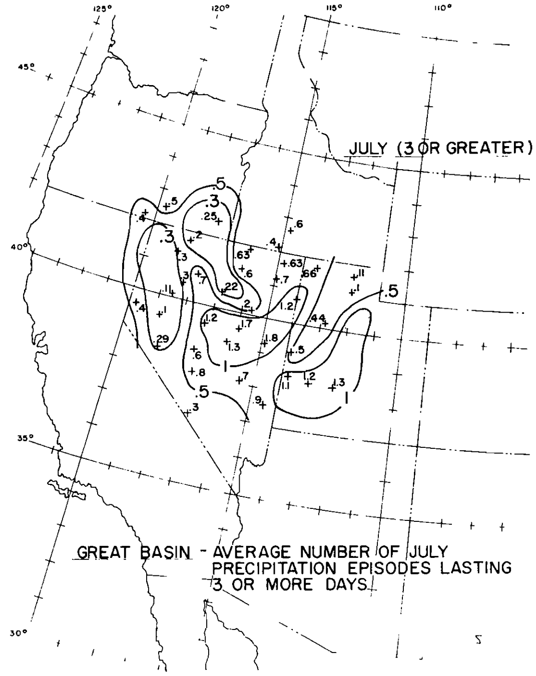


Map D-2. The precipitation probability expressed in frequency units for the two week period beginning July 19.

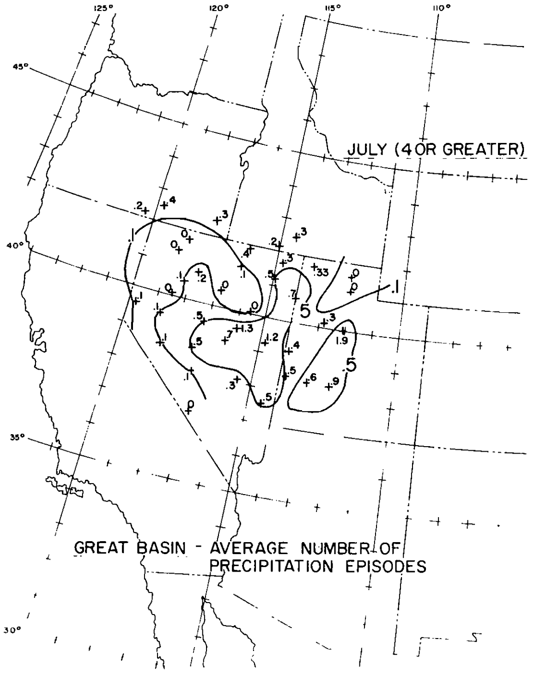
Map D-3. The precipitation probability expressed in frequency units for the two week period beginning August 2.



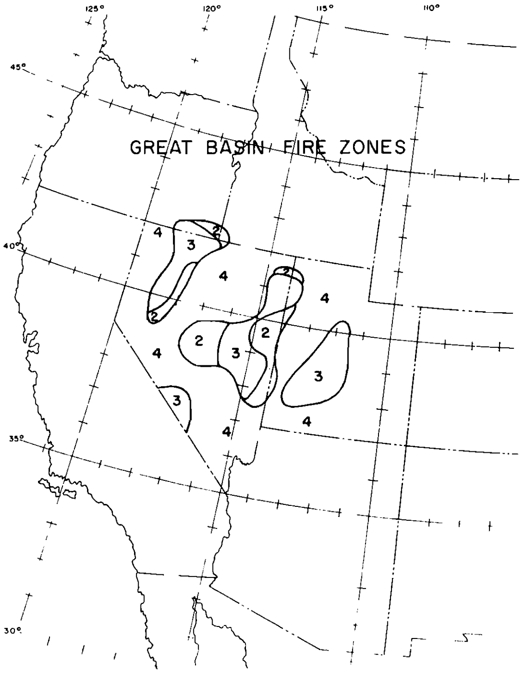
Map D-4. The average number of precipitation episodes in July which are at least one day long. Contours are drawn for 2, 3, and 4 on the basis of values plotted at individual stations.



Map D-5. The average number of precipitation episodes during July which last three or more days. Contours are drawn for 0.3, 0.5, and 1.0 on the basis of values plotted at individual stations.



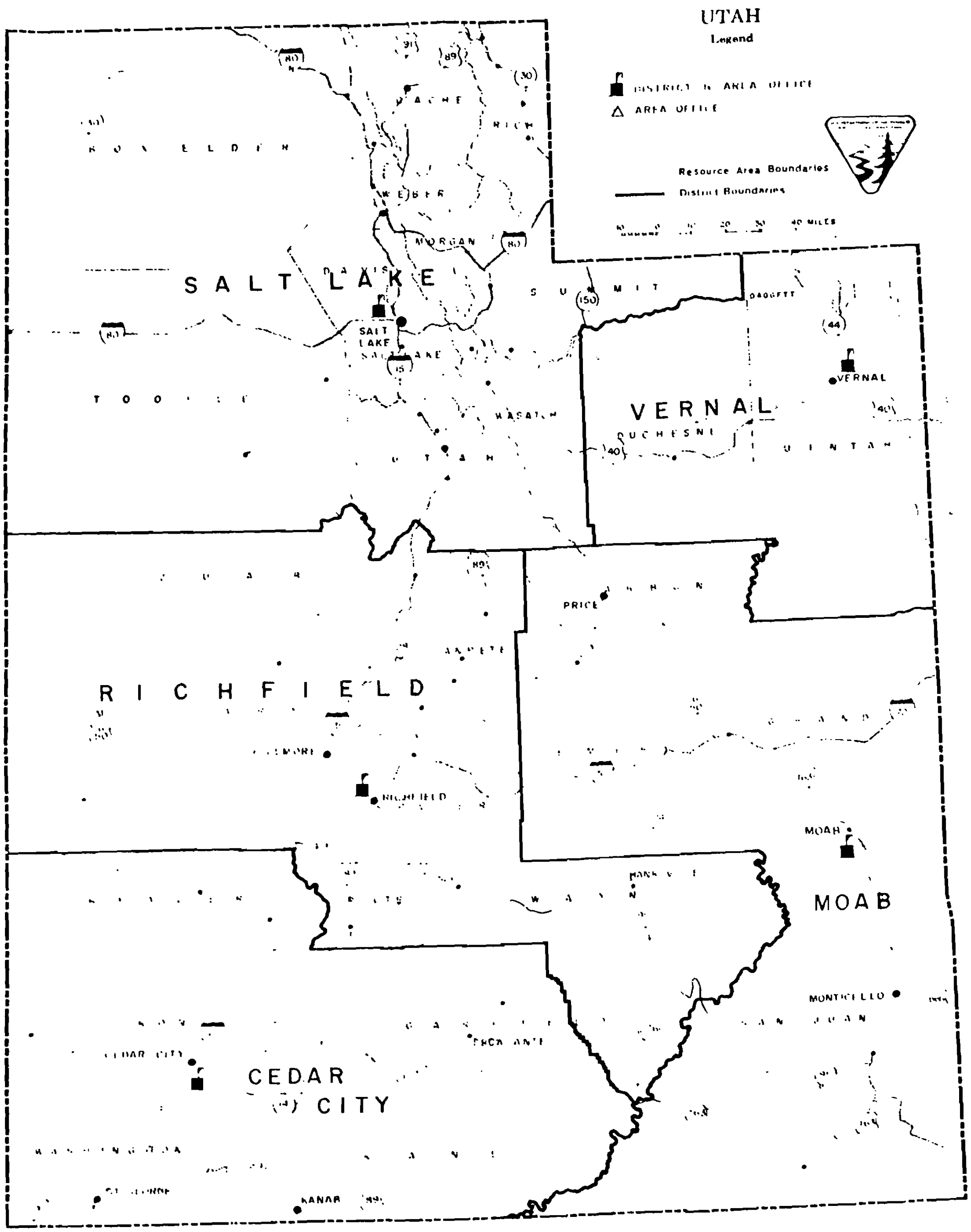
Map D-6. The average number of precipitation episodes during July which last four or more days. Contours are drawn for 0.1 and 0.5 on the basis of values plotted at individual stations.

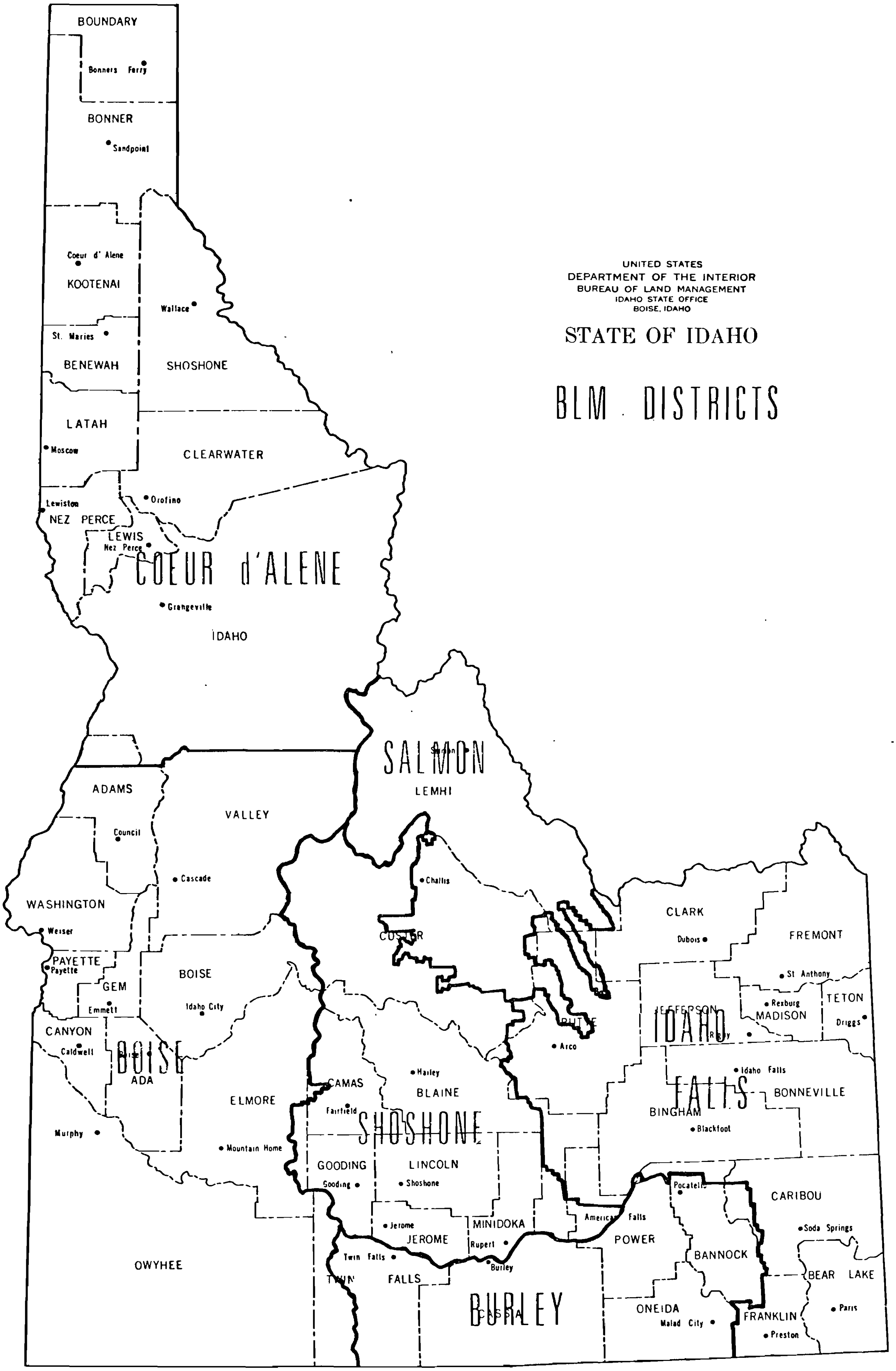


Map D-7. The zones resulting from the combination of maps D-4 and D-6 by using the scheme indicated in Table 2. Higher numbers indicate higher fire occurrence.

APPENDIX E

BLM DISTRICT BOUNDARIES





UNITED STATES
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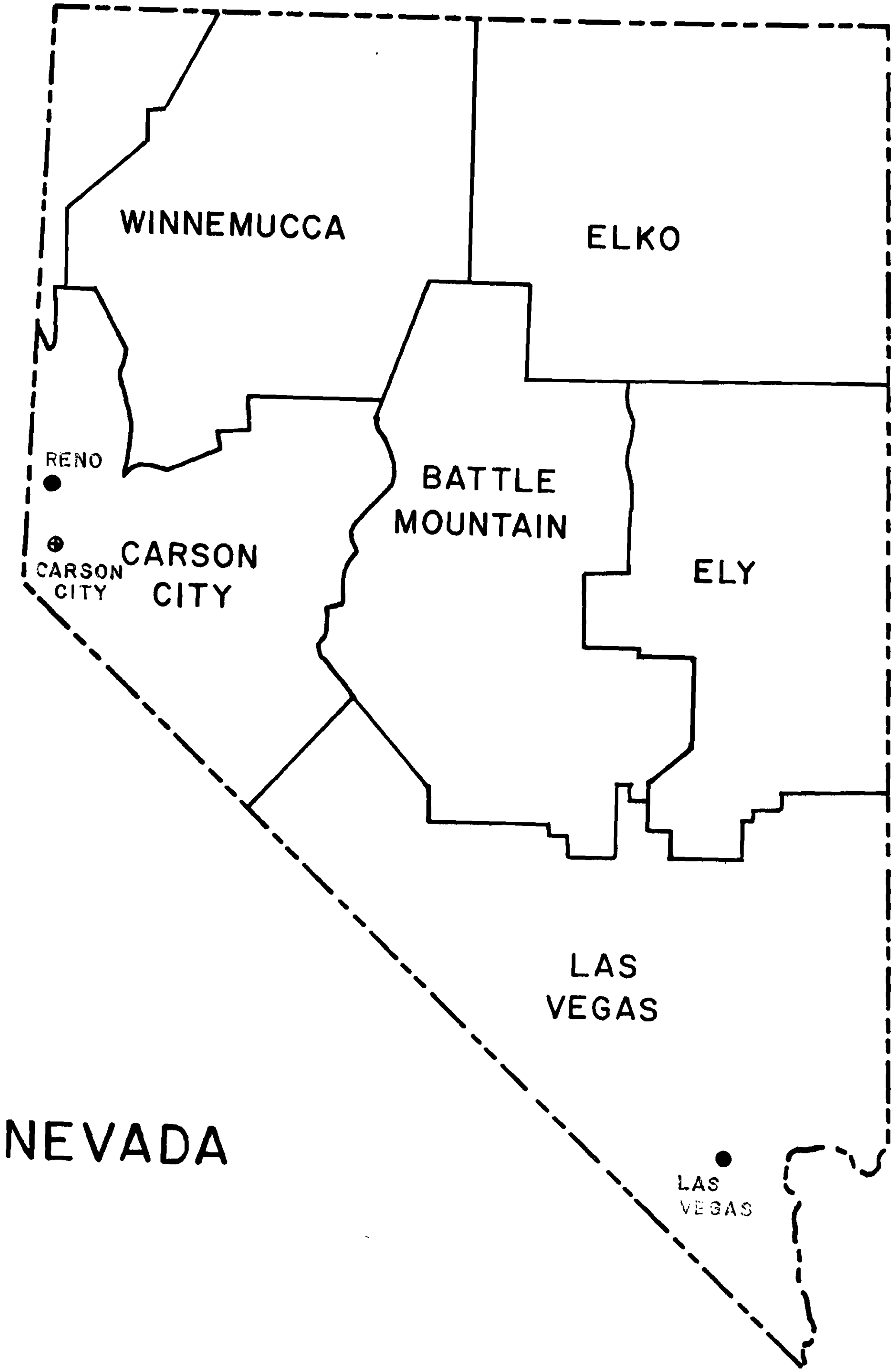
BUREAU OF LAND MANAGEMENT
IDAHO STATE OFFICE
BOISE, IDAHO

STATE OF IDAHO

BLM DISTRICTS


WINNEMUCCA
ELKO
BATTLE MOUNTAIN
ELY
RENO
CARSON CITY
CARSON CITY
LAS VEGAS
LAS VEGAS
NEVADA