HORNBY'S PRINCIPLES OF FIRE CONTROL PLANNING

By H. T. GISBORNE[1]
Northern Rocky Mountain Forest and Range Experiment Station

On August 27, 1937, Lloyd G. Hornby died of heart failure on the Toboggan Creek forest fire in the Clearwater National Forest. Few if any men in or out of the U. S. Forest Service have made a greater contribution to fire control planning than did he. In the following article, H. T. Gisborne outlines the principles of fire control planning developed by Mr. Hornby, emphasizing the major features which have too often been obscured by the detailed technical procedures of the component processes of fuel type classification, seen area mapping, smokechaser coverage, transportation planning, etc.

WHEN Lloyd G. Hornby was placed in charge of fire control planning research at the Northern Rocky Mountain Forest and Range Experiment Station, he brought to the task a background of training, experience, and inherent ability which was unique as it was well suited to the opportunities of this work. His training in both engineering and forestry, his fifteen years of field experience from smokechaser and ranger to supervisor of three national forests, and his exceptional ingenuity, practically assured a research that would make a major contribution to forest fire control. It is universally conceded that his *Fire Control Planning in the Northern Rocky Mountain Region* has revitalized and very nearly revolutionized fire control planning processes throughout the United States.

It was Hornby's plan, before he died on the fire line in August 1937, to summarize the principles basic to his work, but except for a three-page long-hand draft of a memorandum found in his files after his death, this summary was never written. On the basis of this memorandum, his various reports, and six years of almost daily contact and work with him, the writer here attempts to outline those principles as accurately as one person can attempt to present material for another person. The analogies used in several cases to emphasize the similarity between fire control planning and engineering practices are Hornby's own, which he employed frequently.

The eight major principles which, with one exception, are apparent in his published report can be briefly expressed as follows:

1. Held line must be built faster than the fire makes perimeter.
2. Fuel type classification is necessary to show the two basic factors: rate of spread and resistance to control.
3. Plans must be made for first-attack control before the fire commences to spot or crown except under class 6 or class 7 danger in the extreme fuel types.
4. Fuel type, occurrence of fires, and values at stake must be coordinated for most economical yet adequate fire control.
5. Lookouts, firemen, and crews have the dual responsibility of detection and smokechasing.
6. Transportation and communication planning should follow and be based upon fire control planning and other forest-use requirements for multiple use.
7. Fire control planning for the "worst first" automatically simplifies the process.
8. The conditions creating a fire problem are not static. Fire control planning is therefore a continual process of revision and refinement.

The first, and perhaps most basic, principle developed by this research was that successful fire control requires "held line to be built faster than the fire makes perimeter." This principle had been subconsciously and dimly recognized in the past, but it has been within the past few years only that the old method of estimating the job of line building on the basis of acres of fire was replaced by estimates based on *perimeter.* This first principle recognizes the superiority of the perimeter basis, and in addition considers the fact that fuel type is the major determinant of the rate of spread or rate of perimeter increase, which must be assumed for each area in planning normal control measures for it. Omitting proper consideration of fuel types in fire control plan-

[1]Acknowledgment is made to Clayton S. Crocker and Clarence B. Sutliff, who also had worked closely with Mr. Hornby, for reviewing this article and for their suggestions for improving its accuracy and scope.

ning is analogous to an engineer planning to construct a massive building without examining the rock or quicksand on which it is to rest. "Proper consideration" may vary, of course, from broad generalizations in regions of uniform fuel types to detailed measurements, surveys, and maps in regions of great variation in rate of spread of fire.

The second principle, which logically follows, is to measure and rate this basic factor, fuel type. To do this Hornby originated the dual basis, physical classification of fuel types including rate of spread and resistance to control. His methods of evaluating these are described in "Fire Control Planning in the Northern Rocky Mountain Region," and "Fuel Type Mapping in Region One."[2] He assumed "burning severity," class of fire danger, or fuel condition, that should be used in fuel type mapping to be "average bad," leaving its precise definition to be determined later by actual measurement. Here he followed the practice of an engineer who would estimate his costs of making excavations in clay on the basis of the clay being wet, and therefore more difficult to handle than if it were dry. The precise definition of "wet" is of less importance than would be the complete failure to consider this condition. The measurement rather than the approximation of each fuel type is one phase of this work requiring much additional research. Hornby was engaged in such work the day he died.

A brief statement of Hornby's conception of fuel types and their basic use was included in his final memorandum: "When a particular level of burning severity prevails over a large area, the same speed and strength of attack is not required for every kind of fuel" . . . . . "One way to station manpower over an area is to accept the judgment of some person or persons, with or without going to the trouble of comparing fuels and mapping their locations. Another way is to map the fuels, set up minimum standards of speed and strength of attack according to severity of burning conditions, and station manpower to satisfy these requirements. Under the latter procedure the same class of fuels would receive the same treatment (degree of fire control) wherever it existed and whenever the burning severity required it, other considerations being equal."

One impediment to the understanding and proper use of fuel type maps is the fact that individual fires often spread at rates different from that indicated by the map. It is obvious, however, that even the most carefully identified and mapped rate of spread, at a certain, average bad level of burning severity, will not be reached under favorable weather conditions and will be exceeded when the weather is worse than average bad. No single map could be made, and kept simple, which would show all rates of spread for all weather conditions. The major purpose of this work is not to produce a fuel type map which can be used for determining the manpower to send to individual fires, under any combination of weather conditions. The chief purpose is to determine the normal high-rate of perimeter increase which can be expected so often or so consistently that it should be planned for. This normal, high-rate varies significantly according to fuel type. This principle therefore holds that it is better engineering, better forestry, better science, to identify such a factor consciously and according to certain standards rather than subconsciously and without universal standards.

This illustrates the research quality of this work. The objective is the evolution of a *method* which can be used similarly by all men, in preference to "the judgment of some person or persons with or without going to the trouble" of identifying and evaluating all the factors. It has been consistently realized that the present evaluations of fuel type can be improved, with time and additional research, but fire control planning without fuel type classification is, to use another analogy, like estimating the cost of road or railroad construction from a topographic map alone with no knowledge of the soils, clay banks, or rock ledges through which the cuts must be made.

The third principle is that control of a fire (in Region One) by the first attacking forces should be planned for "before the fire begins to spot or crown." Other criteria such as "control before 10 a. m. of the next burning period," and the "percentage of area burned," by timber types as recommended by the regional foresters, Washington conference of 1930, have been used, but for the reduction and gradual elimination of those large fires

[2]Hornby, L. G. Fuel type mapping in Region One. Jour. Forestry 33:67-72. 1935.

which are chiefly responsible for overburn, a more basically natural criterion is needed. Hornby insisted that "after the crown fire stage is reached, no assurance of control at any particular size can be given," and under certain conditions this stage may be reached before 10 a. m. of the next burning period. He also pointed out that the analysis of the records of 12,056 fires in Region One shows that over a period of years silviculturally adequate protection, the basis of the Washington conference standards, can be provided without 99.99 percent control of all fires in the first or even the second work period.

The likelihood of spotting or crowning varies, of course, both with fuel type and with burning severity. The present principles, however, do not include plans to meet the worst possible conditions of either fuel type or class of fire danger in the first attack any more than an engineer builds to withstand the worst possible earthquake or the worst possible flood. Engineers know that the damage in such cases is often less than the cost of complete protection. This third principle of "control before crowning" therefore excludes those rare fires originating in extreme fuel types on class 6 or 7 days, when fuel moistures are under 5 percent, relative humidity under 15 percent, and winds 19 m.p.h. or more. The damages from such explosive fires can most economically be minimized by large crew suppression action, the same as for other fires which for other reasons escape control by a reasonably economical first attack.

The fourth principle is that fuel types, occurrence of fires, and values at stake must be coordinated by the processes of planning if the resultant permanent facilities (buildings, roads, and telephone lines) and the temporary manpower (contact men, lookouts, smokechasers, and small crews), are to be held to an economical minimum, yet adequate protection is to be provided during seasons of critical danger. The use of this principle is not as apparent in Hornby's major reports as are the other principles. This is because it has not been expedient to date to attempt to place dollar values on each of the diversified uses or purposes of forest areas including stream flow regulation, soil conservation, wildlife production, recreation, live-stock, and timber products. Fire control planners cannot escape, however, from the need of attempting to apply this fourth principle, including values as well as fuel types and the occurrence rate.

The fact that valid inferences cannot be drawn unless the measurements or ratings of all the basic factors are integrated led Hornby to his search for a "total danger rating" which would integrate fuel types, occurrence, and values. He was never completely satisfied with the formula that he originated. By this formula there is obtained from the fuel type maps an estimate of the acres per hour that will probably burn during the first few hours after origin on an average bad day. This, multiplied by the damage, in dollars, that would be done, is called "damage per hour." Then damage per hour plus expense per hour (based on the fuel type classification of resistance to control) gave total probable "cost per hour" for any unit of area. And cost per hour multiplied by the occurrence index for that area gives a figure approximating "total danger." Such numerical ratings for different areas can be compared and the relative needs for fire control facilities and manpower thereby determined, with less than previous dependence upon the personal judgment, knowledge, lack of knowledge, or bias of the individual.

This attempt to obtain numerical ratings is additional evidence of the scientific quality of this research. It is emphasized by Lord Kelvin's statement, "that when you can measure what you are speaking about, and express it in numbers, you know something about it. But when you cannot express it in numbers your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of a science."

The impossibility of immediately evaluating all of the factors of "total danger" with consistent dependability is obvious. But here again, as in fuel type mapping, it is evident that carefully prepared estimates can now be made, with a sufficiently low error to give a better basis for fire control planning, more "independent of the idiosyncrasies of the individual."

The fifth principle which is contrary to practices in some sections of the country is the "dual responsibility" of lookouts, firemen, and crews. This had been applied with gradually increasing intensity in Region One beginning about 1920. As national inspector of fire control, Major E. W. Kelley gave marked impetus to the practice in 1927 to 1929. By this principle lookout men are not only to chase smoke when that can be done without impairing the detection coverage, but lookout station locations are to be selected, other things being equal, so that these men can serve this dual purpose. It would appear to be decidedly uneconomical to build a lookout system capable of first discovering 99.99 percent of all fires when firemen, trail crews, and several other units of the fire control organization can be depended upon for considerable detection coverage.

Closely related to this fifth principle of "dual responsibility" is the sixth, or "multiple use of roads." Although not generally recognized at the time Hornby was developing his principles, it is now standard practice to plan for the lower cost, to each line of work, and the greater efficiency of a transportation system designed by correlating the requirements for (1) fire control, (2) utilization or removal of forest products, (3) recreation and (4) general administration. By this principle, transportation planning is a distinctly accessory process which should follow and be based upon the previous determination of manpower placement adequate for fuel types as well as for other forest requirements. Communication planning similarly becomes a subsequent process; it is even dependent upon, or at least affected by, the results of transportation planning. Transportation or communication planning without complete consideration of fuel types and their manpower requirements, or without correlating utilization, recreation, grazing, and other needs is analogous to dam construction without streamflow measurements. Such dams have been built—and rebuilt, after the high-water that should have been foreseen.

The seventh of these principles for fire control planning is to plan first for the worst, or for the "worst first." By "worst" is meant the most dangerous fuel types. The plans for 10 national forests comprising 17 million acres of land in Region One have repeatedly demonstrated that if provisions are made first for the worst fuel types a large proportion of the easier types is automatically given satisfactory, or even superlative detection, smokechaser, and crew coverage. By this principle large crew coverage (provided merely by roads from outside sources of labor) is planned for all areas of fuels in which fire could be expected to escape any reasonably economical first attack, as mentioned in discussing the third principle. Naturally, these most difficult fires are most likely and should be expected most frequently in the worst fuel types. The action demanded, under such conditions, is suppression by large crews, and roads must be available reasonably near such areas of worst fuels to expedite arrival of these large suppression crews. If these roads are planned first, later planning of roads for use by small crews, smokechasers, and firemen-lookouts, will automatically benefit. By the reverse process roads are first planned for the lookouts, smokechasers, and patrolmen, and are often found to be unsatisfactory for expediting the arrival of large crews at the areas of worst fuels where the catastrophic fires are most likely to originate. As the reduction of the size of large fires is the present major requisite to satisfactory fire control, logical planning must be for the "worst first."

The eighth, and final, principle applied throughout all phases of fire control planning in Region One is that none of the basic factors of the fire problem—fuel type, occurrence, or values at stake—is constant or static. Each of these is known to change, perhaps slowly, with time. The rating of the relative weight of each factor therefore undoubtedly will change, slowly but steadily with increased knowledge, and perhaps radically for short periods according to the dominance of some individual's philosophy. Preliminary plans therefore should deal with averages, with indicative trends, with combinations of factors, always endeavoring to prevent single and exceptional cases from resulting in over-building or completely neglecting any essential phase of the fire control organization. Likewise, this principle should temper all finality of conclusion and should predicate continual revision and refinement of the plans.

Hornby's contention, supported by ample evidence in Region One, that a strong and apparently costly first attack is usually the most economical in the most dangerous fuel types, can hardly be called a principle. It is, however, a generality supporting his worst first principle, and one which is basic to the proper financing of adequate fire control in this region.

The personnel factor was recognized by Hornby as vital. He stressed the requirement of both adequate numbers of men and adequate training. His last memorandum states: "Errors (on the fire line) are so numerous that their elimination constitutes an outstanding problem," and, "Rates of fire suppression work, per man per hour, are so slow that unwieldy numbers of men are required even on fires of moderate size." These phases of fire control planning, and the prevention of fires, were recognized by Hornby as calling for such distinctly different action as to be outside the scope of his particular research.

The little pessimism that Hornby felt concerning the possible progress of fire control planning arose from the indeterminacy of the personnel factor. He had had so much personal experience in the loss of trained and competent short-term members of his national forest fire control forces, and had seen the deleterious effects of the short-term limitation on so many other forests, that he was occasionally pessimistic concerning the successful application of his or anyone else's fire control plans. He knew that the best of plans, based on specific identification of all significant factors, each well evaluated, and all consistently integrated, could not function most efficiently unless applied by a competent personnel. He knew that any lack of policy or financial limitation, which interfered with the retention, year after year, of a trained and competent personnel could prevent the full improvement of fire control efficiency that might be expectable from planning methods that he or anyone else might devise. He confined his work, however, to developing *methods* and a planning procedure which would provide any personnel with facilities impersonally suited to local conditions of fuel type, occurrence of fires, and values at stake.

A DESIGN FOR EXPERIMENTS IN THINNING FOREST STANDS

By J. G. OSBORNE

Southern Forest Experiment Station[1]

Thinning experiments have taken up a consistently large share of forest-research programs, and can be expected to continue to do so. This paper presents an experimental design which is intended to aid in increasing the amount of information obtained from such experiments.

MANY of the early experiments in forestry were made to determine the effects of various methods of thinning on tree growth and on the yield per acre in various forest products. Since these studies have continued to occupy a prominent position in forest-research programs, and since, as stated by Yates (*3*), it is profitable to expend considerable work in developing a technique in a field in which much experimental work is likely to be undertaken, it has been considered worth while to devote at least some research to improving the technique of thinning experiments.

Objectives of a Satisfactory Technique

The type of stand to be thinned, the method of thinning employed, and the kind of final stand sought vary widely, but certain principles of experimentation are common to all thinning research. Efforts towards developing an adequate experimental design, therefore, must be made in accord with at least four basic requirements, which briefly stated are:

(1) That adequate provision be made to assure the reliability of the results obtained;

(2) That the experiment be efficient, which means that early and accurate information be obtained, and that the number of plots and total area necessary to provide a given body of information be at a minimum;

(3) That the experiment should permit the induction of general principles of response, from which the probable results of thinning under other conditions may be deduced;

(4) That, in order to obtain assured reliability of the results, the limitations as to original

[1]The author gratefully acknowledges the assistance and helpful suggestions given by R. A. Chapman, H. Bull, and A. L. MacKinney of the Southern Forest Experiment Station, and by F. X. Schumacher formerly of the U. S. Forest Service, Washington, D. C.