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FIRE CONTROL NOTES

A PERIODICAL DEVOTED TO THE TECHNIQUE OF FOREST FIRE CONTROL

FOREST SERVICE • U. S. DEPARTMENT OF AGRICULTURE

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Volume 5 Number 1

FIRE CONTROL NOTES

A Quarterly Periodical Devoted to the TECHNIQUE OF FIRE CONTROL

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The value of this publication will be determined by what Forest Service officers, State forestry workers, and private operators contribute out of their experience and research. The types of articles and notes that will be published will deal with fire research or fire control management: theory, relationships, prevention, equipment, detection, communication, transportation, cooperation, planning, organization, personnel management, training, fire-fighting methods of reporting, and statistical systems. Space limitations require that articles be kept as brief as the nature of the subject matter will permit.

Address DIVISION OF FIRE CONTROL
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A PLANNING BASIS FOR ADEQUATE FIRE CONTROL ON THE SOUTHERN CALIFORNIA NATIONAL FORESTS

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Introduction

This paper represents a method of approach to the fire problem on an area where severity of fires and resulting damage make its solution of paramount importance. The authors define the problem, analyze its elements, and present specifications for reduction of losses to an endurable rate, both on individual watersheds and on the area as a whole. They provide a basis for future program planning in southern California.

As is indicated, the more advanced appreciation of the need for fire control in southern California has led to an intensive system of fire-prevention measures. Similar measures will steadily become appropriate in other regions. The dwindling supply of water and the increasing need for it in southern California suggest what may be expected in many other localities as human use rises to exceed the readily available supply. Experiences related show how forest fires affect the management of water supplies under such conditions.

Believers in the practicability of sustained fire control, particularly the managers of the more recently established national forests, will note the long continued downward trend of area lost despite the rapid accumulation of inflammable material and an increase in number of fires as human use on some of the oldest national forests has become more intense.

The system used in this article for classification of land into "significant fire control zones" is in sharp conflict with the system of classification by fuel types used in most other regions. Understanding of the problem of classifying areas for fire-control purposes may be increased by consideration of the method employed.

As values at stake and intensity of fire-control increase on other forested areas of the United States, more detailed methods of analyzing occurrence and size of fires will steadily become appropriate. Guides of general applicability may be found in the methods used in this instance. The analysis of relationships between size, control time, and percent of total area burned is particularly suggestive for the development of methodology in such studies.

Recognition and handling of bad fire days is a problem with which fire-control managers and analysts have struggled everywhere—without too much success. The methods of analysis used by the authors to get at the significant facts regarding bad fire days may be applied in all other fire-control units.

With the advantage of the new coded statistical reports for the Nation's forest fires, it will be relatively easy on all national forests to bring out the highly important and highly significant facts about trends in speed and strength of attack by the methods of analysis developed by the authors. This is true also, with respect to trends in development of roads and other improvements.

It happens that the use of mechanical equipment, particularly tankers, tractor-trailbuilders and specialized backfiring equipment, has advanced more rapidly in California than elsewhere. This is not because such mechanical aids are important only in California. The discussion and analyses of this subject should promote the recognition of the practical value of such aids under a wide range of conditions.

Failure to make a serious attempt "to determine a rational and demonstrable objective" in fire control is by no means confined to southern California. The methods used by the authors represent a serious attempt and should provide a new level of development on which to base further advances in thought on this point in all other regions as well as in California.

The analysis of the effect of high wind velocities is pertinent evidence bearing on the problem of moisture-wind ratios now under special consideration in all regions.

The analysis of the risk problem, leading to important conclusions about fires from miscellaneous causes is significant generally. As other national forests attain the success reached in the control of the more common causes in some portions of southern California, the same exasperating problem of miscellaneous fires will arise. Analysis and experience in southern California should prepare other regions for more effective treatment of these elusive causes as they rise to relative importance.

Development of Need for Fire Protection

The southern California coastal plain, in 1890, had a population of 217,424 compared to an estimated 3,687,000 in 1940. Irrigation agriculture, the present key industry, was practiced on 153,823 acres, compared to 741,421 acres today. The annual value of agricultural crops was $24,360,070, now $217,608,770. Irrigation was done by direct diversion from streams, by tapping the centuries old subterranean accumulation of water by artesian or other shallow wells. Not even a beginning had been made in the present capital investment of $226,091,128 in major structures for water conservation and flood control. The capital investment in pumping equipment which has multiplied as water tables were lowered had barely begun.

The entire community, with its total assessed valuation of $319,617,081 compared to $3,437,310,351 today, went along on local supplies of water. The importation of water from distant sources, now representing a capital investment of $252,500,000, was unthought of.

But in this relatively simple, self-contained community, the difficult task of protecting the mountain cover quickly came to the fore. Fires were commonplace, severe, and large. Use of the mountains for range and for recreation, use of fire for land clearing, and occasional lightning storms all contributed to the total. Disastrous floods were recognized by the more farseeing leaders as originating from the mountain lands denuded by the frequent fires. The low summer stages of streams, at the very time when water was most needed for irrigation, could, it was believed, be measurably raised by improving the density of cover on the mountains, that is, by protecting it against fire and against the uncontrolled uses that caused fires. The leaders saw, in protection of the mountains, at least a partial solution of the water conservation and flood-control problems of the day. And while perhaps no one anticipated the spectacular increase in population, irrigation agriculture, and intensified need for water, it was recognized that growth was inevitable.

So, as early as 1899 the leaders banded together to further a program of management and protection of the mountains, as an essential step in protection and development of the growing coastal plain community. This movement affiliated itself with other groups scattered over the Nation seeking to curb the reckless wastage of timber on the public domain. Both groups sought the solution in Federal reservation and management. The southern California group was primarily responsible for inclusion, in basic legislation leading to establishment of the present national forest system, of the phrases "insuring favorable conditions of water flows" as a purpose coordinate with "preservation of timber for the use and necessities of citizens of the United States."

Action by the President was prompt on both declared purposes, for almost simultaneously the Yellowstone Timber Reserve and the San Gabriel Forest Reserve were set aside by Executive order. The initial battle had been won. Further reservations were progressively made: San Bernardino Reserve and Trabuco Canyon Reserve, 1893; San Jacinto 1897; Pine Mountain and Zuca Lake Reserve, 1898, and Santa Ynez 1899,, are now part of the four national forests of Southern California.

But the reservation, it was quickly apparent, was not a solution but a mere beginning. Still, there was a change. The thinly spread handful of forest reserve officials, when there was a fire in the mountains, rounded up crews from among mountain men and from the cities and camped on the fires for days or weeks until they were put out—sometimes by the fall rains. Some gradual, but growing progress was made in obtaining care with fire. The mere presence of an effort to curb fire losses, coupled with the missionary zeal of the leaders, led to an increasing interest and participation in the problems by people who had a real, but unrecognized stake in them.

This growing interest found expression in tangible ways. The Tri-Counties Reforestation Committee, the Angeles Forest Protective Association, and the Southern California Conservation Association were formed and not only preached and fought for better protection, but contributed men and money to strengthen the pitifully weak Federal efforts. Mutual water companies contributed to the job. The local courts began to impose fines for causing fires. The Federal Government, for its part, began through the Bureau of Forestry, efforts to reclothe the mountains with timber. Forest nurseries sprang up at hopefully optimistic spots.

By 1905 when the Forest Service took over management of the national forests, progress was well under way. But several factors speeded it up: More aggressive Federal officers; constantly and rapidly expanding growth of the community, and consequent increased need for use of water and protection against floods; expanding public interest and participation; enthusiastic recognition that the southern California area was destined for great things, and that water was the key to growth; local supplies of water were limited, and it was expensive to import.

So more and more water user groups contributed to the job of protection. Counties came in on cooperation with the Forest Service. Led by Los Angeles County, several county forestry organizations were formed to protect watershed lands outside the national forests. Additional public domain areas were set aside. A trail system was built. Firebreaks were constructed, and the spectacular increase in use of the mountains for recreation got under way

Up until 1916 the venture had received no severe test, but in that year heavy, protracted rains in January resulted in severe floods and high damage. Evidently, protection of mountain cover, which had been rather successful, was not a complete answer to the flood problem The Los Angeles County Flood Control District was formed and built an extensive series of flood-control reservoirs. Their vulnerability to silting in and the similar situation of water conservation reservoirs led to an increased interest in and demand for better mountain cover protection.

Perhaps the relative success in protecting mountain cover from 1905–18 was due to the fact that it was recovering from earlier burns, and was thin enough so that fires were relatively easy to control. Whatever the reason, two disastrous fires in 1919 exploded any existing complacent belief that fire organization had caught up with the problem. The San Gabriel and Ravenna fires, totaling 151,000 acres, burned on some of the most valuable watersheds.

In rapid succession there followed other major fires: Kelly Canyon (106,300 acres, 1922, Los Padres); Arrowhead Springs (20,000 acres, 1922, San Bernardino); Oso (68,300 acres, 1923, Los Padres), etc. The culminating blow was the San Gabriel (49,200 acres, 1924, Angeles). Keen dissatisfaction with the whole fire-control program focused in an insistent demand for a far more active and aggressive program.

The special Board of Fire Review of 1924, particpated in by local leaders, led to local sponsorship of the southern California improvement bill, setting up a program of fire-control improvements, financed half by local contributions and half by Federal funds. Its prompt enactment was due to the energy with which its sponsors insisted on a program more nearly adequate to do the fire job. For by this date, heavy public investment in water importation; in flood control and water conservation projects; the tremendous population growth rate; the obvious need to conserve and use every drop of water; the many newly built urban and residential areas subject to flood damage; all combined to make the imperative need for better protection of the mountains a project of major public interest.

With the new improvement program under way, and with prompt cure of some evident weaknesses brought to light by the 1924 disaster, public opinion quickly gravitated toward a renewed feeling of assurance and safety. A short respite—for in 1928 major fires on each of the four national forests burned a total of 158,000 acres inside the boundaries. To be sure, the largest individual loss of 29,540 acres within the protection boundary, was far smaller than the major burns of former years, and was only a little over half the size of the San Gabriel of 4 years earlier. But the total loss was too great to endure, and renewed demand for intensified effort developed. Additional Federal funds became available, county participation increased, the trained suppression crew was developed, tank trucks became a powerful element in suppression, the slow building up of road and trail systems began to show effect in more rapid, heavier, and diversified attack. Again came a major surge ahead.

The Matilija fire (218,000 acres, 1932, Los Padres) the largest fire in the long record of southern California fire control, served to emphasize that the program of fire road construction was sound. For the history of this fire was that of almost complete inaccessibility, and consequent inability to move men and supplies rapidly and in quantity, to attack when and where needed, and lack of already existing backfiring lines, from which quick attack could be safely done. Opinion, both professional and civilian, generally held that rapid expansion of transport systems—breaking down the barrier of inaccessibility—held the key to eventual solving of the fire problem. There was no decrease in the belief and faith that it could be conquered.

The advent of the C. C. C. gave a quickly grasped opportunity to place 54 camps on southern California fire-control improvements in Federal, State, and county areas, and to expand greatly the system of organized crew attack. The tempo of progress speeded up.

During the years since organized efforts at fire control began, there had been no sharp, major demonstration of the vital need for the highest possible level of protection. The La Crescenta flood of January 1934, originating on the Pickens Canyon burn (September 1933, 4,831 acres) resulted in "more than 40 dead" and damage to property of 5 to 5½ million dollars. It became clear that destructible downstream values had grown so great that the occasional coincidence of a burn of even a few thousand acres and heavy protracted rain would lead to major disasters.

Public effort promptly moved to develop a comprehensive downstream flood-control program, in the hands of the Army engineers. Temporarily, this tended to divert emphasis from mountain fire protection, and this trend was accentuated by the major flood of February–March 1938, which set a new high in flood losses.

But as it became evident that the cost of the major works in the downstream program would be enormous, that only part of the whole area would likely be treated, that water conservation in the long run perhaps transcended flood control in importance, opinion in the community shortly came back to emphasis on the fire-control program.

The reawakened interest took two principal directions. First, insistence in the paramount place of fire protection in the upstream flood-control program, established by act of Congress in 1936, and second the development and sponsoring of a new program for what is now regarded as adequate fire control, covering all watershed lands in southern California and taking account of all that has been learned of effective means to prevent and control fires.

It is evident that public opinion now holds:

1. Protection of natural cover alone cannot wholly solve water conservation and flood-control problems, but remains vital.
2. Both upsteam and downstream flood-control programs are needed.
3. Fullest conservation of local water supplies has not diminished in importance, despite large-scale importation of water.
4. Disastrous results of heavy rain on burns of even a few thousand acres show need for higher, rather than lower, standards for mountain protection.
5. The southern California community of 1940, like that of 1890, finds irrigation agriculture a principal base for its economy.
6. This economy rests on full use of local water supplies, which must be protected.

Development of Fire Control

INITIAL STEPS

Prior to 1905, fire-control effort developed slowly. A thinly spread net of fire wardens and rangers, few trails to give access, slow attack, small crews, generally large fires, and long suppression campaigns were usual.

From 1905 on, a rather steady if slow, building up went on. More and better trained men, more trails, and some roads, larger crews, and autos and trucks were used to strengthen and speed up both initial attack and control.

PERIOD OF STUDY

The two major fires of 1919 were the signal for the end of the period of slow development. In the same year, major fires in other national forest regions compelled a fresh and Nation-wide look at forest-fire control on the national forests. The Mather Field Conference in 1921, which undertook this job, resulted, among other things, in recognizing that detailed information on fires was needed, rather than the sketchy outline then followed. So, beginning with 1922, such detailed reports have been made on all national forest fires.

In this study, the principal source of the data is the reports on individual fires. In order to have complete and comparable reports to study, those for 1922–39 were used.

AREA OF STUDY

All of the four national forests in southern California are included in this study, except the Monterey Division of Los Padres National Forest which was omitted, since the unit is geographically isolated, and the fire types and the nature of the fire problems are a mixture of northern and southern California characteristics.

The four forests include an area of 3,716,000 acres of which Los Padres contains 1,655,600, Angeles 690,500, San Bernardino 804,000, and Cleveland 566,000 acres. This area has remained constant during the period of study, except for the not particularly significant elimination of 68,160 acres from the Angeles National Forest in 1925, when the San Bernardino National Forest was established as a separate unit.

Administrative boundaries of all forests have been changed during the period of study, but since the study is concerned principally with the whole area, rather than its several parts, this fact has no bearing of consequence on the methods of study or the conclusions.

METHODS OF STUDY

Card records, abstracted from the reports made by field men throughout the years, giving all available statistics on each individual fire, were used. These covered 3,035 fires, both lightning and man-caused, for the period 1922 through 1939, for which reasonably comparable data were available.

The figures submitted undoubtedly were not mathematically perfect, but in general their completeness and correctness obviously are of a higher quality than those used in the northern California study. This was due not only to greater care in report preparation, but also to the fact that smaller numbers of cases were involved, which permitted more time for each report's preparation. However, absolute accuracy in detail of individual figures is not essential since general trends were being studied, and previous analyses prove that reasonable compensation of errors is to be expected.

Obviously incorrect data were discarded. In many parts of the study the available data were used on all fires reported upon within the national-forest protection boundaries, since action such as initial attack was generally quite uniform. In the consideration of areas burned by fires over 40 acres in size only that area covered within the actual national-forest boundaries was included. This was done primarily because the responsibilities for protection of the outside areas have varied within the period on account of national-forest boundary changes.

The forest reports do not include data on all fires in this outside zone for which more than one protection agency is responsible Hence for burned area studies, the area within national-forest boundaries was chosen as the area upon which complete fire history was known.

The data were assembled in various ways to develop the phases of the study with segregation made by periods and zones of inflammability, since initial tentative analysis showed there were logical differences that justified such an approach.

Each fire used in the present study was classified as to location of origin by reference to large scale inflammability zone maps. In addition, all fires over 40 acres had the burned area broken down according to the zones the fire burned in. One of the first steps in the present study was to verify the existence of real differences between zones from a fire-control standpoint. The integrity of zones was therefore maintained throughout many phases of the present study.

SELECTION OF ELAPSED TIME INTERVAL

Since a primary purpose of this report is to determine the speed with which the attacking force should reach the fire, it appears proper if possible to consider and study only those factors which are of a definite character and related to this subject, if a set of factors with this quality is available with sufficient completeness for the purpose desired.

The factors available for study on this subject are: (1) Time of origin, (2) time of discovery, (3) size on discovery, (4) elapsed time from discovery to arrival of crew, (5) size when reached. Of these, time of discovery, elapsed time from discovery to arrival, and size when reached are the three factors which are definitely measurable and are not weakened to any appreciable extent by the element of estimation which is essential in connection with observations on time of origin and size on discovery.

It should be noted here that the elapsed discovery time in southern California is in general considered relatively shorter than in northern California, because of the more universal use of the limited areas subject to travel in the south, which results in the forest users contributing materially as a primary detection agency. Discovery of the fire is hastened also because of the characteristics of the initial fire in the south, which very quickly makes its presence known by its initial rate of spread and associated smoke column.

Since this study does not pretend to cover the field of detection planning and is interested chiefly in speed of attack, it appears perfectly logical and permissible to limit the study to the three definitely tangible factors mentioned. This study therefore is based on reported elapsed time data concerned with discovery of the fire and arrival of the crew, rather than on the elapsed time from estimated origin to arrival.

PERFORMANCE RECORD BY YEARS

During the period of study the loss in individual years inside national-forest boundaries has ranged (table 1) from 222,208 acres in 1932 (of which 218,000 is represented by the Matilija fire, Los Padres National Forest) to 2,665 acres in 1930. These correspond to 6.0 percent and 0.1 percent, respectively, of the total protected area within the national-forest boundaries. The total loss for the 18-year period was 1,059,591 acres, an average of 58,866 acres a year or nearly 1.6 percent of the above protected area.

Percentage of C, D, and E fires (that is, those 10 acres and over in area), a useful index of performance, has varied from 52 percent in 1923 to 7 percent in 1935. The total number of fires (both man-caused and lightning) has varied from 115 fires in 1924 to 261 in 1938. The tendency to increase from the earlier to the later years of the period is evident.

TABLE 1.—*The fire history of southern California national forests. Number of reportable fires fought by the Forest Service and area burned within the national forest, by years*

Year	Number of fires	Area burned within national forest by C, D, and E fires	Portion of protected area burned	Year	Number of fires	Area burned within national forest by C, D, and E fires	Portion of protected area burned
		Acres	*Percent*			*Acres*	*Percent*
1922	140	177,853	4.8	1931	174	9,829	0.3
1923	160	118,248	3.2	1932	150	222,208	6.0
1924	115	128,765	3.5	1933	172	40,044	1.1
1925	139	35,230	.9	1934	136	11,570	.3
1926	116	26,315	.7	1935	232	9,085	.2
1927	129	22,816	.6	1936	246	8,271	.2
1928	138	158,047	4.3	1937	215	6,744	.2
1929	185	35,237	.9	1938	261	15,535	.4
1930	127	2,665	.1	1939	200	31,129	.8
				Total	3,035	1,059,591	28.5

The most striking features of the record are:

1. The tremendous variation in losses in individual years, particularly in the earlier part of the record.

2. The preponderance of heavy loss years in the earlier part of the record. Undoubtedly, the large burn during the period had some influence on the size of large fires during later years because of the reduction in the amount of inflammable material.

3. The preponderance of light loss years in the latter part of the record.

4. The heaviest loss year in recent years is little greater than the lightest loss in the earlier years.

5. With two exceptions (1930 and 1932) there is very direct relationship between area burned and percentage of C fires.

COMPARATIVE PERFORMANCE ON MAN-CAUSED AND LIGHTNING FIRES

In U. S. D. A. Tech. Bull. 209, "The Determination of Hour Control For Adequate Fire Protection in the Major Cover Types of the California Pine Region," by Show and Kotok, major differences were found between man-caused and lightning fires. Far more rapid spread of the former group was reflected in highly significant differences in size of fire, percentage of C fires, and area burned inside the national-forest boundaries.

In the area of study, lightning fires are not relatively so numerous as in northern California (table 2), though they may make up about one-fourth of all fires (784 out of 3,035). But this 25 percent of the total fires burned only 1.3 percent of the total area burned, and the percentage of lightning C, D, and E fires averaged but 6.5 percent compared to 22 percent for all fires, and 23.6 percent for man-caused fires.

Clearly, then, man-caused fires are for all practical purposes the real fire problem in southern California. Lightning fires are not considered further in this study.

TABLE 2.—*Lightning fires fought by the Forest Service on southern California national forests 1922–39, inclusive*

Total number of lightning fires fought by Forest Service	784 fires.
Portion of lightning fires that became C, D, and E	6.5 percent.
Area burned by lightning fires 10 acres and larger	13,798 acres.
Portion of total burned area due to lightning fires	1.3 percent.

TABLE 3.—*Man-caused fire business and results of control effort on the national forests of southern California. Average annual number of fires, average annual number of C, D, and E fires, and percent of C, D, and E fires by designated periods which have had different levels of accomplishment*

	Average number of fires per year	Average number C, D, and E fires per year	Percent of fires that became C's, D's, or E's
1922–28	100	41	41
1929–31	110	30	27
1932–39	141	17	12

PERFORMANCE LEVELS

As indicated earlier (table 1) there are major differences between the earlier and later years of the record. Without doubt these differences are the result of varying performance levels rather than of accident. The more important major changes in protection effort have been mentioned.

Primarily from the performance record of man-caused fires (table 3) it is clear that there are three quite distinct groups of years—1922 to 1928, 1929 to 1931, and 1932 to 1939. Within each group, there are certain important similarities between years, and, in area burned in individual years (table 1) some sharp contrasts.

The average annual number of man-caused fires has grown from 100 to 141; the number of C, D, and E fires has dropped from 41 to 17; the percentage of such fires has deceased from 41 to 12 (table 3).

So, despite an increase in number of fires, the performance in suppressing them has improved sharply. Detailed consideration of the means by which the results have been obtained is postponed to a later section of the study, since this analysis furnishes the keys to further advances.

The three periods are used through the remainder of the study.

SIGNIFICANT FIRE-CONTROL ZONES AND PROFILES

Botanically, the cover types of the southern California national forests are numerous and complex. From the fire-control standpoint, the botanical types can be grouped into a few zones, broadly characterized as

Zone 1. Flash fuel, grassland, open brush, and open woodland.—Lie at lower elevations. Grassland has grass and other herbs as principal cover. More numerous plants are wild oats (*Avena* spp.), bromegrasses (*Bromus* spp.), fescues (*Festuca* spp.) and alfileria (*Erodium Sicutarium*). Open brush consists of open shrub stands of sages (*Salvia* spp.), sagebrushes (*Artemisia* spp.), buckwheats (*Eriogonum* spp.) and other similar woody vegetation. Shrubs usually are 2 to 4 feet high and frequently intermingled with grassy areas. In some localities Yuccas are an important constituent in the stand from a fire-control standpoint. Open woodland consists of areas of grass and open brush, with scattered individuals and small clumps of woodland trees, such as blue, valley, and Engleman oaks (*Quercus* spp.).

Explosive types of fuel with highest rates of fire spread. Cover is low and open enough for easy movement of suppression forces and the rapid construction of fire lines.

Zone 2. Dense brush.—Usually above zone 1, and characterized by thick, unbroken, almost impenetrable masses of brush from 3 to 15 feet high. The principal genera represented are chamise (*Adenostoma* spp.), manzanitas (*Arctostaphylos* spp.), ceanothus (*Ceanothus* spp.), shrub oaks (*Quercus* spp.), and mountain mahogany (*Cercocarpus* spp.). Litter under the pure chamise stands is usually less than 1 inch deep, but under the other types is deeper, running from 1 to 3 inches, except in older stands of manzanita and shrub oaks, where it is often 4 to 6 inches deep. Yuccas are occasionally found scattered throughout the south slopes. Many narrow stringer canyons of zone 3 are interspersed throughout the dense brush areas.

Fires in this zone spread rapidly, generating a tremendous volume of heat. The movement of suppression forces, except along prepared lines, is slow and dangerous. The construction of fire line requires much labor and proceeds at a slow pace. The dense brush zone contains both the most difficult fire suppression problem and the highest watershed values.

Zone 3. Dense woodland.—Includes the stream bottom type consisting of dense to sparse stands of hardwoods such as sycamore (*Platanus*), alder (*Alnus*), cottonwoods (*Populus* spp.), willows (*Salix* spp.), maple (*Acer*), and oaks (*Quercus* spp.). The latter are more numerous around the fringes as the brush zone is approached. In the stream bottom at higher elevations and on some northerly slopes, stringers and patches of bigcone spruce (*Pseudotsuga macrocarpa*) are found. On higher ridges, and extending varying distance down the slope, depending on exposure, are frequently found dense stands of canyon live oak (*Quercus chrysolepsis*) or coast live oak (*Quercus agrifolia*) averaging from 4 to 12 inches in diameter and 15 to 25 feet high.

General inflammability is low. However, the stream bottom hardwood areas abound with summer homes and recreational areas which generate high risks. For this reason, and because the width of the type is usually not great and fires, therefore, soon spread to open or dense brush, the zone requires fast attack.

Zone 4. Coniferous timber.—Found mainly above the dense brush at elevations of 5,000 to 8,000 feet. Consists of areas of ponderosa pine (*Pinus ponderosa*), Jeffrey, pine (*P. jeffreyi*) Coulter pine (*P. coulteri*), and bigcone spruce, and white fir (*Abies concolor*), usually open in character but occasionally in fairly dense stands. In mnay of the stands there is an understory of brush, usually manzanita and ceanothus.

Rates of spread are usually slow and fire-line construction is relatively easy. Many of the fires are from lightning, but timbered areas have high recreational value and portions are already intensively used, pointing towards an increase in human risks.

Zone 5. Desert brush.—The desert brush zone occupies the lower and middle slopes facing the desert. Contain species similar to those in dense brush, but ordinarily of much less density and shorter, ranging from 4 to 8 feet high. In addition, species of the open brush type, such as sagebrushes and buckwheats and juniper (*Juniperus California*) and pinon (*Pinus* spp.), are also present.

Inflammability is low and line construction easy because of the sparseness of the cover. Fires are few and seldom attain any great size.

Zone 6. Subalpine.—Includes areas of higher elevations, above zone 4, characterized by rocky terrain with shallow soil. The principal trees are lodgepole pine (*Pinus contorta*) and limber pine (*P. flexilis*), usually occurring in scattered groups. The more important kinds of brush are chinquapin (*Castanopsis sempervareus*), ceanothus, and manzanita.

Fires in this zone are few, burn slowly, and do not account for much burned area. The major factor interfering with the suppression of fires that do start is their inaccessibility.

The relative location of cover types by elevations is shown on Figures 1 and 2.

In importance as to area zone 2 is, as might be expected, overwhelmingly first, with 69 percent of the total (table 4), with zones 5 and 6 combined next. Zone 4 and zone 1 follow in order, with zone 3 the smallest, comprising but 0.5 percent.

In fire occurrence, zone 3 leads with 10 percent of all man-caused fires on 0.5 percent of the area (table 4). The heavy recreational use of canyon bottoms is the obvious explanation for the disproportionate incidence of fires. The coniferous timber zone (4) with 20 percent of the fires on 10 percent of the area, is likewise heavily used for recreation. The low elevation flash fuel zone (1) like zone 4, has a two to one ratio between area and number of fires. The brush zone (2) has 47 percent of the fires on 69 percent of the total protected area. The number of fires per 100,000 acres is thus only about one-fifteenth as great as in the canyon bottom types. Lowest rate of fire occurrence is in Zones 5 and 6 combined, with 8 percent of fires on 12 percent of the area.

The distribution of fires over 10 acres in size (C, D, and E) shows 31 percent of the total number originating in the 8 percent of area in the flash fuel of zone 1; 31 percent on the 69 percent of total area in the brush zone; and 14 percent of C, D, and E fires in the 1 percent which is in dense woodland. These three types cover 78 percent of the area, but have 77 percent of the C, D, and E fires.

In percentage of C, D, and E fires, the zones rank: Flash fuels, brush, dense woodland, zones 5 and 6 combined, and timber.

In number of large fires (those 1,000 acres and over), the flash fuels with 33 percent, the brush zone with 56 percent and the canyon bottoms with 6 percent, account for 95 percent of the total for the 18-year period of study.

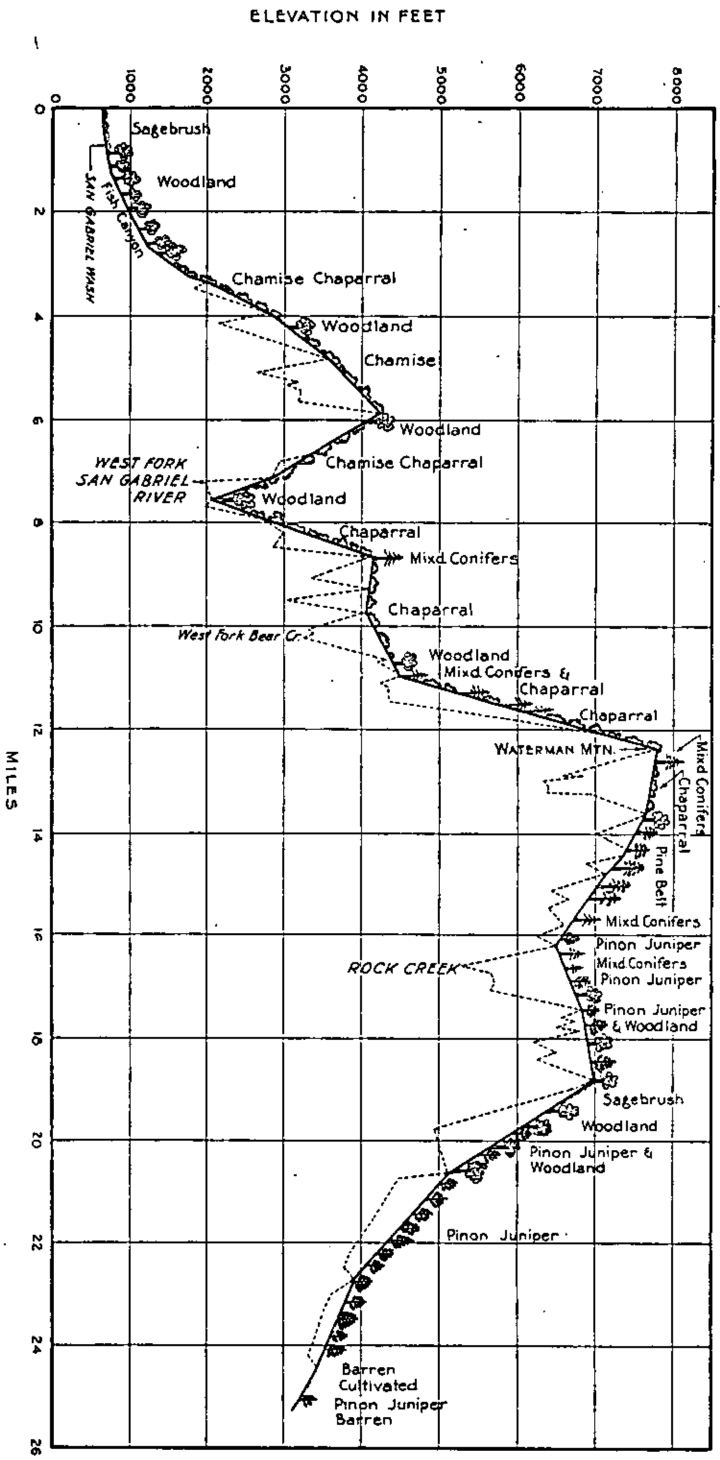

FIGURE 1.—Profile of the Angeles National Forest, showing the approximate life zones and distribution of cover types.

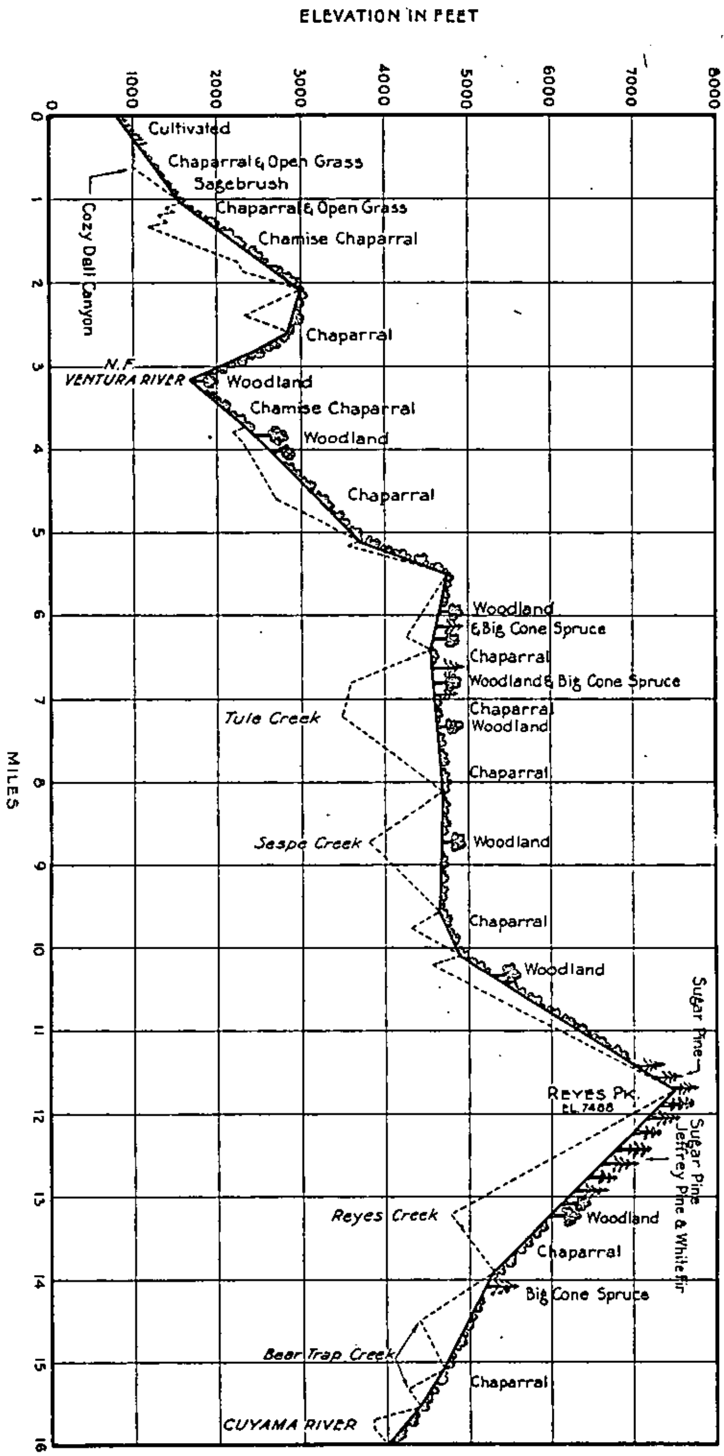

FIGURE 2.—Profile of Los Padres National Forest, showing the approximate life zones and distribution of cover types.

The dominant problem is shown by accumulated experience to lie in the flash fuels and brush zones. The other zones are relatively unimportant.

That these zones are the crux is further indicated by the size of average fires (table 4) which is greatest (911 acres) in the flash fuels, and least (95 acres) in the combined desert brush and subalpine zones.

COMPARATIVE PERFORMANCE IN DIFFERENT ZONES

During the earliest of the three periods of study (1922–28) the average annual rate of loss was 3.25 percent, 3,08 percent, and 3.34 percent (table 5) of the area in the flash fuel, brush, and dense woodland zones, respectively, indicating approximate equality of difficulty under the relatively extensive protection methods then available. The ratio of 0.68 percent and 0.48 percent for the timber and desert-alpine zones show the relative simplicity of the problem in those zones.

TABLE 4.—*Characterization of the inflammability zones recognized in fire-control planning on the national forests of southern California. Data on fires from individual fire reports for the years 1922–39, inclusive*

	All zones	Inflammability zones				
		I	II	III	IV	Other
Area protected within national forest, acres	3,716,100	317,900	2,570,900	17,800	365,500	440,000
Percent of protected area	100	8.5	69.2	0.5	9.8	12.0
Percent of all man-caused fires originating in zone	100	16	47	10	19	8
Average annual number of man-caused fires originating in zone	120	20	57	11	23	9
Average annual number of man-caused fires per 100,000 acres protected in zone	3.2	6.1	2.2	63.4	6.3	2.1
Average annual number of man-caused C, D, and E fires	28.4	6.3	17.7	1.4	1.8	1.2
Number of fires over 1,000 A, originating in zone, 18 years	130	43	72	8	2	5
Average size of man-caused fire originating in zone		911	665	500	226	95
Average rate of initial spread—chains perimeter per hour		43	30	35	10	15

During the most recent period of years (1932–39) the loss rates have been reduced to 0.30 percent, 1.52 percent, and 0.21 percent, respectively, for flash, brush, and dense woodland zones. That is, the loss rates were one-eleventh, one-half, and one-fifteenth as great as in the earlier period of years, a sharp reduction indicating striking success in the use of additional fire-control resources available. The stubborn persistence of heavy losses in the brush area continues. Even with 207,000 acres of such cover burned in the Matilija fire disregarded, the loss rate in the brush type for the last period of years remains over one-sixth as great as in the early period. That is, losses were reduced less than half as fast as in the two other zones discussed.

However, the brush zone, not only because of its dominant importance in area and its recognized key value in watershed management, but because of its continued high average rate of loss, is the major problem of fire-control planning.

The progressive and rapid reduction in loss rates in all the zones, even the crucial brush zones, as additional protection efforts were applied, gives clear indication that the problem of reducing losses to acceptable proportions is solvable, depending on application of further protection efforts.

Historical perspective of the main mechanics of attack on the fire-control problem is necessary before analyzing the present-day problem and the indicated steps for its eventual solution.

TABLE 5.—*Area burned in the major inflammability zones of southern California national forests, by periods. All man-caused fires; area within national forests only*

Periods	Inflammability zones				Other	Total
	I	II	III	IV		
1922–28						
Average annual burn, acres	10,319	79,122	394	2,480	2,134	94,648
Average annual burn, percent of zone	3.25	3.08	3.34	.68	.48	2.55
1929–31						
Average annual burn, acres	1,662	13,090	83	123	596	15,554
Average annual burn, percent of zone	.52	.51	.47	.03	.13	.42
1932–39						
Average annual burn, acres	952	39,111	37	1,630	344	42,075
Average annual burn, percent of zone	.30	1.52	.21	.45	.08	1.13
All years 1922–39						
Average annual burn, acres	4,713	50,334	261	1,709	1,082	58,100
Average annual burn, percent of zone	1.48	1.96	1.47	.47	.24	1.56

SIZE CLASS DISTRIBUTION OF CLASS C, D, AND E FIRES

Major changes have taken place from the earlier to the latter period in both the number and the proportion of C, D, and E fires in different size classes (table 6).

For example, in the earlier period 49.1 percent of all such fires were caught in the 10–100-acres size class; from 1932–39 the corresponding figure was 59.1. This, in effect, leaves relatively fewer going fires which may develop into really large burns.

Similarly, comparing first and last period, 63.1 percent and 75.2 percent, respectively, of C, D, and E fires were caught at less than 300 acres; 77.8 percent and 85.4 percent at 1,000 acres or less. For fires of these size classes the increased transportation system and consequent ability to mobilize adequate forces rapidly have undoubtedly been potent factors in increasing the proportion of smaller C, D, and E fires.

Obviously, the major proportion of the total burned area has come from fires of over 1,000 acres. These, with few exceptions are those not caught during the first work period. From 1922–28, 22.2 percent of all C, D, and E fires burned over 1,000 acres each; from 1932–39, 14.6 percent or about two-thirds as many. This means that the key problem of overnight control has not yet been solved, although progress has been made. In each of the size classes above 1,000 acres, there is an improvement between first and last periods, particularly great in the 5,000–10,000- and the 10,000–20,000-acre fires. One way to state the reduction of major fires is that in 1922–28 the average annual number of fires 5,000 acres and over was 4.3; from

1932–39 the average annual number was 0.5, less than one-ninth as many. But such fires clearly must be eliminated to deliver full protection to the area as a whole, and particularly to deliver protection to individual watersheds.

Least progress has been made in reducing the number of 1,000–5,000-acre fires.

Total number of C, D, and E fires per year has been reduced from 40.7 in first period, to 29.7 in the second, and to 17.1 in the third.

TABLE 6.—*Increase in efficiency in handling large fires, by periods. Classification of C, D, and E fires on southern California national forests according to area burned within forest boundaries. All man-caused fires included*

Period and item	Area burned within national forest boundaries								Total
	C	D	E						
	10–99	100–299	300–999	1,000–4,999	5,000–9,999	10,000–19,999	20,000–49,999	50,000 and up	
1922–28	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	
Number of fires	140	40	42	33	13	10	5	2	285
Number per year	20.0	5.7	6.0	4.7	1.9	1.4	.7	.3	40.7
Portion of total number in each size class, percent	49.1	14.0	14.7	11.6	4.6	3.5	1.8	.7	100
1929–31									
Number of fires	47	18	14	7	3	0	0	0	89
Number per year	15.7	6.0	4.7	2.3	1	--------	--------	--------	29.7
Portion of total number in each size class, percent	52.8	20.2	15.7	7.9	3.4	--------	--------	--------	100
1932–39									
Number of fires	81	22	14	15	1	1	2	1	137
Number per year	10.1	2.8	1.8	1.9	.1	.1	.2	.1	17.1
Portion of total number in each size class, percent	59.1	16.1	10.2	11.0	.7	.7	1.5	.7	100

TREND IN OVERNIGHT CONTROL OF FIRES 1,000 ACRES AND OVER

The fires of 1,000 acres and over in size in zones 1 to 4 (flash fuels, dense brush, dense woodland, and coniferous timber) may be analyzed as to whether they were or were not controlled before burning conditions of the second day (table 7).

The most striking point is that for the entire period 90 percent of the total burned area was accounted for by the 90 fires of over 1,000 acres which went into extra period control. Only 2 percent of the total burned area was accounted for by the 21 fires which were controlled overnight. The percentage by periods is uniformly high.

That increased facilities have been effective in reducing the problem of extra period fires is indicated by the fact that in the first period 86 percent of all fires 1,000 acres and over required extra period control, whereas in the last period the proportion had been reduced to 70 percent. But, equally obviously, the problem is a long way from solution.

A key to the difficulty may lie in the fact that the average size of the 1,000 acre and over fires which were controlled overnight has remained nearly constant at just over 1,000 acres. That is, even today fire organization is unable to effect overnight control on fires of much over 1,000 acres in size.

This stands out as a key problem.

An extra period fire is defined as one which is not controlled by 10 a. m. of the day following discovery.

TABLE 7.—*Importance of overnight control of large fires in successful protection areas burned by extra period fires (those not controlled by 10 a. m. of the day following discovery) and by first period fires on southern California national forests. Includes man-caused fires burning 1,000 acres or more within forest boundaries, inflammability zones 1–4, inclusive, only*

Years	Extra period fires				Nonextra period fires				
	Number of fires	Portion of fires 1,000 acres and up in period	Area burned	Average size of fire	Portion of area burned by fires of all sizes	Number	Acres	Average size	Percent of total
		Percent	*Acres*	*Acres*	*Percent*				
1922–28 percent of total	63	86	598,753	9,504	90.4	10 14	10,480	1,048	1.6
1929–31 percent of total	8	73	29,917	3,740	64.1	3 27	2,660	887	5.7
1932–39 percent of total	19	70	313,632	16,507	93.2	8 30	8,605	1,076	2.6
All periods percent of total	90	81	942,302	10,470	90.1	21 19	21,745	1,035	2.1

LENGTH AND CHARACTER OF THE FIRE SEASON

In the unit of study, fires according to past history, may occur in any month of the year, but with varying degrees of intensity as the season progresses (table 8). The fire business increases gradually from January through May, starts accelerating in June, reaches a maximum in early August, then decreases gradually in number of fires but not in intensity of the individual fire until early November, then drops abruptly in the latter part of that month. A few fires only may be expected in December, with a remote possibility of their developing into fires of damaging proportions.

TABLE 8.—*Distribution of fire occurrence throughout the year on southern California national forests. Percent of all fires and percent of C, D, and E fires by months for the years 1931–39, inclusive*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
						Percent							
All fires	1.2	0.9	1.6	2.9	4.4	9.9	22.6	24.7	17.7	6.1	6.2	1.8	100.0
C, D, and E fires	3.4	------	3.0	2.6	3.0	10.4	21.6	19.0	19.0	7.3	10.3	.4	100.0

TABLE 9.—*Seasonal distribution of fire business on the national forests of southern California. Cumulative percent of all fires and of class C, D, and E fires from Jan. 1 to June 1 and from Jan. 1 to Nov. 1 for the years 1931–39, inclusive*

Forest	Cumulative percent, whole year			
	As of June 1		As of Nov. 1	
	All fires	C, D, and E fires	All fires	C, D, and E fires
Los Padres	12	12	95	92
Angeles	16	5	91	86
San Bernardino	9	11	95	92
Cleveland	11	21	85	85

In general, burning conditions from January through May are moderate in intensity, chiefly because of precipitation and its lingering effect, which increases fuel moisture and produces green annual vegetation in the more open cover types. That fires—particularly in the pure brush types—can burn during this period and, if not suppressed immediately, may become large is evident from table 9, which shows by June 1 the Angeles had 5 percent of its class C, D and E fires and the Cleveland 21 percent. Evidence of the size of fire that can be expected during this early period is found in two instances which occurred inside the Cleveland forest in 1933 and 1934 and with characteristics as follows:

Time of occurrence	Mar. 5	Apr. 15
Elapsed time, discovery to arrival	35 minutes	1 hour, 10 minutes.
Size on arrival	25 acres	300 acres.
Size attacking force	165 men	50 men.
Final area	3,560 acres	1,380 acres.

Some form of suppression organization seems to be required in the early and late months of the year. Evidently, too, the intensity of organization will vary greatly in different parts of the year.

SEASONAL DISTRIBUTION OF BAD FIRE DAYS

The general level of fire danger in southern California is high, often over periods extending up to 8 months. During this time various numbers of critical fire days may occur.

Since the bulk of burned area results from a relatively few large fires, it is important to know at what seasons and how often the days on which such fires start may be expected.

In the first period (1922–28) fires of 1,000 acres or over started on 63 different dates—an average of 9 days per year (table 10). Individual years ranged from 5 days in 1925 and 1926 to 15 days in 1924, a recognized critical season.

In the second period (1929–31) there was an average of 3.7 days per year, on which such fires started with none in 1930, a recognized easy season.

In the last period (1932–1939) there was an average of 2.9 days per year, with great uniformity in number of days in individual seasons.

The progressive reduction in number of days per season, on which major fires started probably means increased ability to catch fires in smaller size classes, rather than any real difference in seasons or in difficulty of control.

Seasonal distribution of 1,000-acre fire days shows, for the first period, days from March to November, though the bulk were in July, August, and September (fig. 3).

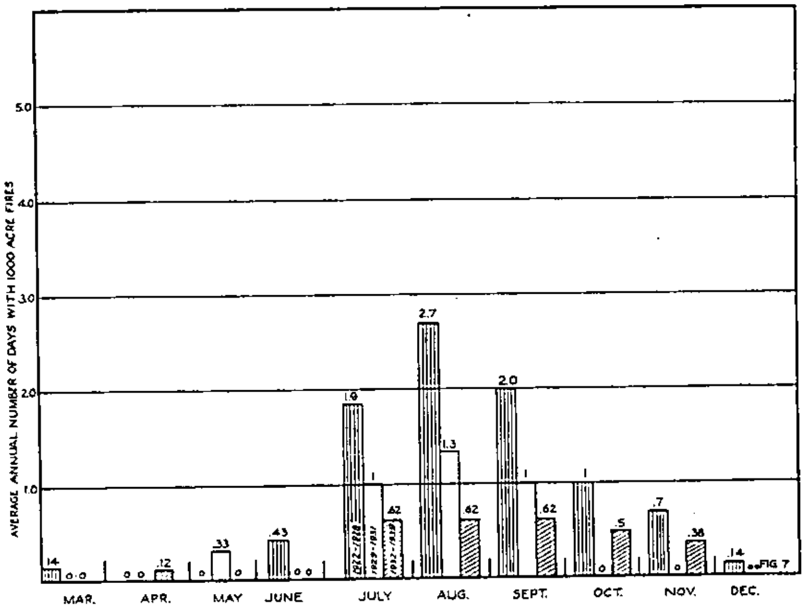

TABLE 10.—*Number of days on which fires started that burned 1,000 acres or more within the national forests of southern California, by months and years. Man-caused fires only*

Year	March	April	May	June	July	August	September	October	November	December	Total
1922				1	2	2	4	2			11
1923	1				4	4	1	1			11
1924				2	5	3	3	1	1		15
1925						4			1		5
1926						1	1	1	2		5
1927					1	2		2		1	6
1928					1	3	5		1		10
Total	1			3	13	19	14	7	5	1	63
1929					3	2	3				8
1930											
1931			1			2					3
Total			1		3	4	3				11
1932					1		1	1			3
1933		1				1		1	1		4
1934					2		1				3
1935					1			1			2
1936							2	1			3
1937					1	1					2
1938							1		2		3
1939						3					3
Total		1			5	5	5	4	3		23

In the last period, with one exception, there were no days in March, April, May, June, or December on which 1,000-acre fires started, thus the problem of major fires is from July to November, inclusive.

The progressive compression of the bad fire days from the earlier to the later period is evident. As facilities for fire control have increased, fewer days each year within fewer months represent a major threat.

A broadly similar historical trend is evident in analyzing the days on which major fires (5,000 acres and over) have started (table 11). In the first period such days were found in each year, with as many as 7 days in 1928. In the last period there is only a single day in any year, and no such day in 3 years out of 8.

The seasonal distribution included all months from June to December in the first period, whereas in the last, only August, September, and November had 5,000-acre fire days.

All this indicates that the attack is catching up with the critical days, but has not wholly done so. The lack of spread in number of bad days per season in the last period, measured either as to 1,000-acre or as to 5,000-acre fires shows that the problem is one of days instead, as in northern California, of whole seasons. This obviously shows an urgent need to identify the characteristics of bad days, and provision for such forecasts of such conditions. It shows urgent need for further progress in methods of attack.

TABLE 11.—*Number of days on which fires started that burned 5,000 acres or more within the national forests of southern California, by months and years. Man-caused fires only*

Year	March	April	May	June	July	August	September	October	November	December	Total
1922				1		1	2	1			5
1923					1	1	1				3
1924					2	2	2				6
1925						3					3
1926								1			1
1927						1				1	2
1928						2	4		1		7
Total				1	3	10	9	2	1	1	27
1929					1	2					3
1930											
1931											
Total					1	2					3
1932							1				1
1933						1					1
1934											
1935											
1936							1				1
1937											
1938									1		1
1939						1					1
Total						2	2		1		5

RECOGNITION AND HANDLING OF BAD FIRE DAYS

That certain days had characteristics resulting in abnormally rapid spread of fire was known from the very beginning of fire-control effort. But in the years up to the early twenties it is far from evident that anything effective was done to offset this well-known fact. Fire suppression was generally with limited sized crews, controlled by the restricted means available for service of supply. The idea of predicting bad days was in its rather formless infancy. Little professional study had been given to defining the characteristics of the bad days.

Perhaps the Arrowhead Springs fire (San Bernardino National Forest, 1922, 20,000 acres) served to focus attention on "Santa Ana" days as the crux of the fire-weather prediction problem. Such days, characterized by high wind velocities from east or northeast, and at times by abnormally low relative humdities at all elevations, are not uncommon in late fall. Strangely, there is evidence that the fire days connected with other and larger fires of the early twenties, which occurred in summer and early fall, were definitely not extreme "Santa Ana" days.

Fire weather forecasting, as a quite incidental phase of general forecasting, began in the early twenties. The results were hardly spectacular. The foresters had not furnished very precise definition of "fire days," and the forecasters in necessarily assuming certain targets, had not yet checked on the fire line the true relations between weather and fire.

This process began in the early thirties, with development of a mobile weather forecast unit and assignment of a qualified forecaster to fire-weather work. Results improved.

But even at the end of the period the diagnostic characteristics of the summer "fire days" were apparently imperfectly known. Common belief of fire fighters remained centered tenaciously on the severe "Santa Ana" days as the critical fire weather phenomenon.

Even before the advent of C. C. C. fire suppression strategy generally depended on scores of men, often more than could be effectively serviced or led. The C. C. C. accentuated this trend. Most effective relation between existing and impending fire weather on the one hand, and strength, intensity, and strategy of attack on the other, was recognized to but a limited degree.

TREND IN SPEED OF ATTACK

When, as in the record heretofore discussed, obvious trends appear in the direction of improved performance on fires, it is necessary to examine the mechanics through which the trends above come into existence.

Speed in reaching fires is one of the well-known means of handling the fire problem. That the increase in effort, which has been frequently mentioned, has increased speed of attack is readily shown (table 12).

For example in the earliest peroid, on the average 24 percent of all man-caused fires in zones 1 to 4 and for the four national forests combined were reached within 15 minutes, and this increased to 30 percent in the period 1929–31, and to 58 percent from 1932–39. The percentage of fires reached within 33 minutes speed increased from 43 percent in the first period to 78 percent in the last. In the early period 13 percent of all fires went over 3 hours before attack and in the last period only 3 percent. The major increase in speed has been obtained in the last period since only a slight increase between the first and second period is evident. Speed of attack is measured from discovery to first attack of fire.

The increase in speed of attack has not been uniform in the four major zones (table 13). For the last period the percentages of fires reached in 15 minutes for zones 1, 2, 3, and 4 are, respectively, 55, 54, 69, and 62 percent. The brush zone (2), which covers the bulk of the area and which all analyses show is the key to the whole problem, has the lowest rate of performance. The dense woodland zone (3), which is smallest in area and is relatively easy to control fires in, shows the highest speed of attack. The same relative position of zone holds true regardless of what period or speed of attack interval is selected as the basis for analysis.

TABLE 12.—*Speed of attack on man-caused fires in southern California national forests. Percentage of fires attacked within specified time following discovery. Major inflammability zones 1 to 4, inclusive*

Period	Elapsed time, discovery to attack—Percent of fires, accumulative								
	3 minutes or less	9 minutes or less	15 minutes or less	21 minutes or less	27 minutes or less	33 minutes or less	1 hour or less	2 hours or less	3 hours or less
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1922-28	5	14	24	31	37	43	57	79	87
1929-31	5	15	30	38	48	54	72	89	94
1932-39	16	42	58	68	74	78	88	95	97
1922-39	10	27	43	51	56	60	74	88	93

TABLE 13.—*Speed of attack on man-caused fires in southern California national forests by inflammability zones by periods. Percentage of fires attacked within specified time following discovery*

Inflammability zone and period	Elapsed time, discovery to arrival—Percent of firse, cumulative			
	3 minutes or less	15 minutes or less	27 minutes or less	1 hour or less
Zone 1	*Percent*	*Percent*	*Percent*	*Percent*
1922-28	6	27	41	58
1929-31	9	22	45	76
1932-39	16	55	74	90
1922-39	11	39	56	75
Zone 2				
1922-28	4	21	31	53
1929-31	4	29	40	65
1932-39	16	54	71	86
1922-39	10	39	52	71
Zone 3				
1922-28	8	42	54	69
1929-31	5	41	59	85
1932-39	18	69	81	95
1922-39	12	56	68	85
Zone 4				
1922-28	2	22	39	61
1929-31	5	31	60	77
1932-39	17	62	76	90
1922-39	11	45	63	79

A strong presumption arises that further speeding up of attack in the overwhelmingly important brush zone is an urgent current problem.

The coniferous timberland zone (4) is, in the area of study, confined to a few high mountain areas—the Lagunas and Palomar Mountain, Cleveland National Forest: the Crest area and parts of the San Jacintos, San Bernardino National Forest: Charleton, Chilao, and Horse Flats, Angeles National Forest: and the Mount Pinos Area, Los Padres National Forest. All these areas are heavily used recreational centers, and most of them have considerable investments in structures, necessitating various types of urban fire-protection organizations.

Fires evidently are not difficult to handle if attacked in any reasonable period, since only five class C fires are recorded out of 230 fires, and two of these were not attacked for over 1 hour after discovery.

The combination of special urban protection organization, recreational management personnel, and overlapping coverage from adjacent brush zones, seems to make unnecessary a detailed analysis of the timber zone speed of attack problem. The type is of very high value, but coverage is not a major problem.

TREND IN REACHING FIRES AT SMALL SIZES

Increased speed in attacking fires should be reflected in reaching them at smaller sizes. The trend has been in this direction (table 14).

When all man-caused fires, zones 1 to 4 inclusive, and all four forests are combined it is found, as an over-all picture, that in the last period of years 73 percent of the fires were reached when they were one-fourth acre or less in size. This is a very great increase from the 40 percent in the first period and 55 percent in the second. Substantially the same increase in attacking fires when small is found in the other size groups.

Particularly significant is the fact that in the first period 26 percent of all fires were already C, D, or E fires (over 10 acres) and that in the last period only 6 percent were already class C, D, or E when first attacked.

There are striking differences in size when reached among the four zones (table 15).

In each type, without exception, a higher proportion of fires were reached at one-fourth acre and subsequent size classes up to 10 acres, from period to period. And conversely a lower percentage of fires were already C, D, or E fires when attacked.

In practically all periods of years and in all size classes up to 10 acres, the flash fuel zone (1) has the lowest percentage, the brush zone (2) ranks second, the dense woodland (3) is third, and coniferous timber zone (4) has the highest percentage.

Inferentially, the rate of spread is highest in zone 1, lowest in zone 4. The contrast is particularly marked, as in the last period of years only 1 percent of zone 4 fires were already class C, D, or E when reached, whereas 13 percent of the fires in the flash fuel zone had gone over this line.

TABLE 14.—*Size of fires when attacked on national forests of southern California. Percentages of fires attacked when of the specified size or smaller by periods. Man-caused fires in inflammability zones 1 to 4, inclusive*

[Cumulative percent, fires in period]

Periods of years	Size upon arrival of initial attacking force				
	0-0.25 acre	0.26-1.0 acre	1.1-4.0 acres	4.1-7.0 acres	7.1-10.0 acres
1922-28	40	52	65	72	74
1929-31	55	66	74	81	83
1932-39	73	85	90	93	94
1922-39 total	59	70	79	84	85

TABLE 15.—*Size of fires when attacked on southern California national forests by inflammability zones. Percentage of man-caused fires attacked when of the specified size or smaller, by periods*

[Cumulative percent, fires in period]

Zone and period	Size upon arrival of initial attacking force				
	0-0.25 acre	0.26-1.0 acre	1.1-4.0 acres	4.1-7.0 acres	7.1-10.0 acres
Zone 1					
1922-28	29	41	57	69	71
1929-31	43	53	62	76	78
1932-39	58	76	84	87	87
1922-39 total	44	59	70	78	79
Zone 2					
1922-28	35	47	60	66	68
1929-31	52	63	71	79	79
1932-39	70	81	88	92	93
1922-39 total	55	66	75	81	82
Zone 3					
1922-28	54	62	78	79	79
1929-31	64	74	82	82	82
1932-39	79	92	93	95	95
1922-39 total	68	79	86	88	88
Zone 4					
1922-28	58	74	86	88	90
1929-31	65	77	86	91	94
1932-39	91	97	99	99	99
1922-39 total	77	87	93	95	96

TREND IN STRENGTH OF INITIAL ATTACK

There is a decided tendency during the last two periods to attack larger percentages of all fires in the high danger zones at greater rates of speed, but with smaller initial attack crews. This is clearly brought out in tables 16 and 17.

The smaller crews arrived on the fires earlier, and while these were in smaller size classes, their efforts in starting the control of such fires were effective in holding many more of them to less than 10 acres in size than was the case in the first period.

The main reasons for more rapid initial attack in the later periods were the better distribution of protection forces, speedier means of transportation, and greatly extended road systems. During the later years of the last period, too, an increased number of speedy light tankers has contributed to the holding of fires to a smaller acreage with reduced numbers of men. The better transportation facilities and ready availability of strong forces of organized labor such as the C. C. C. camps, no doubt, played their part in the prompt backing up of the smaller crew initial attack.

In zones 1 to 4, as the data in table 16 show initial attack crews of from 1 to 3 men started action on 26 percent of all fires in the period 1922–28. In the years 1932–39 similar sized crews began control action on 35 percent of all fires. Similarly, in the first period, in zone 2 (table 17) crews up to 10 men in size arrived and started action to control 28 percent of all fires in the zone while these were one-fourth acre or less in size. In the later period the same sized crews arrived on 55 percent of all fires while they were in the above size class. The same general pattern is evident in studying the rest of the picture of initial attack crew size between the two periods (table 17). Thus in the first period, crews of from 1 to 3 men got to 42 percent of all fires on which control action was started by such sized crews before these fires were one-fourth acre in size, as contrasted with 79 percent in the last period. Corresponding figures on fires that were first attacked when they were from ¼ to 1 acre in size show 57 percent and 89 percent, respectively.

Thus, a very material increased speed of attack supplemented with tanker equipment has made possible reductions in the size of initial attack forces.

TABLE 16.—*Strength of initial attack on man-caused fires in the national forests of southern California. Percentage of man-caused fires in each period attacked by specified numbers of men. Inflammability zones 1 to 4, inclusive*

Period	Size of crew, initial attack					
	1 to 3 men	4 to 5 men	6 to 10 men	11 to 20 men	Over 20 men	Total
1922–28						
Number of fires	180	127	177	131	84	699
Percent of fires, cumulative	26	44	69	88	100	
1929–31						
Number of fires	107	53	55	47	35	297
Percent of fires, cumulative	36	54	72	88	100	
1932–39						
Number of fires	360	167	241	135	116	1,019
Percent of fires, cumulative	35	52	75	89	100	

TABLE 17.—*Comparative strength of initial attack in 1922–28, inclusive, and 1932–39, inclusive, on southern California national forests. Number of fires of various sizes (when attacked) with attack by specified numbers of men. Percentage of fires attacked by each size crew when of specified sizes, or smaller. Man-caused fires in inflammability zone 2*

Size of initial attacking force	Size upon arrival of initial attacking force							
	0–.25 acres	.26–1 acres	1.1–4 acres	4.1–7 acres	7.1–10 acres	10.1–20 acres	20.1–30 acres	Total
	Period 1922–28, inclusive							
1–3 men								
Number of fires	39	13	11	2	4	4	3	92
Percent of fires, cumulative	42	57	68	71	75	79	83	100
4–5 men								
Number of fires	30	7	6	4	1	7	2	63
Percent of fires, cumulative	48	59	68	75	76	87	90	100
6–10 men								
Number of fires	31	4	16	5	0	4	4	84
Percent of fires, cumulative	37	42	61	67	67	71	76	100
1–10 men								
Number of fires	100	24	33	11	5	15	15	239
Percent of fires, cumulative	28	35	44	47	49	53	55	67
	Period 1932–39, inclusive							
1–3 men								
Number of fires	152	18	9	3	1	4	1	192
Percent of fires, cumulative	79	89	93	95	95	97	98	------
4–6 men								
Number of fires	62	8	11	4	1	2	0	89
Percent of fires, cumulative	70	79	91	96	97	99	99	------
6–10 men								
Number of fires	65	8	6	6	1	3	1	94
Percent of fires, cumulative	69	78	84	90	91	95	96	------
1–10 men								
Number of fires	279	34	26	13	3	9	2	375
Percent of fires, cumulative	55	62	67	69	70	72	72	72

TREND IN ROAD AND OTHER PROTECTION IMPROVEMENT DEVELOPMENT

Because of the lack of even a skeleton road system in the period from 1922 to 1928, inclusive, the fires that became large presented serious problems of transportation. This resulted not only in delayed initial attack but also in slow mobilization of adequate control forces, in difficulties of attack through inaccessibility of control lines and lack of mobility of forces on the lines, as well as innumerable handicaps in the service of supply. The operating field of the small number of tank trucks available was limited and no facilities existed for the transport of heavy machinery to fires. Thus, fires such as Kelly Canyon on Los Padres National Forest in 1922 burned 106,300 acres in an area which had absolutely no transportation routes except a poor trail. The Oso fire in 1923 on the same forest burned 68,300 acres and, except that it started fairly near a road, burned in an area in which there were nothing but trails; similar lack of facilities was the case in the 49,200-acre San Gabriel fire on the Angeles in 1924. Naturally, these fires were not only extended campaigns but were suppressed with the greatest of difficulty.

The Matilija fire in 1932 burned in an area in which a major highway was being built, but practically the entire area of 218,000 acres was merely touched by roads on the edge and no appreciable road mileage was inside its perimeter.

The development of a primary road system started in 1925 after the disastrous season of 1924 when a special southern California improvement appropriation of $100,000 was obtained. This money was matched by local interested agencies. The special fund continued in varying amounts for the next several years.

With the advent of C. C. C. in 1933, rapid strides were made in the development of needed improvements with special attention given to roads.

This has meant much in meeting the difficulties in fire control mentioned earlier. Several large areas still lack even a primary network of roads, chiefly on Los Padres National Forest, where several major essential trunk routes exist only in part.

Large mileages of firebreaks were built on which to make stands as fires approached the prepared lines. They were also of value as means of access into hitherto unbroken brush areas.

Rapid progress was made, too, in the construction of other fire control improvements designed to speed up attack as well as to make actual control of large fires more certain and easier to accomplish. More lookout houses, tied in by extensive, high-grade telephone systems, were built to complete the detection program and campgrounds were developed in large numbers to concentrate the campers in prepared and fireproofed grounds.

In recent years extensive radio networks have been built to supplement the telephone system and to facilitate the actual communication on fires in the field. Airplanes have been called into use in scouting and in dropping food to crews on isolated fires.

Thus all of the facilities were developed to provide speed in attack on fires through shortening the period during which fires burned undetected; to permit rapid attack by motorized equipment and full utilization of tank trucks and heavy machinery over a prepared network of roads and to provide modern facilities such as radio and airplanes to use on the suppression jobs themselves. Table 18 shows the work accomplished on the improvement program by periods.

TABLE 18.—*Approximate accomplishments in fire protection improvement development by periods in southern California national forests (Monterey district of Los Padres eliminated)*

	Jan. 1, 1922–Dec. 31, 1928	Jan. 1, 1929–June 30, 1931	July 1, 1931–Dec. 31, 1939
Truck trail construction:			
Total...miles..	73	299	1,899
Per year...do...	10.3	120	223.4
Trail construction:			
Total...do...	407	189	508
Per year...do...	58.1	75.6	59.7
Telephone line:			
Construction, total...do...	348	244	775
Construction, per year...do...	49.7	97.6	91.1
Firebreak construction:			
Total...do...	455	732	1,262
Per year...do...	65	292.8	150
Lookout houses, construction:			
Total...	20	7	50
Per year...	2.8	2.8	5.8
Campground item, construction:			
Total...	174	121	350
Per year...	24.8	48.4	41.1

TREND IN MECHANIZATION

Obviously, fire suppression had to remain chiefly in the shovel and ax hand-labor stage until a road system was created, regardless of known deficiencies of unmechanized attack and regardless of known opportunities to strengthen as well as to speed up the attack.

So the use of tank trucks in forest fire suppression did not really start until the period 1929–31, during which time they were used on about 10 percent of the man-caused fires occurring on national forest lands in southern California. With the continuing expansion of the road system, their usefulness from then on increased as shown by their use on 60 percent of all similar fires during the period 1932–39.

The value of this equipment is due primarily to its usefulness in rapidly decreasing the spread of fire through the application of water from a distance. This, in part, overcomes the difficulties and dangers of working men too close to the actual fire edge.

That this equipment can be used on a great majority of the fires is clearly evident from analysis of table 19. This shows how the fire problem is tied in with roadsides, especially on the Angeles, San Bernardino, and Cleveland Forests, which have intensive road systems and where 78 percent of the fires which accounted for 69 percent of the burned area, originated within 265 feet of some road. This distance is readily within the range of tanker equipment.

TABLE 19.—*Occurrence of fires in relation to roads on southern California national forests, number of fires, percent of C, D, and E and burned area according to distance from roads. Man-caused fires, years 1934–38, inclusive.*

Distance from road	All fires		C, D, and E fires		Burned area	
	Number	Cumulative percent	Number	Cumulative percent	Acres	Cumulative percent
	Angeles, San Bernardino, and Cleveland National Forests					
0–265 feet	513	78	51	77	41,271	69
265–800 feet	70	89	2	80	5,875	78
800 feet–¼ mile	34	94	4	86	5,667	88
Over ¼ mile	40	100	9	100	7,334	100
Total	657	----------	66	----------	60,147	----------
	Los Padres National Forest					
0–265 feet	75	60	12	40	3,746	31
265–800 feet	11	69	2	47	1,204	41
800 feet–¼ mile	5	73	----------	47	----------	41
Over ¼ mile	34	100	16	100	7,037	100
Total	125	----------	30	----------	11,987	----------

The effectiveness of tank trucks is dependent on reaching the fire while it is small and confined to an area close to the road, since it is difficult to move the hose rapidly in dense brush so characteristic of zone 2 conditions.

Effectiveness is also dependent on a highly trained crew working as a coordinated unit. The effectiveness and use of tankers is expected to increase, especially when units are developed to negotiate more of the steeper brush-covered slopes under their own power while traveling cross country from adjacent roads.

Use of trail builders for line construction is recent, largely in gentler slopes at the lower elevations. The road system was not designed for transport of the heaviest units, which are generally needed in the heavy cover of the brush zone. But more and more opportunities are being found for effective use of the machines, as greater operating experience builds up. Extensive redesigning of key roads remains to be done.

Servicing of suppression forces on fires in the extensive roadless and trailless areas, particularly on the Los Padres National Forest, has always been a bottleneck. The attack has been limited to the size crew which limited numbers of pack stock could service. Development of successful airplane servicing technique has in the past two years removed this barrier. The most effective coordination of airplane and pack string on inaccessible fires remains to be worked out.

Lack of efficient backfiring equipment has always been a major barrier in executing control plans. Commonly, key backfiring jobs have had to be done at night, when burning conditions were poor, and the burning has been patchy and incomplete.

New, portable power backfiring equipment, of the flame-thrower principle, though not yet fully tested under service conditions, is expected to solve many of the technical questions of backfiring. Solution of this problem is expected to reduce the disinclination to backfire, which has been a marked characteristic of fire fighting in the unit of study, and which has, in large part, been due to known difficulties of backfiring.

TREND AND EFFECT OF FIRE-PREVENTION EFFORTS

Attack on the fire problem has included not only the measures designed to speed up and strengthen attack, but the fire-prevention problem as well, for early in the history of the southern California national forests' venture, it became evident that preaching care with fire and imposing fines on apprehended violators of the fire law was far from a complete answer to the problem of fire prevention. The insistent public interest in the problem, and public willingness to accept reasonable restrictions and policing have given an opportunity to devise and test on a large scale many methods aimed at prevention of man-caused fires.

A mere listing of fire-prevention measures gives an idea of the diversification of the attack on prevention of fires.

Summary of specialized fire-prevention measures

Measure	Date started	Purpose	Planned enforcement or execution
Law enforcement	1901 [1] 1918	To build idea of importance of laws.	Fire prevention officers.
Burning permits	1905	To train in safe methods. To put needed burning in safe seasons.	State, county, and forest officers.
Blasting permits	1905	To remove chance for fires to start. To train industrial users in habit of care.	Do.
Campfire permits	1915	Chance for prevention emphasis. To give feeling of individual responsibility. To assist in law enforcement.	Issued largely by forest officers and limited cooperating agencies. Enforced in field by forest officers.
Prepared campgrounds	1915	Same as for closure to use	Rangers and patrolmen.
Requiring camping only in prepared camps.	1915	do	Do.
Prevention patrol	1920	To maintain active realization of dangers.	Field patrolmen.
Building inspection	1920	To decrease fires from structures.	Rangers and guards.
Closures to recreational use.	1924	Removing chance for fires to start.	Posting in the field and patrol.
No smoking	1924	To train people in recognition of dangers.	Posting, patrolmen, and registrars.
Hunter camps	1924	Specialized care. Same as for all prepared camps.	Patrolmen.
Controlled use of roads	1924	To prevent use in high-hazard areas.	Locked gates.
Registration	1926	Same as for campfire permits	Registrars.
Shovel and ax	1926	To emphasize and train in care with safe methods.	Campfire permit agents, all forest officers.
Fag stations	1930	To train people in recognizing safety. To offset burden of smoking closure.	Patrolmen.
Permit system for recreational use (Gibraltar area).	1934	Same purpose as other measures intensified.	Patrolmen and registrars.
Local ordinances		Facilitate law enforcement	State, county, and forest officers.
Newspaper, radio publicity, public talks, exhibits, etc., signing.		To build up appreciation of problems. To capitalize on educational effect of repetition.	All forest officers.
Road cleanup		To prevent opportunity for fires to start.	Highway organization and forest officers.
Railroad cleanup		Same as road cleanup	By railroad companies.
Power-line clearing		do	By power companies.
Helping users to do needed burning.		To train in safe methods	Forest officers.
Boundary contacts		Same as for campfire permits	Registrars and patrolmen.
Prohibition against open fires.		Same as for prepared closures to use.	Campfire permits patrolmen.
Fire clauses in right-of-way permits.		Same as for blasting permits	Forest supervisor.
Fire clauses in special use of grazing permits.		do	Do.
Change in hunting season		To put use in relatively nonhazardous seasons.	Legislation.

[1] Intensive program.

The list indicates, too, that successive steps were taken as old ones failed to solve the problems at which they were aimed. In total, these measures have succeeded in reducing the number of man-caused fires per 100,000 users (table 20). In the first period the index figure was 2.24, in the second 0.86, and in the third had dropped to 0.82. It is noticeable that the rate of decrease seems to have slackened, and evidently further decrease is likely to be won at considerable effort and expense.

This decrease in number of fires per 100,000 users has not, however, been accompanied by a decrease in absolute number of fires. On the contrary, there has been an increase. So from that standpoint, prevention effort has failed to keep up with the growth of the problem. A large part of the difficulty lies in the great importance of miscellaneous fire causes, many of which are little susceptible to prevention effort, or are stubbornly resistant.

The summary indicates the methods of application or enforcement used for each measure. There is a rather queer mixture of dependence on specialized personnel and on the regular yearlong ranger force and on guards hired primarily for suppression. Reconsideration of methods seems desirable.

TABLE 20.—*Results of organized fire prevention effort on the national forests of southern California. Number of man-caused fires and number per 100,000 user-days, by periods*

Period	Average annual number of man-caused fires	Average number of fires per 100,000 users
1922–1928	100	2.24
1929–31	110	.86
1932–39	141	.82

TREND IN THE CONCEPT OF ALLOWABLE BURN

The almost complete absence of published serious analyses of the distinctive southern California fire problem is perhaps responsible for the lack of a cohesive, reasoned, and widely accepted statement of the basic fire-control objective. At the start, the elimination of the very large burns of preorganization days was accepted as a goal. Later, from time to time major fires—the San Gabriel and Ravenna, 151,000 acres, of 1919; the Kelly Canyon, 106,300 acres, of 1922; Oso, 68,300 acres, of 1923; San Gabriel, 49,200 acres, 1924; Devore, 14,400 acres, 1928; climaxed in the Matilja, 218,000 acres, in 1932; were emphatically recognized at the respective times as too large to tolerate, even occasionally and on widely scattered watersheds.

The disastrous La Crescenta flood resulting from the Pickens Canyon fire, 4,831 acres in 1933, stepped down to below 5,000 acres the general concept of allowable burn in a watershed.

But no serious effort seems to have been made to determine the probable real consequences of burns of different sizes in different watersheds and hence to settle on allowable burn objectives, and to relate the attainment of these to certain levels of protection.

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A general figure of two-tenths of 1 percent annual loss for the entire protected area has been mentioned, and the same figure has been discussed as the objective for single major watersheds, though the two are demonstrably vastly different.

Inauguration of the study phase of the upstream flood control program was at the end of the period of this study, compelling fresh consideration of the objective.

TREND IN FUND EXPENDITURES

Tremendous increases in funds have been granted for development work on the southern forests since the need for such increases was shown after the serious losses of 1924. This money started to come from the special improvement funds passed by Congress for use in southern California, which had to be matched by cooperative funds. In addition to this, very large emergency appropriations were made available, such as C. C. C., C. W. A., and E. R. A. Thus the expenditures that averaged $472,901 in the first period were stepped up to $777,878 per year in the second, and $1,980,694 in the third. It should be kept in mind, too, that the cost and value of the C. C. C. enrollee labor is not included in the figures, and when it is remembered that there were some 10,800 such enrollees on the job in the first period an idea of the magnitude of the contribution can be secured. (See table 21.)

There has been a steady increase in strength of protection forces since 1922. Thus the crew has grown from 76 the first year to 192 in 1939. This has meant a lot, not only in strengthening detection and prevention efforts, but in a better distribution of small crews, more widely scattered over the greatly extended transportation system to give more complete coverage.

TABLE 21.—*Approximate fund expenditures on the southern California national forests—by periods* [1]

Funds	Jan. 1, 1922–Dec. 31, 1928		Jan. 1, 1929–Dec. 31, 1931		Jan. 1, 1932–Dec. 31, 1939	
	Total	Yearly average	Total	Yearly average	Total	Yearly average
General operating and fire suppression	$1,915,019	$273,574	$851,431	$283,814	$2,778,774	$347,347
Southern California improvement	264,126	37,732	476,137	158,712	104,947	13,118
Cooperative funds deposited	294,356	42,050	269,328	89,773	456,998	57,087
Cooperative funds undeposited	377,004	53,853	372,394	124,131	306,610	38,326
Road funds	459,805	65,687	363,346	121,448	1,232,136	154,017
Emergency funds					10,966,391	1,370,799
Total	3,310,310	472,901	2,333,636	777,878	15,845,856	1,980,694

[1] Exclusive of Monterey division of Los Padres forest.

TREND IN TRAINING OF FIRE-CONTROL PERSONNEL

Clearly, the great advances in speed, strength, and diversity of attack during the period of study impose increasing opportunities for success or failure on fire-control personnel. At the start of the period only the most casual and sporadic attention was given to training of the fire guards and patrolmen who made up the initial attack forces. This nearly exclusive reliance on mere experience resulted in costly failures to control fires at small sizes.

So, beginning in the early twenties, more systematic group training of the seasonal fire-control employees was begun in the southern California area as elsewhere. The program of training has measurably kept in step with the mechanization of fire control, with substitution of organized stand-by crews for pick-up crews, and with the increasing mass of mobilization of labor and material on the larger fires. But this process is never-ending, and there is a quite evident lag in the training of leadership to take fullest advantage of forces and equipment which are now made available. The existing financial set-up provides but a few days a year for training in advance of the fire season. The cost of failure of leadership on a single fire is so great that evident progress in training serves as an indicator of major remaining opportunities.

Present Problems and Means for Solution

FOREWORD

The problem of fire control in southern California has long been recognized as perhaps the most difficult in the Nation because of the very long dry season, the rugged terrain, the exceptionally heavy cover, and the close proximity of enormous destructible values to the forest areas, as well as the value of the watersheds themselves to the local economic interest.

The analysis of trends in the many phases of the fire-control problem in the southern California national forests has indicated varying progress in different fields; persisting uncertainties in such vital matters as the fire-control objective; and some apparent lack of progress, notably in inability to increase the size of fires handled by overnight control. Some indication in general terms of urgency or importance has been given.

In briefest summary form the problems as recognized included:

1. The flash fuel and brush zones, particularly the latter, represent the crux of the problem.
2. Progress in solution of overnight control problem is far from complete.
3. Sure and reliable forecasting of the relatively few bad fire days a season is a prerequisite to better and more flexible fire-control organization.
4. Clear definition of the fire-control objective, that is, the maximum allowable burn, is urgently needed.
5. There is a large field for further progress in fire-prevention to reduce not only relative but absolute numbers of fires.
6. Required speed of attack in brush and flash fuel zones has not been worked out.
7. Most effective strength and type of attacking brush and flash fuel zones need clarification.
8. The program of mechanization lags behind the development of the road system.
9. There are great opportunities for more training of fire-control personnel and capitalization on past training through stabilization of employment of high quality personnel.

The following sections undertake to analyze accumulated experience and to develop reasoned answers to these questions.

SETTING THE OBJECTIVE

It has been customary to state the objective of organized fire-control in terms of holding average annual loss to a stated percentage of the entire protected area. The latter has usually been an entire national forest region, or a group of several national forests, or a major widespread type, or a group of types having similar values and uses. Or the two bases are sometimes combined. Thus the accepted burned area objective for the timberlands of the northern California national forests is not to exceed 0.2 of 1 percent average annual burn. This is based on an average rotation of 100 years, on the fact that fires are customarily very destructive, and that loss of over one-fifth of a working circle would tend to disrupt it.

In the southern California national forests, no serious attempt has been made to determine rational and demonstrable objective. In a general way, there has been some belief that if an average annual rate of loss of not over 0.1 percent to 0.2 percent could be attained, the problem would be solved.

Since the primary purpose of this study is to develop the planning basis for adequate fire-control in the region under study, it is necessary first to have an arithmetical expression of "adequate." The recorded fire history for the period of study affords a basis for investigation.

For the entire protected area of 3,716,000 acres, individual years have had burned areas ranging from 2,665 acres in 1930, or 0.1 percent of the total up to 222,200 acres in 1932, or 6.0 percent of the total. The years have been sorted into groups, or classes, having respectively 0.1–0.2 percent burn, 0.2–0.4 percent, 0.4–0.8 percent, 0.8–1.5 percent, 1.5–3.0 percent and 3.0–6.0 percent, thus covering the whole range of experience (table 22). Then for each class the size of average fire, 10 acres or over, average size of five largest fires in each year, average size of single largest fire in each year, and size of largest single fire have been computed. The minor irregularities in relation between classes have been smoothed out by curving (fig. 4).

In the years when 0.2 percent or less of the total area was lost the average fire was 42 acres, a very comforting figure if it is assumed to mean that each fire was of that size. Of course, that is a fiction.

In the same years the average fire, 10 acres or over, was 334 acres, and if this were a true measure of maximum size of fires, there would be relatively few watersheds on which such a loss would be really serious. But all fires in the C, D, or E class are not of the same size, any more than all fires are of the same size.

TABLE 22.—*Years grouped according to percentage of protected area burned showing related data for each group on largest fire and average size of fire for specified classes. Man-caused fires on the national forests of southern California*

Percent protected area burned annually	Years	Largest single fire per group of years	Average largest single fire each year in group	Average area 5 largest fires each year in group	Average size fire over 10 acres, all year	Average size fire, all years
		Acres	*Acres*	*Acres*	*Acres*	*Acres*
0–0.2	1930, 1935, 1936, and 1937	5,370	3,045	1,045	334	42
0.3–0.4	1931, 1934, and 1938	11,302	5,484	2,095	573	95
0.5–0.8	1926, 1927, 1929, and 1939	22,720	12,462	4,901	946	265
0.9–1.5	1925 and 1933	30,800	20,458	6,589	1,474	359
3.1–6.0	1922, 1923, 1924, 1928, and 1932	218,000	94,278	27,967	3,873	1,416

In the same years, with an over-all loss of less than 0.2 percent, the five largest fires in each year average 1,045 acres. This is coming close to the point where general judgment might say that single fires of around 1,000 acres can be of serious consequence. But this figure, like average fire, and average fire 10 acres or over, is only a fictional

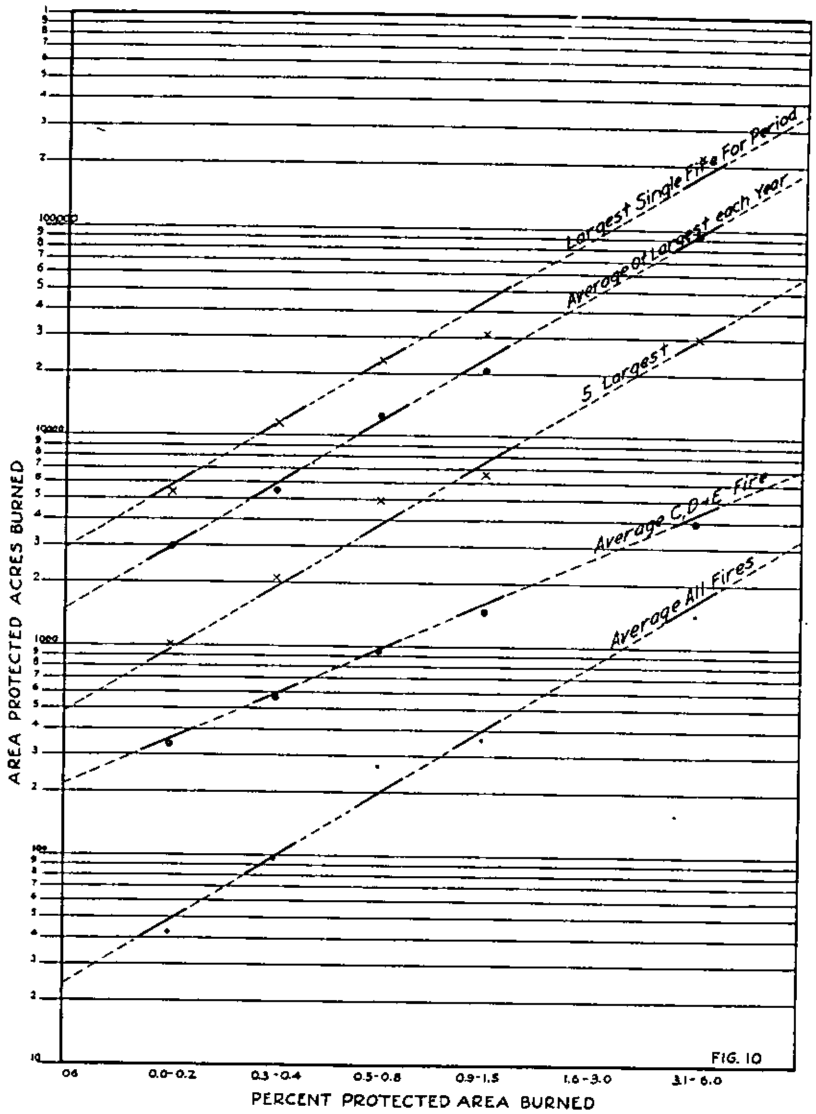

FIGURE 4.

way of expressing the results of a given over-all level of protection. For in the same group of years, the average of the single largest fires in each year is 3,045 acres, and a 3,000-acre fire in some particular watershed is in most cases something to be concerned about.

The final possible criterion is the largest single fire which occurred in any of the 4 years in the group. This fire was 5,370 acres. The well-remembered LaCrescenta flood, originating from the 4,831-acre Pickens Canyon fire, indicates that a fire of this magnitude can lead to a major disaster. The group of years in which burned area was 0.3–0.4 percent have, as comparable figures, an average fire of 95 acres, average fire over 10 acres in size was 573 acres, average of 5 largest fires each year 2,095 acres, average of single largest fire each year 5,484 acres, and largest single fire in any year 11,302 acres.

The curve for each of the above units of measure (fig. 4) is a strong one, and for all measures except average fire, 10 acres or over, the curves are parallel on semilog paper. The fact that average fire, 10 acres or over, and average fire curves converge is due obviously to the fact that with poorer and poorer protection, all fires would finally be C, D, or E fires.

The key to a rational and defensible statement of objectives lies in the fact that the purpose of fire control in the unit of study is to protect each individual watershed. That is, the water users subject to water shortage or the community subject to flood damage, or the investors in reservoirs subject to silting on watershed A, are not in any better shape if a 5,000-acre fire in their unit is the only large fire in the whole of southern California forests, and if the record for the year is below the general objective for the entire unit.

So, in dealing with watershed protection, the realistic way to state the fire-control objective is in terms of the absolute or, at most, average maximum fire to be expected under a level of protection that will deliver a given degree of control for the entire protected area.

In planning protection of a single watershed, it is impossible to ignore protection on other watersheds. The well-known fact that fires can and do migrate from one drainage to another means that substantial equality of protection organization on all units of essentially similar types and value is required to attain the calculated level of protection on any unit.

The question how best to express the objective lies in a choice between average of the five largest fires per year, or average of single largest fire per year, or the absolute largest fire expected occasionally from a given protection level.

Here one enters the field of watershed values, rather than that of fire control. Final decision on the largest endurable fire will finally have to come from flood-control and water-conservation experts. No such documented and supported decision has so far been made.

As a matter of fire-control planning it can be said that known opportunities exist to reduce the size, both absolute and average, of the larger fires by a substantial margin. The expansion of current programs of transport facilities, specialized equipment, machinery, crew organization and leadership, and better forecasting can probably be expected to reduce by about 40 percent the absolute and average maximum size of fires below the present level of protection.

From the data available the conclusion is reached that an absolute maximum fire of not over 2,000 acres should be the goal, that with expected increased efficiency this corresponds to, or will be associated with a general protection level allowing not over 0.15 of 1 percent average annual burn on the entire national forest protected area.

DETERMINING SPEED OF ATTACK

In planning to attain this objective, the mechanism of attack, already examined from the standpoint of historical trends, must be reexamined as to cause and effect between the mechanism and performance level. Of these mechanisms, speed of attack is first.

As previously shown, the speed of attack on fires has increased greatly. That this has been a major factor in the progressive reduction in fire losses is clear. But the discussion of historical trends in attack on the southern California fire problem did not attempt to determine what speed of attack was required to attain a particular level of performance. Either in all or in each of the principal zones, such a determination is, of course, an essential in the setting of a fire-control planning basis.

Required speed depends on a series of steps—relationship between area burned and percentage of fires 10 acres or over, between percentage of fires 10 acres or over and size when reached, and similar factors.

Relation of Area Burned to Percentage of Fires Over 10 Acres.—In earlier work in northern California, this relationship has proved useful and fairly consistent.

For the 18 years in the period of study in this investigation, percentage of C, D, and E fires for the whole has ranged from 9 percent in 1938 to 51 percent in 1923 (table 23 and fig. 5). Two years are highly inconsistent with the whole record—1932 with only 13 percent of C, D, and E fires and the largest area burned (because of the 218,000-acre Matilija fire), and 1930 with 22 percent of C, D, and E fires and the lowest area burned.

The other years, however, establish a strong curve, indicating that with 10 percent C, D, and E fires the average expectancy is for 7,400 acres burned (that is 0.2 of 1 percent of the entire protected area), and that burned area expectancy has slightly more than doubled (to 15,700 acres) or 0.4 of 1 percent with 20 percent C, D, and E fires.

If the suggested objective of 0.15 of 1 percent is accepted (that is 5,574 acres), percentage of C, D, and E fires will have to be reduced below 10 percent.

Since the curve is a weighted average of all zones, it does not serve to set this relation for the two most important zones—the flash fuels and the brush zones (1 and 2).

TABLE 23.—*Characterization of the man-caused fire problem on the national forests of southern California. Numbers of man-caused fires and percentage which became C, D, or E fires, area burned, man-caused fires by years, for the years 1922–39, inclusive*

Year	All man-caused fires	Portion of man-caused fires which became C, D, or E fires	Area burned within national forests by man-caused fires
	Number	*Percent*	*Acres*
1922	108	40	174, 588
1923	112	51	118, 063
1924	98	50	128, 765
1925	81	36	34, 680
1926	86	37	25, 794
1927	100	34	22, 616
1928	113	36	158, 027
1929	121	28	35, 022
1930	102	22	2, 665
1931	107	31	8, 975
1932	135	13	222, 208
1933	116	16	36, 089
1934	100	14	11, 570
1935	155	10	9, 085
1936	155	12	8, 251
1937	172	10	4, 744
1938	174	9	15, 535
1939	118	16	29, 116
Total	2, 153	24	1, 045, 793

For the latter (table 24 and fig. 5) the general relationship between percentage of C, D, and E fires and area burned is well established. With 10 percent of C, D, and E fires the average expected burn is 4,700 acres for the entire protected area (that is a little less than the 5,140 acres which represents 0.2 of 1 percent of the 2,572,000 acres in the brush zone). With 20 percent C, D, and E fires, the expected burned area is 9,100 acres or slightly less than twice the expected loss associated with 10 percent C fires.

TABLE 24.—*Relation between area burned and percentage of class C, D, and E fires on southern California national forests. Man-caused fires for the years 1922–39, inclusive*

Area	10 percent			11–20 percent			21–30 percent		
	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's
		Acres	*Percent*		*Acres*	*Percent*		*Acres*	*Percent*
All zones [1]	3	9, 788	10	5	17, 847	14	2	18, 844	25
Zone 2 [2]	1	4, 000	9	6	6, 180	16	2	17, 435	23

[1] Matilija fire omitted.
[2] Fires originating in zone 2. Matilija fire omitted.

TABLE 24.—*Relation between area burned and percentage of class C, D, and E fires on southern California national forests. Man-caused fires for the years 1922–39, inclusive*—Continued

Area	31–40 percent			41–50 percent			51–60 percent		
	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's	Number of years	Average annual burn	Portion of fires that became C's, D's, or E's
		Acres	*Percent*		*Acres*	*Percent*		*Acres*	*Percent*
All zones [1]	6	70,780	36	1	128,765	50	1	118,063	51
Zone 2 [2]	3	18,835	36	3	56,235	44	3	71,206	57

[1] Matilija fire omitted. [2] Fires originating in zone 2. Matilija fire omitted.

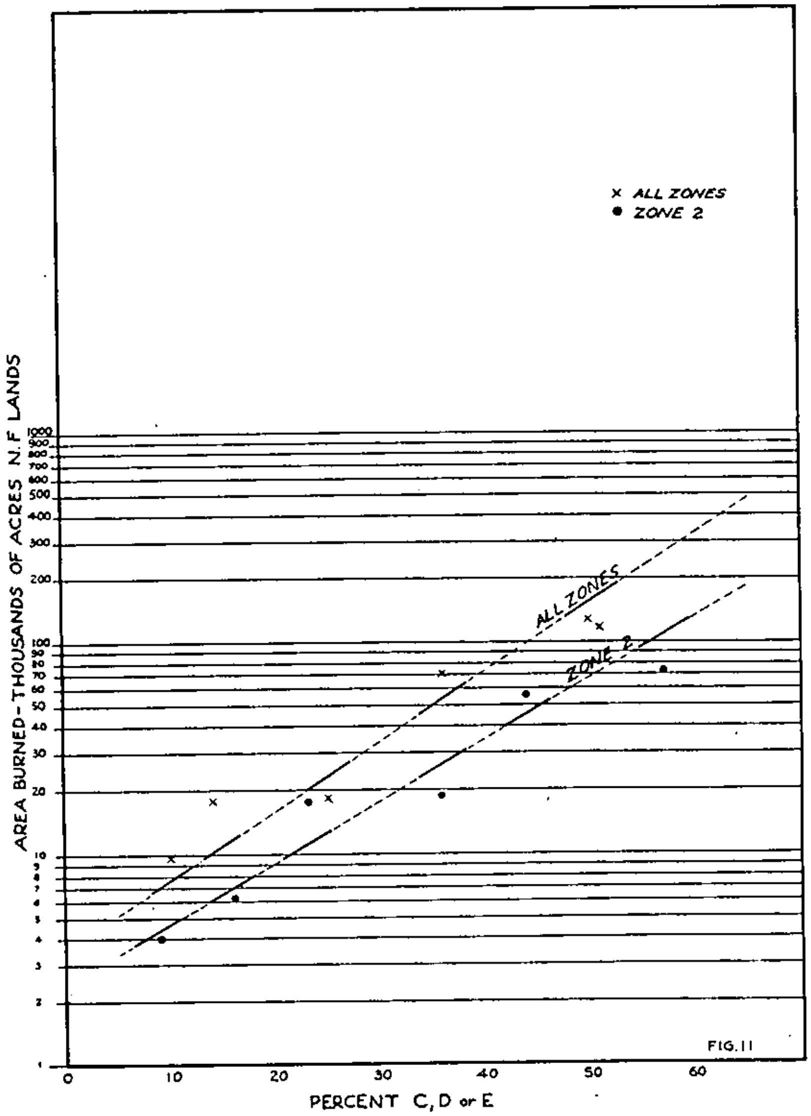

FIGURE 5.—Relation of area burned to percent of Class C, D, and E fires. (Weighted values used.)

Relation of Speed of Attack to Percentage of C, D, and E, Fires.— Leaving aside for, the moment the important variables of strength of attack and size of fire when attacked, which will be examined later, the over-all relation between speed of attack and percentage of C, D, and E fires has to be established (table 25).

For the period 1932–39, 4.9 percent of fires in the brush zone (2) have, with attack 3 minutes after discovery become class C, D, and E fires. Of those attacked within 9 minutes, 8.0 percent are class C, D, and E. The cumulative percentage of C, D, and E fires rises gradually reaching 16.6 percent for the entire group of 512 fires. These figures are particularly important because this zone has the greatest area (69 percent of total), highest value, and the largest number of fires.

In the flash fuel zone (1) the percentage of C, D, and E fires is 8.4 for 9-minute attack, and increases to 23.8 for the entire group of 172 fires. Since the two zones intermingle, the average is of interest. This shows 7.3 percent of C, D, and E fires for 3-minute and 8.1 percent C, D, and E for 9-minute attack, rising to 18.4 percent C, D, and E for the entire group of 684 fires.

As previously shown, the accepted objective of holding individual fires to 2,000 acres or less, could be attained only with less than 10 percent class C, D, and E fires. Thus speed of attack in the brush zone (defined as elapsed time from discovery of fire till work began) is indicated as between 15 and 21 minutes. Since a few minutes necessarily are used for report and getaway time, a travel-time control of 15 minutes is indicated.

TABLE 25.—*Relation between elapsed time, discovery to arrival, and percentage of class C, D, and E fires on southern California national forests. All man-caused fires in inflammability Zones 1 and 2 during the years 1932–39, inclusive*

Elapsed time discovery arrival	Zone 1			Zone 2			Zone 1 and 2		
	All fires	C, D, and E fires	Portion of fires that became C's, D's, and E's	All fires	C, D, and E fires	Portion of fires that became C's, D's, and E's	All fires	C, D, and E fires	Portion of fires that became C's, D's, and E's
	Cumulative number	*Cumulative number*	*Cumulative percent*	*Cumulative number*	*Cumulative number*	*Cumulative percent*	*Cumulative number*	*Cumulative number*	*Cumulative percent*
3 minutes or less	28	4	4.3	81	4	4.9	109	8	7.3
9 minutes or less	71	6	8.4	199	16	8.0	270	22	8.1
15 minutes or less	94	10	10.6	277	24	8.7	371	34	9.2
21 minutes or less	121	16	13.2	326	30	9.2	447	46	10.3
27 minutes or less	128	19	14.8	361	35	9.7	489	54	11.0
33 minutes or less	137	22	16.1	282	41	10.7	519	63	12.1
1 hour or less	154	31	20.1	439	62	14.1	593	93	15.7
2 hours or less	164	37	22.6	482	70	14.5	646	107	16.6
3 hours or less	168	39	23.2	496	78	15.7	664	117	17.6
3 hours or more	172	41	23.8	512	85	16.6	684	126	18.4

In zone 1, the flash fuels, as already noted in the historical section (table 4) rate of spread is more rapid than in the brush zone. This is brought out in table 25 where 8.4 percent of C, D, and E fires result from 9-minute attack, 10.6 percent from 15 minutes, and 13.2 percent from 21-minute attack, all being higher than for the comparable figures in the brush zone.

The indications are that required speed of attack for this zone should be no greater than in the brush (about 15 minutes) and preferably a little less. But as the combined average of the flash fuels and brush zones (table 25) shows that 15-minute attack should hold C, D, and E fires to 9.2 percent, apparently 15-minute attack should be sufficient for both zones.

As a matter of practice, this will, of course, vary, generally tending toward faster speeds in the flash fuels, because attack centers will largely be located in this zone at the lower elevations where the flash fuels and brush join.

Analysis of performance under Forest Service attack showed this to be slightly more effective when measured by percentage of C, D, and E fires than when all sources of attack are considered. The differences are not significant, so the larger mass of data obtained by using records on all sources of attack has been used.

Relation between speed of attack and size when reached.—Increased speed of attack is effective in reducing percentage of C, D, and E fires in part through reaching them at smaller sizes and in part through increased efficiency of attack.

For the flash-fuel zone (1), all fires reached within 3 minutes were less than one-fourth acre in size when reached (table 26). But as further time elapsed by successive steps the rapid spread in this zone decreased the percentage of one-fourth-acre fires. In 9 minutes only 72 percent, in 15 minutes only 65 percent, and in 21 minutes only 59 percent were one-fourth acre or less when reached. At the end of 9 minutes 19 percent of all reached in that time were from one-fourth to 1 acre. Of those reached in 15 minutes 5 percent were already over 10 acres in size, and from that point the percentage that were already C when attacked increased to 11 at 21 minutes, 14 at 27 minutes, and 22 percent at 33 minutes. This is striking evidence of the aforementioned conclusion that speed of attack in the flash-fuel zone should be not over 15 minutes.

In the brush zone (2), rate of spread is generally substantially slower than in the flash-fuel zone. Still, at the end of 15 minutes only 77 percent remain in the 0–¼-acre size class, and in 21 minutes 6 percent are already class C in size. So in general, as concluded earlier, a possibly slightly slower but strong attack in the brush zone might be considered.

In the coniferous timber zone (4), the percentage of fires in the one-fourth-acre class remains at or near 100 percent for a full half hour, and there were no fires already over 10 acres on arrival of crew until over an hour had passed.

TABLE 26.—*Relation between speed of attack (elapsed time, discovery to arrival) and size of fire when reached by attacking force on southern California national forests. Percentage of fires attacked within specified time periods which were of designated areas upon arrival. Man-caused fires occurring in inflammability zones 1, 2, and 4 during the years 1932–39, inclusive*

[Percentage of fires in indicated time interval]

Size when reached	Elapsed time, discovery to arrival									
	3 minutes	4 to 9 minutes	10 to 15 minutes	16 to 21 minutes	22 to 27 minutes	28 to 33 minutes	34 minutes to 1 hour	1 hour, 1 minute to 2 hours	2 hours, 1 minute to 3 hours	Over 3 hours
Zone 1:										
0–¼ acre	100	72	65	59		45	12	20	25	25
¼–1 acre		19	22	15	57	22	35	20		
1–4 acres		9	4	7	29	11	12		25	
4–7 acres			4	8			18			
7–10 acres										
10 acres			5	11	14	22	23	60	50	75
Zone 2:										
0–¼ acre	98	86	77	76	66	57	32	46	22	19
¼–1 acre	2	10	10	6	8	14	26	21	7	12
1–4 acres		2	8	10	8	5	12	16	7	19
4–7 acres		1	4	2	6	14	10	5	7	13
7–10 acres			1		3		2			6
10 acres		1		6	9	10	18	12	57	31
Zone 4:										
0–¼ acre	95	95	95	90	92	100	75	87	67	43
¼–1 acre	5	3	5	5	8		20	6	33	14
1–4 acres		2		5			5			
4–7 acres										29
7–10 acres										
10 acres								7		14

Percentage of C, D, and E Fires in Relation to Size of Fires When Reached.—An additional light on the mechanics of controlling fires of small sizes is afforded by the relation between percentage of C, D, and E fires and size of fires when attacked (table 27).

With a strength of attack of 1–10 men in the flash fuels (zone 1) only 4.7 percent of fires reached at 0–¼-acre size become class C, D, or E, 8.3 percent of those reached at ¼–1 acre, 12.5 percent of those reached at 1–4 acres, but 100 percent of those 4–7 acres when reached.

For the brush zone (2), 1.4 percent of the smallest size class become class C, D, or E, but in the next size class 23.5 percent are C's, D's, or E's, and this figure rises steadily to 38.5 percent in 1–4-acre fires, 46.2 percent in the 4–7-acre class, and 66.7 percent in the 7–10-acre group.

The pronounced difference between these two important zones means that, because of the far heavier cover and hence greater difficulty of control in the brush, suppression forces are more seriously handicapped by each increase in size of fire beyond the smallest size class. The question of whether this handicap can be measurably overcome by more general use of tank trucks in initial attack will be considered later. But it is evidently imperative to plan fire organization to reach brush fires at small size, and that means speedy attack.

TABLE 27.—*Relation between area of fire upon arrival of suppression force and its final size class. Percentage of class C, D, and E fires resulting from attack by 1–10 men according to size classes upon attack. Man-caused fires in inflammability zones 1, 2, and 4 for the years 1932–39, inclusive, on the national forests of southern California*

[Percent of fires in size, class, and zone which became C, D, and E fires]

Area	Area of fire upon arrival of initial attacking force					Number of fires in zone
	0.0–0.25 acre	0.26–1.0 acre	1.1–4.0 acres	4.1–7.0 acres	7.1–10.0 acres	
	Percent	*Percent*	*Percent*	*Percent*		
Zone 1	4.7	8.3	12.5	100	No fires	123
Zone 2	1.4	23.5	38.5	46.2	66.7 percent	355
Zone 4	0	18.2	50.0	0	No fires	176

Attacking forces have nearly a 3 to 1 chance in flash fuels, as compared with brush areas, to hold fires to less than 10-acre size when fires are reached at sizes between one-fourth and 4 acres. This greater effectiveness of attack seems to mean that despite the previously shown greater rate of spread in zone 1, about the same speed of attack as in the brush can be expected to be effective because of the relatively easier job of control line construction.

From studies of rate of spread of fires in zone 2 and corresponding studies of rate of fire-line construction, it is known that the average fire will make perimeter from three to six times as fast as a 10-man crew can construct fire line. Fires that are controlled in the smaller sizes are caught by reducing the spread of the fire through direct attack of the fast moving head, by the application of water or dirt, or removal of the fuel—thus providing time to complete the flanking lines. Since zone 2 is characterized by heavy brush cover, the probabilities that it will be possible to maneuver men safely in front of any but the smallest fire for these purposes are decidedly remote. This emphasizes the necessity for attacking the fires when small and, where possible, with tanker equipment and trained tanker crews.

In the coniferous forest zone (4) there are no C, D, or E fires when attack is made in the 0–¼-acre size class, but percentage of C, D, and E fires build up rapidly as size increases.

Particularly in the brush zone, a reasonable inference seems to be that reaching fires with small crews rapidly and when fires are small is likely to be more effective than slower attack at larger sizes with large crews. That is, in terms of fire-control organization, more attack centers with small crews, means of rapid transportation and supplementary tanker equipment, rather than fewer attack centers with larger crews and slower transportation. Further consideration of this inference, as well as of the question of what size attack crew is most effective in the different zones is postponed to a later section.

Increase in effectiveness of attack.—The period 1932–39 has been used in analyzing relation of C, D, and E fires to size of fire when reached for the very good reason that the relationship has changed rapidly from period to period, that is, as a starting point for appraising future fire-control needs the use of the full 18-year period would show a greater problem than exists today.

In zone 1, with 1–5-man attack, the percentage of C, D, and E fires of all those reached at 7 acres or under has been reduced from 35 percent in the period 1922–28 to 7 percent in the period 1932–39. In zone 2 the comparable reduction from 17 percent to 8 percent, while less striking is still substantial.

DETERMINING STRENGTH OF ATTACK

Strength, like speed of attack, is one of the key mechanisms in building fire-control organization to attain a specified objective. Operating experience shows that in southern California one man initial attack is hopelessly inadequate. Thus, two major questions require analysis.

1. What size initial attack crew in the major types is sufficiently effective in catching fires at sizes under 10 acres?

2. What effect does progressively heavier attack have in reducing size of those fires which reach class C, D, and E size?

Because, as already shown, speedier initial attack with small crews has had strikingly improved results from period to period, only the recent period (1932–39) is used in the analysis.

Initial attack strength.—For the flash fuel zone 1, 1–3-man attack held all but 4 percent to size C, if they were one-fourth-acre or less in size when reached (table 28). With the same strength of attack, there were 12 percent C, D, or E fires among those reached at one-fourth–1 acre-size and 25 percent C, D, or E's in the 1–4-acre class.

In this zone 4–5-man attack (based on only a small number of cases) shows higher percentages of C, D, or E fires in all size classes, but with 6–10-man attack the percentages of C, D, and E fires are substantially the same as in the 1–3 attack groups. This seems to mean that on initial attack the size of crew, at least beyond 3-man size, is not particularly important in itself in the open light cover of the flash fuel zone.

In the brush zone, on the contrary, there is progressive reduction in percentage of C, D, and E fires in each size class as strength of initial attack increases, except for one-fourth-acre fires on which 3-man attack is highly effective. But in the one-fourth–1-acre class 3-man attack has 26 percent C, D, and E fires, 4–5-man attack has 15 percent, and 6–10-man attack has but 12 percent. In the 1–4-acre class the percentages are respectively 45, 31, and 23; in the 4–7-acre class they are 67, 50, and 34 percent.

The consistency of the figures (based on a large number of cases) shows unmistakably that strength of initial attack is highly important in the brush zone. In general, the greatest decrease in percentage of C, D, and E fires is obtained by increasing strength of attacking crew of 1–3 men to 4–5 men, rather than by increasing from 4–5, to 6–10 men.

TABLE 28.—*Relation between size of fire when attacked, number of men in suppression force, and final size class of fire. Percentage of fires becoming class C, D, or E fires according to area when attacked and size of suppression force. Man-caused fires in inflammability zones 1, 2, and 4 for the years 1932–39, inclusive, on the southern California national forests*

[Cumulative percent of fire in zone which became C, D, or E]

Crew size and zone	Area of fire upon arrival of initial attacking force, acres				
	0–0.25 percent	0.26–1.0 percent	1.1–4.0 percent	4.1–7.0 percent	Curve values
1–3-man attack:					
Zone 1	4	12	25	75	
Zone 2	2	26	45	67	
Zone 4	0				
4–5-man attack:					
Zone 1	5	25	50	100	
Zone 2	2	15	31	50	
Zone 4	0				
6–10-man attack:					
Zone 1	5	12	25	75	
Zone 2	1	12	23	34	
Zone 4	0				
11–20-man attack:					
Zone 1					
Zone 2	0				
Zone 4					
Zone 1					123
Zone 2					356
Zone 4					176

Follow-Up Attack Strength.—Strong and aggressive follow-up attack on those fires which escape initial attack is clearly necessary to hold acreage as low as possible. In analyzing the relationship, the period 1932–39 is used, for the reasons already stated in the discussion on strength of initial attack and percentage of C, D, and E fires.

For the period, of the 469 fires in the brush zone reached before they were 10 acres in size (table 29) 48 became class C, D, or E. Of these, four became major fires (3,270, 3,550, 5,370, and 9,486 acres, respectively), and their acreage has been deducted. A fairly regular decrease in size of the average fire 10 acres or over (C, D, or E) is found as attacking strength increases. Once a fire on this zone has escaped initial attack, increased forces following immediately are evidently a good investment.

In the flash fuel zone, with rather scanty data, it is evident that increase of forces up to a moderate point results in reducing size of average fires 10 acres or over. But it seems doubtful from the data whether very heavy initial crews are particularly useful in this zone of light cover.

The problem in the coniferous timber zone (4) has already been disposed of as one of fairly prompt arrival of small or medium size crew when the fire is small in size. Class C, D, and E fires do not now occur when these conditions are fulfilled.

The most effective type of attack crew in the brush zone cannot be determined solely from this analysis. The cost becomes important, since the unit wage of 6–10-man crews is far greater than for 4–5-man crews. Since, as already shown, the greatest possible speed in reaching fires is imperative, hence the travel speed for 4–5- and 6–10-man crews has to be considered. The smaller crew usually can use motor equipment of the pick-up type, and travel safely as fast as the available roads will permit. A crew of 6 to 10 men, on the contrary, usually requires a truck, and hence slower road speeds are attainable than with lighter cars.

There is a strong presumption, considering these factors together with the conclusions from the fire data, that 5-man crew attack is in general the most effective basis to set up for the brush zone. Obviously, special cases may require special treatment.

The data showing effectiveness in holding down percentage of C, D, and E fires in the brush zone with initial attack by 11 men up to 50 men include relatively few cases, and individual class values are too irregular to curve. But, in general, there is little if any further reduction in percentage of C, D, and E fires below that attained by 6 to 10 men. The heavier attacking crews have not therefore been considered as a possibility or a need in planning fire-control organization.

TABLE 29.—*Relation between number of men in suppression force and final area of those fires which were attacked when smaller than 10 acres and finally became class C, D, or E fires. Man-caused fires in inflammability zones 1 and 2 during the years 1932–39, inclusive, on southern California national forests*

	Size of initial attacking force—number of men						
	1-3	4-5	6-10	11-20	21-30	31-50	51 plus
Zone 1:							
umber of C, D, and E fires	3	2	6	3	1	1	----------
Area burned, acres	3,622	105	1,567	203	360	75	----------
Area of average C, D, and E fires, acres	1,207	52	261	152	360	75	----------
Zone 2:							
Number C, D, and E fires	14	8	6	8	4	4	----------
Area burned, acres	7,004	1,809	1,219	1,780	258	156	----------
Area of average C, D, or E fire, acres	500	237	203	222	64	39	----------

PROBLEM OF HIGH-DANGER DAYS

As previously shown, during the last period (1932–1939) all fires which reached sizes of 1,000 acres and over started on an average of only 2.9 days per season. That is, the vast majority of the burned area resulted from failure on from 1 to 2 percent of the total days in the fire season. For the same period the major fires of 5,000 acres and over started on not over a single day in any one season. A large part, though by no means all of the fire problem, is in more effective handling of the few fires occurring on the bad-fire days.

Part of this problem is clearly that of fully dependable and sure predictions of the weather conditions which cause bad-fire days. Much work has already been done and is continuing. The fire-danger rating system, based on current and widespread observation of such key elements as fuel moisture, wind, and relative humidity, is systematically used by the weather forecasting agencies.

The most spectacular type of bad-fire day—that of the "Santa Ana"—is apparently readily identified for forecasting purposes. This weather type occurs in late fall and early winter, and has been responsible for several of the major fires during the period of study, notably in recent years the Arrowhead fire, 10,814 acres, San Bernardino National Forest; and the San Antonio fire, 3,317 acres, Angeles National Forest, both starting in November 1938

But Santa Anas are not, contrary to common belief, the only kind of bad-fire day. August 14 and 15, 1939, on which all large fires of that year started, were not severe Santa Ana days, nor was September 7, 1932, the date of start of the largest fire, the Matilija. The problem of identifying and predicting the bad days during summer and early fall, which includes milder Santa Anas, seems to be more difficult than forecasting severe Santa Anas.

The problem of critical weather conditions that develop in fire areas from the major fires themselves is one that requires special study and analysis. With a bad-fire day predicted, the problem of fire organization has several possible fields in which solution may be sought.

The first is that of fire prevention. Although the normal season-long practices are already fairly intensive, there is opportunity for additional measures on key days. Closure of certain areas to use, intensified patrol, and general use of registrars to warn users are among the obvious steps.

A second field is in increasing strength of organized fire-suppression units. Since bad days are reflected in more rapid initial spread of fires, it is clear that for a given station, fires normally reached at 0–¼-acre size may on bad days be expected to be ¼–1 acre on arrival of crew. Increased crew strength is certainly a necessity to overcome such a handicap, and particularly in the brush zone.

The greater initial spread may in some cases be offset by installing additional normal size crew units in hazard areas. These, by decreasing the normal attack time, may be expected to reach fires on bad days at manageable size. This form of emergency action has the practical difficulty that temporary and self-sustaining stations must be set up. But, since the emergency is short lived, there appears to be no compelling reason against use of temporary tent camps, with all facilities in proportion.

Once fires start on bad days, the existing tremendous capacity to concentrate trained and organized crews on a given spot can be utilized. It is a demonstrated fact that powerful attack on fires in early stages will on the average hold fires to a relatively small area.

More effective handling of the few bad days requires advance warning of their impending occurrence.

Effectiveness is also dependent on a highly trained crew working as a coordinated unit. The effectiveness and popularity of tankers is expected to increase, especially when units are developed to negotiate under their own power more of the steeper brush-covered slopes while travelling cross country from adjacent roads.

Relation Between the Occurrence of Large Fires and Continental Winds (Known Locally as "Santa Anas").—In the late fall almost every year winds of high velocity and of from 3 to 5 days duration blow across the suthern forests from northerly or easterly directions. These winds frequently reach 50 miles an hour and are often accompanied by very low humidities, especially in the flash-fuel and dense-brush area at intermediate and low elevations. Obviously the high winds and low humidities, which, during Santa Anas extend over areas normally occupied by moister marine air, create conditions under which it is extremely difficult to control fires once they gain headway.

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In the discussion that follows about Santa Anas the data are from Frazier Mountain, elevation 8,026 feet; Oat Mountain, elevation 3,756 feet; Keller Peak, elevation 7,863 feet; and Cuyamaca Peak, elevation 6,515 feet. Severe Santa Ana conditions were considered to be represented at these stations by noon relative humidity of 15 percent, or less, and noon wind velocity of 30 miles per hour, or more. These stations do not fully represent all geographical areas and altitudinal ranges affected by Santa Anas, but the information derived from their records, in spite of its limitations, may be taken as indicative.

In spite of the occurrence of these dangerous conditions practically every year the major proportion of the burned area has not occurred during these spectacular periods. Fortunately, in some years the heavy winds start after the fall rains have begun. Actually, large fires have developed during the Santa Ana conditions specified in only 10 out of the 18 years studied, hence the major fire problem in southern California is not the reduction in size of the few fires that became large during these periods.

As shown in table 30, fires that exceeded 1,000 acres which started during Santa Ana conditions covered but 45,868 acres within national-forest boundaries in the 18-year period. This was but 4.4 percent of the total area burned by all fires 10 acres and larger.

TABLE 30.—*Area burned during extremely dangerous fire weather (Santa Ana conditions)*[1] *on the national forests of southern California. Number of man-caused fires 1,000 acres and over, area burned within national-forest boundaries and percent of total area burned within the national forests, by years*

Year	Number of man-caused fires 1,000 acres and over	Total area burned within national forests	Percent of total burned area within national forest boundaries
1923	1	20	0.02
1924	1	950	.74
1926	1	9,790	37.20
1927	1	8,000	35.06
1928	1	5,600	3.54
Period total	5	24,360	3.65
1929	1	1,380	3.92
Period total	1	1,380	2.89
1933	1	2,140	5.34
1935	2	3,356	36.94
1936	1	60	.73
1938	2	14,572	93.80
Period total	6	20,128	5.84
Grand total	12	45,868	4.33

[1] Winds 30 miles per hour or more, relative humidites 15 percent or lower, both at noon, at Frazier Mountain (8,026) or Big Pine Mountain (6,500); Oat Mountain (3,756); Keller Peak (7,863) or Butter Peak (8,502); and Cuyamaca Peak (6,515).

Further analysis has been made of weather reports made from the four lookout points previously mentioned within and adjacent to the southern forests for the years 1932–39, inclusive. The data showed that during the following periods Santa Ana conditions were reported from one or more of the observation points, but no serious fires developed from those that started during such times

TABLE 31.—*Occurrence of extremely dangerous fire weather (Santa Ana conditions* [1]*) on any of the southern California national forests during which no major forest fires developed. Showing total length and number of dangerous periods by years, for the years 1932–39, inclusive*

Year	Number of periods	Total number of days
1932	4	16
1933	3	13
1934	1	3
1935	3	9
1936	4	9
1937	0	----------
1938	5	18
1939	2	7
Total	22	75

[1] Winds 30 miles per hour or more, relative humidities 15 percent or lower, both at noon, at Frazier or Big Pine Mountain, Oat Mountain, Keller or Butter Peak, and Cuyacama Peak.

Periods of less than 2 days duration were not included in the foregoing tabulation. The longest period reported lasted 6 days. The analysis also shows that in many cases Santa Ana conditions do not obtain throughout the entire area concerned in this study. In fact, occurrence of highly dangerous conditions over the whole of southern California at one time is exceptional.

The extent of the Santa Ana periods during which fires were prevented from becoming disastrous is surprising and represents real public cooperation and accomplishment in fire control. This statement is borne out by the record of 2 years of two forests that were selected as a random sample While two fires during the period became large, 11 fires that started when conditions were as bad were controlled as 6 A's, 3 B's, and 2 small C's, with a total area of only 132 acres burned. This shows clearly that a small percentage of the fires that start in Santa Ana periods become conflagrations. Such fires do present a major problem, but by no means an insurmountable one.

PROBLEM OF RISKS

In the southern California national forests the problem of risks in fire planning is almost wholly one of man-caused fires, for, as already shown, lightning fires are neither numerous nor so difficult to control as to be a source of serious difficulty. Coverage is required for lightning fires, but that already existing has for many years resulted in not a single fire of over 1,000 acres from this cause. Lightning fires have never occurred in large numbers on a single day or group of days, as they commonly do in northern California and in other western forest regions, so there is no organization problem in handling concentrations.

Debris burning fires remain a rather important cause (table 32), with 106 fires, or 13 average per year. They are a factor on all four forests. Percentage of C, D, and E fires is moderately low, at 8.

Camper fires total 64, or an average of 8 per year. The percentage of C, D, and E fires is 11. Obviously the long-sustained prevention programs, involving various steps, has reduced this once important cause to a relatively minor position.

Among the recognized human causes (table 32) lumbering is nonexistent. Only a thin sprinkling of fires have been due to incendiaries, one of the major causes of trouble in the northern California forests.

But of the 51 such fires, an average of 6 per year, which are localized in a few restricted areas, 20, or 39 percent, were class C, D, and E. This is the highest percentage of C, D, and E fires from any cause, and, as in northern California, incendiary fires are individually the most dangerous cause.

TABLE 32.—*Summary of causes of man-caused fires on the national forests of southern California. Total number of fires, number of C, D, or E fires, percent of C, D, or E fires, and area burned by fires ascribed to different causes. All man-caused fires for the years 1932–39, inclusive*

Cause	Fires	C, D, and E fires	Portion of fires which became C, D, or E's	Area burned inside national forests	Percent of total area burned inside national forests
	Number	*Number*	*Percent*	*Acres*	
Debris burning	106	9	8	4,393	1
Camper	64	7	11	219,106	[1] 65
Incendiary	51	20	39	9,335	3
Miscellaneous	390	27	7	28,266	9
Railroad	58	4	7	362	
Smoker	435	65	15	74,263	22
Unknown	21	5	24	873	
Total	1,125	137	12	336,598	100

[1] Includes Matilija fire, 218,000 acres.

Railroad fires, 58 in number, are almost wholly on the San Bernardino National Forest where they average 7 per year. The problem is a specific localized one. Percentage of C, D, and E fires is only 7.

The two major causes are the miscellaneous group, with a total of 390 fires, and smoker fires, with a total of 435. The former are low in percentage of C, D and E fires with 7; the latter relatively high with 15.

Possibilities of prevention effort in reducing the several causes vary greatly. Debris burning fires occur in restricted and known zones around ranches and mountain recreation communities. The persistence of the cause indicates clear need for more systematic, on-the-ground, prevention effort and actual cooperation in and supervision of needed burning, rather than dependence on rare visits or on letters.

Further reduction of camper fires should be possible by expansion of past efforts—concentration in safe, prepared and fire-proofed campgrounds out of hazardous canyons, prepared fireplaces, registration, resident guards, etc. The persistence of the cause again indicates too thinly spread on-the-ground prevention effort, and too much casual, rather than systematic contact work.

The only remaining unexhausted remedy for incendiary fires in this portion of the region is law enforcement, attainable only through systematic and persistent year-long effort by men qualified to handle these unusual and difficult cases. Existing effort is sporadic and occasional, and has been ineffective. Experience elsewhere indicates that the cause can be practically eliminated by unremitting attention to it. Incendiarism in this area seems to be, as elsewhere in the State, largely a reflection of seriously submarginal hill agriculture. Use of fire to clear land in an attempt to obtain feed for stock is commonly associated with such ventures.

Railroad fires have been indicated as a local problem. The means to eliminate the cause are well known, but require sustained regular pressure if they are actually put into effect. This has evidently not been regularly given.

The smoker fire has been subjected to intensive prevention effort for many years, but obviously is nowhere near conquered. "No smoking" ordinances and regulations, closing roads—even major highways—to smoking, fairly good police effort in enforcing rules and laws, fireproofing of many main highways and lesser roads, and concentrating recreational use in prepared campgrounds, in combination, have had the effect of reducing the number of fires per 100,000 users, but have not succeeded in preventing an increase in the total number of smoker fires. Evidently the problem is of the same persistence and nature as that of obtaining safe driving on the highways. In both problems police effort is effective up to a point, but it is unthinkable to have, in either case, enough officers to fully police everybody all the time. In both cases, reducing the opportunity for carelessness to lead to disaster has a place—in the one, by building safer highways and cars and, in the other, by fireproofing roadsides and campgrounds. But not all (the trouble in start of) fires start from the edges of major or even minor roads or from campgrounds. In both cases it is equally impossible to solve the problem by continuously refusing all use. The highways are built for public travel and the national forests are administered for public use. Possibly on high danger days, use of the national forests can be more generally restricted than in the past.

Solution of both problems finally must be sought in the slow, laborious, and discouraging process of educating the public as individuals into habits of safe driving and safe smoking. Both programs face the queer perversities of human nature, which leads individuals to assert heatedly their own caution at the very moment they are taking foolish and unnecessary chances.

The route to take in the necessarily long-time solution of the smoker fire problem is clear. Continuation and expansion of policing, greater attention to fireproofing so that fires cannot start, and a systematic planned and continuous campaign of individual education, perhaps seeking out new and untried methods.

Two such ventures are already under way. The first involves shifting recreational use from the low elevation, hazardous canyons, to the higher elevation, coniferous timber plateaus. An extensive and expensive system of public highways is under construction as a first essential to accomplish this major shift. The usable new areas have been or are being developed to provide safe and convenient places for recreational use.

The second method, particularly urgent on Los Padres National Forest, but also important elsewhere, is to work out a major shift in the deer hunting season. A very high percentage of the burned area over a period of years has resulted from deer hunter fires, including the Matilija fire (Los Padres 1932, 218,000 acres). This shift involves action by the State, and thus is less readily applicable than methods within the control of the Forest Service.

Another possible method is the closure to hunting of all burns over 1,000 acres in size until the cover is reestablished as a deterrent to intentional hunter fires.

As a matter of fire planning, it has to be accepted that both numbers and distribution of smoker fires are likely to be reduced but slowly. The known zones of occurrence must be covered in the organized suppression crew network. Greatly expanded effort in all phases of prevention is required as a parallel program.

The catch-all class of miscellaneous fires includes the following specific causes:

Burning automobiles, automobile and farm machinery exhausts, burning buildings, spontaneous combustion, smoking out bees, burning out woodrats and rattlesnakes, friction in industrial operations, blasting, breaking or short-circuiting power lines, airplane crashes, tracer bullets, hot ash disposal, sun rays on broken glass, woodrats or mice with matches, children playing with matches.

It can readily be seen by reviewing the specific causes of this group that the problem of preventing fires caused by the large numbers of visitors seeking recreation in these forests is by no means the predominant part of the entire problem that one would at first expect. The problem of prevention of fires resulting from miscellaneous causes as listed is extremely complicated, elusive and of no small magnitude. The fires are scattered promiscuously over any area that is being put to use, and may be expected in rare instances to occur in areas not associated with regular human occupancy. Due to this peculiarity, resulting fires are not anticipated and the element of relative unpreparedness or inaccessibility of the fire generally is responsible for large resulting burned area, especially when adverse weather conditions, such as high winds, or drying out of the fuels contribute to the cause.

Prevention of this type of fire requires ingenuity and continuously sustained well-directed effort. Due to the fact that the fires start in the most out-of-the way localities or result from entirely unexpected occurrences, the prevention program must be carefully planned and applied on a widespread basis. Only through inspection, education and resulting corrective action can a portion of these fires be prevented.

One way to characterize the over-all problem of risks is illustrated by table 19, which shows the distribution of starting points of man-caused fires in relation to distance from roads, as well as percentage of C, D, and E fires, and area burned by fires grouped in this way.

On the Angeles, San Bernardino, and Cleveland National Forests, all of which already have relatively intensive road systems, 78 percent of all man-caused fires start within 265 feet of roads, but account for only 69 percent of the area burned. This group of fires is, therefore, susceptible to rapid attack by crews, provided their attack centers are correctly located. They are also susceptible to use of tankers, in the initial attack. And of course, a considerable number of these fires are "roadside fires."

On the same group of forests, 11 percent of all man-caused fires started from 265 to 800 feet from roads and accounted for 9 percent of total area. That is, the attack still held area burned to a lower percentage of total than that represented by numbers.

From 800 feet to one-fourth mile from roads, 5 percent of fires started and burned 10 percent of total area. The relatively slight increase in handicap to the attack meant a real difference in results. And the 6 percent of all fires starting over one-fourth mile from roads caused 12 percent of all burned area.

On Los Padres National Forest, with only part of the skeleton road system completed, 60 percent of all fires started within 265 feet of roads and burned 31 percent of the total area; 9 percent of fires started within 265 to 800 feet and burned 10 percent of the area; 31 percent started over 800 feet from roads and burned 59 percent of the total.

Both sets of data indicate that existing road systems facilitate effective attack on the majority of present fires, but that large numbers of fires start at a distance from roads, and on these the attack is heavily handicapped. Another way to look at it is that without any more roads, fires will start in relatively inaccessible places. With roads to reach them, the attack can hold down size to a figure markedly lower than at present. As indicated earlier, many of the specific causes grouped as miscellaneous fires are highly resistant to prevention, and these fires are largely at a distance from roads.

The complexity of the prevention problem indicates need for going much further than heretofore in developing and assigning specialized personnel to specific prevention tasks. Methods and procedures are needed for stepping up the tempo of prevention effort rapidly during periods of high danger, particularly extreme "Santa Anas." Possibly more general closure of critical areas to all public travel and use is justified when other efforts are not holding the numbers of fires to an acceptable level.

PROBLEM OF SUPPRESSION OF THE LARGE FIRE

Even with a very intensive fire-control plan for preventing the excape of the small fire, the expectations are that periodically a small number of these will not be successfully controlled by the initial attacking force. One of the main reasons is rapidity of initial spread.

Table 33 shows the extreme initial rates of spread associated with a small percentage of the fires which occur. Ten percent of the fires in zone 2 can be expected to have a rate of perimeter increase while free burning in excess of 80 chains or 1 mile per hour, and in the flashy fuels of zone 1 in excess of 115 chains per hour; while 5 percent can be expected to increase at rates in excess of 135 chains per hour and 175 chains per hour, respectively. It is at present inconceivable that an initial attacking organization can be created which will cope successfully with all cases of such rapid initial spread, although the use of water has so materially increased the chances of suppression by initial attack that maximum effort to control the fire by this means is amply justified. Plans, therefore, must be provided for the suppression of the large fire.

TABLE 33.—*Rate of initial spread of free burning fire on the national forests of southern California. Percentage of fires which spread at specified rates*

Zone	Number of fires	Average perimeter increase	50 percent spread less than—	10 percent spread more than—	5 percent spread more than—
		Chains per hour	*Chains per hour*	*Chains per hour*	*Chains per hour*
Zone 1	160	45	20	115	175
Zone 2	572	30	20	80	135

Table 7, shows 1,035 acres to be the average area of the 21 fires which reached 1,000 acres and which were controlled before the second burning period began, and it is readily seen that satisfactory suppression of the large fires is dependent on securing control before the second burning period, at the worst. This is essential to reach any reasonable burned area objective (table 22), but in itself may not prove satisfactory, since some fires may be expected to burn a much larger area than 1,000 acres during the first period.

Records for the period 1932–39 show the action in respect to overnight control is far from satisfactory, since 70 percent of all fires over 1,000 acres have required more than one burning period to control. These fires have accounted for 93 percent of the total burned area.

That this problem is difficult and complex is well known. The chief difficulty lies in the inability to work large numbers of men effectively in direct attack until the night influences cause the fire to subside. Sufficient time is then not available to complete the entire control job, before the burning period of the second day and the extra period fire results.

Rate of line construction in typical zone 2 cover is notoriously slow. Studies of production in this type by fresh, trained crews show that, for short shifts of 2 hours, it requires from 20 to 30 men to build 10 chains of line per hour. The size of job in the dense brush and resultant low efficiency is a major reason for this low production.

Enormous rates of spread are evident, especially after the fire becomes established on the slopes and generates its own weather to a certain extent. Longitudinal advance of the fires during the period they are burning most rapidly averages between 1 and 1¼ miles per hour, according to the best information available. The resultant perimeter is terrific.

Consideration of this problem has resulted in planning a network of roads supplemented by firebreaks and fire lanes on the more important ridges. A large part of the plan has been put into effect. Approximately 2,500 miles of firebreaks have been constructed.

Experience has shown that the use of the firebreaks has as yet been unsatisfactory in controlling the initial run of fire. This has been due, first, to the impossibility of placing an adequate crew on the break in time to backfire it and at the same time provide for control by direct attack; second, that running fires have in almost every instance spotted over these breaks.

That the first reason is authentic and may be expected to repeat itself requires little imagination. The mobilization and travel time of an adequate backfiring crew of 50 to 100 men will require, under the best planning, a minimum of 1 hour after report of fire to place it on the more accessible firebreaks. During this time the fire has moved forward a half mile to a mile or more, as has been previously shown. The break must be prepared for burning, and the crew organized and put into action. All this is time-consuming, and time is a very important factor in establishing an effective backfire. Actual backfiring of these breaks in advance of threatening fires has been employed to a minor degree in the past on fires burning inside the national-forest boundaries.

The use of water in backfiring is becoming more and more important. Los Angeles County backfired 16½ miles of break successfully with water in 1935. Water was used extensively in the control of the Arrowhead fire on San Bernardino Forest in 1938. This requires a road along or adjacent to the break for tank trucks to operate on, which limits its use seriously on the rougher steep topography in the forests.

Firebreaks and lanes have, however, contributed materially to suppression, in moving men and providing for their safety.

Tractors, preferably with trailbuilders and winch attachments, are becoming more universally usee in line construction and other suppression activities. The chief limitation to their use is extremes of slope or excessive rock, but it has been found that most large fires have a reasonably large part of their perimeters on areas which are subject to work by this machinery. Their use will continue, undoubtedly, in many diversified forms.

Better fire suppression practices which should result in a lower percentage of extra period fires and much less burned area if properly employed depend on:

1. Trained leadership, resulting in good judgment, decisiveness, and rapid, well coordinated action.
2. Proper equipment, with particular reference to tractors, tank trucks, aerial photographs, maps, etc.
3. Effective service of supply.
4. Current information on fire, weather, and suppression efforts.
5. A supply of capable seasonal labor.
6. Physical improvements in the form of roads, trails, lanes and firebreaks sufficiently numerous to permit early access to the perimeter at numerous points.
7. The will to backfire early and aggressively as an attacking measure and not solely as a last defense.
8. Greater skill in forecasting behavior of fire in the broken topography typical of the region.
9. Planning and providing for possible backfiring if initial attack fails to hold the line. This requires manning of the line which may be used, concurrently with the initial attack.

PROBLEM OF ROADS AND OTHER FIRE-CONTROL FACILITIES

As indicated earlier, progress in solving the fire problem in southern California has been closely associated with an expansion in the road system. Increased road mileage has been the first essential in faster, stronger, and more diversified and mechanized attack.

In the general expansion of road mileage, some watersheds or parts of watersheds, particularly on the Angeles and San Bernardino National Forests, have approached the present concept of an "ultimate" transportation system. On other watersheds, notably on Los Padres National Forest, not even the primary system of roads is yet completed. These watersheds thus represent the immediate urgent problem of carrying to a reasonable level of completeness methods of proven merit. Less urgent, but important, is completion of the planned transportation system on watersheds of particularly great value.

Full use of the present road system is not being had. It has been possible to build the roads, but it has not been financially possible to build the other things needed to get best use of the roads. In particular, organized trained suppression crews, housing for them, transportation and other mechanized equipment for their use, and sources of water supply have been but partially developed. A large problem remains in obtaining balance between existing road systems and means for their effective use. At present, the two are seriously out of balance.

PROBLEM OF PERSONNEL

The need for the highest possible caliber of personnel to operate the complex, fast-moving job of fire supression has already been referred to. The problem is twofold. First, for the most skilled leadership. Many men have learned much from hard experience in fighting fires. But no armed service in the world depends on actual war experience to train its leaders. The job of directing fire suppression is parallel in difficulty to the problems of war. Altogether too much dependence has had to be placed on experience alone in training leadership.

Second, for the most effective suppression crews. Jobs on these crews have not been attractive to the type of man required in the swift-moving task of fire supression in southern California. The seasonal work for only a few months a year has resulted in rapid turnover, and consequent inability to maintain the highest type of crew organization. This must be remedied to hold capable personnel and obtain the accumulated benefits of their training and experience.

Selection and training, both of leaders and of crew workers is thus a step in raising the effectiveness of fire control, coordinate in importance with roads, mechanized equipment, and the other phases.

EXPECTED FLEXIBILITY IN APPLICATION OF RECOMMENDED STANDARDS

The study has resulted in recommendations of 15-minute attack time with five-man crew and tanker in the brush zone, and 15-minute time with three-men and tanker in the flash fuels. These should, of course, be accepted as averages for normal conditions and not prescriptions to be followed slavishly on each part of each watershed. Time requirements obviously will be much shorter during more dangerous fire weather. Many other modifying factors are important locally.

One known variable, for example, for which no arithmetical measure is available, is faster spread in the lower elevations of the brush zone except those with marine exposure than is to be expected in the higher areas of the same zone.

Another known variable, lacking in arithmetical measure, is faster spread on south than on north slopes within the brush zone at the same elevation.

Yet another unmeasured variable is significant difference in density of cover within both the flash fuel and brush zones at the same elevations and on the same aspects, because of minor differences in site or number of years since the last burn.

Yet another is the great variation in soil condition, that is, amount of rock, which is reflected in difficulty or ease of line construction, all other conditions being equal.

A further variable is the complicated way in which wind at a given time blows uphill and hence spreads fire rapidly, at one point, and elsewhere blows downhill and tends to retard spread. A highly important variable is topography, and particularly whether "wind-gaps" cause abnormally high local winds and hence abnormally high rate of spread.

The individual and combined effect of these and other unmeasured variables is, of course, included in the averages by zones, which have been used as the basis for conclusions. The mere listing of the more important variables enforces the conclusion that the most skilful working out of protection organization in the brush zone on a given watershed or national forest will probably involve a variation of from 5 minutes to as much as 30 minutes in planned attack time for particular crews. Determination of the actual on-the-ground organization has not been a problem considered by this study. But flexibility in application, rather than rigid adherence to averages, is the desirable and indeed necessary course. As a matter of local planning, it is not, of course, part of the subject matter of this study.

Similarly, the average crew strength of five men in the brush zone and three men in the flash fuel zone is by no means expected to be inflexible and unvarying. Local differences in line construction problems or local rates of spread should be reflected in skillful varying of strength of individual crews.

Length of fire season, comparing year with year, varies materially. Within a single season, the change in rate of fire spread and hence in needed size of crew varies greatly. Flexible and skillful use of crew members on maintenance of improvement rather than on standby during periods of subnormal danger can increase greatly the effectiveness of fire control.

Not only behavior of fires, but values at stake will have to be considered in local planning. On watersheds of very high value where there are heavy investments in reservoirs, and particularly where fires followed by floods would cause loss of life, protection organization will surely aim at holding fires to much less than the 2,000-acre maximum size provisionally adopted in this study as a general average.

Consideration of values will mean that, since simultaneously build-up of protection organization to the recommended levels can hardly be accomplished, regardless of money available, first priority will be given to most urgent problems, that is, value at stake. And values for a given watershed change radically from time to time, as for example, when a costly water conservation dam is built, subject to rapid silting up unless hitherto endurable rate of fire loss is sharply reduced.

Most effective application of the general average formulas to local conditions will require a high level of planning and analysis.

But none of this means that, because local variations in planning are needed, the zone averages can be ignored. The latitude of variation from average is probably of the order of from one-half average to two times average, although this needs further study.

Characteristics of Required Fire-Control Organization

The study indicates, and this is indeed obvious, that the objective of fire control must be thought of in terms of holding losses in individual watersheds to an endurable maximum. In very general terms, this means no individual fires of over about 2,000 acres, and this figure is probably now too large on many of the more valuable watersheds. The ultimate level at which fire control must aim has not yet been fully and finally set.

The study indicates that, contrary to widely held opinion, the problem of fire prevention is by no means confined to reduction or elimination of fires caused by recreational use, that is, smoker and camper fires. Although recreational use is undoubtedly responsible for a majority of the fires, they could be eliminated and still leave numerous other obstinate prevention problems. A major conclusion of the study is that many opportunities remain for effective fire-prevention effort. In terms of fire-control organization, the indicated needs are principally in intensifying, expanding, and carrying out continuously the policing, hazard reduction, and educational programs already under way, and in developing more specialized means of attack on particular problems. Far greater volume of effort, as an integral part of the fire-control organization, is the essential; special prevention measures for bad fire days are needed.

The needed characteristics of the fire-suppression organization have been developed by the study. First, fast attack in the important brush and flash-fuel zones, averaging 15 minutes from discovery of fire to first attack. Handling of fires in these zones is the overwhelming bulk of the fire problem.

Second, small crew rather than one-man or large crew attack in these zones, averaging five-man crew in the brush zone and three men in the flash fuel zone.

Third, use wherever possible of tankers as an integral part of initial attack, rather than as follow-up of fires that escape. Full use of tankers is indicated as a major means to increase the effectiveness of attack on fires of a given size in a given zone by a given number of men.

Fourth, to attain the required speed of attack, a relatively large number of attack centers with small crews, rather than a smaller number of centers with larger crews is indicated. And each crew unit needs as standard equipment, the fastest possible motor equipment. The greatest economy is attained by quick attack by a small crew, not by slower attack by large crews.

Fifth, the attack crew must evidently be a highly skilled, integrated, and trained team, with high-grade leadership. The need for the most careful selection of men and leaders and the most thorough training of both are evident. The tempo of the required attack leaves no room for indecision, fumbling, lack of team play or mistakes in strategy, if the attack is to succeed.

Sixth, the problem of handling fires on bad days requires, first of all, sure, reliable identification and forecasting of the weather conditions causing bad days.

Seventh, advance plans and procedures are needed to increase immediately both size and number of crew units when current fire danger ratings or fire weather forecasts justify it.

Eighth, known risk areas have to be covered within time limits, if burned area is to be held to accepted rates of loss. The potentialities of single major fires, resulting from slow or ineffective initial attack, are so great that partial coverage of risks is in effect no protection at all.

Ninth, at least a skeleton organization will be needed almost year long, even in the early and late months of the year, subject to building up when hazards are increasing rapidly.

Tenth, a full-road system is required so that all risk areas may be brought within the scope of rapid, mechanized attack. Firebreaks to be used when backfiring is required are another necessity.

This type of organization depends on uniform and balanced strength. Careful selection and training of men; the best possible mechanized equipment, both for travel and attack; employment for the full season of danger; and means to keep the entire complex physical plant and equipment in first-class shape are all required.

The major conclusion from the study is that full-scale attack in accordance with foregoing specifications can reduce losses, both for the area as a whole and for individual watersheds, to an endurable rate.

The study makes no attempt to develop the detailed program having the characteristics above enumerated. That is a job for planning, and this study has confined itself to establishing a sound basis for planning.

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FORESTRY cannot restore the American heritage of natural resources if the appalling wastage by fire continues. This publication will serve as a channel through which creative developments in management and technique may flow to and from every worker in the field of forest fire control.