FIRE BEHAVIOR of the BASIN FIRE, *Sierra National Forest*, JULY 13-22, 1961

Craig C. Chandler

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY - CALIFORNIA

U.S. FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

The Basin Fire burned 17,000 acres of the Sierra National Forest in July 1961. It was not the largest, the most damaging, the most expensive, nor the most spectacular fire in recent California history. In many ways its behavior was typical of that of most large fires of central and northern California during critical burning conditions. We have chosen the Basin Fire for this special report because:

1. Local weather documentation is available in considerable detail for the entire period of the fire.

2. Although the fire burned for 8 days in a relatively unchanging synoptic weather pattern, local weather varied markedly during this period. Local weather was dominant during much of the fire's history.

3. The fire area was characterized by a wide diversity in fuels and topography. Much of the observed fire behavior resulted from differences in fuels and topography rather than from changes in weather.

These features make the Basin Fire uniquely valuable as a case study in fire behavior.

FIRE BEHAVIOR OF THE BASIN FIRE, SIERRA NATIONAL FOREST, JULY 13-22, 1961

By
Craig C. Chandler

Contents

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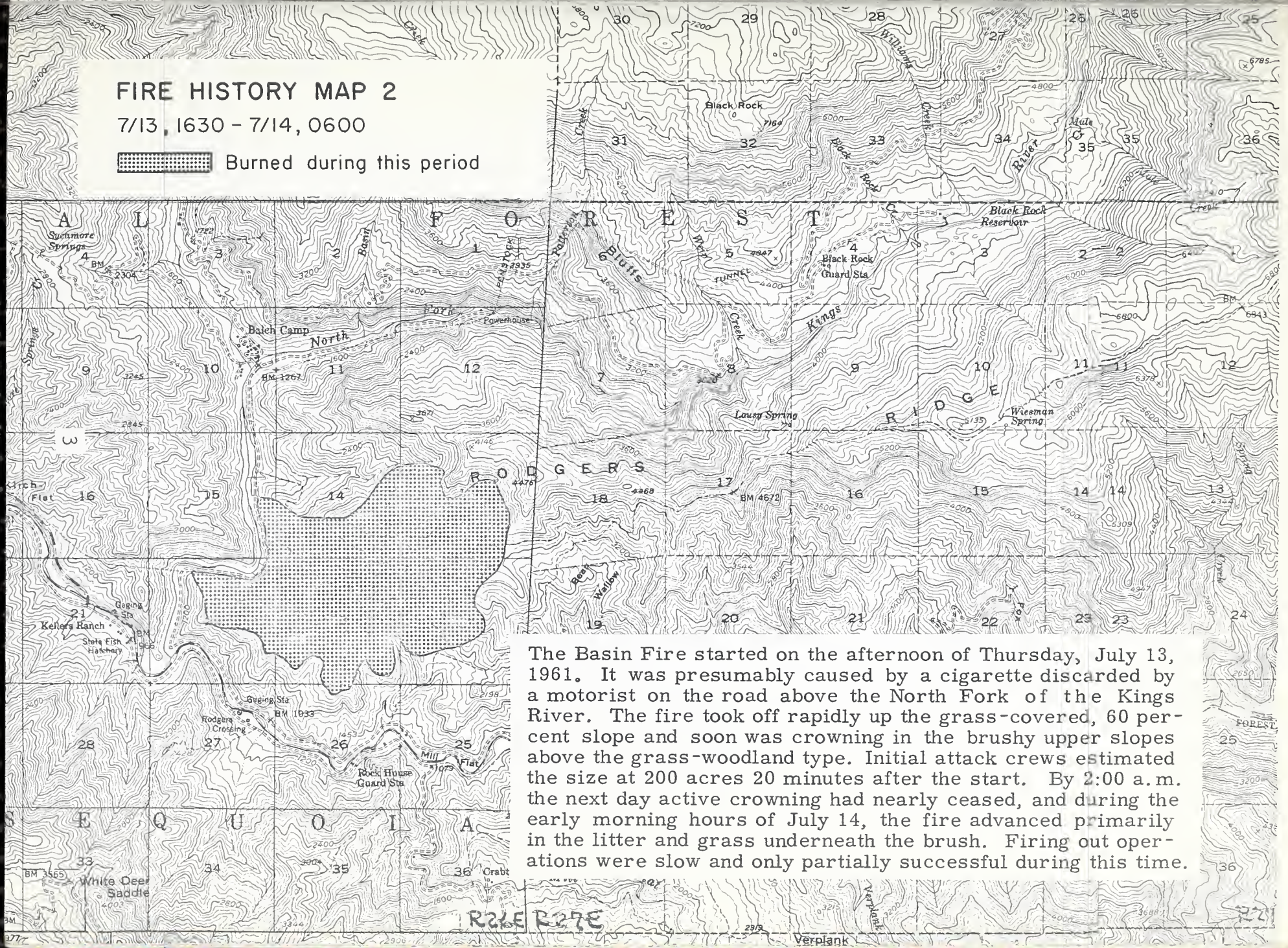
U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Berkeley, California


STATE OF CALIFORNIA
FIRE HISTORY MAP 1
BASIN FIRE
7/13/61
DEL NORTE
SISKIYOU
MODOC
Yreka
HUMBOLDT
TRINITY
SHASTA
LASSEN
Eureka
Redding
TEHAMA
Susanville
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
LAKE
COLUSA
YUBA
NEVADA
Ukiah
SUTTER
PLACER
YOLO
ELDORADO
SONOMA
NAPA
SACRAMENTO
ALPINE
SOLANO
SACRAMENTO
AMADOR
MONO
MARIN
SAN
JOAQUIN
CALAVERAS
CONTRA
COSTA
TUOLUMNE
San Francisco
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
MERCED
INYO
SAN MATEO
SANTA
CLARA
SANTA CRUZ
MADERA
FRESNO
Fresno
TULARE
Salinas
SAN BENITO
KINGS
MONTEREY
SAN LUIS OBISPO
KERN
SAN BERNARDINO
Bakersfield
SANTA
BARBARA
LOS ANGELES
VENTURA
Santa Barbara
Los Angeles
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
San Diego
PACIFIC
OCEAN

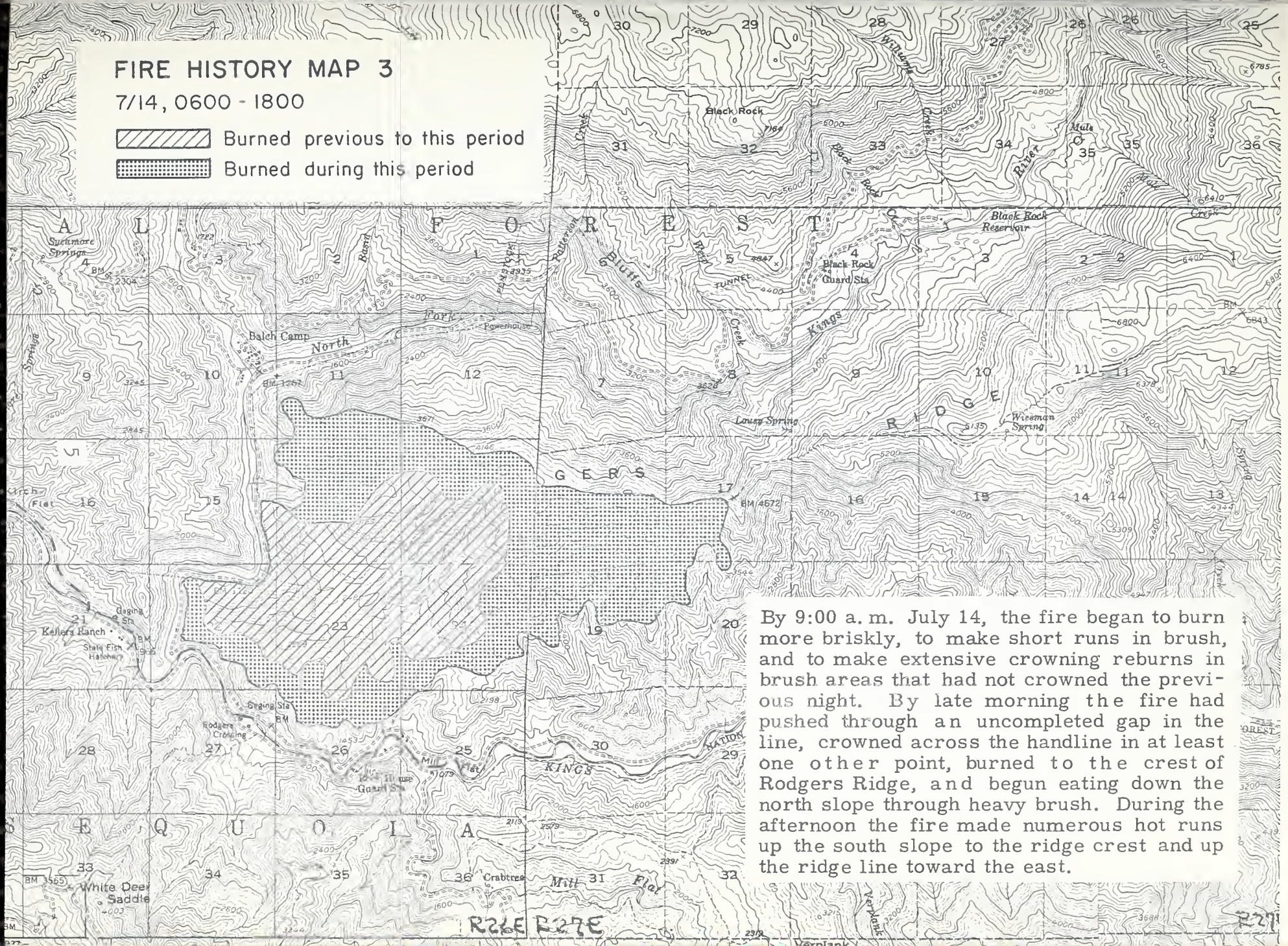
FIRE HISTORY MAP 2

7/13, 1630 - 7/14, 0600

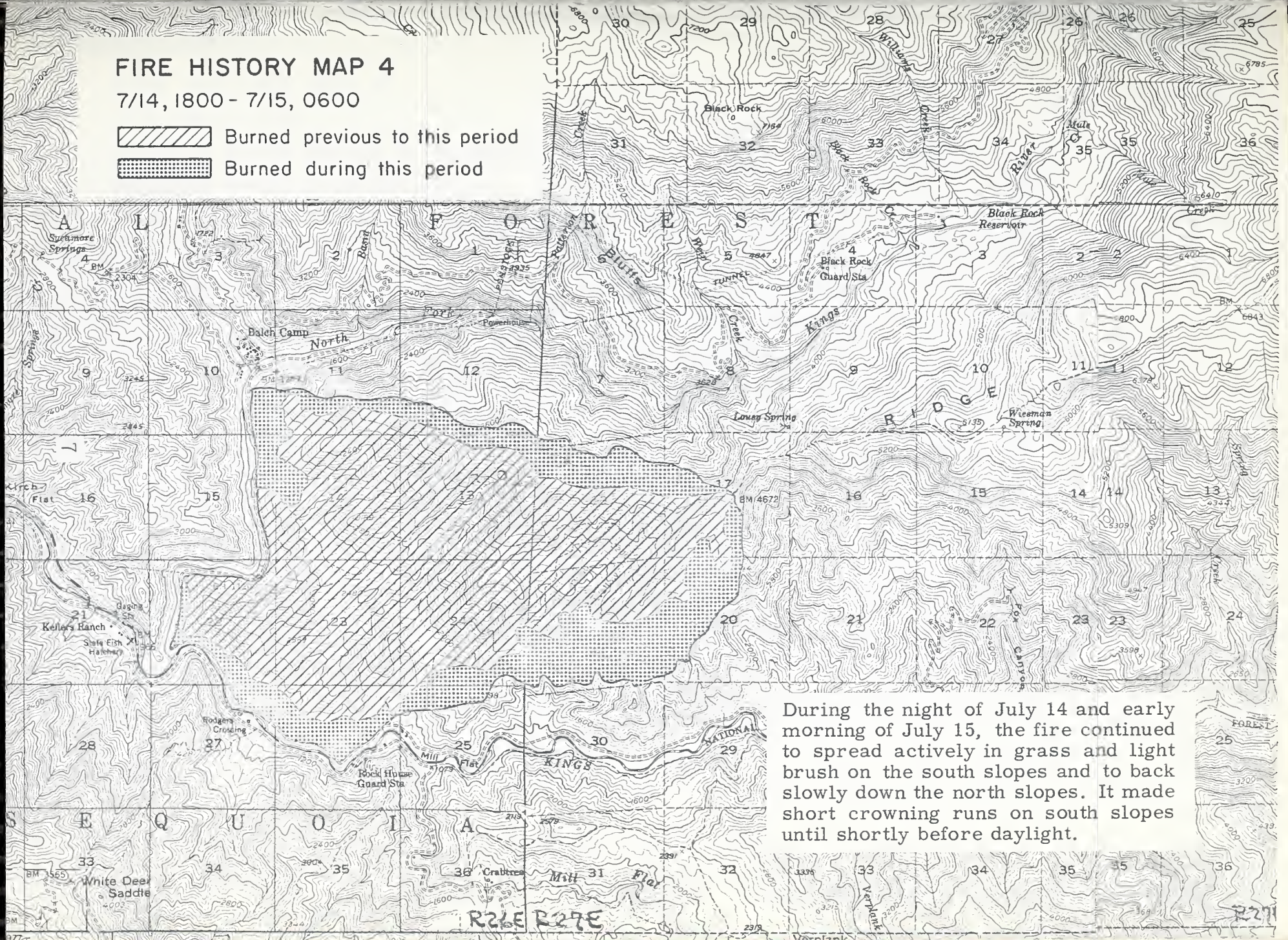
Burned during this period

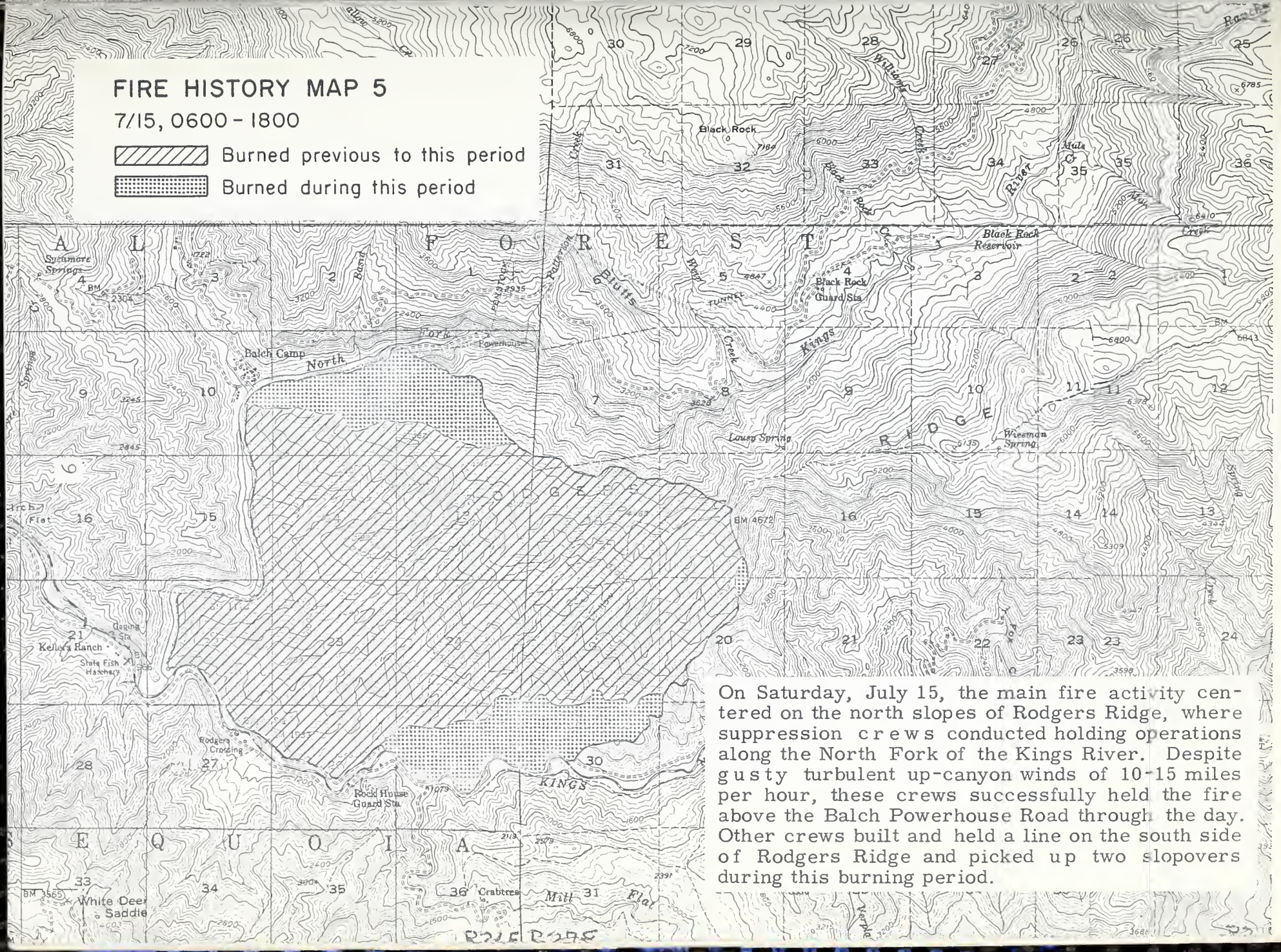


The Basin Fire started on the afternoon of Thursday, July 13, 1961. It was presumably caused by a cigarette discarded by a motorist on the road above the North Fork of the Kings River. The fire took off rapidly up the grass-covered, 60 percent slope and soon was crowning in the brushy upper slopes above the grass-woodland type. Initial attack crews estimated the size at 200 acres 20 minutes after the start. By 2:00 a.m. the next day active crowning had nearly ceased, and during the early morning hours of July 14, the fire advanced primarily in the litter and grass underneath the brush. Firing out operations were slow and only partially successful during this time.

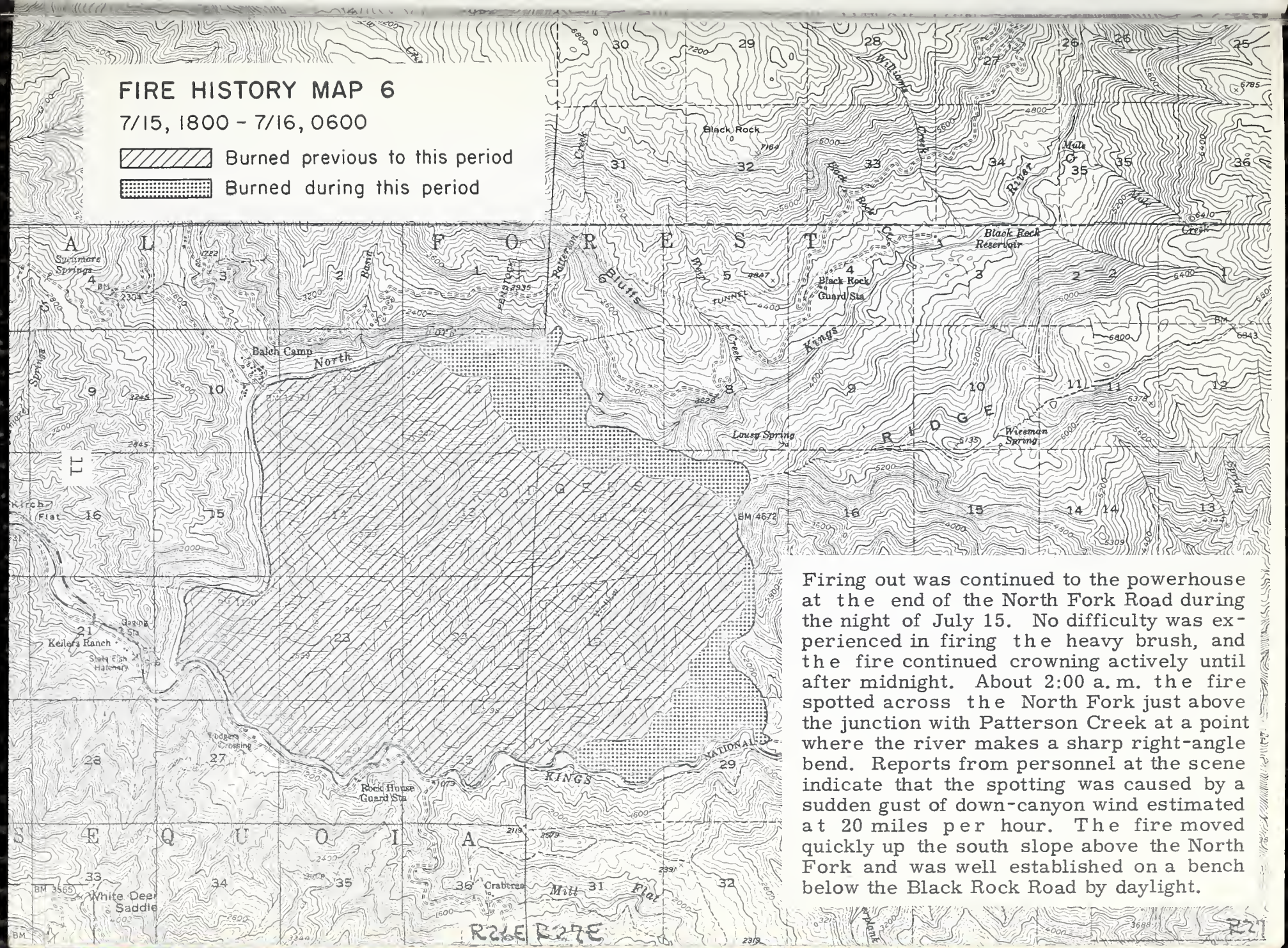


By 9:00 a.m. July 14, the fire began to burn more briskly, to make short runs in brush, and to make extensive crowning reburns in brush areas that had not crowned the previous night. By late morning the fire had pushed through an uncompleted gap in the line, crowned across the handline in at least one other point, burned to the crest of Rodgers Ridge, and begun eating down the north slope through heavy brush. During the afternoon the fire made numerous hot runs up the south slope to the ridge crest and up the ridge line toward the east.

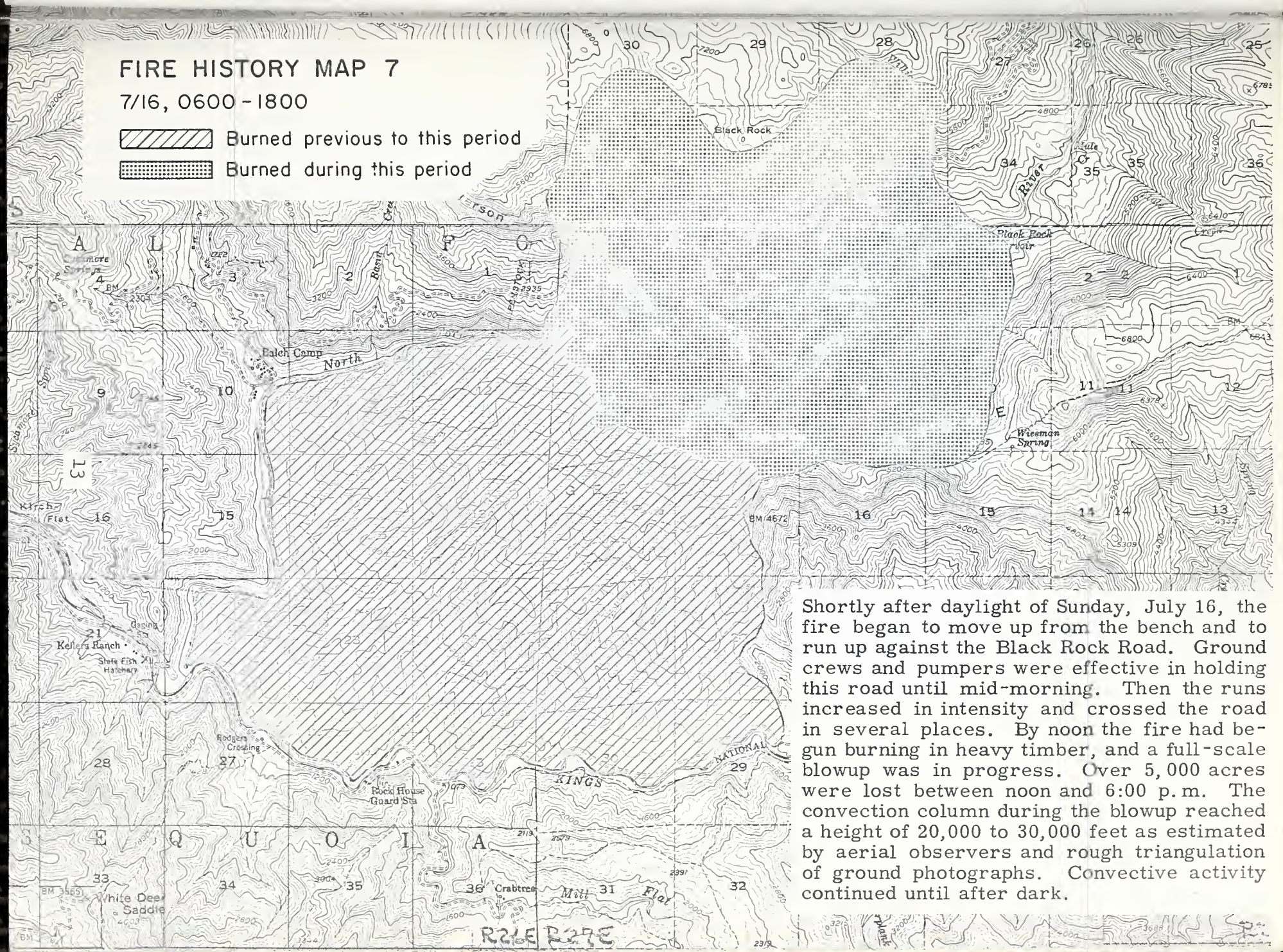

FIRE HISTORY MAP 4
7/14, 1800 - 7/15, 0600
Burned previous to this period
Burned during this period
During the night of July 14 and early morning of July 15, the fire continued to spread actively in grass and light brush on the south slopes and to back slowly down the north slopes. It made short crowning runs on south slopes until shortly before daylight.
ALTA
FOREST
SEQUOIA
KINGS
NATIONAL
FOREST
Black Rock
Black Rock Guard Sta
Black Rock Reservoir
Kings
Ridge
Wiesman Spring
Louse Spring
Balch Camp
North Fork
Powerhouse
Keller's Ranch
State Fish Hatchery
Rodgers Crossing
Rock House Guard Sta
Mill Flat
Crabtree
White Deer Saddle
Wilsonia
Mule
Creek
Canyon
Fork
Tunnel
Sycamore Springs
Kirch Flat
Verplank
R27E
R28E



On Saturday, July 15, the main fire activity centered on the north slopes of Rodgers Ridge, where suppression crews conducted holding operations along the North Fork of the Kings River. Despite gusty turbulent up-canyon winds of 10-15 miles per hour, these crews successfully held the fire above the Balch Powerhouse Road through the day. Other crews built and held a line on the south side of Rodgers Ridge and picked up two slopovers during this burning period.



Firing out was continued to the powerhouse at the end of the North Fork Road during the night of July 15. No difficulty was experienced in firing the heavy brush, and the fire continued crowning actively until after midnight. About 2:00 a.m. the fire spotted across the North Fork just above the junction with Patterson Creek at a point where the river makes a sharp right-angle bend. Reports from personnel at the scene indicate that the spotting was caused by a sudden gust of down-canyon wind estimated at 20 miles per hour. The fire moved quickly up the south slope above the North Fork and was well established on a bench below the Black Rock Road by daylight.



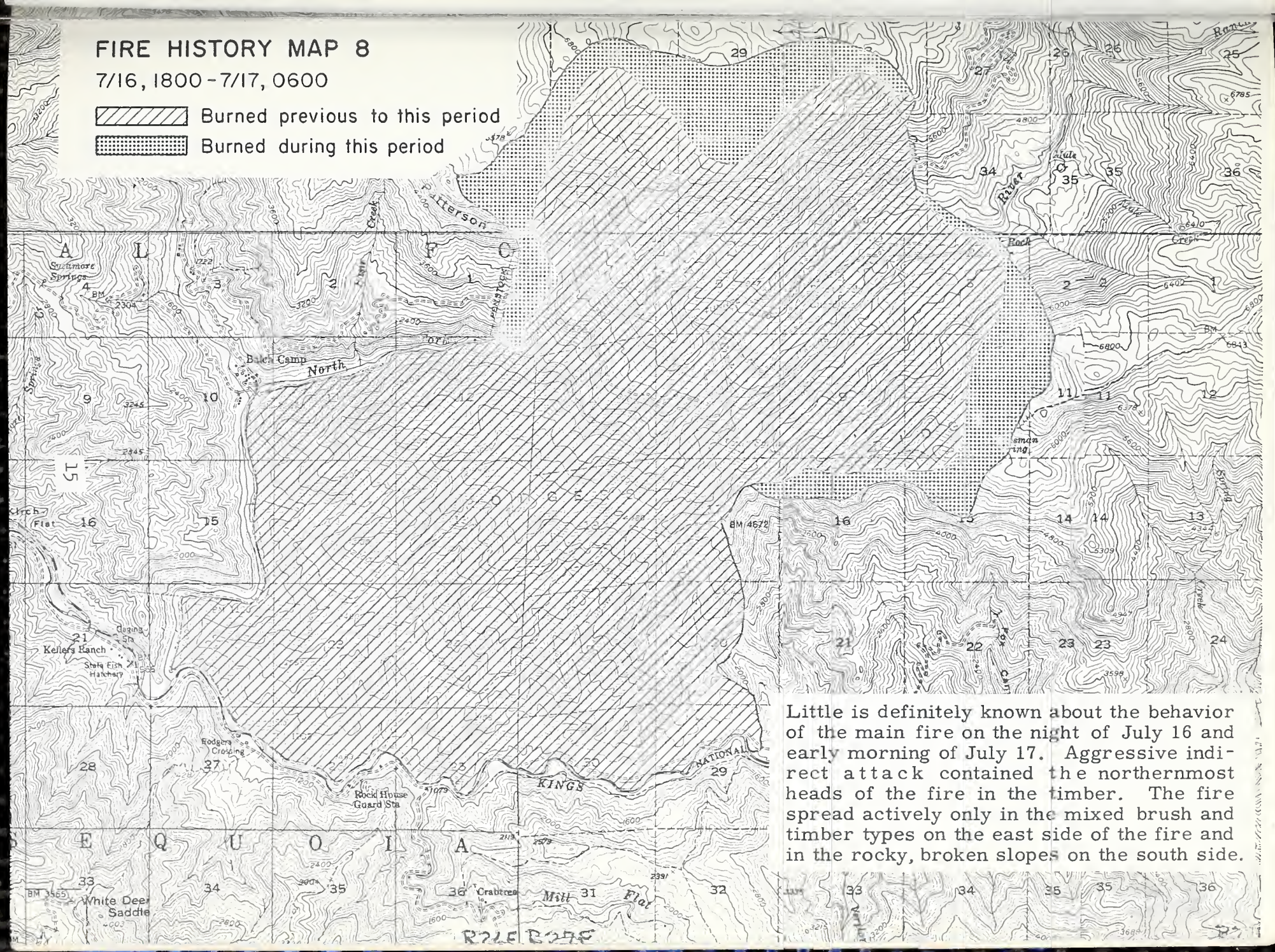
Shortly after daylight of Sunday, July 16, the fire began to move up from the bench and to run up against the Black Rock Road. Ground crews and pumpers were effective in holding this road until mid-morning. Then the runs increased in intensity and crossed the road in several places. By noon the fire had begun burning in heavy timber, and a full-scale blowup was in progress. Over 5,000 acres were lost between noon and 6:00 p.m. The convection column during the blowup reached a height of 20,000 to 30,000 feet as estimated by aerial observers and rough triangulation of ground photographs. Convective activity continued until after dark.

FIRE HISTORY MAP 8

7/16, 1800 - 7/17, 0600

Burned previous to this period

Burned during this period



Little is definitely known about the behavior of the main fire on the night of July 16 and early morning of July 17. Aggressive indirect attack contained the northernmost heads of the fire in the timber. The fire spread actively only in the mixed brush and timber types on the east side of the fire and in the rocky, broken slopes on the south side.

FIRE HISTORY MAP 9

7/17, 0600-1800

Burned previous to this period

Burned during this period

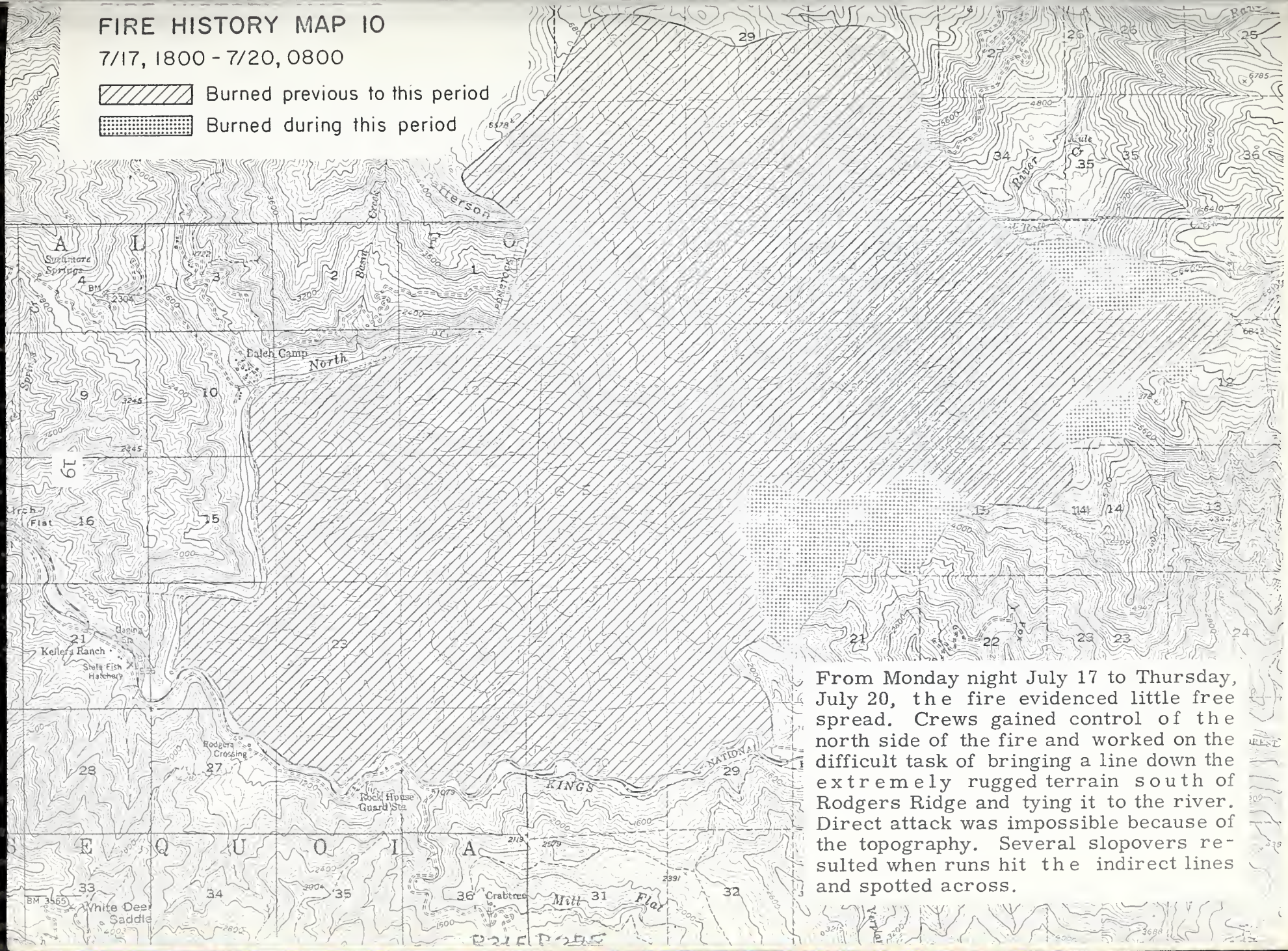
On Monday, July 17, the fire continued to spread to the east up the backbone of Rodgers Ridge. Several hot runs occurred, but none built up into blowup proportions.

FIRE HISTORY MAP 10

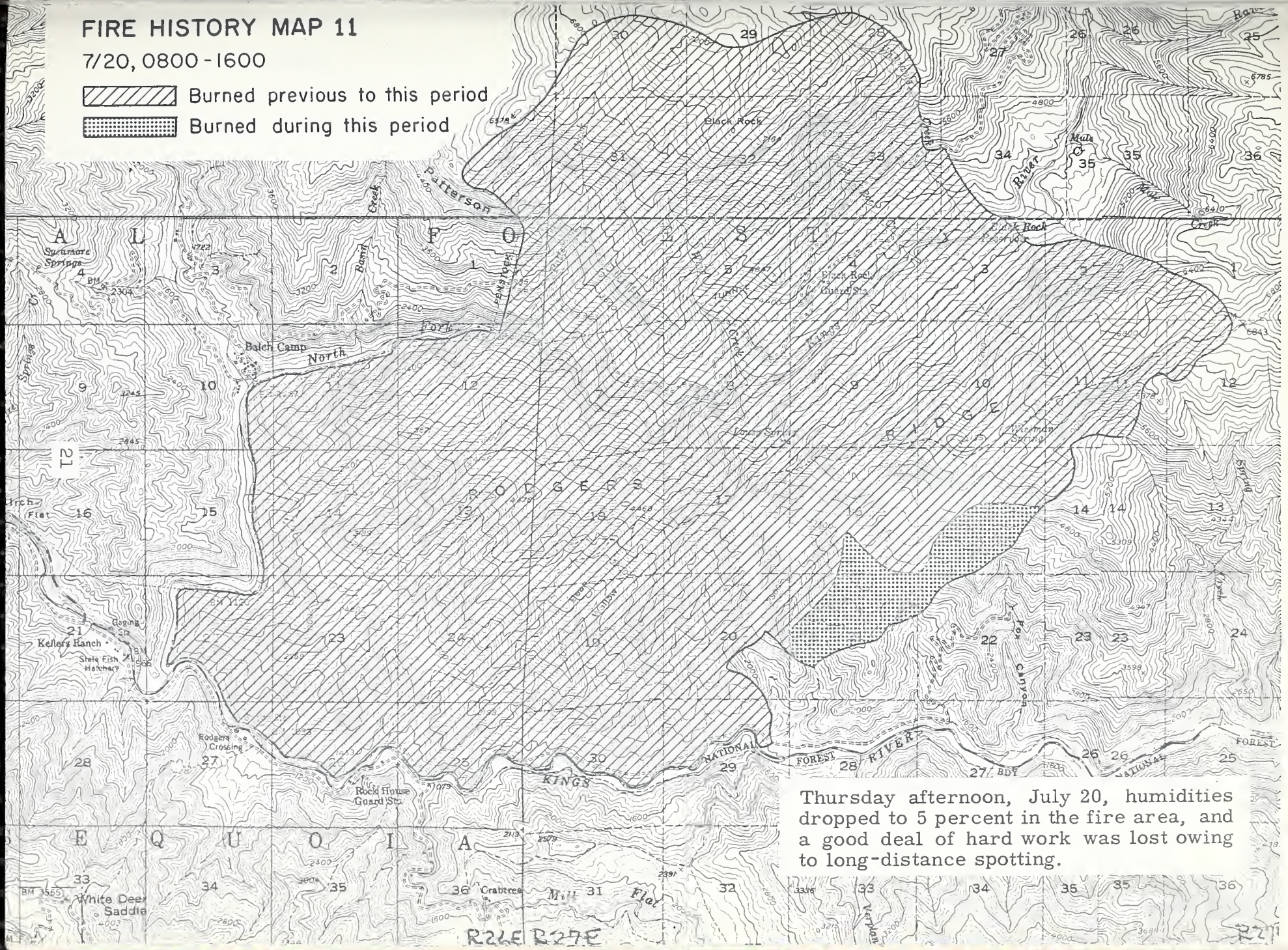
7/17, 1800 - 7/20, 0800

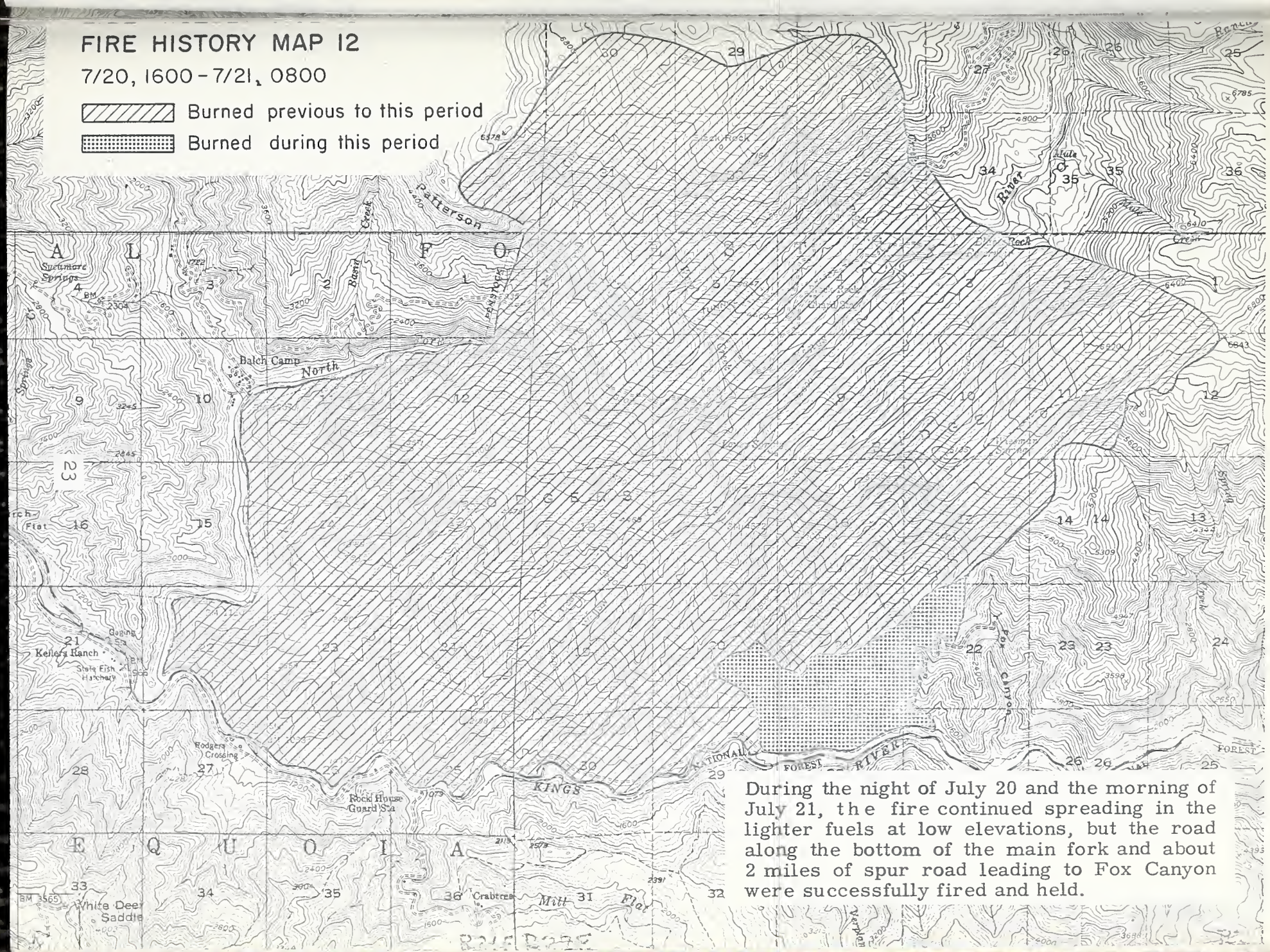
Burned previous to this period

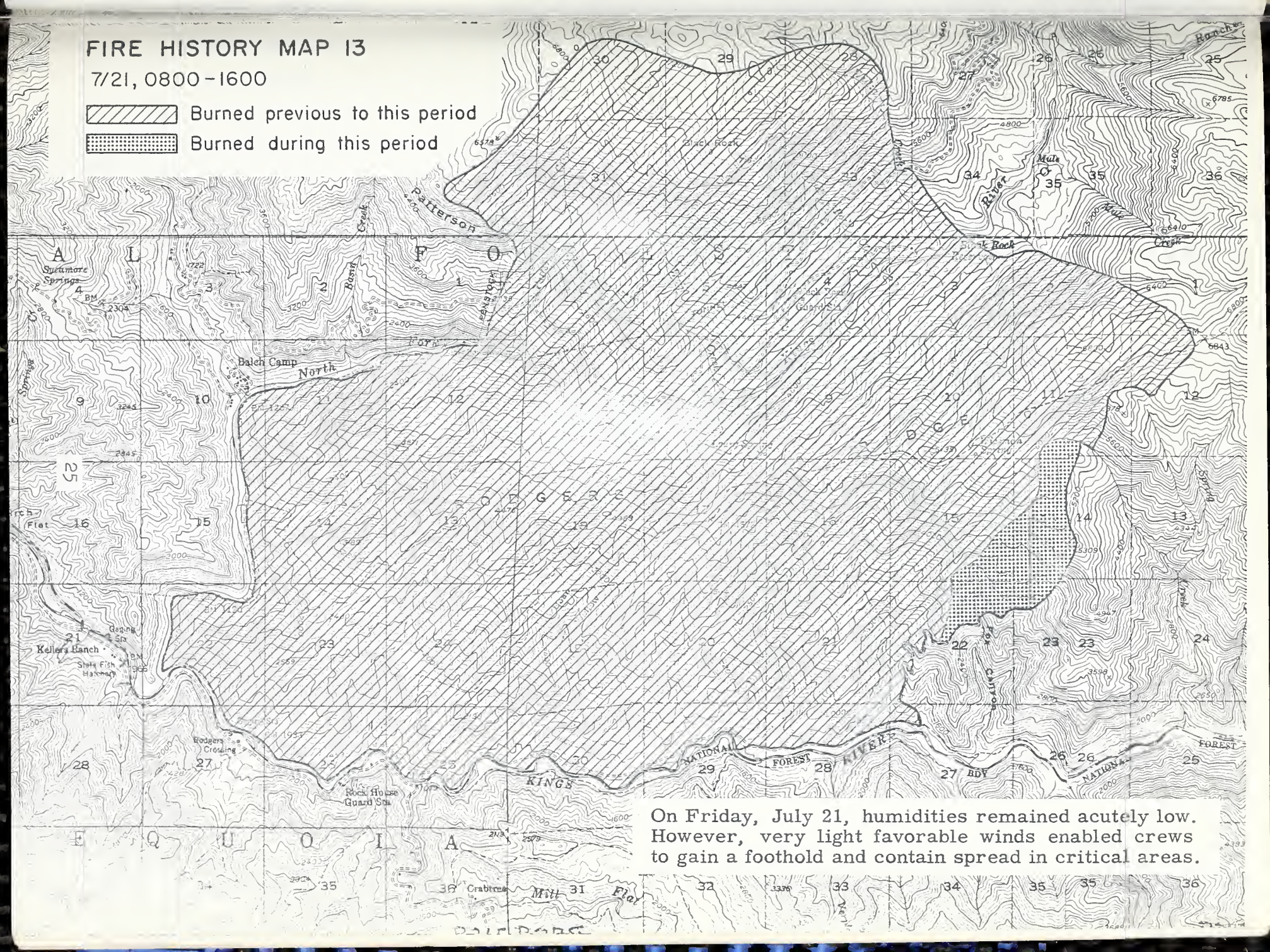
Burned during this period

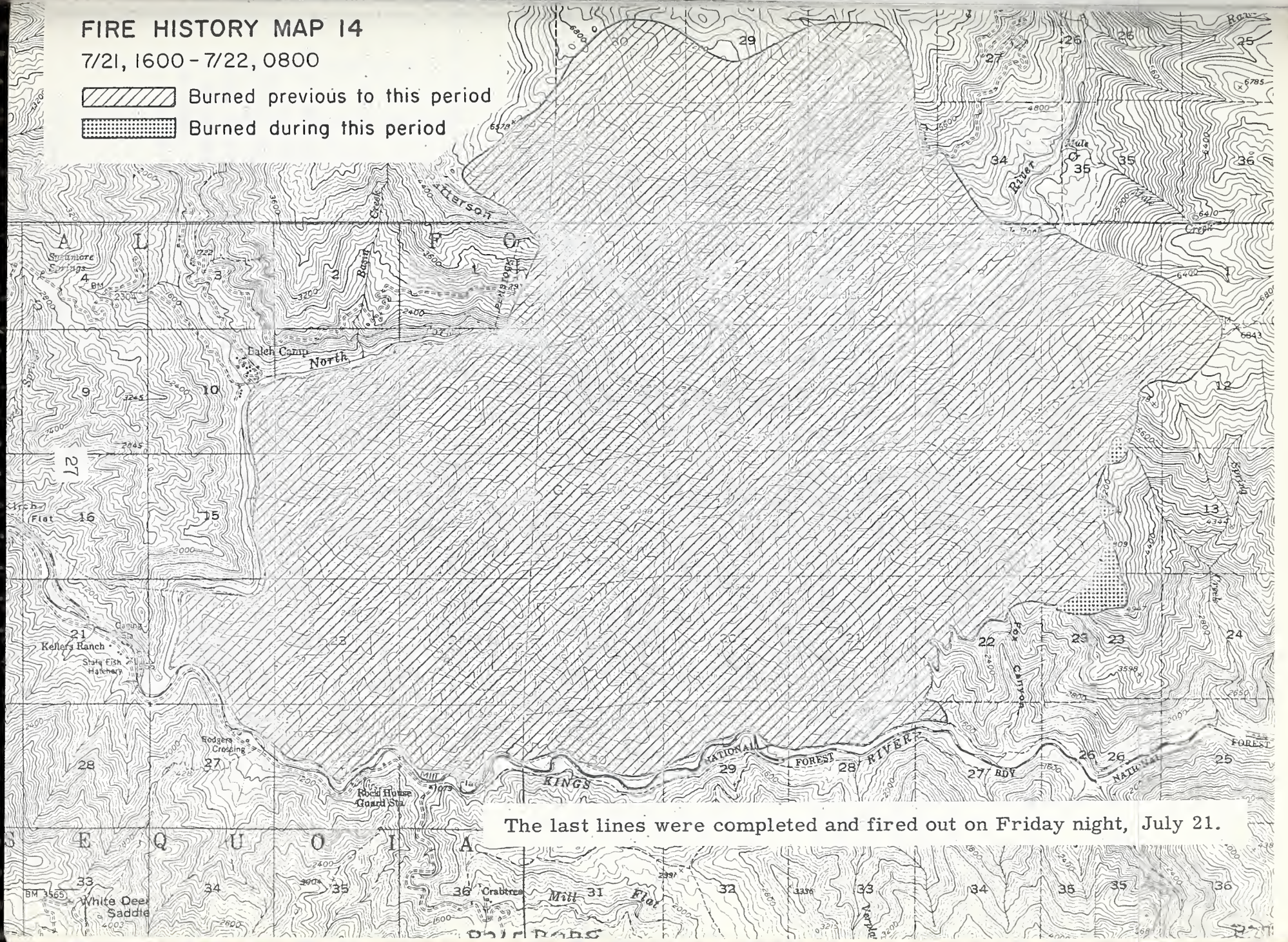


From Monday night July 17 to Thursday, July 20, the fire evidenced little free spread. Crews gained control of the north side of the fire and worked on the difficult task of bringing a line down the extremely rugged terrain south of Rodgers Ridge and tying it to the river. Direct attack was impossible because of the topography. Several slopovers resulted when runs hit the indirect lines and spotted across.


FIRE HISTORY MAP 11
7/20, 0800 - 1600
Burned previous to this period
Burned during this period
Black Rock
Patterson Creek
Balch Camp
North Fork
Kings River
Mule Creek
Black Rock Reservoir
Black Rock Guard Sta.
Tunnel
Ridge
Sycamore Springs
Keller's Ranch
State Fish Hatchery
Rodgers Crossing
Rocky House Guard Sta.
Kings River Canyon
National Forest
White Deer Saddle
Crabtree
Mill Flat
R24E R27E
T21S
T22S
Thursday afternoon, July 20, humidities dropped to 5 percent in the fire area, and a good deal of hard work was lost owing to long-distance spotting.


FIRE HISTORY MAP 12
7/20, 1600 - 7/21, 0800
Burned previous to this period
Burned during this period
Patterson
Balch Camp
North
Sycamore Springs
Keller's Ranch
Rodgers Crossing
Rock House Guard Sta
White Deer Saddle
Crabtree
Mill Flat
KINGS
RIVER
FOREST
During the night of July 20 and the morning of July 21, the fire continued spreading in the lighter fuels at low elevations, but the road along the bottom of the main fork and about 2 miles of spur road leading to Fox Canyon were successfully fired and held.


FIRE HISTORY MAP 13
7/21, 0800-1600
Burned previous to this period
Burned during this period
Patterson Creek
Balch Camp
North
Fork
Sycamore Springs
Keller's Ranch
State Fish Hatchery
Rodgers Crossing
Rock House Guard Sta.
KINGS
RIVER
NATIONAL FOREST
Black Rock
Mule Creek
Sunk Rock
Crabtree
Mill
Flat
On Friday, July 21, humidities remained acutely low. However, very light favorable winds enabled crews to gain a foothold and contain spread in critical areas.


FIRE HISTORY MAP 14
7/21, 1600 - 7/22, 0800
Burned previous to this period
Burned during this period
Balch Camp
North
Kellers Ranch
State Fish Hatchery
Rodgers Crossing
Rock House Guard Sta.
Crabtree
Mill
Flat
White Deer Saddle
KINGS
RIVER
FOREST
The last lines were completed and fired out on Friday night, July 21.

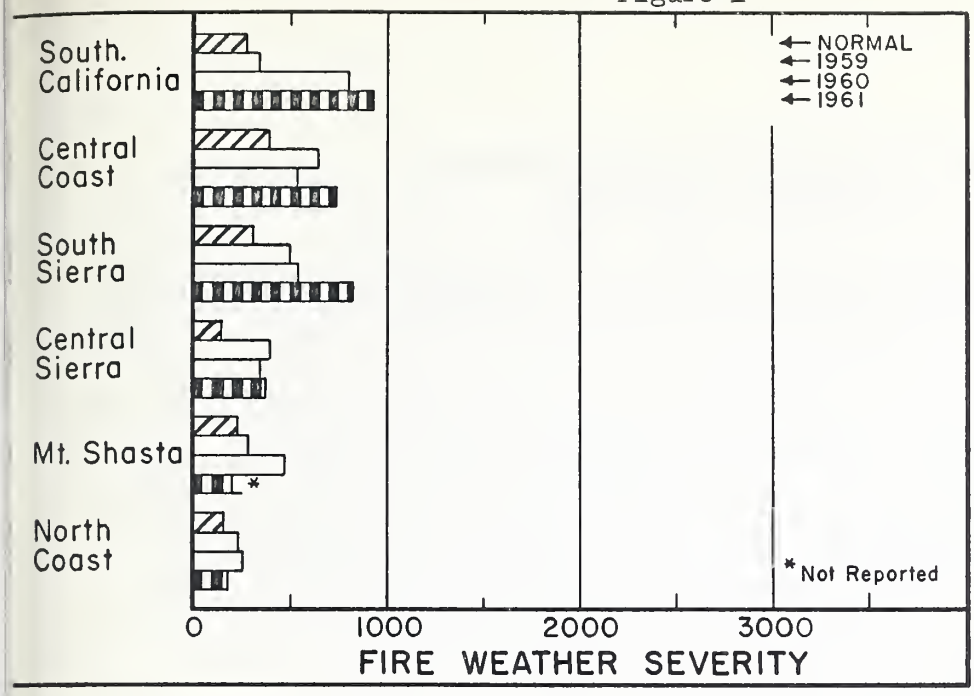
Weather Conditions for the 1961 Fire Season up to July 13, 1961

In 1961 California entered its third consecutive year of drought. Because of the lack of precipitation, logs and other heavy fuels probably had moisture contents much below normal at the start of the fire season; succulent new growth on brush plants, which normally retards fire spread until July or August, was scanty or missing in the spring of 1961; and by July 10, the moisture content of green foliage in the southern part of the State had fallen to record low levels. A fire weather summary issued by the Pacific Southwest Forest and Range Experiment Station on July 10 (fig. 1) shows the cumulative trend in fire danger for the State.

In the southern Sierra, daily fire danger was above normal every week from the opening of the fire weather stations in late May until the start of the Basin Fire. By July 10, the cumulative Fire Load Index[1/] was nearly 3 times normal, and 50 percent above the cumulative index for 1960, the worst previous year on record.

1/ The Wildland Fire Danger Rating System used in California is a multiple index system with five main components. An index of rate of spread and an index of fire intensity are combined into a burning index that measures the initial attack job load for a single fire. An ignition index that indicates the probability of a fire starting is combined with the burning index to obtain a fire load index. The fire load index is a measure of the total potential daily job load facing the fire control organization. It is also the best index to use on large fires where long distance spotting may be a problem.

Figure 1



California FIRE WEATHER

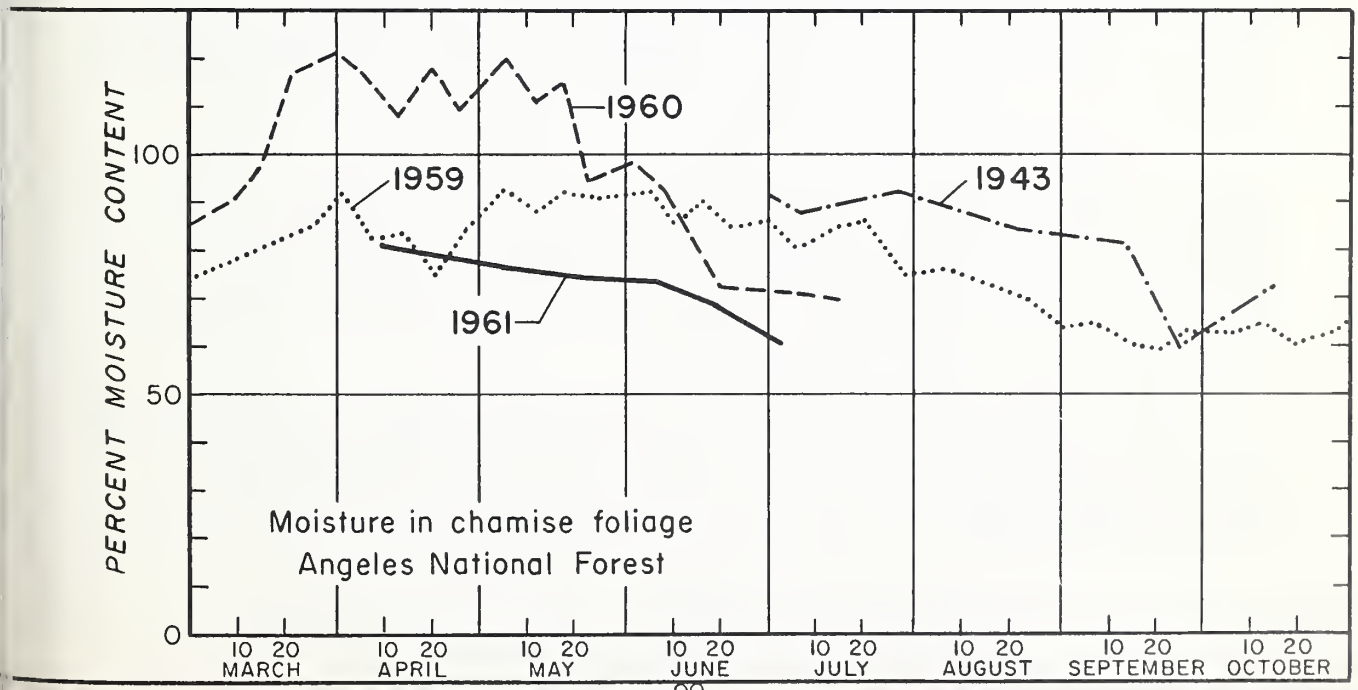
JULY 10, 1961

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
Berkeley - California

FOREST SERVICE
UNITED STATES
DEPARTMENT OF AGRICULTURE

California is far into its third consecutive year of drought, and the possibility of large fire losses again this year is becoming more and more real. Just how bad is the potential for large fires? The fire weather severity index (above) provides a measure of this potential in comparison with other years. As of July 10 all areas in the State had worse-than-normal fire weather, and in all areas except the North Coast conditions were worse than in the two previous "bad" years of 1959 and 1960.

The moisture content of living fuels is another way of estimating the potential for large fires. In chaparral fuels in the southern Sierra and southern California, living fuel moisture has been unusually low this year. On sample plots (below), moisture content has reached a point critical for survival of the plants. Already smaller twigs and branchlets are beginning to die. The potential for large fires in these areas is extremely great.



General Weather Pattern July 13-22, 1961

(See also Appendix A)

During the period of the Basin Fire, both the Pacific high pressure area and the California thermal trough were persistent and relatively stationary, except for a pronounced deepening of the thermal trough on July 21.

On July 13, a small low pressure area was situated off the coast of northern California between the east Pacific high and the inland thermal trough. By July 15, this low had filled at the surface. Two cold fronts crossed the Pacific Northwest during the period. The first moved across Oregon on July 16 and into Idaho on July 17. The second, with a different trajectory, entered Washington on July 20 and moved across Oregon and northern California during the next 2 days. Its trailing end moved into central California on July 23. Falling surface pressures ahead of this front may have caused the deepening of the thermal trough on July 21.

The belt of westerlies remained far north of the fire area throughout the period and there was only a weak upper air flow over central California.

The broadscale pressure pattern at 700 millibars on July 13 showed a high over the eastern Pacific, approximately above the surface high, a low off the coast about over the surface low, and a high over California and the southwestern states. The low weakened rapidly into a trough and was nearly gone by July 17. The inland high elongated to the west and formed two centers, one off the California coast and the other over the Southwest.

Local Weather Patterns July 13-22, 1961

As soon as it became apparent that the initial effort to control the Basin Fire had failed, the fire boss ordered a fire behavior team. The fire behavior officer, dispatched from a nearby fire, arrived at Kirch Flat at 10:00 p.m., July 13. Two meteorological observers were dispatched from Berkeley and arrived at the fire on July 14. Additional weather observers were recruited from line and camp personnel as the fire progressed.

The fire behavior team maintained twice-daily telephone contact with U.S. Weather Bureau fire-weather personnel in San Francisco and Fresno. They exchanged information and cooperated in preparing the detailed fire weather and fire behavior forecasts for each shift (see Appendix C). The fire behavior team also undertook responsibility for all local weather measurements, thus freeing the Weather Bureau personnel to concentrate on synoptic developments.

The recording weather trailer[2/] was set up at Kirch Flat (T12S, R26E, S16. Elev. 950 ft.) on July 13 and moved to Black Rock Guard Station

2/ Dibble, D. L., Fireclimate survey trailer. Fire Control Notes 21(4):116-120, 1960.

(T12S, R27E, S4, Elev. 4,250 ft.) on July 17. The trailer's equipment made continuous 24-hour recordings of temperature, relative humidity, and wind direction and speed. Additional intermittent observations were taken with portable instruments at various key locations around the fire perimeter. Helicopter soundings of temperature and humidity were made each morning from Kirch Flat to 18,000 ft. elevation (except on the morning of July 16, when all helicopters were tied up on rescue work).

Figure 2 shows the typical daily cycle of temperature, humidity, and wind at the two fixed station locations. Although maximum and minimum values varied, as shown in Figure 3, these cycles were nearly constant in timing throughout the period of the fire. The afternoon fire load index as estimated at Kirch Flat was either very high or extreme throughout the entire period of the fire:

Day	Fire Load Index
July 13	28 - very high
14	24 - very high
15	33 - very high
16	24 - very high
17	24 - very high
18	24 - very high
19	24 - very high
20	43 - extreme
21	52 - extreme
22	21 - high

Spot readings taken at various points about the fire show much the same pattern as at the fixed locations. Upcanyon afternoon winds in both the main fork and the north fork of the Kings were generally stronger than indicated by the recorder at Kirch Flat. Most observers recorded gusty upcanyon winds of 10 to 15 m.p.h. from noon to 1800 with higher velocities in the narrower portions of both canyons. Nighttime down-canyon winds were below 5 m.p.h. except for some higher gusts where canyons had abrupt bends or at entrances to side drainages.

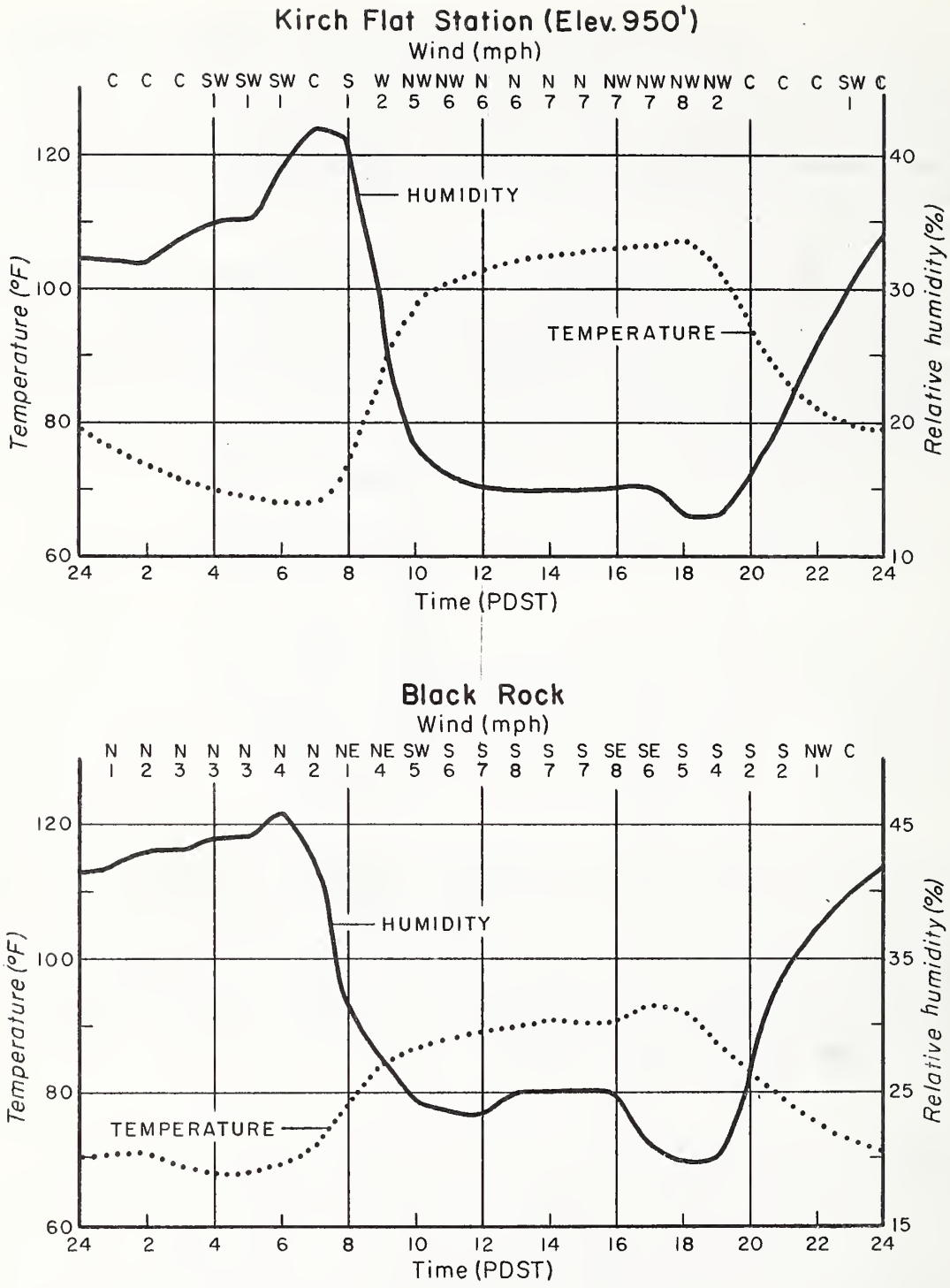


Figure 2.--Typical daily temperature, humidity, and wind cycles. Note: Winds are 60 minute averages. At Kirch Flat site, N is upcanyon, S is downcanyon. At Black Rock site, S is upslope, N is downslope.

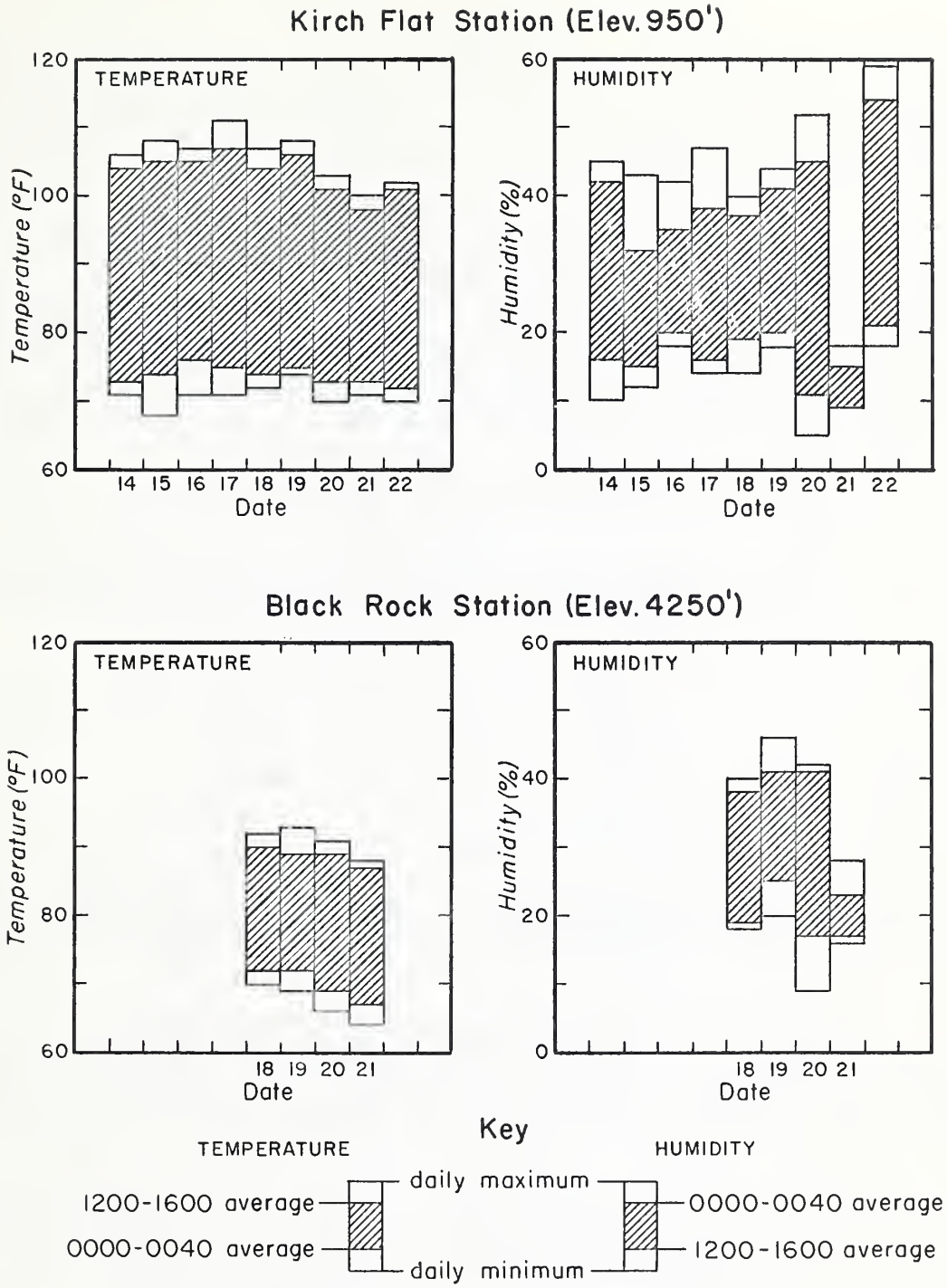


Figure 3.--Daily temperatures and humidities.

Although scattered cumulus and possible thunderstorms were anticipated over the fire area daily through July 20, skies remained clear except for a few cumulus clouds to the northeast over Kings Canyon National Park with bases about 22,000 feet.

The atmosphere over the fire was quite unstable from the second day, July 15, until July 21 when subsiding air entered the fire area. Table 1 shows the cycle of average afternoon lapse rates calculated from helicopter soundings taken over the fire area (Appendix B contains the complete soundings from the fire area and from Oakland, California, the nearest Weather Bureau Rawinsonde Station). Average lapse rates were superadiabatic to 5,000 feet above the fire during the entire period, and superadiabatic to 10,000 feet on July 19.

Table 1.--Average afternoon lapse rates[1/]

Date	Lapse rate	
	To 9,000 ft. MSL	To 14,000 ft. MSL
July 15	5.6	4.9
16	--	--
17	5.8	5.3
18	5.5	5.1
19	5.9	5.5
20	5.6	4.9
21	4.3	4.8
22	4.6	4.9

1/ Kirch Flat average afternoon temperature minus sounding temperature at indicated elevation, divided by difference in elevation.

Although the Oakland soundings provided an adequate picture of stability in the fire area, there was absolutely no correspondence between dewpoint temperatures measured from Oakland and the humidity structure of the air over the fire. This lack of correspondence appeared to be equally true of winds aloft.

Therefore upper air measurements should be made at the fire site whenever possible. If soundings cannot be made in the fire area, observations from distant stations (Oakland is 185 miles air line from the fire site) should be used only with great caution in making behavior forecasts.

Fuels

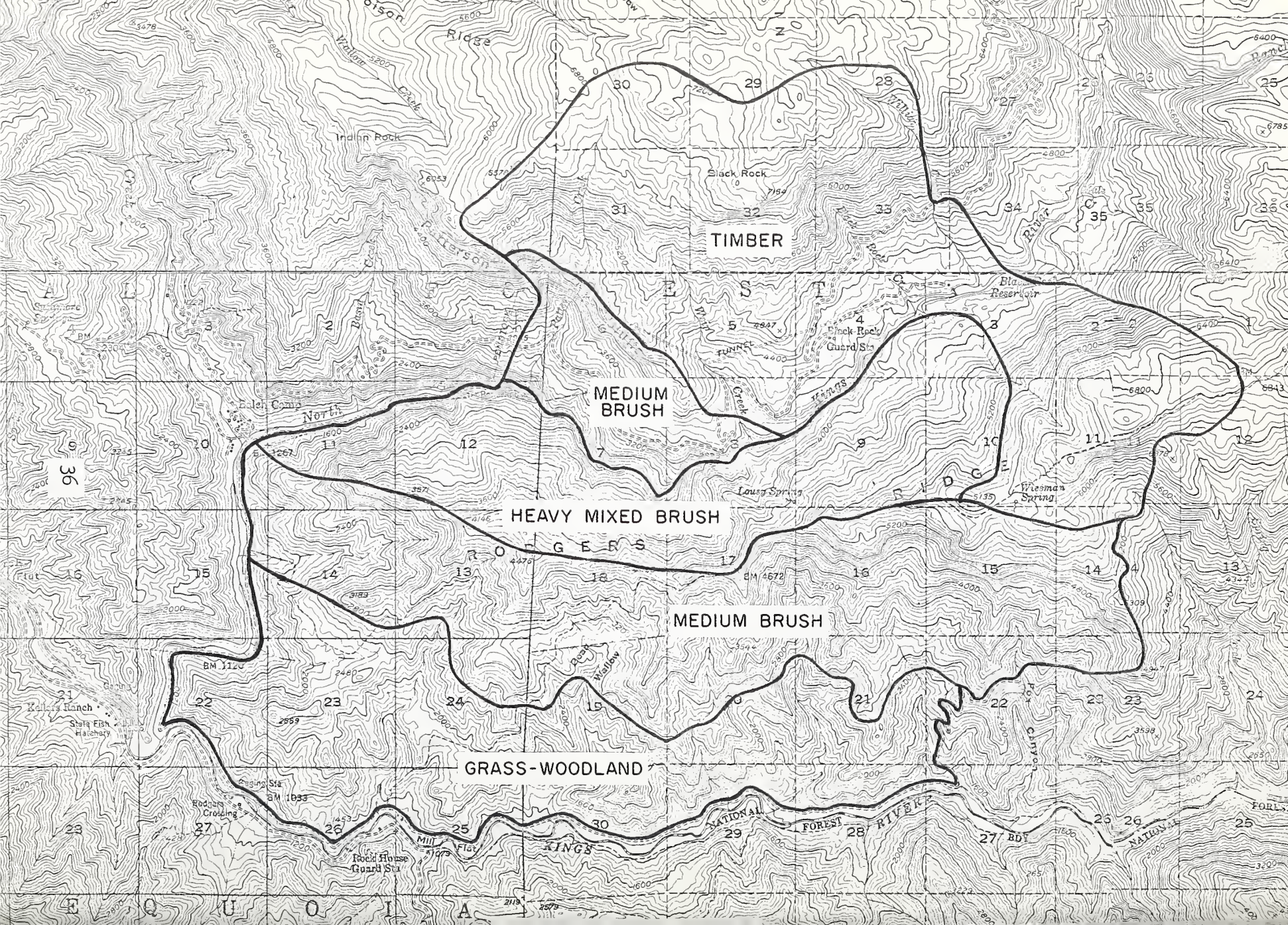
With a 6,000-foot range in elevation and very broken topography, the Basin Fire included nearly every major fuel type to be found in California. In general, however, there were four distinctive classes of fuels (fig. 4).

1. Grass woodland occupied elevations below 2,500 feet on the slopes north of the main fork of the Kings River. The principal fuel in this type was grass and scattered live oak and digger pine trees with occasional clumps of light brush and concentrations of brush in the bottoms of side canyons. Fuel volumes were light, averaging about 1-1/2 tons per acre in the grass areas and 7 to 10 tons per acre in the brushier sites. Unusual difficulty with spotting was encountered in the grass-woodland type because a large number of dead leaves and needles adhered to brush and trees at elevations below 3,000 feet. This dead foliage resulted from a sudden, severe hot spell in the middle of June after an unusually cool spring. Similar foliage kill in many areas of northern and central California at elevations below 3,000 feet contributed greatly to the severity of the early fire season in 1961.

2. Light to medium brush occupied the south-facing slopes between the grass-woodland type and the lower timberline. Chamise, sage, and various shrubs were characteristic of this type. Fuel volumes varied from 7 to 20 tons per acre, the denser stands being in areas of relatively gentle slope and deeper soil. In general there was very little ground litter beneath the brush, but enough grass grew beneath and between the plants to catch sparks and to permit fire to move on the ground. Although the moisture content of green foliage was not measured in the fire area, the trend of green foliage moisture on the San Dimas Experimental Forest in southern California was downward (fig. 1). Though not so acute as at San Dimas, the 1961 drought had a similar effect on living fuels throughout central and southern California.

3. North and east facing slopes below the timberline were covered with stands of ceanothus, scrub oak, and other of the larger brush species. Here, too, fuel volumes varied, depending on soil depth and steepness. Volumes ranged from 15 to 20 tons per acre on steep rocky slopes to about 40 tons per acre on basins and benches. Litter was unusually scanty and fire on these slopes tended to move through the crowns or not at all.

4. Although the entire area above timberline is lumped into a single fuel type (timber), fuel conditions actually varied a good deal. At the lower elevations ponderosa pine was liberally mixed with a brush understory. The higher elevations contained solid stands of true firs. However, the entire type contained a litter layer of needles sufficient to support a moving surface fire and enough brush or reproduction to permit easy crowning of the mature timber.


TIMBER
MEDIUM BRUSH
HEAVY MIXED BRUSH
MEDIUM BRUSH
GRASS-WOODLAND
Indian Rock
Black Rock
Black Rock Guard Sta
Wiesman Spring
Lousy Spring
Keller's Ranch
State Fish Hatchery
Rodgers Crossing
Rock House Guard Sta
Mill Flat
NATIONAL FOREST
KINGS RIVER

Fire Behavior Problems

In general, firefighters found the localized fire behavior forecasts (Appendix C) accurate. However, the reasoning behind some of these forecasts may not be obvious from the data included in this report. There were also some instances of unanticipated fire behavior. Some examples of both circumstances are discussed here since they may be of value to students of fire behavior.

Fire Behavior Problem #1

Considering the weather conditions and the behavior of the fire on preceding and succeeding days, why was so little acreage burned on July 15? (See fire history map 5)

A combination of fuels, topography, and effective fire-control action accounts for the pattern of burned area. On the south side of the fire, firelines were put in and held in front of a fire backing down against an upslope wind in grass and light brush. Lines from Rodgers Ridge to the southwest corner of section 20 had been established during the night. These held except for the small slopovers near the ridge crest.

Crews also held the north side of the fire above the Balch Powerhouse Road despite turbulent winds. This line was held by delaying firing until the main fire had backed downslope to within a few hundred feet of the road; then heat from the main fire pulled backfires upslope and prevented an upcanyon run. During most of the afternoon heavy brush burning in the basins and benches in the center of section 12 also acted as an effective source of convective activity and helped prevent extension of the fire to either the north or east. Figure 5, a photo taken about 2:00 p.m., July 15, from the road just east of Basin Creek in section 2 and looking southeast, shows the effectiveness of these heavy brush islands in controlling local winds.

In summary, the position of the fire relative to the topography, fuels, and established control lines was such that the fire tended to pull back into the area previously burned.

Figure 5.--Fire on north slopes of Rodgers Ridge affecting slope and canyon winds.

Fire Behavior Problem #2

Why did the fire jump the North Fork near Patterson Creek at 2:00 a.m., July 16, when fire activity was at a minimum and the river had held all day? (See fire history map 6)

The fire spotted across on a sudden surge of down-canyon wind. But why should the down-canyon wind have occurred on that particular night and at that particular time? Probably we will never know. The recording station at Kirch Flat theoretically should pick up all the drainage winds from both the North Fork and the Main Fork. Yet no down-canyon winds stronger than 1 mile per hour were recorded on any night from July 15 through 17. Spot readings taken the previous night (July 14-15) at Balch Powerhouse showed downcanyon winds below 5 miles per hour even in gusts. The night of July 15-16 was not colder than usual; in fact, both the average and the minimum temperatures at Kirch Flat were higher than those of the preceding night. (See fig. 3)

On the other hand, the North Fork actually drains more high country over a steeper gradient than does the Main Fork and thus might be expected to have earlier, better developed, down-canyon winds. Geiger, in his book on microclimate[3/], notes that on steeper gradients the downflow of cold air often occurs in bursts. Consequently, sudden gustiness in the North Fork might not be recorded by the station at Kirch Flat.

The point at which the fire jumped the river is also a logical place to expect turbulent canyon winds since it was at one apex of a "Z"-shaped bend in the river and also at the junction of an intersecting drainage. Thus, although the timing was both unfortunate and inexplicable, it is most likely that spotting was due to turbulent eddying of downcanyon drainage winds.

3/ Geiger, R. The climate near the ground. Harvard Univ. Press, 482 pp., 1950.

Fire Behavior Problem #3

Why did the fire blow up on July 16 rather than on July 15, and why didn't the run continue on July 17 when weather conditions were nearly identical to the day of the blow-up? (See fire history maps 5, 7, and 9)

Byram has defined a "blow-up" as a radical change in fire behavior occurring when a fire changes from a forced convection type to a free convection type.[4/] One may quarrel with Byram's definition of a "blow-up" as being unduly restrictive because the phenomena he describes require both high intensity fires and relatively low gradient wind speeds. Regardless of how one defines a blow-up, however, the Basin Fire run of July 16 meets both these conditions.

To "blow up," a fire must first reach sufficient intensity to overcome atmospheric factors that tend to restrict free convection. Weather, then, controls the minimum degree of intensity required. However, regardless of this minimum value, the fire must build up to this intensity ("get hot enough") under forced convection conditions before it can change to a free convection type. The ability to reach this intensity depends as much on fuel and topographic conditions as on weather. On July 15 and 17, the Basin Fire was simply in no position to build up to high intensities.

On July 15, the fire was backing downslope in heavy fuels. Backfiring was deliberately slowed to prevent too great a build up of heat, and the area on fire at one time was kept to a minimum.

On July 16, fire had reached the bottom of a south-facing slope covered with relatively light but flashy fuels. Upslope runs increased in speed and intensity until the critical point was reached and "blow-up" behavior began.

By July 17, the fire was again in heavier and slower burning fuels, and runs started too near the ridge crest to build up to critical intensities.

Although weather conditions and the point of minimum intensity for blow-up were nearly identical on the three days, the fuel, the topography, and the position of the fire precluded large runs, and no unusual fire behavior was experienced on July 15 or 17.

4/ Byram, G. M. Forest fire control and use. Forest fire behavior (Davis, K. P., Ed.). Chapter 4:90-123. McGraw Hill & Co., New York, 1959.

Fire Behavior Problem #4

Where did the dry air come from on July 20 and 21?

This is another puzzler. At the time of the fire it was theorized that the dry air noted at 11,000 feet during helicopter soundings taken over the fire area was moving westward out of Nevada across the crest of the Sierra. However, later examination of weather records for the period showed that the dry air apparently moved from west to east at the surface (see Appendix D). The U.S. Weather Bureau and the Pacific Southwest Forest and Range Experiment Station are cooperating in a further study of this incident.

In any event, it is important to note that the drop in humidity at the fire was predicted from the soundings taken at the fire site. It could not have been predicted without these local observations.

Fire Behavior Problem #5

Why was there no trouble with spotting on July 21?

On Friday, July 21, weather conditions were ideal for producing spot fires at long distances from the main fire. By 3:00 p.m. humidities had been below 15 percent for 24 consecutive hours. The moisture content of fine fuels had dropped from 4 percent on July 19 to 1-1/2 percent on July 21. The Ignition Index was 97 (on a scale of 0-100) and grass fuels on south-facing slopes were ready to ignite at the slightest opportunity.

In addition, atmospheric stability above the fire was unusually conducive to long-distance spotting. Ordinarily, long-distance spotting has been linked to unstable lapse rates. The theory is that an unstable atmosphere permits higher combustion rates and that, with increased fire intensity, heavier material is lifted into the convection column and carried farther before dropping out. In heavy fuels such as timber, experience bears out this theory. However, in light fuels where all the embers are small-sized, the reverse is true. With unstable lapse rates, embers tend to burn up completely before reaching the ground. The ideal stability pattern for long-distance spotting in brush fuels with a light ground litter is one in which convection is limited to a few hundred feet above the ground and embers have a relatively flat trajectory.

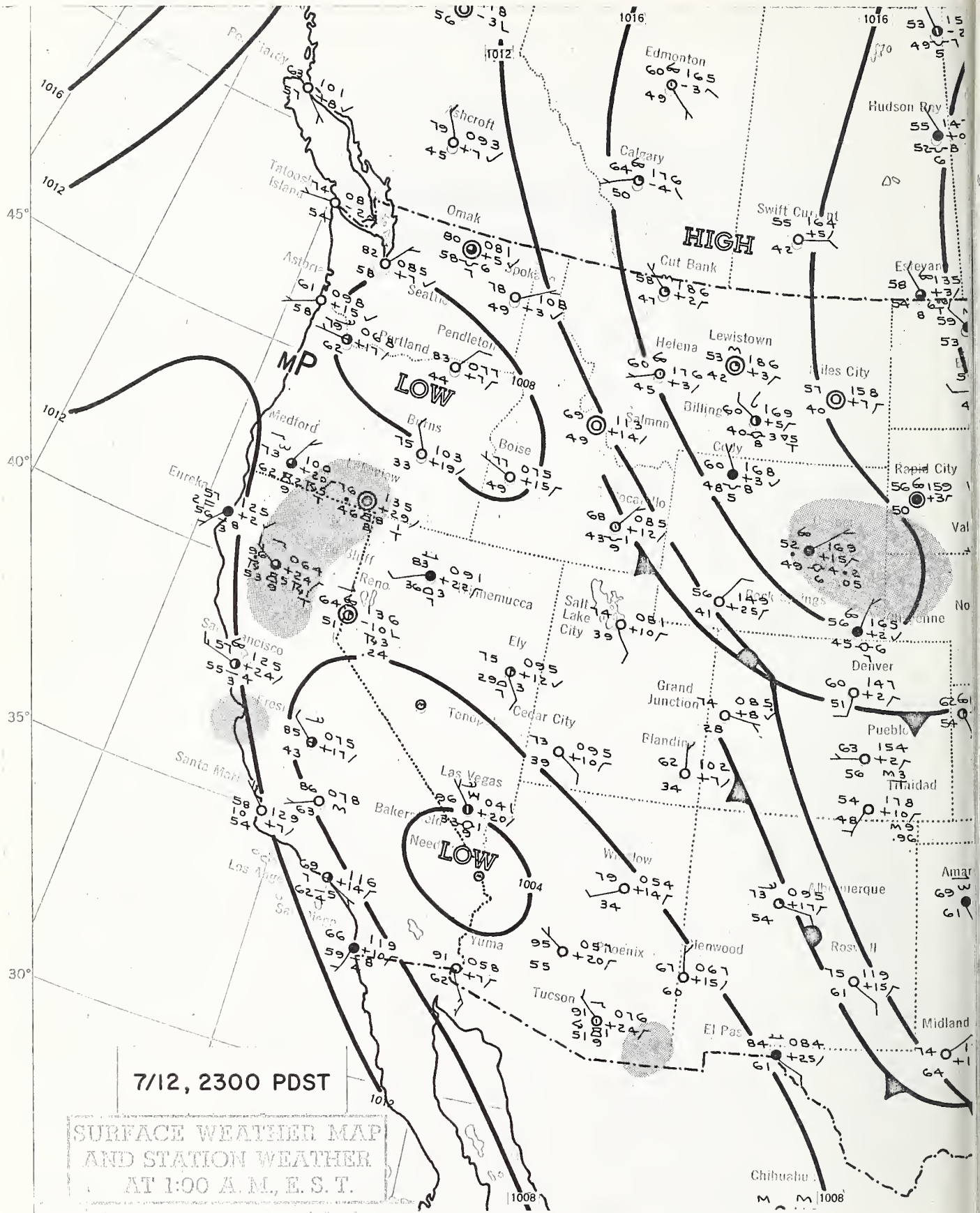
On July 21 the lapse rate above the fire was stable to 8,000 feet (Appendix B). The unstable layer caused by afternoon surface heating was limited to a shallow layer. Despite the fact that fuels were easily ignitable and ignition sources were numerous, spot fires were not a problem.

The reason was both simple and extremely fortunate. On Friday winds switched from northwest to east and carried all embers back into the burned-over area. The wind switch was predicted and its implications were recognized at the time the fire behavior forecast was written. However, gradient velocities were expected to be low, possibly less than slope or canyon wind speeds. Spots might have been carried across the line by local winds despite an adverse gradient wind. Then, too, if the easterly winds failed to materialize on schedule, the consequences would have been disastrous to the fire control effort. Therefore, the forecast was written to cover the less probable, but more dangerous situation.

APPENDIX A

Daily Surface Weather Maps

July 12-23, 1961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AND STATION WEATHER
AT 1:00 A.M., E.S.T.
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Ashcroft
Hudson Bay
Swift Current
Omak
Spokane
Cut Bank
Seattle
Portland
Pendleton
Helena
Lewistown
Billings
Miles City
Boise
Salmon
Rapid City
Medford
Burns
Eureka
Reno
Winnemucca
Salt Lake City
Ely
Cedar City
Grand Junction
Denver
Pueblo
Trinidad
Las Vegas
Blanding
Albuquerque
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El Paso
Midland
Chihuahua
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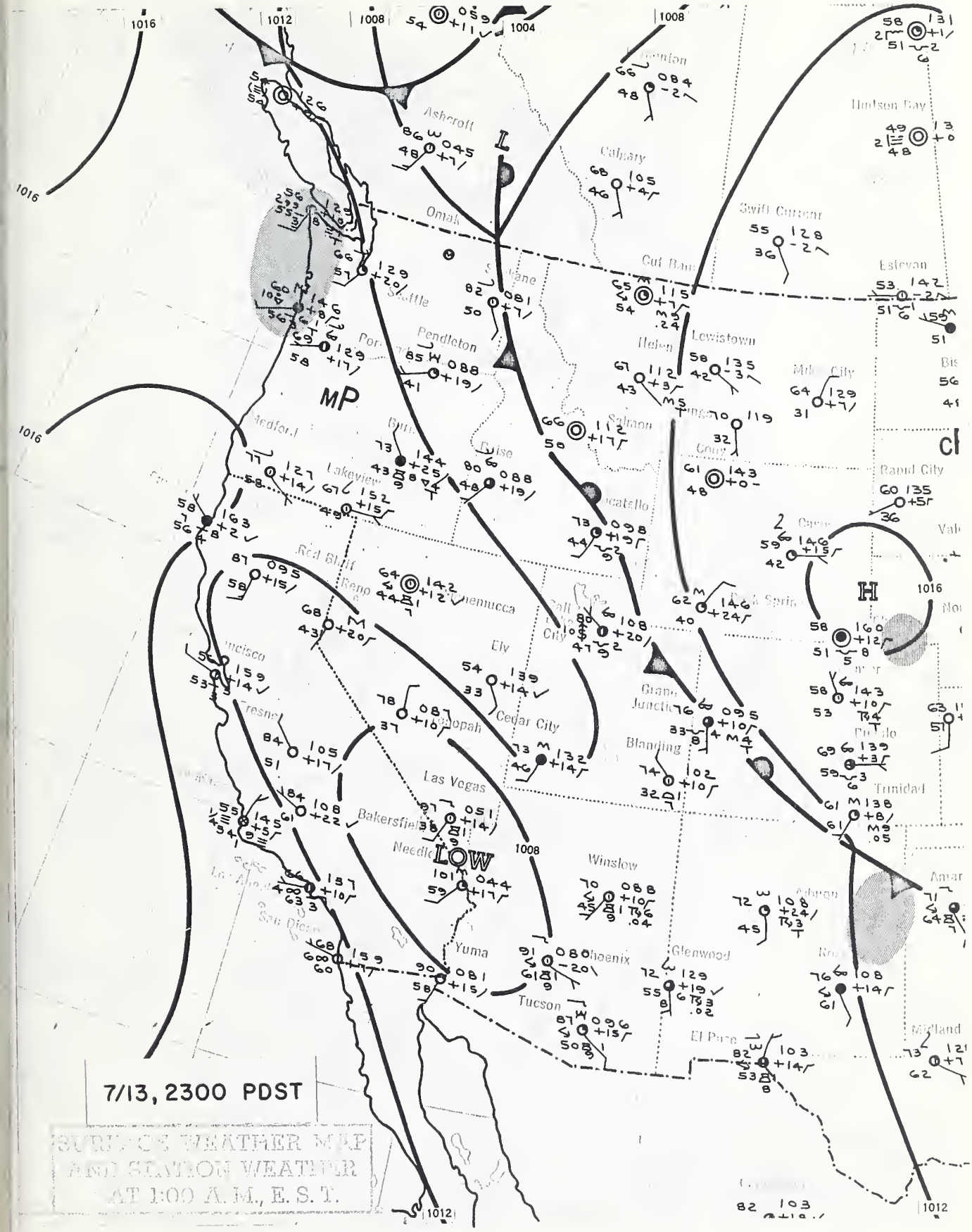
45°
40°
35°
30°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AND STATION WEATHER
AT 1:00 A.M., E.S.T.
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Swift Current
Hudson Bay
Estevan
Lewistown
Pendleton
Boise
Lakeview
Red Bluff
Reno
Winnemucca
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Cedar City
Las Vegas
Bakersfield
Needles
Yuma
Phoenix
Tucson
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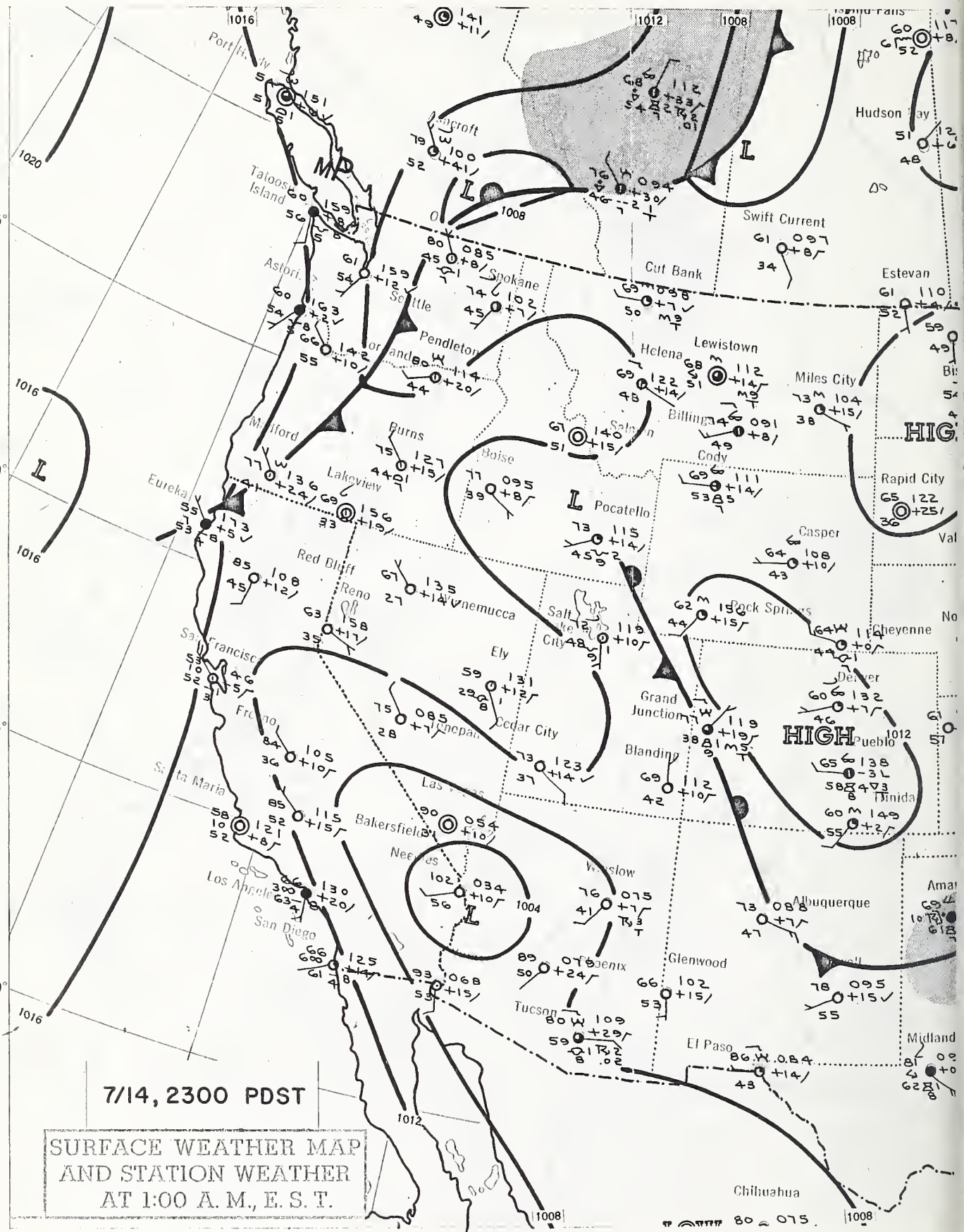
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Rapid City
Cody
Casper
Cheyenne
Denver
Pueblo
Grand Junction
Blanding
Albuquerque
Glenwood
Phoenix
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El Paso
Midland
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Salt Lake City
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Bakersfield
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Santa Maria
Los Angeles
San Diego
San Francisco
Eureka
Red Bluff
Reno
Winnemucca
Lakeview
Burns
Pendleton
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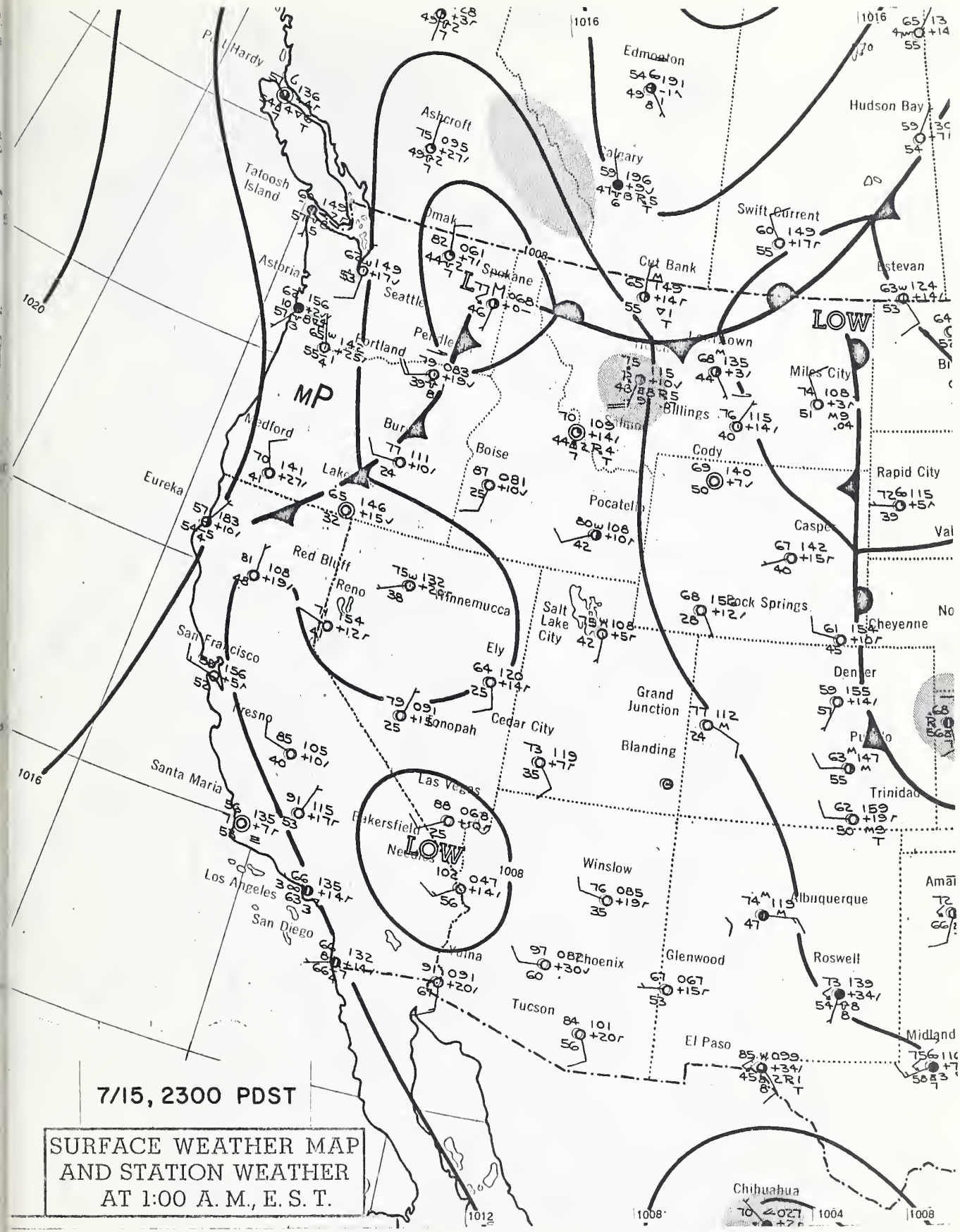
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Needles
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Albuquerque
Los Angeles
San Diego
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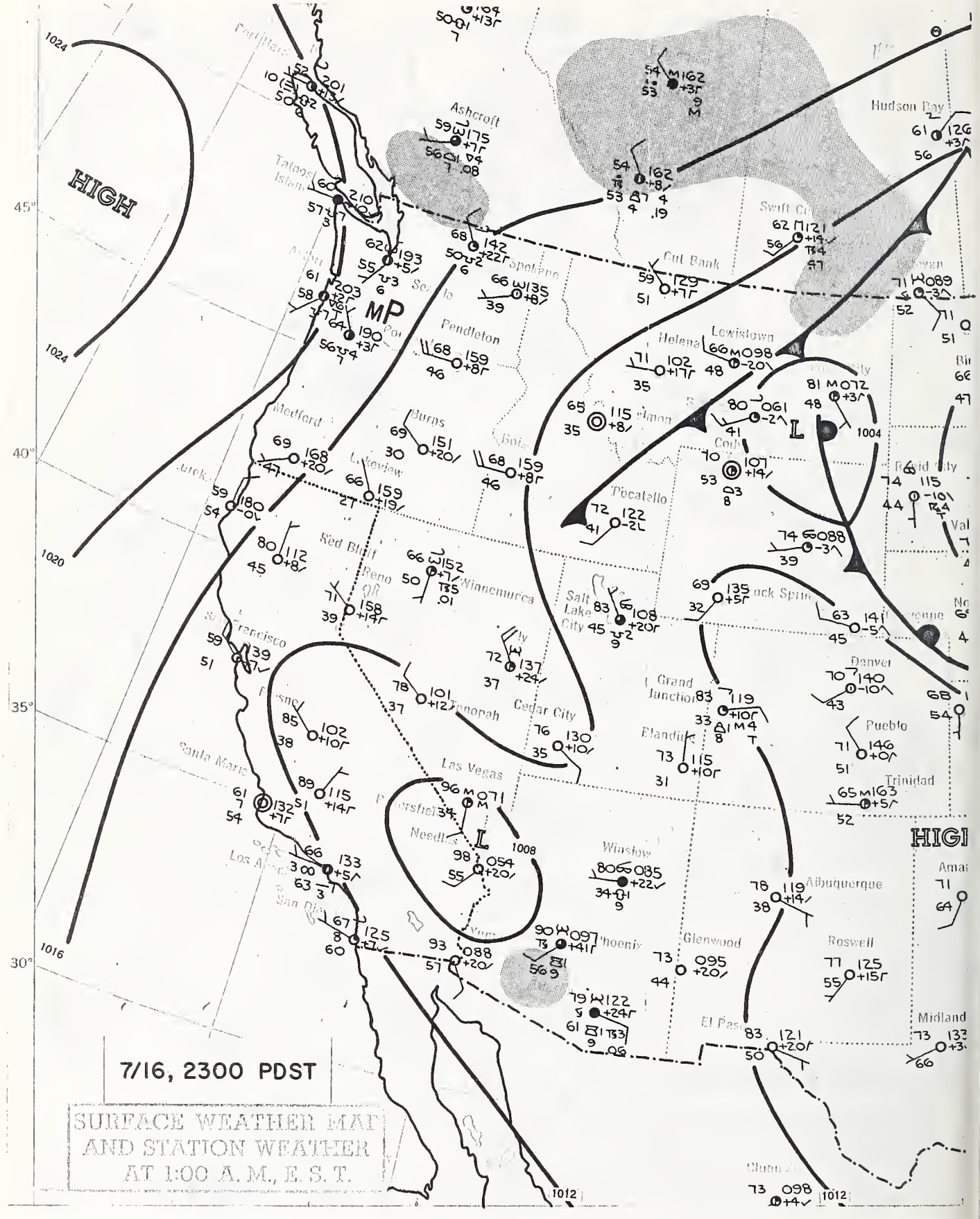
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AND STATION WEATHER
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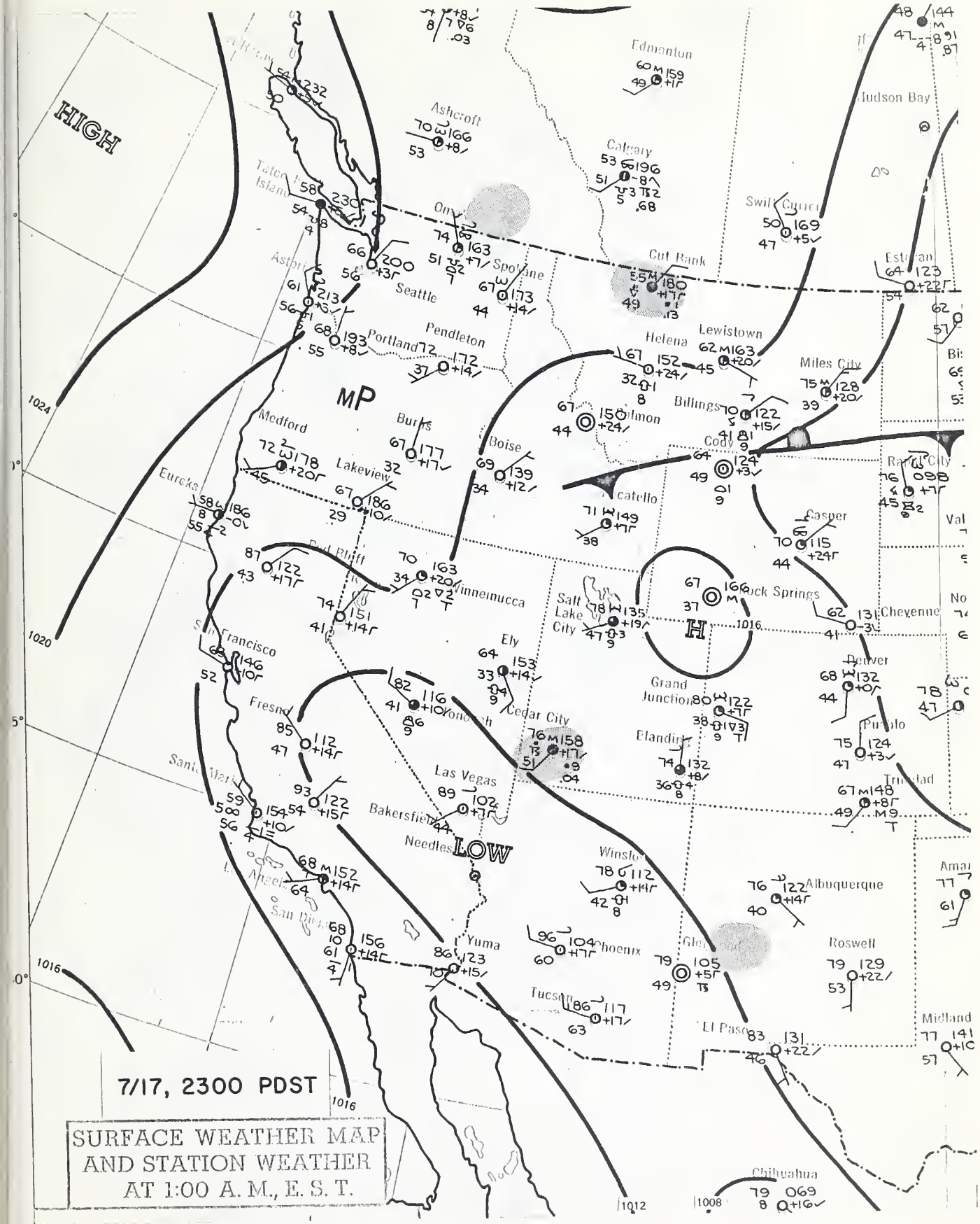
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SURFACE WEATHER MAP
AND STATION WEATHER
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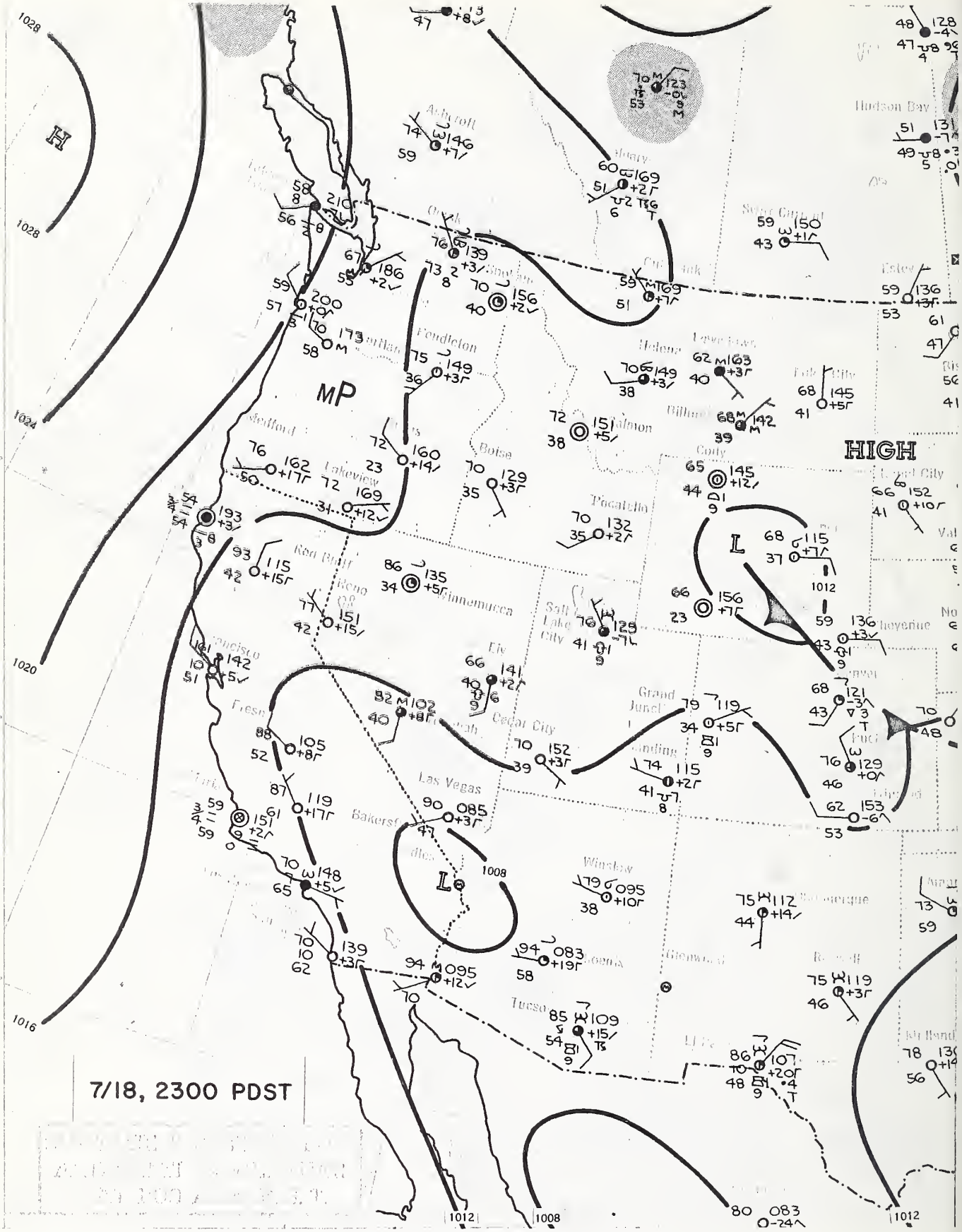
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Prince George
Hudson Bay
Fort St. John
Dawson Creek
Grande Prairie
Peace River
Fort Nelson
Watson Lake
Whitehorse
Yukon Territory
Northwest Territories
Alberta
Saskatchewan
Manitoba
Ontario
Minnesota
North Dakota
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Sault Ste. Marie
Timmins
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Fort Nelson
Fort St. John
Dawson Creek
Prince George
Quesnel
Ashcroft
Kamloops
Vancouver
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Ely
Tonopah
Goldfield
Needles
Yuma
Phoenix
Flagstaff
Gallup
Albuquerque
Roswell
Amarillo
Lubbock
El Paso
Midland
Abilene
Wichita Falls
Oklahoma City
Tulsa
Wichita
Dodge City
Goodland
North Platte
Scottsbluff
Valentine
Rapid City
Pierre
Aberdeen
Bismarck
Williston
Minot
Grand Forks
Fargo
Devils Lake
Jamestown
Dickinson
Miles City
Glasgow
Havre
Great Falls
Helena
Butte
Missoula
Kalispell
Cranbrook
Kelowna
Penticton
Vernon
Kamloops
Williams Lake
Quesnel
Prince George
Fort St. James
Fort St. John
Dawson Creek
Grande Prairie
Peace River
Fort Nelson
Watson Lake
Whitehorse
Yukon Territory
Northwest Territories
Alberta
Saskatchewan
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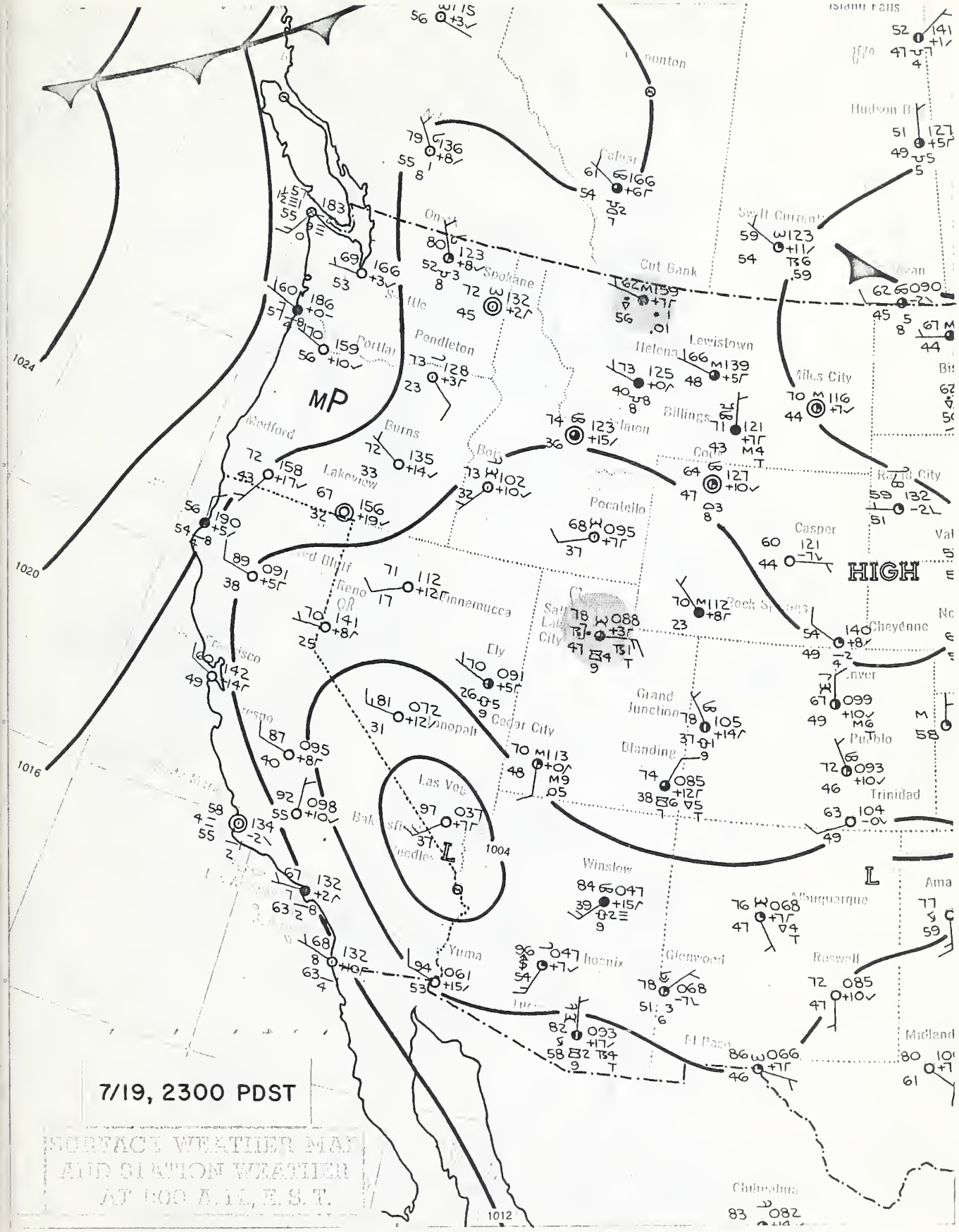
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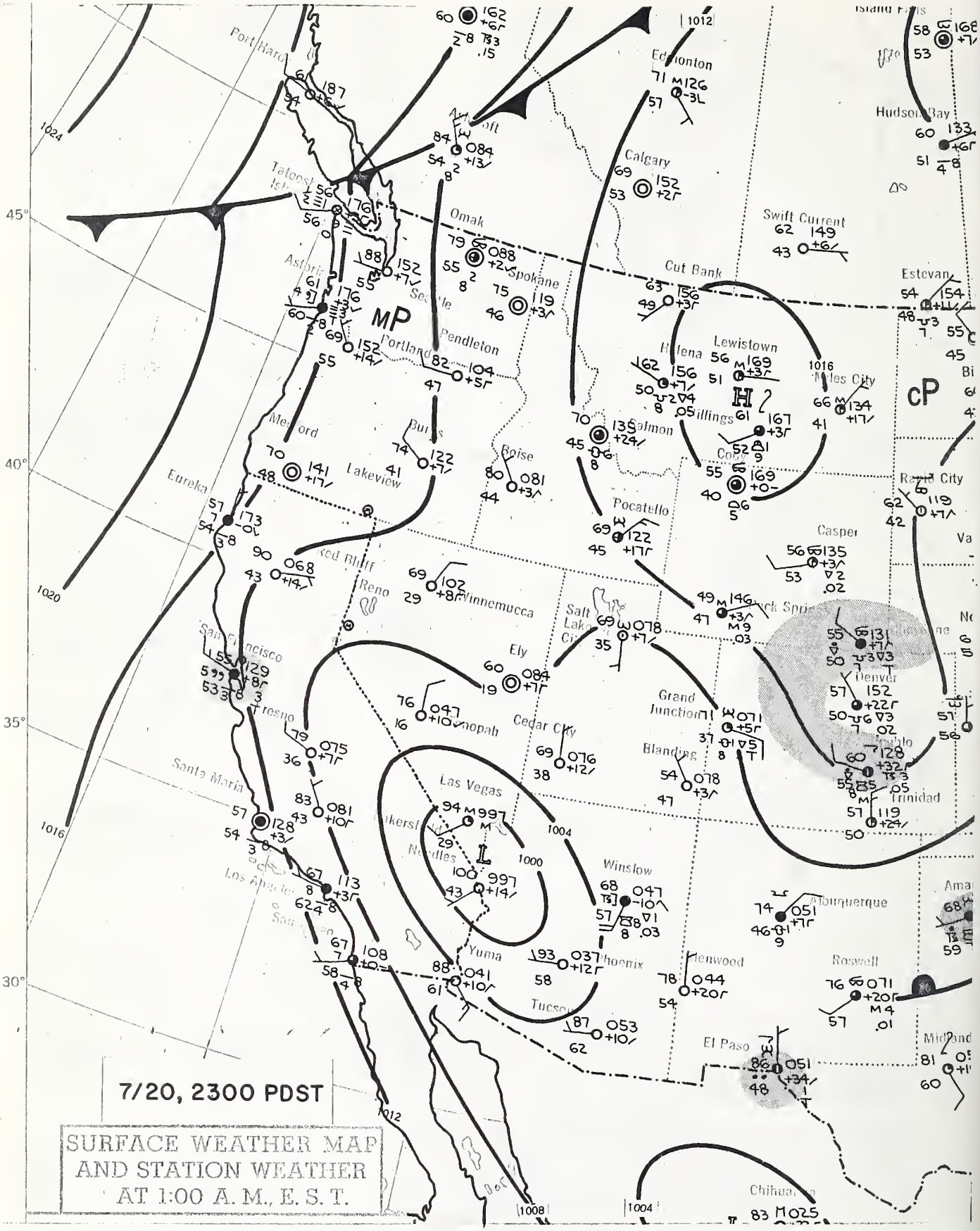
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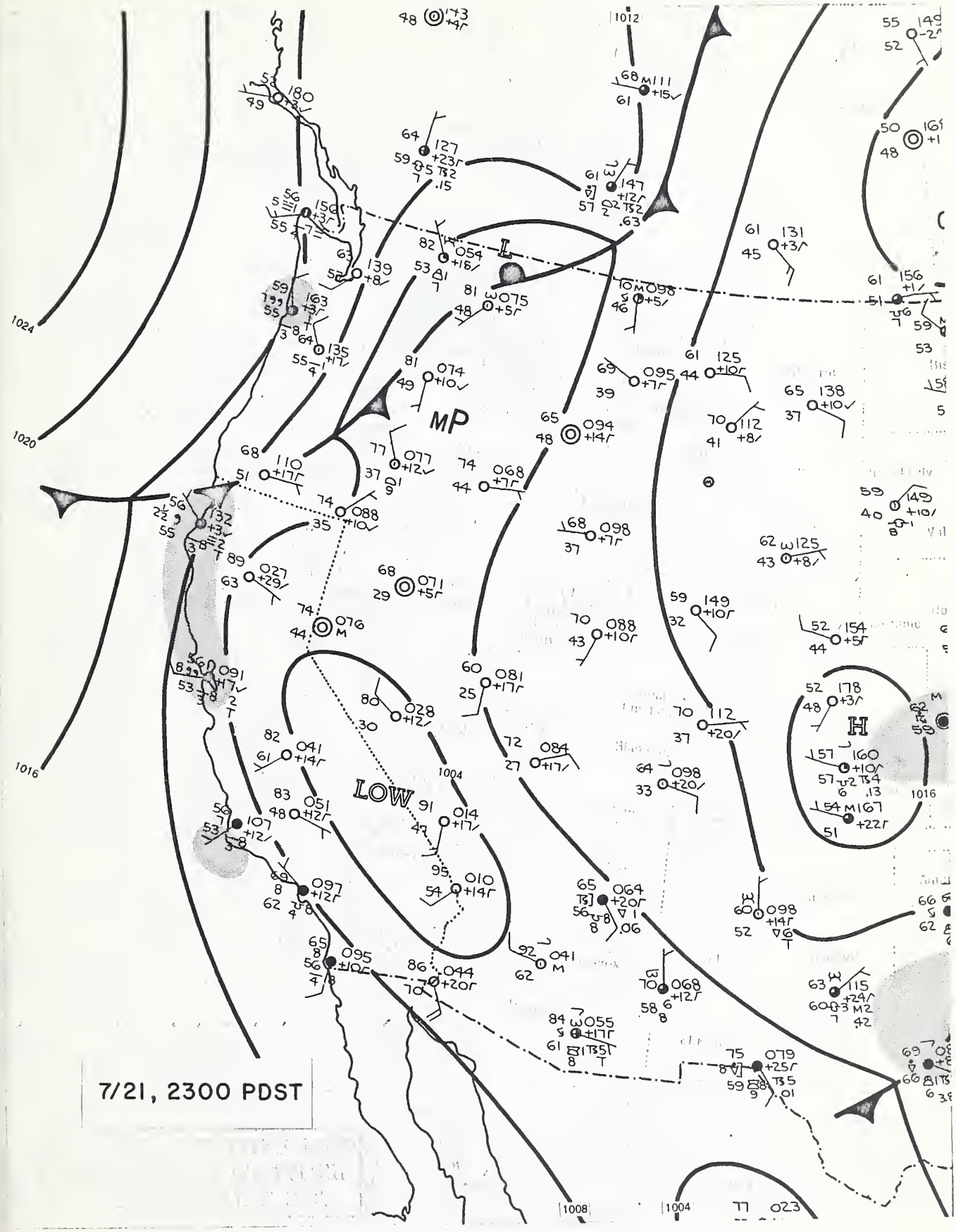
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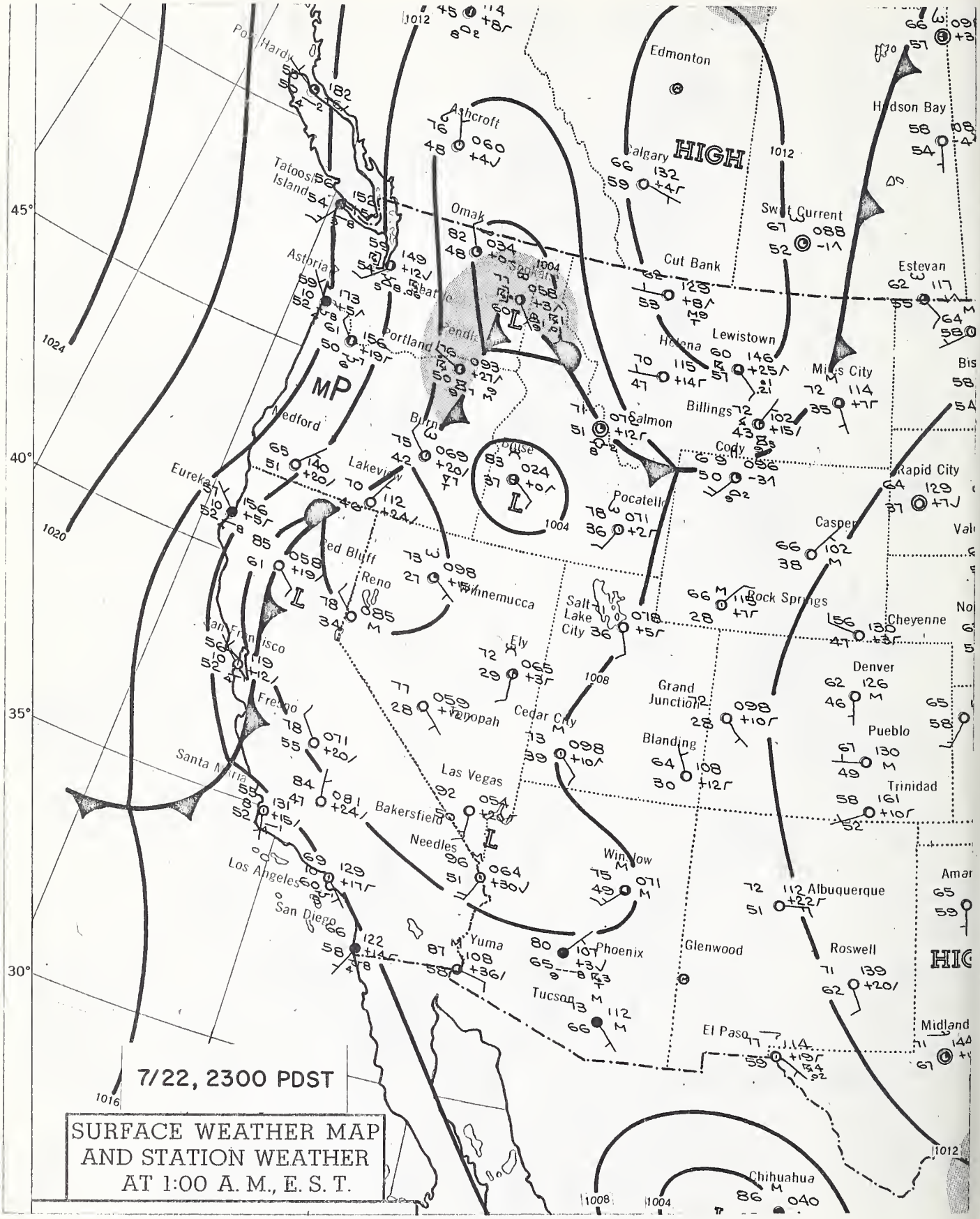
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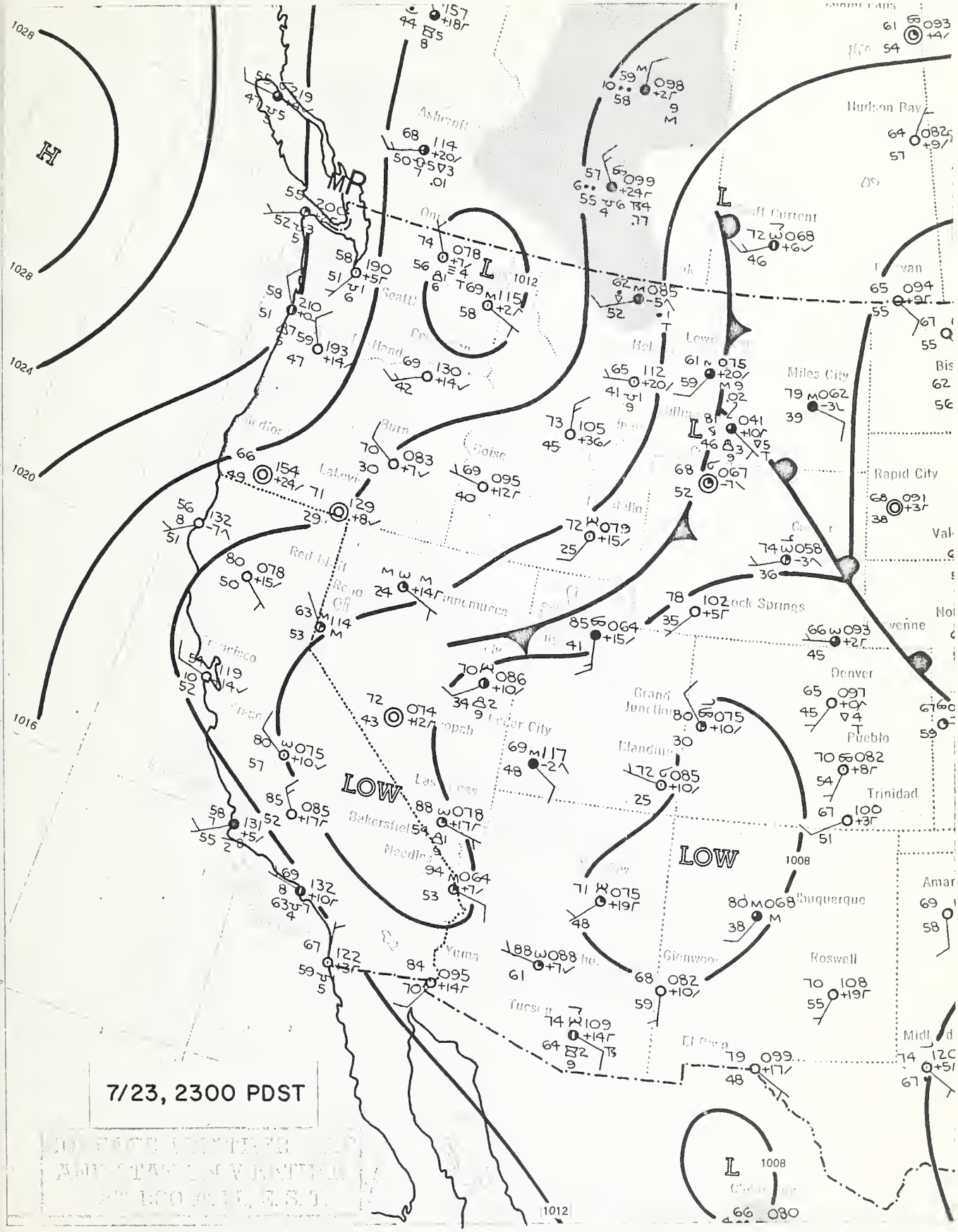
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Rock Springs
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Winnipeg
Regina
Swift Current
Medicine Hat
Lethbridge
Calgary
Edmonton
Prince Albert
Saskatoon
Yorkton
Brandon
Thunder Bay
Sault Ste. Marie
Sioux Lookout
Kenora
Fort Frances
Dryden
Kapuskasing
Timmins
Sudbury
North Bay
Ottawa
Montreal
Quebec
Moncton
Saint John
Halifax
Sydney
Charlottetown
Gander
Goose Bay
Labrador City
Wabush
Schefferville
Churchill
Thompson
Flin Flon
The Pas
Portland
Spokane
Pendleton
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Lakeview
Klamath Falls
Medford
Redding
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Reno
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Phoenix
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Flagstaff
Winslow
Gallup
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Durango
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Pueblo
Dodge City
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Hays
Concordia
Salina
Wichita
Oklahoma City
Amarillo
Lubbock
Midland
Abilene
San Angelo
Del Rio
Laredo
Corpus Christi
Brownsville
Houston
Galveston
Beaumont
Lake Charles
New Orleans
Shreveport
Little Rock
Memphis
Jackson
Meridian
Birmingham
Montgomery
Mobile
Tallahassee
Jacksonville
Orlando
Tampa
Miami
Key West
Atlanta
Chattanooga
Knoxville
Nashville
Louisville
Cincinnati
Columbus
Dayton
Cleveland
Akron
Toledo
Detroit
Flint
Saginaw
Grand Rapids
Muskegon
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Indianapolis
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Terre Haute
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Springfield
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Rockford
Chicago
Milwaukee
Madison
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La Crosse
Eau Claire
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Minneapolis
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Rochester
Mason City
Sioux City
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Casper
Riverton
Billings
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Kenora
Fort Frances
Dryden
Kapuskasing
Timmins
Sudbury
North Bay
Ottawa
Montreal
Quebec
Moncton
Saint John
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Gander
Goose Bay
Labrador City
Wabush
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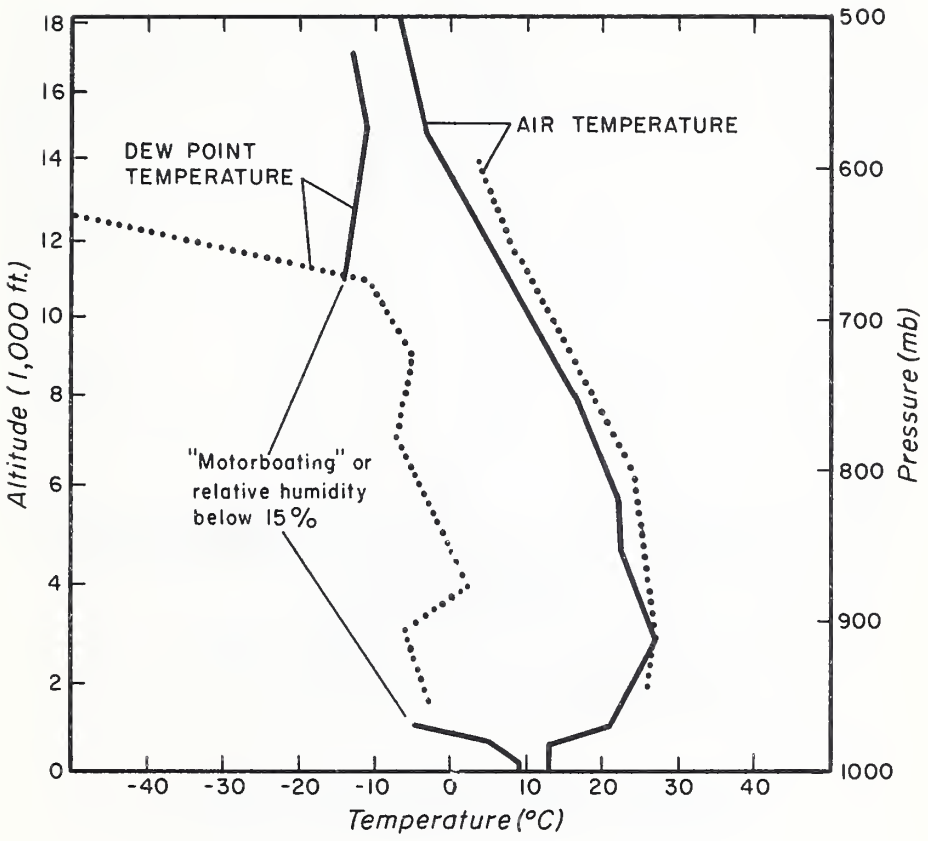
Churchill
Thompson
Flin Flon
The Pas

APPENDIX B

Morning Temperature - Dew Point Soundings

Oakland and Kirch Flat

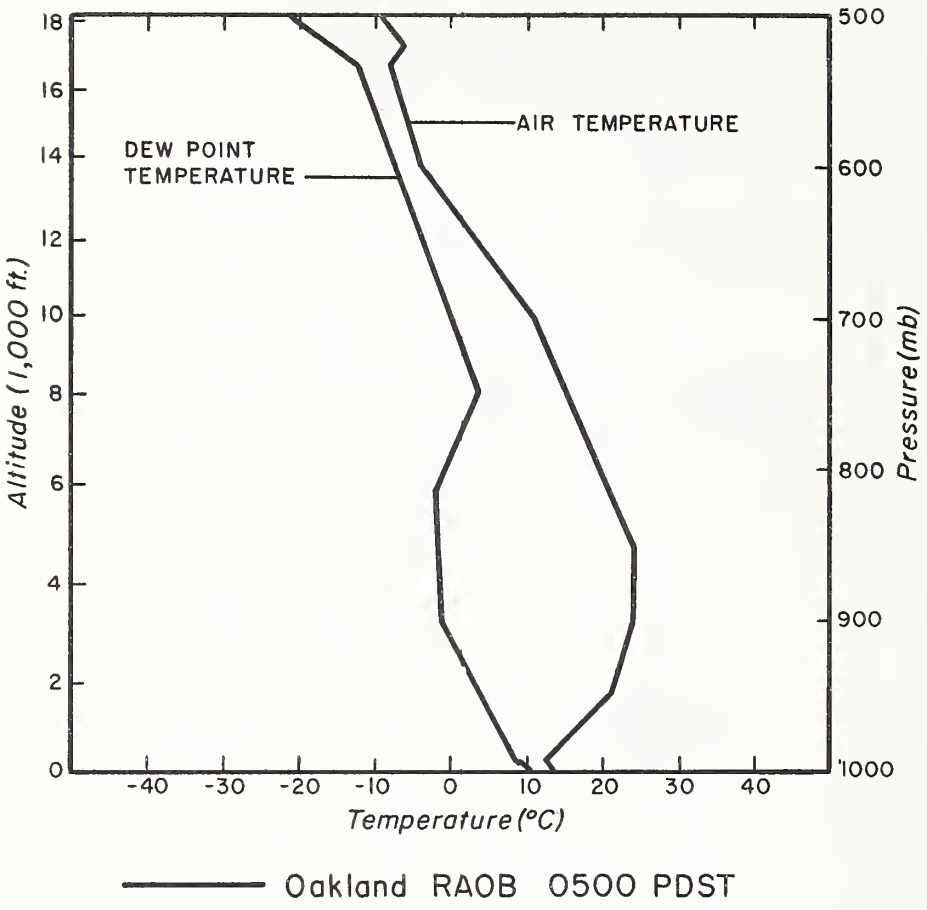
July 15-22, 1961



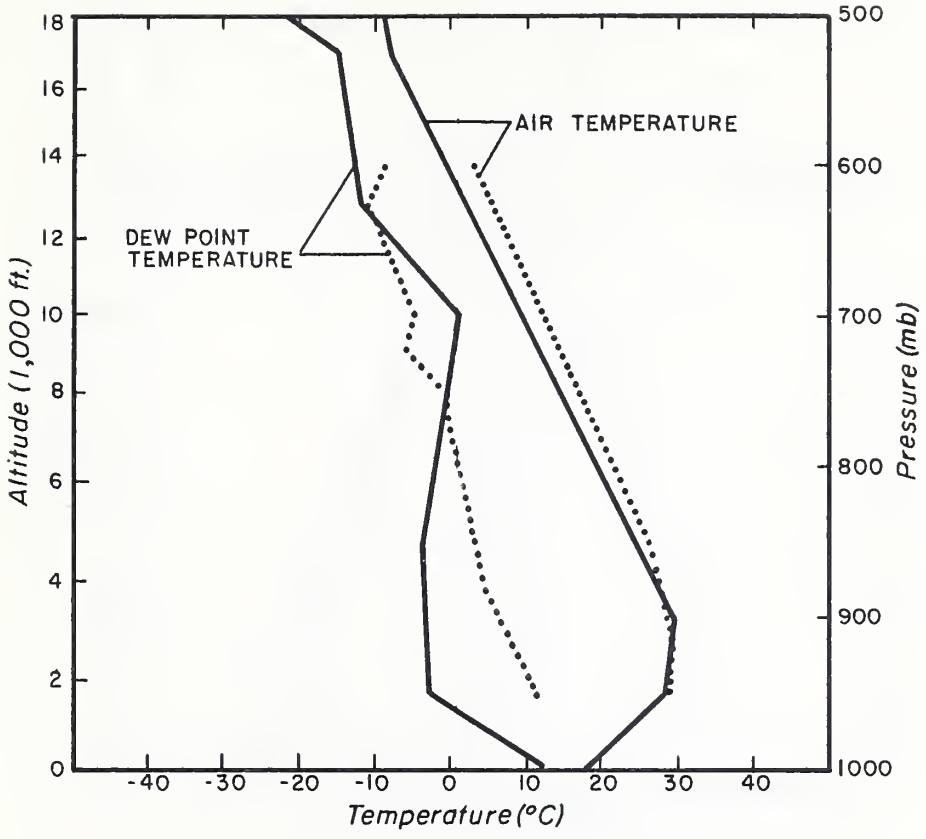
——— Oakland RAOB 0500 PDST

····· Kirch Flat sounding 0700 PDST

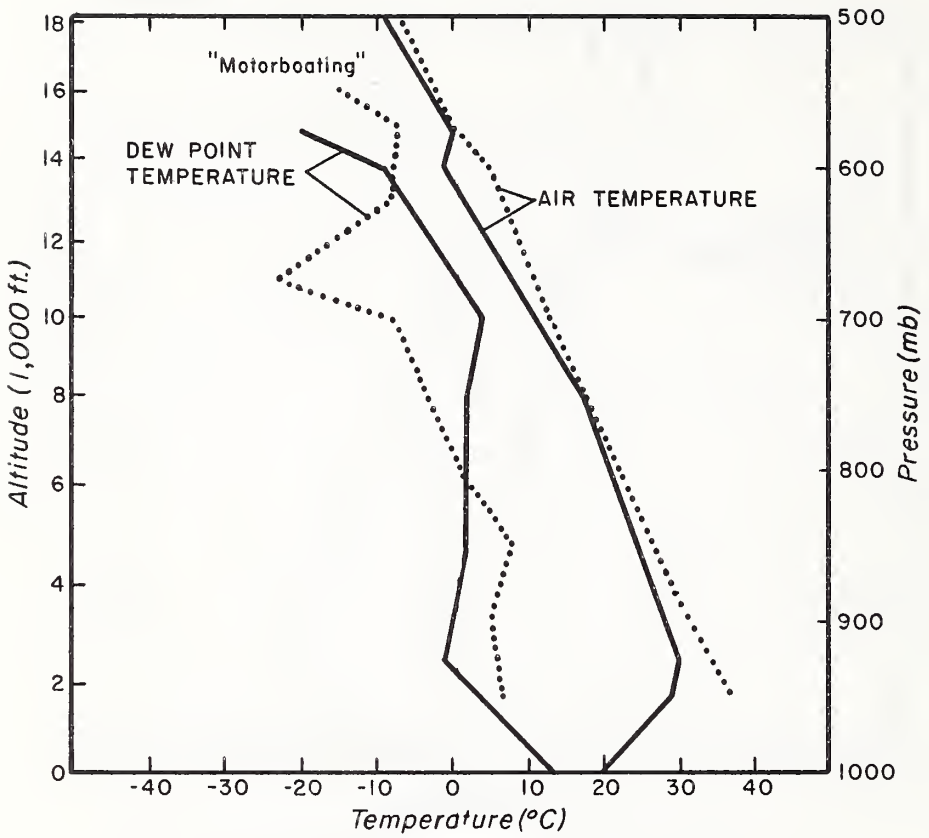
July 15 Upper air soundings



July 16 Upper air soundings



July 17 Upper air soundings



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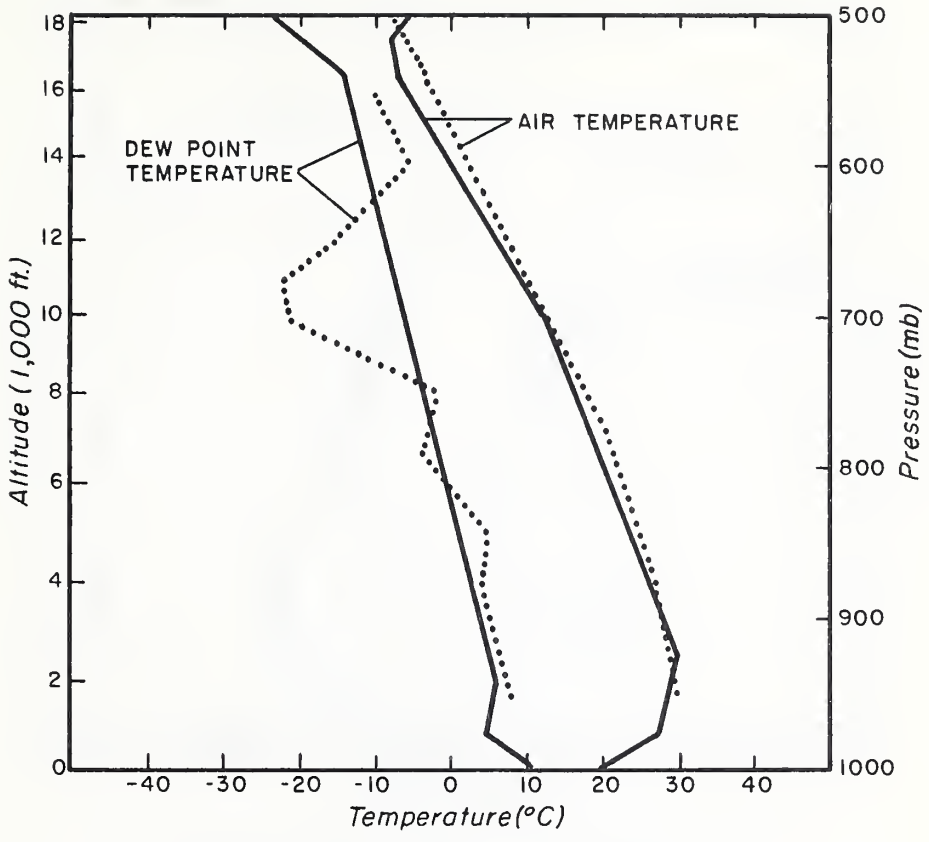

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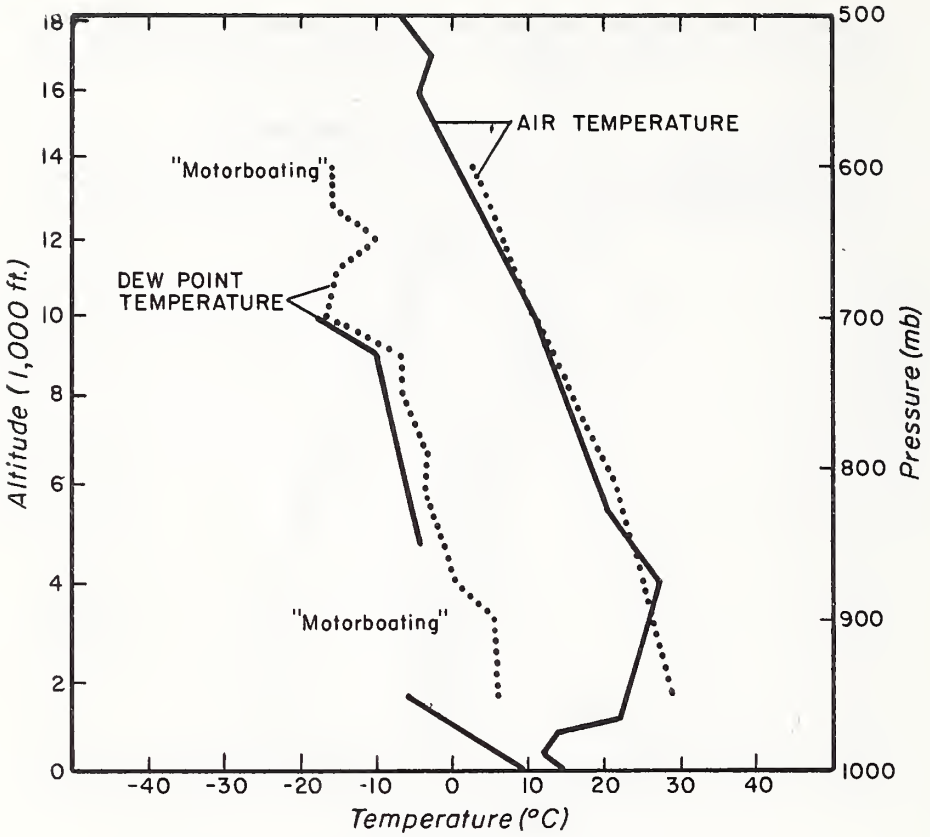

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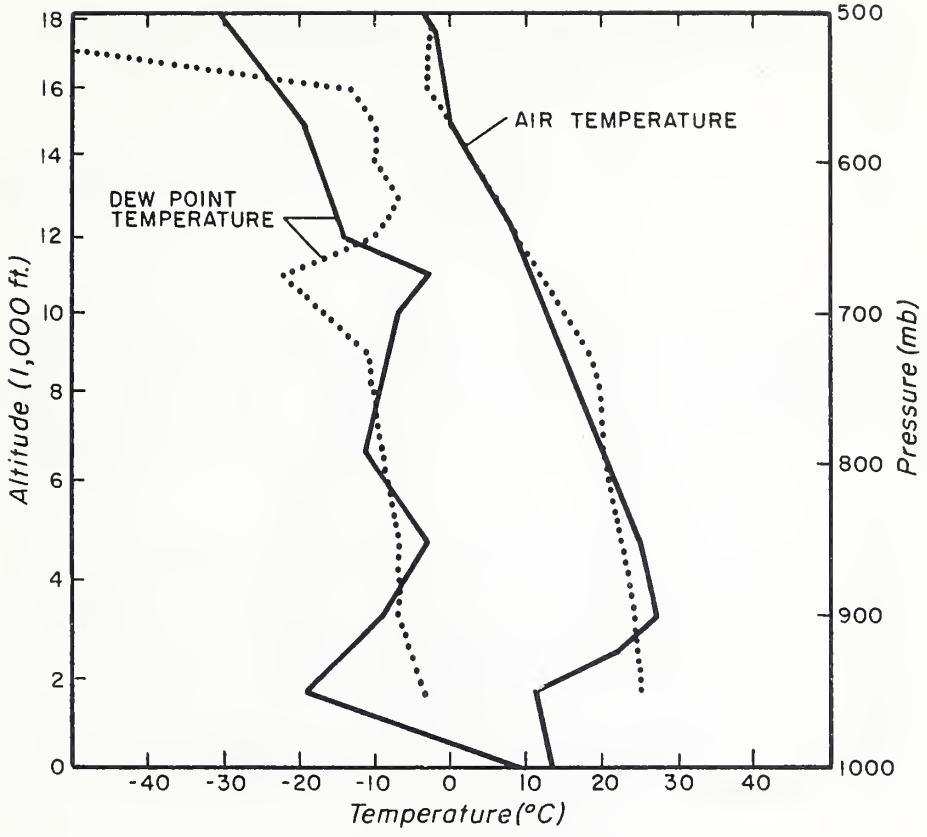
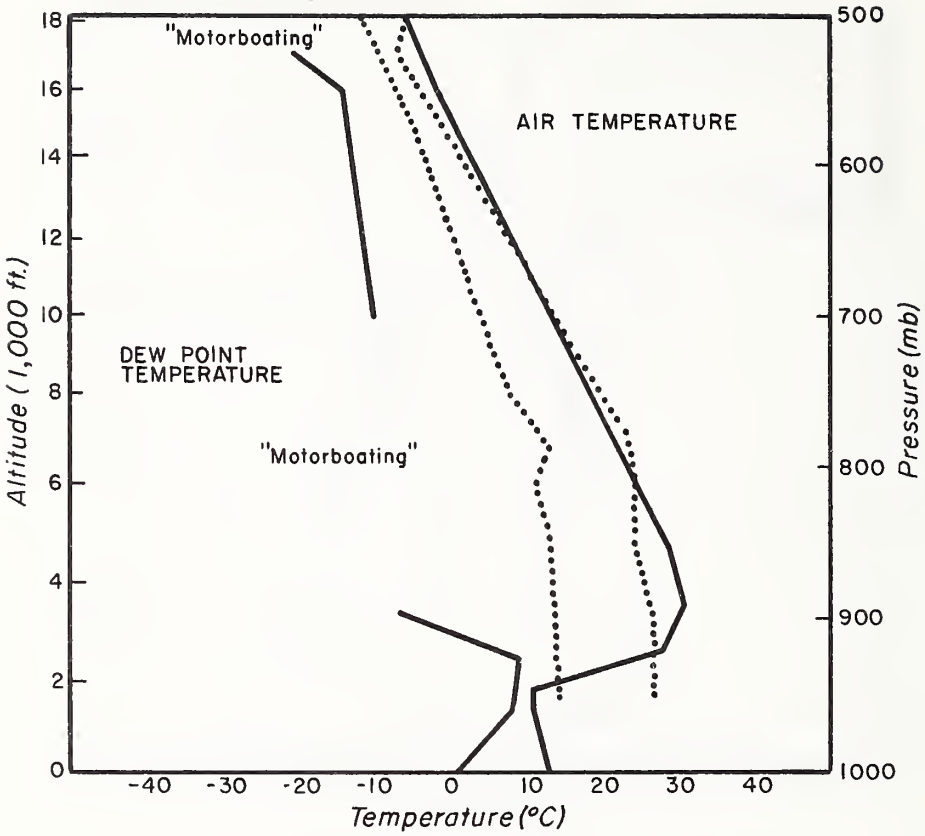


July 21 Upper air soundings



July 22 Upper air soundings

APPENDIX C

Fire Weather-Fire Behavior Forecasts

July 14-22, 1961

0400

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/14.

Weather:

Winds today will be mostly from topography: upslope and upcanyon starting about 0700 on east slopes, 1000 in canyon bottoms and 1100 to 1200 on west slopes. Maximum temperatures today about 105 in canyon bottoms and 95 to 100 on ridges. Minimum humidities around 13 percent all levels.

Fire Behavior:

Fire will pick up early, all areas except the immediate river bottom should burn well by 0900. Winds will be gusty and turbulent by noon particularly on the north side of Rodgers Ridge and about 1/4 to 1/3 of the way up the slopes above the Kings River where winds will shift from upcanyon to upslope. Stability should not be a problem today unless we get hit with a thunderstorm (possible but very unlikely). There will be plenty of short distance spotting, but long distance spotting (1/2 mile or more) is unlikely.

Safety:

This is a hot fire in flashy fuels and can move in a hurry anytime after 0900. Lee slopes will be critical and so will areas where upcanyon winds change to upslope. Watch the smoke for indicators of this.

1530

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/14.

Weather:

Gusty winds should die down around dark except for continued upcanyon winds in canyon bottoms until 9 or 10 p.m. Humidities will rise very gradually, reaching a maximum of 40 to 45 percent by 1 a.m. at the 5,000 ft. level, 35 to 40 percent by 3 a.m. at the 2,500 ft. level, and 40 to 45 percent by 6 a.m. at the 1,500 ft. level in canyon bottoms.

Fire Behavior:

Spread in heavy fuels should slow down markedly by 9 p.m. with little or no spread after 1 or 2 a.m. Fires in grass and light brush will burn well until at least 3 a.m. and may continue to spread all night.

Safety:

Flareups in light brush are possible at any time tonight. Play it safe.

0330

Fire Weather and Fire Behavior Forecasts: Basin Fire.
Forecast for day shift 7/15.

Weather:

A little hotter, a little drier, a little windier, a little less stable. Except for SW winds 5-10 m.p.h. over ridge crests, winds again will be upcanyon, upslope, and gusty. Up-canyon winds will begin earlier, about 0900, will increase to 8-10 m.p.h. by noon or shortly before, and reach 15-20 m.p.h. with higher gusts by 1600 to 1700. Up-slope winds will begin around 1000 and will be 10 m.p.h. or less except when helped along by fire. Maximum temperatures today 105 to 108° at about 1600. Minimum humidities around 15 percent between noon and 1500 dropping to 7-10 percent from 1500 to 1800 or 1900.

Fire Behavior:

All these "little bits" add up to a lot. Yesterday's burning index was 19, fire load index 24. If today's forecast pans out we will have a BI of 40 and a load index of 68. Fire will pick up earlier, burn hotter, spot further, and heads will not have the tendency to run out of gas noted yesterday. Conditions are less stable than yesterday, and there is real potential for firestorms, particularly in canyon bottoms if winds are as gusty as yesterday.

Safety:

Definitely a "one foot in the burn day," particularly in heavy fuels. Avoid building concentrations of heat. Firing out after 1000 should be attempted strictly as a last resort emergency measure.

0815

Special Fire Weather Warning. Basin Fire. 7/15.

The stability picture on this fire does not look good. By 0930 this morning all crews on the fire must have positive escape routes in mind at all times.

The southwest winds forecast this morning did not pan out. Winds are light and variable below 7,000 ft. and north to northwest up to 25 m.p.h., above 7,000 ft.

1500

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/15.

Weather:

About the same as last night with one important exception. Humidities will not rise much at elevations above 3,500 to 4,000 ft. and maximum humidities on ridgetops tonight will be 14 to 20 percent. Otherwise, winds will die down around dark and humidities in canyons and lower slopes will reach a maximum of 38 to 42 percent by sunrise.

Fire Behavior:

Fire will continue to spread all night in areas above 4,000 ft. Spread in heavy fuels on lower slopes will slow down before midnight. Fire will continue to spread in grass and light brush all night in all areas.

Safety:

Flareups are possible all night. Be alert.

0330

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/16.

Weather:

Not quite so hot, but otherwise about the same as yesterday's forecast. Maximum temperature 103° at about 1600. Minimum humidities 12 to 15 percent by noon dropping to near 10 percent from 1500 to 1800. Up-slope winds same as yesterday, 10 m.p.h. or less. Wind across ridges NW 10 to 15 m.p.h. by noon, swinging to west 10 to 15 m.p.h. in afternoon. Stronger canyon winds than yesterday. Up-canyon winds starting around 9 to 10 a.m., increasing to 8 to 10 m.p.h. by noon and 10 to 15 m.p.h. with stronger gusts by 1400 to 1600. There is some moisture at 13,000 to 17,000 ft. and some cumulus buildup over the fire area is possible.

Fire Behavior:

If canyon winds develop as expected, burning conditions will be extreme. The air remains quite unstable and the potential for big runs and erratic fire behavior remains high.

Safety:

Don't get overconfident just because we were lucky yesterday. This fire can still run fast and hard. Keep safety routes in mind and watch for possible cumulus buildups over fire area.

1600

Fire weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/16.

Weather:

Identical to last night. Maximum humidities 45 percent in canyons and 25 to 35 percent on upper slopes and where smoke hangs in all night. Down-slope winds light and late on account of smoke.

Fire Behavior:

Hard to forecast without knowing just where the fire is, but in general: fire should stop booming by 9 to 10 p.m. but may make local crowning runs until 2 a.m. or maybe all night. Strong down-canyon winds should not develop tonight and the lower areas should look pretty cool by morning.

Safety:

If you won't be careful after today, you're pretty hard to convince.

Outlook for tomorrow: No better than today, possibly worse.

0330

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift 7/17.

Weather:

Little change from yesterday except for slightly cooler and slightly more unstable with greater chance of cumulus and some chance of thunderstorms. Maximum temperatures 95 to 100 below 4,000 ft., except 100 to 105 in canyon bottoms. Maximum temperatures above 4,000 ft. 90 to 95. Minimum relative humidity 10 to 15 percent at all levels to 7,000 ft. Winds across ridges about the same or a little stronger than yesterday, 12 to 15 m.p.h., westerly in the morning and early afternoon, moving to southwest by 1400 to 1500. Slope and canyon winds starting later today, possibly not until noon, but again reaching 12 to 15 m.p.h. by 1500.

Fire Behavior:

All the potential for the same thing as yesterday with the possible added complication of thunderheads. Fire in the timber should be held down by smoke until 1000 or so, but hot burning conditions by 1300. Fire should move out to the northeast unless we get thunderheads over the area in which case it could move in any direction.

Safety:

Watch yourself, particularly in heavy timber with restricted mobility. Be alert for cumulus, and if you hear thunder near the fire area be <u>sure</u> you have a good safe hole to crawl into.

1600

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/17.

Weather:

No change. Maximum humidities 45 percent in canyon bottoms, 35 percent on ridges and all areas above 4,500 ft. Down-slope winds light and late on account of smoke.

Fire Behavior:

Runs should start slowing down by 2100 and the fire should lay pretty quiet after midnight.

Safety:

Normal safety precautions should be observed.

7/17/61 2200

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/18.

Weather:

I think the record's stuck. Continued unstable with 25 percent chance of thunderstorms. Continued hot; 105 to 110 below 2,000 ft., 95 to 100 at 4,000 ft., around 80 at 8,000 ft. Continued dry; minimum humidities near 10 percent at all elevations. Winds continued same as yesterday, northwest 15 m.p.h. over ridges in afternoon.

Fire Behavior:

Continued high blowup potential. For the last four days we have been at the point where an addition of the right amount of heat by one extra hot run can trigger a real firestorm. Saturday we didn't get it. Sunday we did. Yesterday it tried hard but didn't quite make it. Today will be like one of those three. Let's hope it's like Saturday, but let's be prepared for another Sunday.

Safety:

Stay alert, have safety routes in mind, and check that one chance in four of thunderstorms.

1200

Revised Fire Weather Forecast for day shift of 7/18.

Northeast to east winds this afternoon and early evening, 15 to 20 m.p.h. over ridges increasing late afternoon. Otherwise no change in humidity (10 to 15 percent) or stability (very unstable).

1600

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/18.

Weather:

Light east winds over ridges all night tonight. Down-canyon winds starting about 2100 to 2200 and somewhat stronger than last night, up to 10 to 15 m.p.h. in main canyons, 4 to 6 m.p.h. in side canyons. Maximum humidities tonight 35 to 40 percent below 3,000 ft., 25 to 30 percent above 4,500 ft.

Fire Behavior:

Fire will spread well past midnight, probably until 2 to 3 a.m., but no sustained runs are likely.

Safety:

Normal safety precautions should be observed.

7/18/61 2200

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/19.

Weather:

Higher humidities today, particularly at the 4,000 to 6,000 ft. level. Minimum humidities 14 to 16 percent at 2,000 ft., 20 to 25 percent at 4,000 to 6,000 ft. Winds over ridges northwest 10 to 15 m.p.h. Stronger up-canyon winds than yesterday, reaching 15 to 20 m.p.h. around 2 p.m. Continued highly unstable.

Fire Behavior:

Fire should be less active in heavy fuels, but will continue to spread in grass and light brush. Hot runs are possible where topography or winds are favorable.

Safety:

Continued highly unstable. Fire can blow up at any time a big run produces enough heat. Avoid building concentrations of heat by firing out large areas at once.

1600

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/19.

Weather:

Winds same or slightly stronger than last night. Northwest 5 to 10 m.p.h. over ridges, down-canyon and down-slope winds starting between 2100 and 2200 and reaching 4 to 6 m.p.h. on side canyons and exposed slopes, and up to 10 to 15 m.p.h. in main canyons. Maximum humidities 43 to 48 percent all levels.

Fire Behavior:

Fires in light fuels can still spread if exposed to the wind, but this looks more like mop-up weather than anything we've had yet.

Safety:

Normal safety precautions should be observed.

7/19/61 2200

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/20.

Weather:

We have a problem. The extremely dry air that has been holding for the past three days at 9,000 to 12,000 ft. may be starting to lower. If this tendency continues we may get humidities to 10 percent or below by this afternoon. If this dry air does not lower, humidities will be about the same as yesterday, 20 to 25 at 4,000 to 6,000 ft., and 14 to 18 at 2,000 ft. There is no way of telling which way this will break until we get some more measurements later this morning. A special forecast will be issued between 0800 and 0900 today. Either way, winds today will be stronger than yesterday and more from the north. Winds over ridges will be 15 to 20 m.p.h., and up-canyon and up-slope winds will reach 10 to 15 m.p.h. by early afternoon and be quite gusty. Continued highly unstable.

Fire Behavior:

Humidities below 10 percent with stronger winds would be very hard to live with. Wait for special forecast by 0900.

Safety:

Same as above.

0900

Fire Weather and Fire Behavior Forecasts: Basin Fire. Special Forecast for day shift of 7/20.

Dry air from aloft is subsiding and mixing. Minimum humidities today around 10 to 14 percent and continued drying trend through tonight and tomorrow. Winds will be northerly as forecast, but probably no stronger than yesterday, 15 m.p.h. across ridges. Gusty up-slope and up-canyon winds this afternoon.

1600

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/20.

Weather:

Maximum humidities tonight 18 to 21 percent at 1,000 to 4,000 ft. and 22 to 25 percent at 4,000 to 8,000 ft. Maximums will not occur until near dawn and most of the night humidities will be 4 to 6 percent lower than those above. Winds over ridges will be north to northwest 10 to 15 m.p.h. all night except for a short lull about sunrise. Down-slope and down-canyon winds starting about 2200 and stronger than last night: 5 to 10 m.p.h. on slopes and 10 to 15 m.p.h. in main canyons. Air aloft is more stable.

Fire Behavior:

About the same as an average summer DAY. Fire will burn well all night in all fuels and hot runs may occur at any time in light brush. Topography and winds will be conflicting and runs will be erratic.

Safety:

It is doubly important to have preplanned safety routes after dark. Do not get in front of fire in brush without good safety spot or carrying your fire with you. The direction of runs will be unusually hard to judge tonight.

7/20/61 2000

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/21.

Weather:

Things are in a state of flux. There are four possibilities for tomorrow, each about equally likely.

1) Continued subsidence and very low humidities (yesterday's minimum was 4 percent).
2) Gradual return to Wednesday's weather (northwest to west winds 10 to 15 m.p.h. and humidities 20 to 25 percent).
3) Marine air moving into fire area (wind switching to west with some gustiness for an hour or so and humidities rising to 35 to 40 percent in the late afternoon).
4) A cold front passing over the area. This would give very gusty and turbulent winds for at least an hour and no increase in humidity today.

Only one of these is worse than yesterday, and I will get a special forecast out just as soon as things settle down.

Fire Behavior:

Obviously, I just don't know.

Safety:

If past history on this fire is any guide, be prepared for the worst.

7/21/61 0900

Fire Weather and Fire Behavior Forecasts: Basin Fire. Special forecast for day shift of 7/21.

Weather:

Continued very low humidities. Minimum humidities today 7 to 11 percent at 2,000 ft. and 9 to 13 percent at 4,000 to 8,000 ft. Light easterly winds 3 to 8 m.p.h. across ridges. Up-canyon winds later than yesterday, about 10 m.p.h. in main canyons and 3 to 8 m.p.h. on slopes. Air aloft is very stable and area will be smoked in off and on all day.

Fire Behavior:

Continuing dry and hot burning weather. Hot runs likely wherever fuels permit. No blowups like Sunday, but long distance spotting of one half mile or more is quite possible.

Safety:

Watch for spots.

1600

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/21.

Weather:

A little more like "normal." Humidities rising after about 2200 reaching a maximum of 37 to 42 at the 2,000 ft. level and 28 to 33 at the 4,000 to 6,000 ft. level. Winds across ridges very light tonight, below 5 m.p.h. and from the east. Down-slope and down-canyon winds also below 5 m.p.h. except a little stronger in main drainages.

Fire Behavior:

No spread tonight in heavy fuels, and not so much as last night in light fuels.

Safety:

Normal safety precautions should be observed.

7/21/61 2200

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for day shift of 7/22.

Weather:

Warmer today. Maximum temperatures about 103 at 2,000 ft. and 95 to 98 at 4,000 to 6,000 ft. Minimum humidities 16 to 18 percent at all elevations. Light and variable winds over ridges but up-canyon and up-slope winds about 12 m.p.h. in the afternoon. Air aloft more unstable than the last two days, but still not too bad.

Fire Behavior:

Average bad burning weather.

Safety:

Normal safety precautions. Don't get above fire in light fuels.

Fire Weather and Fire Behavior Forecasts: Basin Fire. Forecast for night shift of 7/22.

Weather:

Humidity will be higher tonight than last night rising after 2,000 hours to a maximum of 60 to 65 percent at all levels by sunrise. Wind over ridges will be light and variable, mostly from east or southeast. Down-slope winds can be expected in canyons and on slopes.

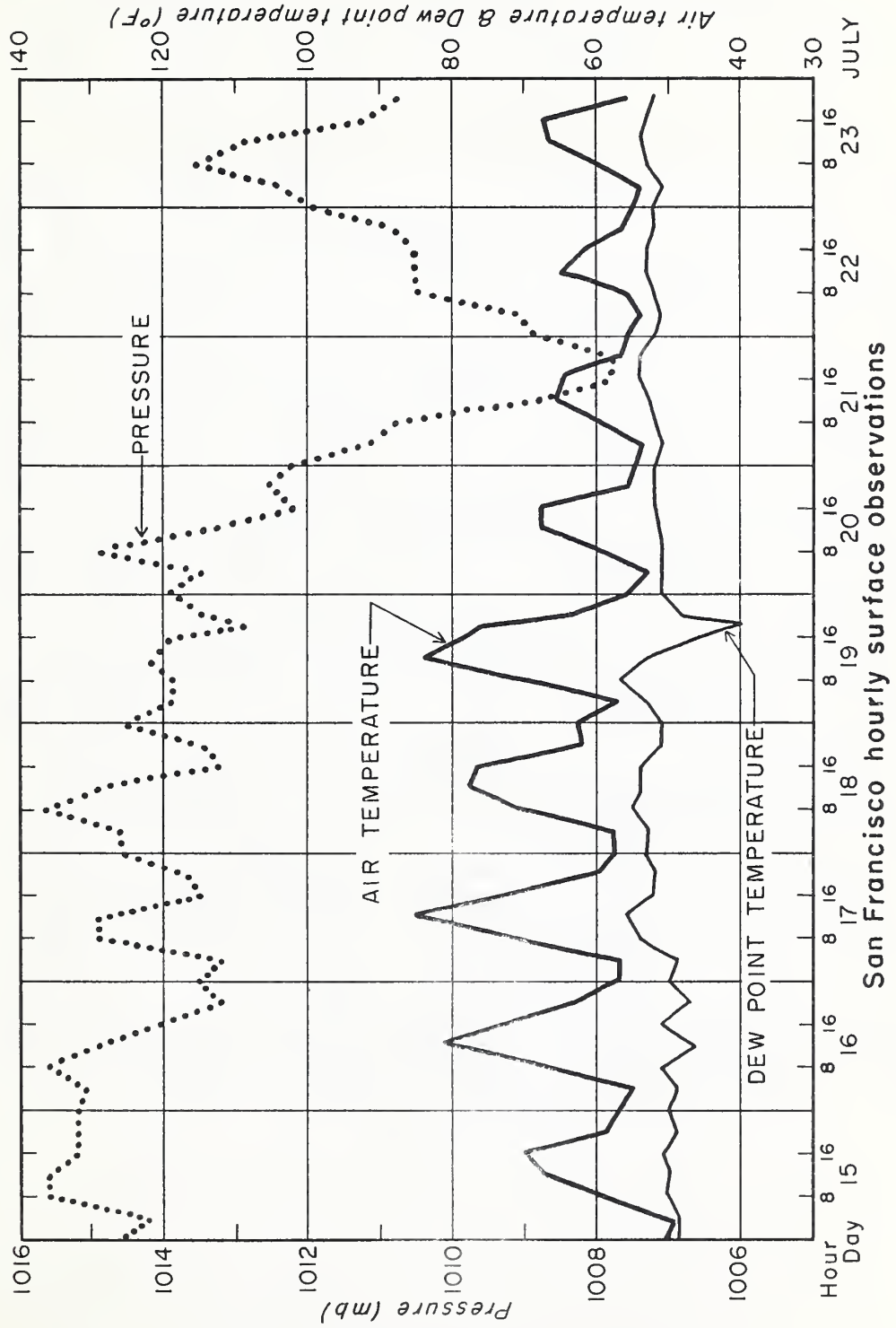
Fire Behavior:

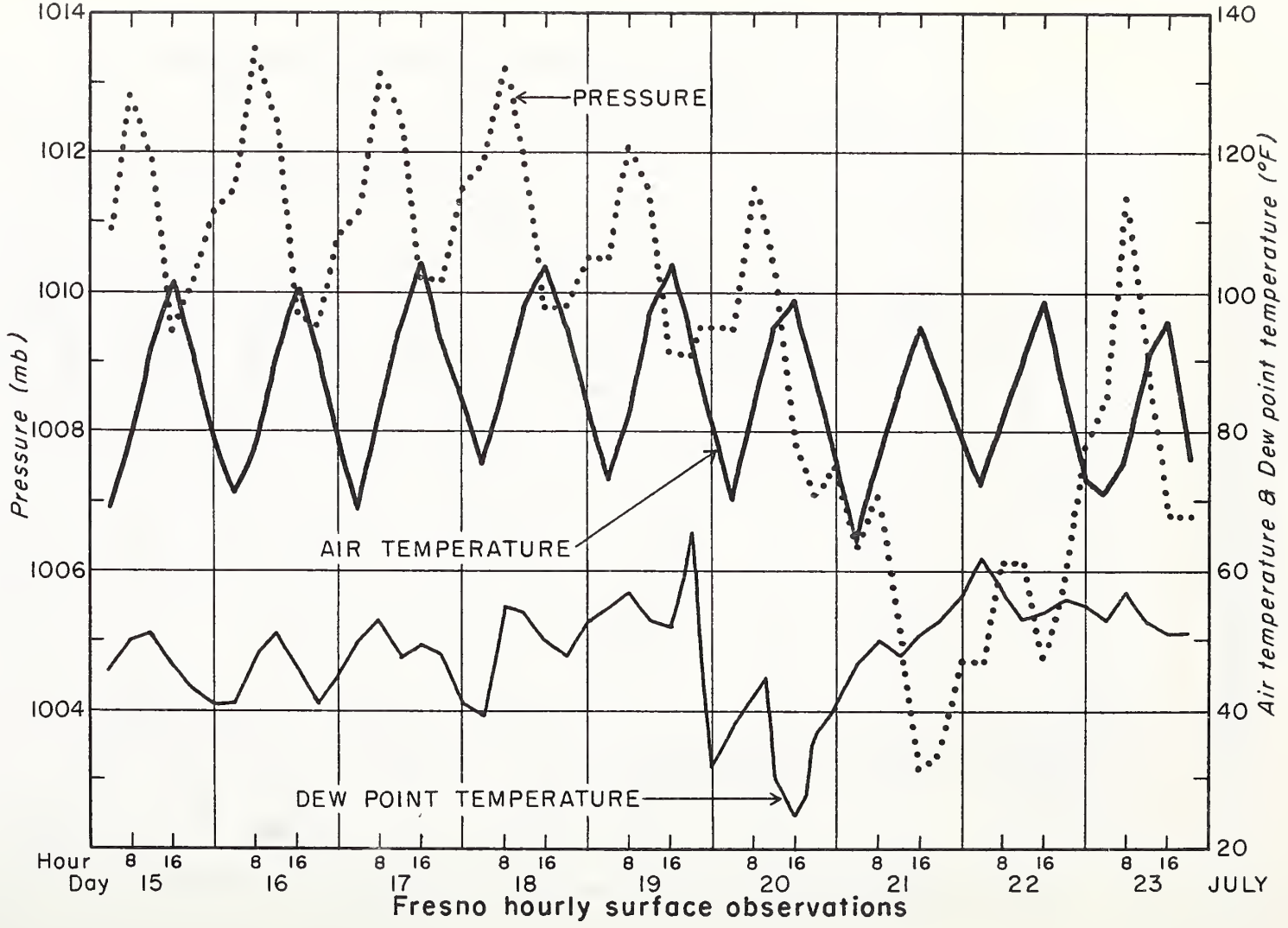
Fire will burn less intensely tonight than any night so far. Due to the extremely dry fuels fire will continue to spread where dead fuel is available until early in the morning. This will be a good night for mopup.

NOTE: Watch for an increase in fire activity about 1730 to 1830 tonight. The increase will last about an hour.

APPENDIX D

Hourly Surface Observations
San Francisco, Fresno, Fire Area, Bishop
July 15-23, 1961

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Air temperature & Dew point temperature (°F)
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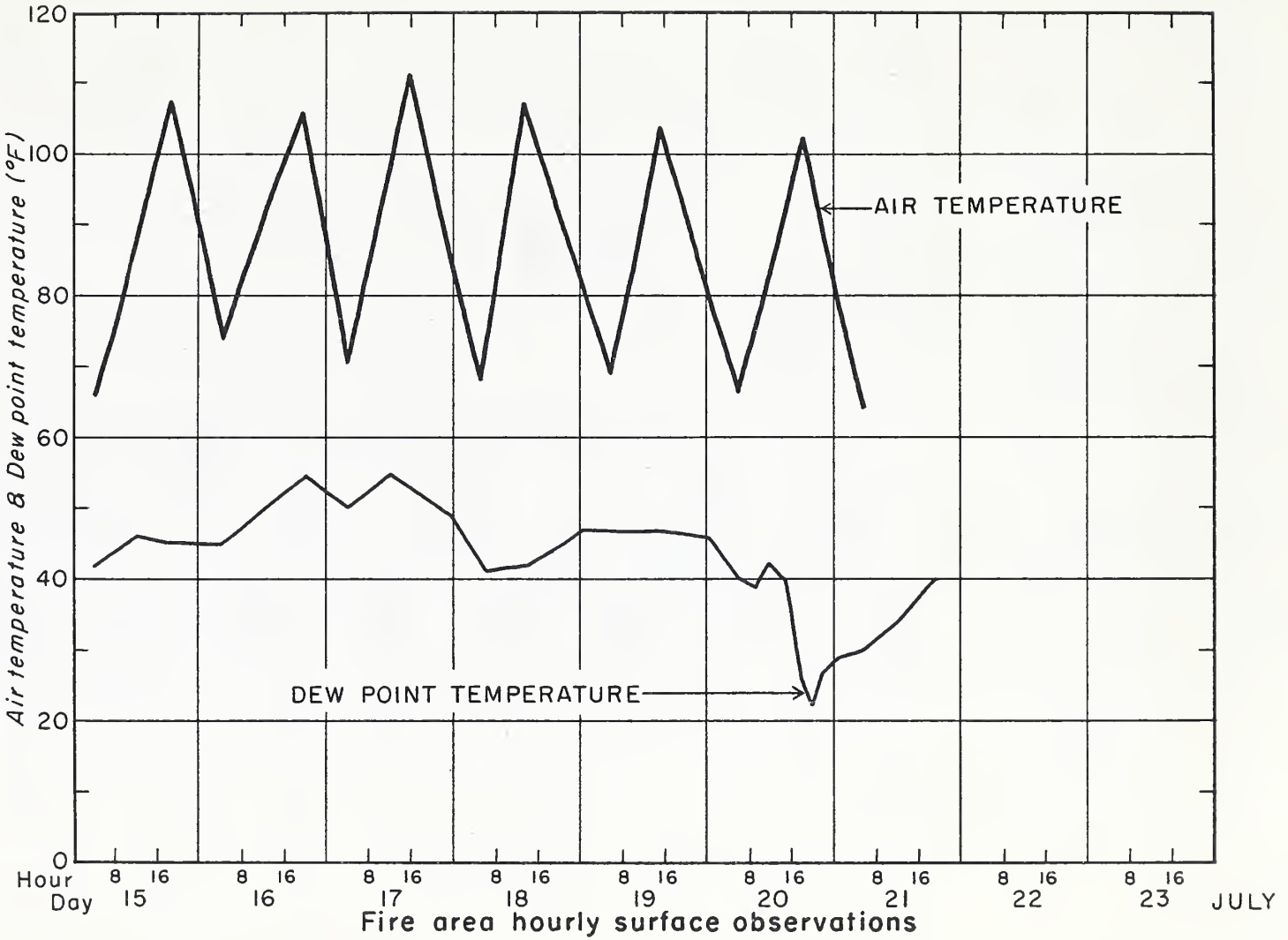
Fresno hourly surface observations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Air temperature & Dew point temperature (°F)
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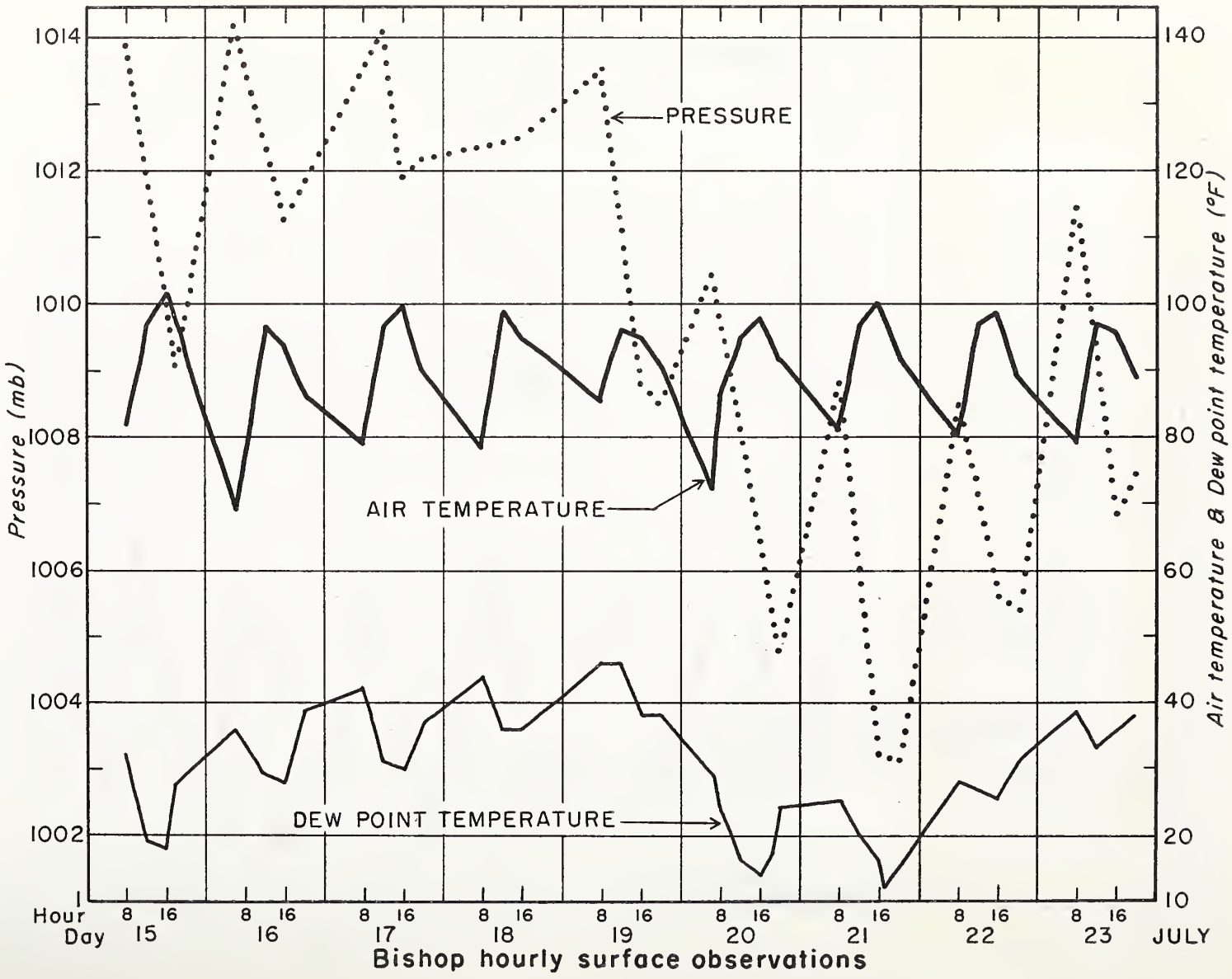
Day 15 16 17 18 19 20 21 22 23 JULY
Fire area hourly surface observations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Pressure (mb)
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Air temperature & Dew point temperature (°F)
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Day 15 16 17 18 19 20 21 22 23 JULY
Bishop hourly surface observations

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