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FOCUS: a fire management planning system—final report

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FOREWORD

The Forest Service, U.S. Department of Agriculture, maintains what is generally recognized as the world's largest and most efficient fire control organization. It is also the world's most expensive one. Current expenditures for forest fire control now exceed $200 million annually—and the costs continue to climb (Gibson and others 1976).

In 1975, the U.S. Office of Management and Budget queried the Chief of the Forest Service about improved efficiency in fire control: How much did real fire management costs rise from 1964 to 1975, and why? What practices and procedures are best, given an evaluation of appropriate costs and results? Are management procedures capable of selecting appropriate strategies and limiting fire fund use to approved activities (USDA Forest Service 1977b)? Clearly, anything to increase fire management and organizational efficiency potentially could save millions of dollars in public funds.

Historically, the Forest Service has operated under a series of 5-year planning programs, each directed to developing the best possible fire control organization for its time; however, these programs produced only a single plan with no procedure for evaluation of its implementation. A method to quantitatively evaluate the effectiveness of alternative plans in terms of cost/benefit was urgently needed. A modeling framework was required whereby the forestry planner could assess organizational resources—personnel, equipment, transportation—in a variety of configurations and thereby deploy those resources in the most efficient and cost-effective manner.

Such concerns were uppermost when, in 1970, members of the Forest Service's Southwestern Region approached the Pacific Southwest Forest and Range Experiment Station's research staff, at Riverside, California, with a management problem: How to plan an organization to cope with the incidence of high fire occurrence in low value areas that, in turn, pose a threat to adjacent high value areas. Contributing to the problem were the intrinsically low land values that prevented justification of a strong fire organization. A modeling framework ideally could show the relationship of the spread of fire risk between these areas. This would allow land planning management to rank its concerns—suppression, detection, prevention, hazard reduction, and fuel treatment—by priority and allocate its resources accordingly.

The implications of such a program on the national level were not lost. The relationship of fire occurrence patterns to values at risk is one issue confronting forestry management nationwide that could benefit from such a program. The challenge to develop a fire management project of this scope was to become the inaugural investigation of the Fire Management Systems Research Unit, then a newly formed group at the Station's Forest Fire Laboratory, at Riverside, consisting of operations research analysts, mathematicians, computer programmers, and foresters.

Several approaches were considered, including mathematical analysis techniques such as linear programming; however, systems designers felt that a simulation model would be far more practical. The information needed to support a mathematical approach was lacking, but enough was known about the problem that simulation appeared to be a feasible alternative. This led directly to the development of FOCUS (Fire Operational Characteristics Using Simulation).

The development of FOCUS benefited at the onset from the cooperation of various Forest Service units at its 1972 fire planning conference. It was there that representatives of the Division of Forest Fire Research met with the Division of Fire Control and all Forest Service regional fire chiefs. The principal objective was to define the methods and scheduling for reorganizing fire control planning programs within the National Forest System with particular attention to fuel and fire spread models, the National Fire Danger Rating System, fire simulation models, and fire control planning technology. It was agreed that FOCUS would support this national planning effort.

The Bureau of Land Management and the National Park Service, U.S. Department of Interior, and the various State fire protection organizations also indicated strong interest and willingness to cooperate in the proposed development. The California Department of Forestry became an enthusiastic supporter, providing financial as well as advisory assistance throughout the FOCUS development effort.

The initial FOCUS design was ambitious. It envisioned a full-, developed, probabilistic computer simulation model that included fire start generation, detection, prevention, and large fire modeling capability (Storey 1972). The fire generation system was to have the capability of generating both man-caused and lightning fires as they would have occurred in nature (Bjornsen and Chase 1971). The model builders recognized that such a comprehensive program would require large quantities of data. An early design feature, therefore, was a system to automate data input as much as possible.

In addition to the technical aspects of computer simulation, several key elements were incorporated that facilitated design capability:

- The FOCUS design was modular. Major system parts were modules that could operate independently of or in cooperation with other modules.

This FOCUS software design feature was particularly useful when revising the program.

- Close user liaison was utilized from the start. Throughout the life of the FOCUS project, liaison officers—personnel familiar with fire control—ensured that the system represented real world concerns. The liaison officers also provided management leadership in the development of the user manuals and system documentation vital to operational testing.
- The FOCUS effort was guided by a steering committee comprised of representatives of the Forest Service's National Forest System and State and Private Forestry; Bureau of Land Management; and individual States—each with a strong fire background. These representatives reviewed FOCUS progress and made recommendations for future development. Because computer simulation was relatively new to fire planning in the early 1970's, a major role of the steering committee was to transfer information to their home units to ensure successful system implementation.
- Eight test areas, including seven National Forests and one California Department of Forestry ranger unit, were selected as test areas from which data would be supplied and preliminary versions of the model tried out. This cross section was considered representative of all fire problems throughout the nation.

Some modules progressed rapidly, others lagged. It eventually became apparent that if FOCUS was to be completed on schedule, the original model would have to be revised. Consequently, it was decided to develop a deterministic model. A set of several hundred historical fires was adopted, rather than generating fires as originally planned. Also, the fire detection and fire prevention modules would be developed independently and a manual gaming technique would be used in place of a computer-based large fire module.

At the same time, the fire suppression and cost modules were becoming increasingly complex. A comprehensive FOCUS system was to be used nationwide. Consequently, the model had to accommodate any conceivable fire control operation. As new techniques such as rapelling from helicopters were developed, they were incorporated into FOCUS.

By mid-1975, system developers prepared for FOCUS technology transfer. Teams from the Forest Service and other Federal and State agencies met at Riverside for a 2-week training session. Armed with the new technology, the teams returned to their respective units, and over the next 2 years were able to successfully operate the FOCUS system. Some regions were outstandingly creative in their application and interpretation of FOCUS.

Following the technology transfer, the Forest Service Research Branch began reducing its role. By October 1978, all user manuals were prepared and the computer program was reasonably debugged. Most importantly, the Forest Service's Aviation and Fire Management Staff recruited a three-member team with the principal responsibilities of providing user support and maintaining FOCUS for the National Forest System and State and Private Forestry and a national training program was started (USDA Forest Service 1978b). Computer access to FOCUS was converted to the U.S. Department of Agriculture's Computer Center at Fort Collins, Colorado. By the end of 1978, about 30 units from the Forest Service, the Bureau of Land Management, and several States had some experience testing or applying FOCUS.

In March 1979, FOCUS was established as an operational system by National Forest Systems, and a Forest Service Manual Amendment (No. 59) was issued in June 1979 to provide national policy and direction for the use of FOCUS.

Today the Forest Service is beginning to realize a return on its investment. From the standpoint of operational planning costs, FOCUS has proven cost effective. The FOCUS system provides substantially more savings than those derived from other existing techniques to measure fixed presuppression costs, variable suppression costs, and damages.

Historically, the Forest Service has taken several approaches to the problem of organizational efficiency and resource management (Lowry 1965). Not the least of these is experience and intuition which, during the past 75 years, have helped create the world's most effective, albeit expensive, fire control organization (*fig. 1*). But this system prevented managers from testing alternatives and yielded only a sketchy idea about cost/benefit relationships.

Trial and error have also been part of the process in the past. And while these techniques may be effective in theory, they are inefficient in the practice of fire control. Because of variability from one fire season to another, it may take 5 to 10 years to evaluate a fire plan. Conditions change over this period of time and costs and damages may be expensive.

Another approach to forestry issues has been mathematical modeling, including linear programming. Examples are Timber RAM, a resource allocation model to aid timber management; and VIEWIT, a recreational planning model. Unfortunately, fire research has not developed to the point that we know all the mathematical interrelationships that exist, including the total combustion process, fire effects, and suppression activities, to effectively develop linear programming or other mathematical models.

Fire control planners have, however, a general knowledge of the probabilities of certain fire-related events and sufficient understanding of actual fire processes to allow these aspects of fire planning to be computer simulated. Supplied with this knowledge, the Station's Fire Management Systems Research Unit, at the Forest Fire Laboratory, Riverside, California, developed the large-scale computer simulation model called FOCUS (Fire Operational Characteristics Using Simulation).

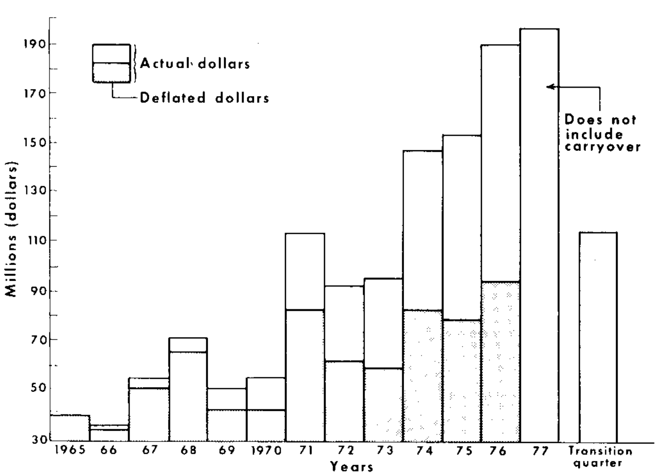


Figure 1—Total expenditures by the Forest Service in forest fire control and suppression now exceed $200 million annually.

Mathematical models may be categorized as either deterministic or probabilistic. Deterministic models are devoid of uncertainty and can predict exact changes (McMillan and Gonzalez 1968). FOCUS is basically deterministic. Conversely, probabilistic, or stochastic, models reject such certainty and proceed in a more random manner. Ideally, FOCUS should have been probabilistic, since uncertainty is more the rule than the exception; however, the FOCUS suppression model is designed to represent a complex process that is not amenable to overall representation by a mathematical model. Operations research workers and others (Hillier and Lieberman 1968, ch. 14) generally recognize that simulation often provides the only practical approach to analyzing such a process. Simulation is particularly applicable when a process can be divided into a logical sequence of subordinate operations, each of which can be analyzed by a mathematical or computer model. The FOCUS fire suppression model represents such a process.

Statistical validation of the FOCUS simulation model is not practical for two reasons: first, the model is basically deterministic, though it does contain stochastic aspects—particularly in simulated fire occurrence; second, data from the actual process generally are not available for comparison, except in a limited sense. Input to FOCUS is quite extensive, involving literally thousands of data items, a large percentage of which are derived from imprecise measurements or estimates of physical parameters. It would therefore be impractical to attempt stochastic interpretations of many of these items, particularly in the absence of sufficient data on which to base probability distributions. Beyond this, computer costs of repeated FOCUS runs to obtain stochastic outputs would preclude its use by many users.[1] Instructions for FOCUS data preparation usually require that average or typical values be provided for data parameters. In tests to date, users have had little trouble giving such estimates. (As hoped for by the FOCUS developers, some users have conducted inquiries aimed at correcting data deficiencies.) Thus, even though the model is deterministic, it could be termed an "expected value" model.

Input to the model simulating fire occurrence usually includes hypothetical fire data for several "seasons" based on historical fire reports. Model output is ordinarily

[1]Computer costs per run have typically been $20-$50. If the desired statistical reliability could be obtained using 10 iterations (probably a low estimate), users would be faced with computer costs in the hundreds of dollars per alternative evaluated.

aggregated and printed by season where variability between seasons is desired. Seasons are selected from the past 10 years or more for their relevance to specific fire problems. This procedure comprises many of the elements of a stochastic input for a critical set of data. An historical season of fires is certainly a sample of the population of fire seasons. "Importance sampling" (Hillier and Lieberman 1968, ch. 14) is used, however informally, to give system performance estimates that are much improved over a purely random sampling procedure such as selecting historical fire seasons at random.

The FOCUS computer simulation model offers several advantages over other methods of fire planning:

- An attractive management tool to evaluate objectively various planning schemes
- Rapid evaluation of alternative plans
- Simultaneous consideration of numerous data variables and the insights derived from correlating these
- The elimination of human bias in evaluating several plans or in scrutinizing the elements of a single plan (Naylor and others 1966).

In using the FOCUS system, experience has shown that from $20-$60 thousand, including labor, computer time, travel, and overhead, may be required to gather all information needed to make the first few successful and realistic runs. Considerable time is required to collect and debug data and to refine the input variable so that FOCUS output represents realistic values. The expenditure of time and money corresponds roughly to that spent in previous planning efforts.

1. FOCUS AND FIRE PLANNING

FOCUS is designed to evaluate alternatives provided by the fire planner (Davis and Irwin 1976). It is not self-determining in the sense that it develops its own alternatives, nor is it an "optimum-seeking" model. For example, the fire manager tests two or more possible fire plans for his protection unit, evaluates these in the FOCUS system along with other constraints such as political considerations, then selects and implements that plan most closely approximating existing needs.

FOCUS can also be applied to make minor adjustments or pursue leads revealed in preliminary FOCUS runs. In this manner, the user may continue to make minor changes (fine tune) until achieving the best mix of available resources, including labor, equipment, transportation network, and other capital facilities.

Previous systems provided no opportunity to test alternatives. FOCUS, however, provides multiple tests and evaluations to the skilled analyst at minimum cost. Many have viewed the initial cost of the system as a capital investment, with the profit margin increasing in proportion to system use.

FOCUS simulation has been termed "what-if planning." A fire manager may ask, "What if I change the location of an air attack base? What if my budget is cut by 10 percent? What if I use prescribed fire on selected areas on a 3-year cycle?" Any of a multitude of possible alternatives can be tested in a matter of hours. It must be emphasized, however, that FOCUS is an organizational planning tool—it is not designed to help fight fires; although portions of the program, such as the transportation network, are being used outside of FOCUS on actual fires using commercial time-sharing systems. Nor does the availability of computers and the use of operations research automatically provide an adequate simulation technique. Proper systems analysis must account for the total dynamics of a problem. If basic data are not available or proven, the value of the resultant output is weakened (Drake and others 1972). Because of its very large data input and output, FOCUS can be operated only on very large computers with high speed input-output equipment.

The FOCUS system provides a unique research opportunity to evaluate the effectiveness of alternate fire suppression organizations at different budget levels and to define the frontier of efficient organizations (*fig. 2*).

1.1 System Validity and Usefulness

Simulation results have been validated against real values in two ways. First, statistics and distributions of

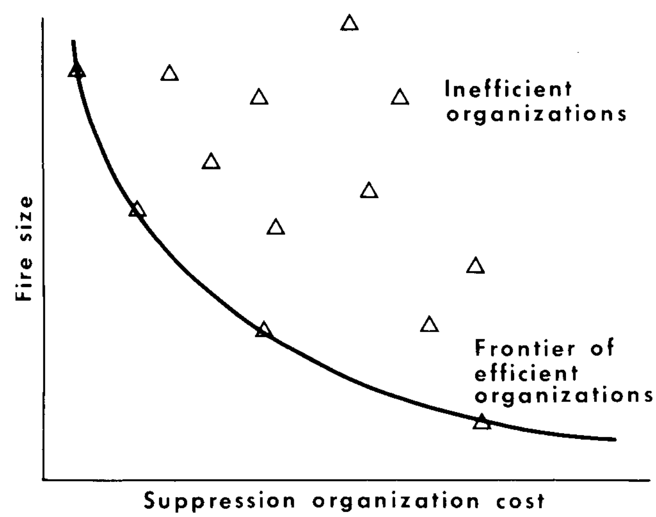


Figure 2—Estimation of the frontier of efficient fire suppression organizations by using effectiveness-cost evaluations (all other conditions held constant).

key variables have been compared, where possible; such checks have been made but remain unpublished. Second, systems users have performed benchmark testing to ensure the accuracy of data inputs and the compatibility of the simulation with suppression operations for their particular planning units.

This simulation validation means not only that the model is a faithful representation but that it also is a useful fire planning tool: Does it provide the planner with the information needed? Are personnel adequately trained to perform the FOCUS tasks within the controls of budget and time? The answers vary among the nearly 30 agencies that have tested FOCUS; however, three-fourths of the users have been able to produce reliable FOCUS runs for their units. An estimated 50 percent of these users have made crucial management decisions, involving millions of dollars, that will affect their organizations for years to come. In addition, the Forest Service used FOCUS in early 1979 in a major budget and policy analysis, using six National Forests. The analysis may help determine budget levels and the balance between fuel management, prevention, and suppression expenditures.

1.2 FOCUS Cost Effectiveness

A common concern of FOCUS users is the cost effectiveness of the system in terms of dollars and reductions in fire loss. Both of these savings are difficult to assess, since they reflect the result of a series of events. Let us demonstrate this point hypothetically.

Assume that a FOCUS program costs $5,000 to analyze a given transportation system. The study shows that if a $100,000 road link were built, a major savings will be realized in loss and suppression costs, averaging $50,000 for 10 years or a present worth of $307,228 at 10 percent interest. This looks like a 60:1 return on the initial FOCUS investment of $5,000—clearly cost effective. But the forest engineer points out that it is a 3:1 investment on road construction and the fire management officer points out that it is a rather large return on money invested in his salary while making and implementing the decision. Then how do these savings relate to FOCUS? The size of some of these returns can be based on various levels of FOCUS investments (*fig. 3*). In a sense, the values reflect the cost effectiveness of FOCUS if no significant investment were needed to achieve the savings. If investments must be made to achieve the savings, then FOCUS can only share in the cost effective relationship.

The object is that FOCUS should be viewed as the key for making management decisions with very high payoff values. Those payoff values, in turn, are the result of several factors entering into the cost effectiveness equation.

2. FOCUS SYSTEM OVERVIEW

Input to the FOCUS model includes a set of several hundred, perhaps thousands, of fires that actually occurred. These fires are selected from fire seasons representative of the unit's workload, usually including one extreme season and one or more average seasons. Fires must be considered on a yearly basis, since weather considerations and multiple fire situations are important in FOCUS analysis. Computer modeling simulates the start of real world fires, including time and location. The model assumes that fires spread at the same rate, within the same fuel type, and on the same terrain, as actually occurred.

Each simulated fire starts to spread in an ellipse, suppression forces are rushed over the appropriate transportation network, ground transport is by the forest road and trail system, and helicopters and fixed-wing aircraft use the most direct air route. As they arrive on the scene, crews are given assignments appropriate to conditions of fuel, topography, and fire behavior. As portions of the fire ellipse are held by control forces, its shape is greatly modified. The growing ellipse is a suitable simulation model of the spread of a fire burning within uniform con-

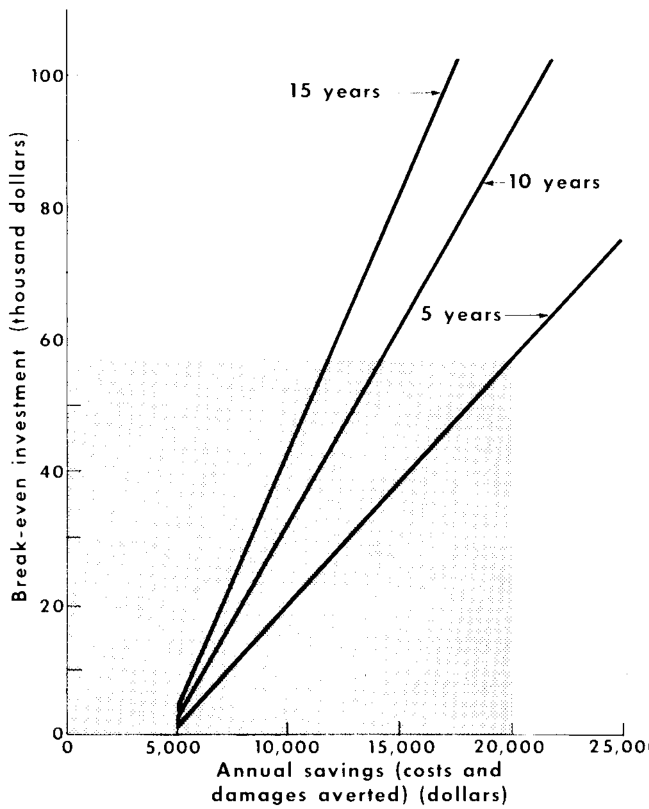


Figure 3—Annual savings needed to cover initial investment costs in using FOCUS over periods of 5, 10, and 15 years.

ditions of fuel topography and weather (Pirsko 1961). A large fire, however, will soon burn into different fuel, terrain, and weather conditions, and the perimeter may no longer approximate an ellipse. Those few fires, say 1 in 50 or so, that exceed user-defined size or suppression time parameters are called escapes. These escapes are analyzed by a team of local experts who game them by following a precise set of rules and instructions, as frequently done in advanced fire management schools. The garners are given a variety of information, including maps and computer printouts showing the time of escape, suppression forces on the fire and en route, and weather prediction for the next 4 days. Both the computer and the gamers calculate cost, damages, and acres burned. Each candidate plan is tested against the same set of fires. The results are expressed in terms of cost effectiveness. Cost elements consist of the actual fixed and variable cost of the planning unit's protection organization. At present, effectiveness is considered the difference in cost and damages between the current and proposed plan. Damage values can be taken from the damage potential classes used in the Forest Service National Fire Planning Effort of 1972[2] or can be established by the user.

Although the original FOCUS model was intended to have basic data arranged in a cellular form and be entered in input to the computer automatically, the current version uses data obtained from a variety of sources in various formats, including fire reports, vegetation and value class maps, and a series of magnetic computer tapes giving elevation for points located 208 feet (63.4 m) apart over the test area (Podufaly 1969). Only portions are input automatically.

Most data can be obtained from existing records, but certain information, such as travel times for each of the transportation systems, must be measured or estimated. Times are determined for three vehicle weight classes and for foot travel on trails, in both directions for each segment of the road and trail system.

Agency procedures and rules, such as dispatch action under various conditions, must also be analyzed for computer entry. These dispatch rules also show how forces not financed as part of the agency's fire management organization are utilized, when or on what kind of fires they are called, and how long it takes to dispatch them.

2.1 System Assumptions

The following assumptions relate to the FOCUS model in general (assumptions which apply to specific modules are discussed later):

- FOCUS uses a historical set of fires, usually from the past decade, assuming that the same pattern and distribution will occur for the planning period, say the next 5 years. This assumption is not exactly correct because human activity and fuel conditions are not constant. Consequently, FOCUS users are encouraged to select their set of historical fires from a base that is as current as possible. Also, FOCUS provides an opportunity to update data, such as spread rates and resistance to control, based on known changes in fuel condition. Modifying and updating FOCUS is relatively quick and inexpensive.
- Although no fire spreads in a neat elliptical pattern, the elliptical spread model reflects fairly realistically what actually takes place.
- FOCUS does not measure the real world precisely. For example, no one breaks a leg, trucks do not blow out tires, division bosses do not get lost. But since all candidate plans being evaluated are tested against the same set of conditions—even though they are not a perfect match for the real world—the ranking of the various candidate plans will be relatively accurate.
- FOCUS is really a system for comparing alternate plans for initial attack, first reinforcement actions, and use of existing cooperators. FOCUS is not designed to evaluate and follow up reinforcement action on major campaign fires. Nor does FOCUS normally account for back-up forces that might come from other States, far-away National Forests, or organizations not typically used such as the military. (Garners may want to include such resources on escaped fires.)

2.2 Submodels

The FOCUS model at its highest level of organization comprises the data collection and verification subsystem which uses both manual and computer methods (ch. 6); the suppression module (ch. 3) and cost module (ch. 4) computer programs; and the large fire gaming manual procedure (ch. 5).

Data are assembled where possible from existing computer-based files, otherwise manually from maps or other graphic sources. Computer programs are available for data assembly and checking (ch. 6). In addition to the computerized data checking procedures, users are instructed to examine initial program outputs carefully (ch. 2) to uncover data errors such as omissions or misrepresentations which do not have the kinds of logical inconsistencies which can be detected by the data checking programs.

The suppression module comprises two computer programs—STORETT and RUNPLAN—that are run sequentially. STORETT uses road network data along with simulated fire and ground unit base locations to calculate and store in the computer the travel times from bases to

[2]USDA Forest Service. 1972. National fire planning instructions (draft). Washington, D.C.

fires. RUNPLAN uses the ground unit travel times with other data to simulate and print results of individual fire attacks and to accumulate the results for tabular listing of important quantities. Individual fire results also are stored for later use in the cost module.

The cost module consists of two programs. SMOKEY I reads and prints the costing data, checks for errors, and stores the data for use in SMOKEY II. The latter program uses the data from SMOKEY I and from the suppression module to calculate and print suppression costs and damage values for the fires. These results can be printed in a variety of optional formats.

Inputs to the large fire gaming procedure (ch. 5) are provided by the suppression module output. The parameters provided are the size and time that each "escaped" fire exceeded escape conditions, and the list of suppression resources which the suppression module has dispatched to the fire along with arrival times. The length of fireline constructed, by escape time, also is provided. The large-fire gamers thus have a set of initial conditions for beginning the gaming procedure which is completely consistent with the operation of the suppression module.

Computer and personnel cost considerations preclude the performance of iterations between suppression module execution and large fire gaming which would be required to reflect the large fire gaming results back into the suppression module. The effects of this assumption are mitigated by two considerations. First, in real life, many resources for large fire suppression ordinarily are drawn from sources outside the local organization for which the FOCUS suppression module data base is designed. Second, the impact of large fire operations is estimated within the "mop-up" section of the suppression module (see *sec. 3.5*) by tying up the local resources dispatched to the fire for set lengths of time, depending on the kind of units involved.

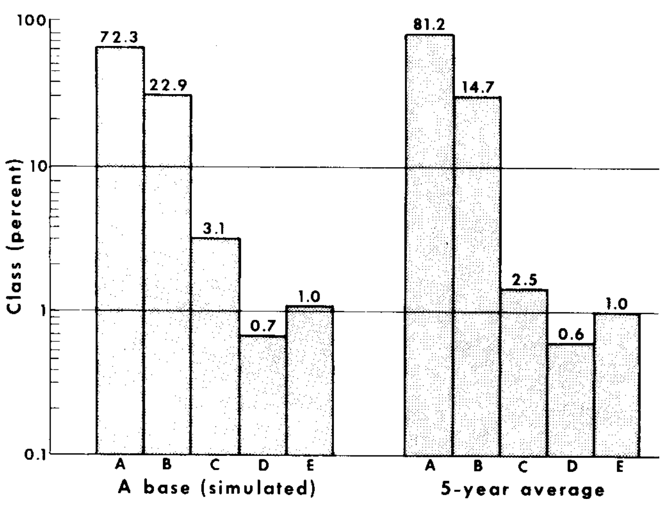


Figure 4—Fire size and frequency simulated by FOCUS were comparable to that based on 5 years of historical records.

2.3 Validation and Sensitivity Analyses

2.3.1 Validation

A statistical chi-square test determined the goodness-of-fit of the actual data (number and size of fires from reports) compared to theoretical distributions from FOCUS. The conclusion was that FOCUS adequately simulates frequency and sizes of fires from historical records (*fig. 4*).

Expert evaluation of FOCUS output was also supplied by a team of experts familiar with the unit's area. Final size and suppression action taken were examined for reasonableness of fit. Types and composition of computer material and scenarios describing suppression action were judged for reasonableness and usefulness to fire managers. FOCUS output and scenarios were found to be generally reasonable and useful.

2.3.2 Sensitivity Analysis

The sensitivity of FOCUS to changes within fire plans was another important concern. Because the Forest Service plans on the basis of worst fire situations (90th percentile), organizational overstrength might be expected most of the time. Thus, wild fluctuations in FOCUS output related to a small plan change would not be realistic. Results of a sensitivity test in which plans were changed while holding all other variables constant showed that FOCUS produced reasonable fluctuations in frequency of fire sizes, thereby verifying this aspect of FOCUS.

Sensitivity analysis can also be used to determine the preciseness of data required to minimize data collection and preparation. This procedure has not been used because of insufficient time but is strongly recommended for the future.

3. FIRE SUPPRESSION MODULE

The FOCUS Suppression Module is a computer simulation model which represents the functioning of a wildland fire protection organization in response to simulated fire occurrences (*fig. 5*). The basic model simulates attacks on single or multiple fires, but it is intended as a planning tool on the seasonal or yearly time scale. As such, the model is designed to evaluate the overall performance of a fire suppression organization over one or more seasons in response to a large number of fires.

For each simulated fire start, the model generates a list of alternative resource arrivals at the fire. This list includes ground transported units such as crews, engines and tractors, as well as air units—helicopter attack crews, smokejumpers, or air tankers. Each such resource is

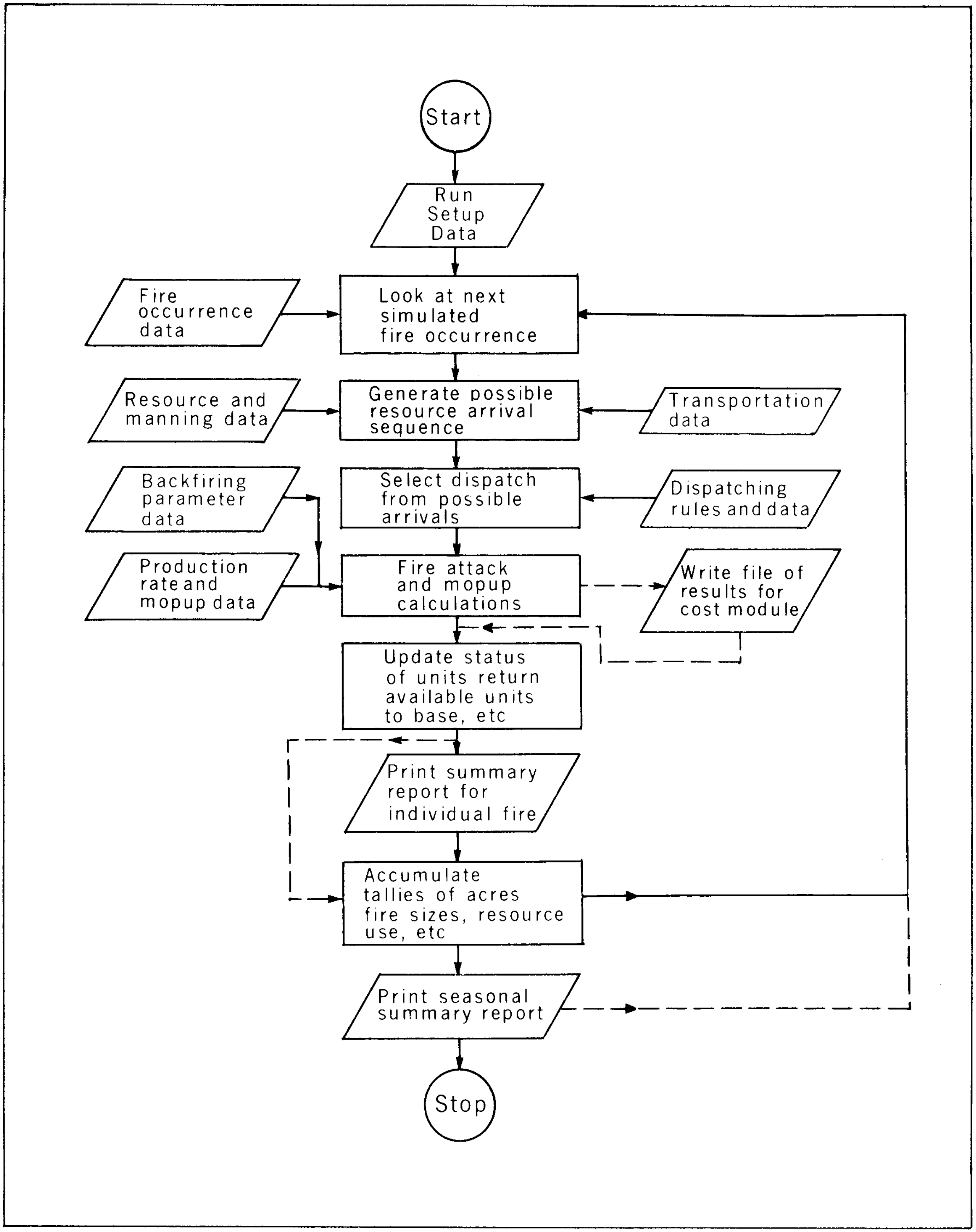


Figure 5—FOCUS suppression module simulates attacks on single or multiple fires.

defined by user-supplied data. Certain kinds of units may not be included if they are prohibited from or cannot operate in the fire area, or if they are air units and the simulated time of day is after dark.

A subset of the possible arrival list is selected for dispatch using one of two dispatching schemes, or a combination thereof: Threat response dispatching, intended to represent the procedures of a knowledgeable dispatcher aided by some information about the fire and conditions at the fire site; and preplanned area dispatching, a scheme that uses dispatch levels for various combinations of units which are planned in advance, based on geographical areas and fire danger levels.

Once the dispatch to the fire has been selected, the results of the fire attack are estimated. A simple table is used to estimate final size and time of containment for fires contained at less than 10 acres and within 2 hours of the initial attack. A more complex calculation is used to simulate the attacks on fires which exceed either of these limits. Crews, tractor plows, and bulldozers construct a fireline at rates which depend on the kind of unit, fuel type, slope, and unit size. Air tanker retardant drops are linear fire barriers, with effective length dependent on quantity of retardant, fuel type, and fire rate of spread.

The fire list may contain nonspreading fires if a user considers that these form a significant part of the protection workload. A nonspreading fire may be one of five types: structure, vehicle, improvement, refuse, or false alarm. For each of these types, a typical dispatch is specified using the preplanned area dispatch scheme. Units dispatched to nonspreading fires are held for set times, then returned to their bases. No attempt is made to simulate attacks on nonspreading fires beyond this rudimentary level.

The users can choose to print a summary report for each fire in a seasonal list. A short one-line form or a longer form which gives complete information about the fire parameters, the resource arrivals, and the outcome of the attack may be used (*fig. 6*). Fires which exceed an escape size or escape time as specified by the user are carried no further in the computations. Results for these fires are printed on the long form, giving information about time and size at escape and length of held fireline completed in the calculations. Calculations normally terminate when no units are available for dispatch to a fire. These fires are labeled "no-dispatch" and the fire parameters are printed with an estimate of when and how the fire would reach escape conditions, if not attacked. Nonspreading fires are appropriately labeled, and the dispatched units are listed along with the time they are held on the fire.

FIRE NO.	FIRE YDAY	FIRE TIME	CONT. TIME	BURNED ACRES	----FIRST ARRIVAL----- TYPE	BASE	UNIT	TIME	-----------TOTALS------------ MEN	PUMPERS	DOZERS	PLOWS	A.T.	FUEL TYPE	SPREAD RATE
1	5180	1805	2034	.12	5	5	2	41	2	0	0	0	042		.14
2	5187	1916	1924	.01	2	2	1	5	3	1	0	0	042		.48
3	5197	1612	1702	18.31	1	1	1	2	23	4	0	0	342		40.00
4	5205	1505	1550	3.54	9	2	2	5	21	4	0	0	127		9.00

SHORT REPORT FORM

**** FIRE PARAMETERS FIRE NO. 8 FIRE TYPE - BACKFIREHEAD

FIRE YEAR	FIRE DAY	FIRE TIME	FIRE LAT.	FIRE LONG.	INIT. ACRES	FUEL TYPE	SLOPE CLASS	MANNING PLAN NO.	DISP LEVEL	ROP CLASS	FORWARD R.O.S.	LATRL R.O.S.	ATTACK FROM
1965	225	1645	36.670	118.956	.20	26	4	3	3	6	2.00	1.00	HEAD

CURRENT MULTIPLE FIRES ARE NOS. 1 7, 8,

RESOURCE TYPES EXCLUDED: PUMPERCREW ,

RESOURCE ARRIVAL SEQUENCE

TIME (MIN.)	BASE NAME	UNIT NAME	UNIT TYPE	UNIT SIZE
46	LOCAL SOURCE	HALFWAY 206B	AIRTANKER	DROPLNTH .8 CH.
50	LOCAL SOURCE	HALFWAY 206B	AIRTANKER	DROPLNTH .8 CH.
54	LOCAL SOURCE	HALFWAY 206B	AIRTANKER	DROPLNTH .8 CH.
63	HALFWAY HELIT. BASE	HALFWAY 206B	HELITAK CREW	2 MEN
269	PINEHURST	PINEHURST AFMO	HANDCREW	1 MEN
274	BADGER	BADGER SDF CREW	HANDCREW	2 MEN
284	BIG MEADOWS	BIG MEADOW FPT	HANDCREW	1 MEN
284	BIG MEADOWS MUB2	BIG MEADOW CREW MU2	HANDCREW	4 MEN

FIRE CONTAINED AT 439 MINUTES AFTER REPORTED. BURNED AREA WAS 8,502 ACRES.

LONG REPORT FORM

Figure 6—Example of suppression module output: individual fires.

NUMBER/PERCENT OF CONTAINED FIRES

R.D.P. CLASS	SIZE CLASS --A--	SIZE CLASS --B--	SIZE CLASS --C--	TOTALS
1	0/ 0	0/ 0	0/ 0	0/ 0
2	0/ 0	0/ 0	0/ 0	0/ 0
3	0/ 0	0/ 0	0/ 0	0/ 0
4	2/17	2/17	1/ 8	5/42
5	1/ 8	2/17	0/ 0	3/25
6	1/ 8	2/17	0/ 0	3/25
7	0/ 0	0/ 0	0/ 0	0/ 0
TOTALS	4/33	6/51	1/ 8	11/ 92%

NOTE: CLASS C FIRES ARE ALL FIRES LARGER THAN 10. ACRES AND SMALLER THAN ESCAPE SIZE. (100.0 ACRES)

Figure 7—Example of suppression module output: seasonal summaries.

GROUND UNIT USE TALLY
(NUMBER OF DISPATCHES PER UNIT ON EACH BASE)

UNIT NUMBER

BASE #	1	2	3	4	5	6	7	8	9	10
1	4	3								
2	7	1								
3	4									
4	0									
5	4									
6	1									
7	0									
8	3									
9	4									
10	1									

HELICOPTER USE TALLY
(NUMBER OF TRIPS PER HELICOPTER ON EACH BASE)

HELICOPTER NUMBER

BASE #	1	2	3	4	5	6	7	8	9	10
1	0	0								
2	0	0								
3	1	1								
4	0	0								
5	0	5								

HELICOPTER DISPATCHES

COPTER	# FIRES
1	1
2	6

Figure 8—Example of suppression module output: resource-use summaries.

At any point, though usually at the end of a season, tables are generated which summarize the results of contained, escaped, and no-dispatch fires. The number of nonspreading fires is also given. For contained fires, the numbers and percentages of fires in size classes A, B, and C are given. Class A fires have a final burned area of less than 0.25 acre, class B fires between 0.25 and 10 acres, and class C fires between 10 acres and escape size in final area (*fig. 7*). Another table lists the acres burned within the various fire size classes, weighted by resource damage potential class numbers.

A summary is also available that lists the usage for each resource unit including the number of times dispatched, and number of trips for air units (*fig. 8*).

3.1 Fire Occurrence

3.1.1 Planning Assumptions

The fire occurrence data needed for the suppression module consists of a set of data describing each fire. A maximum of 40 data items can be used for each fire, though ordinarily about 20 are employed (USDA Forest Service 1977c, p. B2-B9). These items can be grouped in six categories: identification, geographic, time of occurrence, access, fire behavior, and dispatching factors.

A "special work force" category is also included in the fire data which relates generally to time and location of a fire. The "special work force" entry is used typically to establish evening or weekend crew size changes, or for lightning storm move-up operations.

An early decision in FOCUS development was to base the fire occurrence data on historical descriptions. Early work was based on Forest Service fire reports from the 1960 decade. All information needed for the FOCUS fire occurrence data was on the report forms or could be derived from the recorded items by some reasonable assumptions and procedures. But three major difficulties were found. First, the 1960's data were old by the middle 1970's. Some forest areas had changed in important ways, thus affecting fire occurrence patterns, fuel patterns, and fire behavior. Second, reliability and consistency are variable within specific data items. Third, the Forest Service revised its fire report forms in the early 1970's, eliminating the information about rate of fire spread. Forest Service users who wished to use historical fires from the 1970 decade in order to reflect more current conditions, were required to use other methods to derive the important rate-of-fire-spread data. Several user groups were able to solve this problem to their own satisfaction, but standardized procedures did not materialize. For example, some regions developed spread rate tables based on data such as fuel type and weather. Hopefully, the new Forest Service report form for the 1980's will again contain spread rate information.

The process simulated by the FOCUS suppression module is basically a competition between the ability of suppression forces to build and hold fireline, and the ability of a fire to generate fire perimeter as it spreads. Rate-of-spread assumptions are critical in determining the outcome of this competition. However, the importance of accurate values for spread rates is diminished greatly by two factors. First, spread rate in nature is a stochastic or chance variable. Significant variations can occur due to small changes in location (fuel, topography) and weather factors (wind, relative humidity). It follows that, for a planning use of fire spread as in FOCUS, there is no correct value for a particular hypothetical fire. However, spread rate distributions and significant correlations found in nature must be preserved. The use of historical fire occurrence data ensures that a fire spread rate will be consistent with fuel, slope, and weather factors related to the day, time, and location of the fire.

Exact spread rates are also unimportant because FOCUS is a comparative system. Importantly, planning alternatives must be compared on the basis of one set of consistent, reasonable fire occurrence data. Less important is the exact correspondence of these data to historical fires.

3.1.2 Program Assumptions

A fire workload is a user-supplied set of simulated fire occurrences based generally on historical data. Approximately 20 data items which are used to describe a FOCUS fire apply throughout the course of the simulation. That is, fuel, slope, rate of spread, and other factors are assumed constant for a given fire.

A free-spreading fire is assumed to have an elliptical shape with the fire origin at a focus of the ellipse (*fig. 9*). The length-to-width ratio of the ellipse is one of the fire occurrence data items. *Section 3.4* discusses how suppression action alters the free fire ellipse.

Table 1—*Maximum numbers per planning unit of fire suppression resources*

Resources	Maximum number
Ground bases (fire stations)	100
Helitack bases[1]	30
Prepared helispots	500
Smokejumper bases	10
Air tanker bases	10
Ground units (total per ground base)	10
Hand crews	
Pumper crews (fire trucks)	
Tractor plows	
Bulldozers	
Nurse tankers (water wagons)	
Helicopters[2]	15
Smokejumper transport aircraft	[3]5
Air tankers[2]	15

[1] Helitack bases may be co-located and share men with ground bases.
[2] Dual mode aircraft may be defined as personnel-carrying helicopters for the first trip and helicopter air tankers (helitankers) thereafter.
[3] Per base.

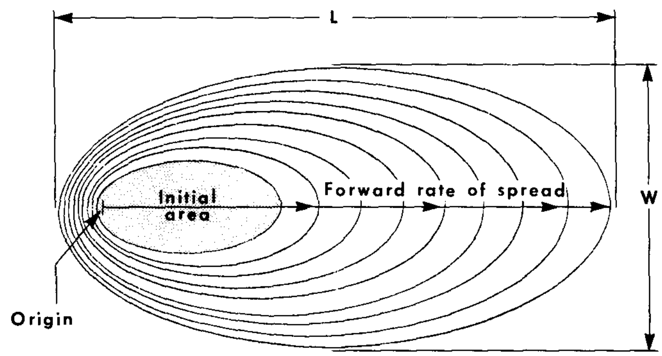


Figure 9—Elliptical fire model is specified by initial area, forward spread rate, and length/width (L/W is constant for all sizes).

3.2 Generating the Resource Arrival Sequences

3.2.1 Planning Assumptions

FOCUS users are required to assemble a set of data which describes the fire resources available for a given fire plan or alternative. These data describe operation bases and eight types of units—ground crews with handtools, pumper crews, tractor plows, bulldozers, helicopter attack crews, smokejumpers, air tankers, and nurse tankers (*table 1*).

For helitack crew operations, the available helicopters must be described, and transport aircraft data are required for smokejumpers. An additional dual mode operation uses an aircraft to deliver crewmen on the first trip, then switches to an air tanker (bucket or water scooping) operation.

Ground Units—The time interval required for ground units (hand and pumper crews, tractors) to arrive at a simulated fire location is the sum of several time increments. Two kinds of time delay can occur before a unit leaves its base. First, a straight getaway time can be specified in the data for each unit. Secondly, a return-to-base time which depends on fire danger level can be used. The latter simulates conditions for backup fire crews working on other projects, but required to stay within a given distance from base, depending on fire danger conditions. Another time increment is actual travel time on the road and trail system from a base to the unloading point, that is the closest point to the fire. Then, unless the fire is next to the road or trail, a final cross-country walking time increment is added. This time is calculated using a level-ground, cross-country walking speed specified by the user. Optionally, if elevation above sea level is provided for roads and fires, a correction in walking speed is calculated to account for the difference in elevation between the unloading point and fire. The total travel is subject to a maximum value that can be specified for units such as those from cooperators which will not respond to fires beyond a certain travel time away from their bases.

The road network data can include up to three travel times over each road segment corresponding to classes of vehicles. Also, two-way travel times must be specified to account for uphill and downhill differences. The computer program determines the best routes from bases to fires to minimize travel times.

Storing base-to-fire travel times on the FOCUS system proves highly cost effective. Subsequent computer runs using all or some of the same base and fire locations can use these stored travel times at a considerable cost saving.

An optional program capability provides for refilling pumpers from local water sources rather than the alternatives of nurse tankers or staying empty. Users can partition the planning area into four sectors and specify an average refill time for pumpers on fires in each sector. This is time from water exhaustion until the pumper is back on the line with a full load of water. In the refill operation, one man is assumed to accompany the pumper while the remaining crew continues to work with handtools, unless otherwise prohibited by a data option. When a nurse tanker arrives at a fire, 5 minutes are assumed for hook-up before empty pumpers at the fire start using the water. A pumper can be specified as a portable pump which obtains water from a nearby source and never runs out of water.

Pumper crews always become hand crews when water is exhausted, unless prohibited by a data option. A data-specified subtype associated with the pumper determines which of three possible hand crew production tables is used.

Helicopter Attack Crews—Crews delivered by helicopter may be actual helicopter attack crews or ground crews. Helicopter attack proceeds from the home base followed by reinforcements from the nearest base to the fire with a suitable crew and facilities. In multiple fire situations, a backlog of demand for a helicopter may build up. In such cases, a helicopter may deliver a partial load to one fire before proceeding to the next. When the helicopter is empty, it will reload at the nonempty base nearest the fire to which it is next committed. These activities are governed by a set of user-specified priorities for helitack use of bases and by a specified minimum load. The minimum load restriction becomes invalid if all bases of a given priority lack the specified force level. More than one helicopter can be dispatched to a fire using preplanned area dispatch, or by specifying a maximum number of helicopters to be used on one fire. FOCUS does not impose any density- altitude limitations on helicopter load capabilities.

The user may specify that helicopters also be assigned to lift road vehicle-transported crews from the road to the fire when certain conditions are met. These are:

- Walk time from road to fire exceeds 15 minutes.
- The helicopter will not wait more than 30 minutes for the crew to arrive. The actual limiting wait time for the helicopter varies from 1 minute if walk time is just over 15 minutes to 30 minutes if walk time is 60 minutes or more.
- The crew would not get to the fire sooner by walking.

Helicopters are assumed to land near the fire on prepared and maintained landing spots or on natural landing areas as specified. A combination mode may be chosen in which a prepared landing spot is used if located within a specified distance from the fire, otherwise a natural landing spot is used. A fixed average walk distance from natural landing spots to fires is specified by the user.

Dual mode aircraft, which may or may not be rotating wing aircraft, use the data coding and program logic for helicopters. The defining property of a dual mode unit is that it delivers men close to a fire on a first trip, then switches to an air tanker operation. A walk distance from landing to fire which is different from that for other helicopter-delivered crews may be specified. The intent here is to model water-based fixed-wing aircraft as well as dual mode helicopter operations. The fixed-wing planes land on water bodies to deliver crews, then begin a water scooping and dropping operation. More will be said about dual mode units in the discussion of air tankers below.

Smokejumpers— Decisions about smokejumper use and crew size are made for each fire by the FOCUS dispatching logic. Jumpers are dispatched from bases or from airborne planes with uncommitted jumpers aboard. The locations and load status for all smokejumper transports are determined at the time of the fire, and the total time for placing the specified number of jumpers at the fire is minimized. This objective may require immediate dispatch of one or more plane loads from one or more bases, multiple trips by one aircraft, the use of partial loads already in the air, or some combination of these modes. Smokejumper delivery times are calculated from user-supplied load times and cruise speeds for aircraft, assuming straight point-to-point distances. Total times also include user's streamer plus drop times along with an additional time per man for assembling the crew and equipment on the ground. Streamer time refers to the practice of dropping and observing ribbon streamers for estimating the wind drift of parachutes.

Air Tankers—Three operational modes are available to an air tanker. The first mode limits an air tanker to operation from its home base. The second mode allows initial dispatch from home base; but in multiple fire situations, refills and subsequent dispatches will be from bases which can handle the aircraft and which are closest to the fires. The third mode provides for helicopters or water scooping tankers to refill at a source close to the fire. Dual mode aircraft operate as air tankers in the local refill mode. When assigning aircraft to this mode, the user may partition his planning unit into four sectors and specify an average distance from fires to local refill sources in each sector. An air tanker's complement of full tanks can be expended on a single fire; or, in a multiple fire situation and depending on need, the payload can be divided among two or more fires.

Sequence Generation—Using the parameters and operational modes for ground and air attack, a sequence of possible unit arrivals, ordered in time without regard to production rate, is generated for each fire. Unit types, or line building resources, are not included in this list if they are excluded from the fire area by the fire occurrence data. The program truncates the list, that is, sequence generation is stopped for each type of line building resource, when line production capability is sufficient to allow easy containment of a fire. The dispatching portion of the program (see *sec. 3.3*) decides what part of the potential arrival sequence list is actually made available for fire suppression calculations.

3.2.2 Program Assumptions

Ground Units—The parameters which define ground units, associated limitations on size and numbers, and other pertinent requirements are defined in the *FOCUS User Manual* (USDA Forest Service 1977c, p. C-1). No attempt is made to duplicate that information here.

An important ground unit consideration is staffing. The FOCUS program has the capability to vary the available units and total personnel on a daily basis, depending on the fire danger situation for a given day. This capability simulates the use of "manning and specific action guides" (USDA Forest Service 1972), based on predicted fire weather. In actual operations, work force changes are sometimes instituted for reasons not directly related to daily weather, such as a reduced work force at night, increased personnel on weekends, or movement of crews in response to lightning storm conditions. These and similar staffing changes are handled in the FOCUS program by up to three user-defined special conditions for each unit. On the individual fire occurrence records, any one or combination of these conditions can be started, or stopped if previously in effect. Crews and equipment are placed on or off duty at the time of each fire as determined by an appropriate set of data. Movements between bases are accomplished by taking units or workers "off" one base and putting them "on" another.

Another staffing capability in FOCUS allows users to specify two sequential days off during the week for those units which are on a 5-day workweek.

One limitation occurs when a special work force condition is initiated. In this event, work force levels for all ground units are reset to normal prior to initiating the special work force adjustments. This situation could cause an unrealistic use of units if, for example, the special work force mode were initiated within a multiple fire sequence. Units which should remain committed to specific fires would suddenly be on base and available for dispatch. This program limitation circumvents the difficult simulation and programming problems which would occur when a previously committed unit suddenly goes off duty or has its work force level changed.

Travel times from ground bases to fires are calculated using a set of user-supplied road network data. The computer program determines the routes which give the earliest arrival times. The road data include node locations (such as intersections and resource bases), two direction travel times between nodes for three vehicle classes, roadside barrier flags to stop units from leaving a road segment on either or both sides, and designations of segments as vehicle roads or as trails for foot travel only. Node elevations above sea level are optional data.

Road configurations are approximated by straight-line segments from node-to-node. Off-road travel is along straight-line paths to fire locations from either of the two road segments nearest in time to a fire. Off-road travel rates can be set by users for each vehicle class. A level-ground cross-country walking speed is also provided by users. If pumper use is excluded in a data option for a particular fire, off-road travel for crews is set at the foot travel rate.

The data may also provide for off-road travel barriers, such as rivers, cliffs, and other obstacles that impede travel. These barriers are optionally effective for any combination of the three vehicle levels and foot travel. If the straight-line path from any road segment to a fire location is interrupted by an off-road barrier segment, that path is not used in the travel time calculations.

It should be noted that off-road barriers are used for travel time calculations only and are not considered in fire spread calculations. Also, roadside barriers defined in the road network data affect only travel from the road segment to which they are attached and do not act like off-road barriers to prevent crossing from, for example, a nearby parallel road segment to a fire.

In some parts of the country, ground units routinely go from one fire to another without returning to their base. FOCUS cannot currently model such a "hot dispatch." As a partial solution for ground crews only, a user option for each simulated fire allows a zero return-to-base time thus eliminating the normal return travel time prior to the next dispatch.

Air Units—The data parameters which describe air units, including limitations on size and numbers, are described in detail in the *FOCUS User Manual* (USDA Forest Service 1977c, p. D-1).

The only FOCUS program restriction on the use of aircraft relates to darkness. Aircraft operating hours are assumed to be from 30 minutes before sunrise to 30 minutes after sunset. Since weather and terrain factors which might limit aircraft are neither required nor entered as data items, the burden rests on the user to restrict aircraft use (in the fire occurrence data) when such factors are involved.

Aircraft refueling and maintenance are not simulated. Aircraft availability is limited only by on-duty and off-duty dates, priority considerations, prior fire commitments, and darkness. Point-to-point air travel times are calculated using cruise speeds provided by the user for each air unit.

Helicopters and Helitack—Some crews can be transported by either ground vehicles or helicopters. The program assumes that that mode will be used which results in the quickest arrival at the fire. Ground transport could be used when helicopters are backlogged or are at a considerable distance from the crew and fire. When the helicopter option is chosen to deliver crews to the fire location, 1 minute is allowed as walking time in addition to the load and unload time which is part of the helicopter data.

Generating possible helitack arrivals is stopped when sufficient forces are in the arrival list for easy containment of the fire, considering both ground and helitack arrivals.

Smokejumpers—When a user option allows jumping on multiple fires with one plane load, transports are fully loaded when taking off to a fire which has occurred within 30 minutes of the previous fire, otherwise only sufficient jumpers for the one fire are loaded. The 30-minute criterion is used to indicate a possible multiple fire situation. Planes with men aboard, returning to base, may be diverted to any fire which occurs before arrival at base; 5 minutes are added to the flight time for changing course and finding the new fire.

A required number of smokejumpers is calculated for inclusion in the list of possible arrivals at a fire, assuming that no other type of line-building resource will be used. This number is subject to limitations by minimum and maximum values specified by users. The smallest transport plane that can carry the required number from the nearest base to the fire will be used. If required, more transports and additional bases may be used to obtain the calculated number of jumpers.

In the simulation, return-to-base times are the same as base-to-fire times, except for smokejumpers where the user provides a unique return-to-base time.

Air Tankers—Effective air tanker drop lengths are based on a table which is entered using a fuel loading index included in the data and a rate of fire spread index derived from the rate in the fire data. For multiple tank planes, a drop length per tank is calculated. The salvo size is then determined based on a nominal drop length of 3 chains. Tanks are combined if required until the effective drop length is 3 chains or more. Salvos are dropped using this number of tanks until no more are required on the fire or all the tanks are empty. Of course, the last salvo may use less tanks than the previous salvos.

The number of air tankers is based both on the dispatching decision rules and the fire rate of spread. Since air tankers are not considered to build and hold fireline except in association with ground crews, they are not considered in direct trade-off relationship with crews and equipment. The initial air tanker demand is anticipated by preplanned dispatch, then augmented when the actual ground dispatch and the fire rate-of-spread are determined. The number of air tankers is increased when the dispatch criteria for ground attack cannot be met or spread rate is high.

3.3 Dispatching Calculations

3.3.1 Planning Assumptions

The function of the dispatching portion of the FOCUS suppression module is to select a subset of possible resource arrivals at the fire for actual dispatch. Two dispatch modes are available and may be used exclusively or in combination: threat response dispatch (TRD) and preplanned area dispatch (PPAD). As implied, TRD is a response to the threat posed by an individual fire; whereas PPAD is a preplanned response which depends on the response area in which the fire is located and on the fire danger level. Follow-up dispatches in the PPAD mode are based on the TRD scheme. On individual fires, users may choose to use TRD, even though the PPAD mode is in effect. In PPAD, follow-up dispatches are delayed long enough to allow the first PPAD unit to arrive at the fire. A reconnaissance option may be chosen in the TRD mode in which dispatch of units after the first to arrive at the fire is delayed until the first unit arrives.

The TRD scheme attempts to match the total user-defined fireline production capability of dispatched units to a value several times the forward spread rate of the fire. This value is nominally 3.5 times the spread rate, but can have other optional values. The minimum value is either 2.0 times the spread rate or a value which assures a fireline production rate of at least 1 chain per hour. The program attempts to meet this criterion by the time the fire reaches a selected size, generally 1 to 5 acres. If line-production capability conditions cannot be met, the situation is judged as potentially dangerous and the attack is strengthened. An air tanker is dispatched, if available, and the production rate requirement is raised to 5.0 times the forward spread rate of the fire.

In the TRD mode, the user can select a fire danger level for automatic dispatch of an air tanker. If the fire danger in the fire vicinity is at or over the selected level, a single air tanker is dispatched. Additional air tankers are dispatched depending on the spread rate of the fire. Dispatch of additional air tankers is delayed until the first ground unit arrives at the fire.

When PPAD is used for initial attack, the TRD scheme is used as a back- up. If the preplanned area dispatch does not meet TRD criteria, these criteria are used to determine a follow-up dispatch. Calculating the dispatch to a fire is further refined in the attack calculation process. Units which have not arrived at the fire by the time the fire is contained are assumed never to have been sent and do not appear in the arrival list printout.

Dispatches to nonspreading fires (such as structures and vehicles) always use the PPAD scheme. A typical, or average, dispatch to each type of nonspreading fire is determined by the user and entered as PPAD data.

A priority scheme specified by the user determines the order in which various classes of resources will be dispatched. Resources are classified optionally by organizational or jurisdictional criteria. Class I ordinarily consists of primary attack forces within the planning unit. Class 2 may consist of planning unit resources such as work crews. Class 3 might consist of cooperators, including—for the Forest Service—State or county agencies. A maximum of 15 such classes can be defined. FOCUS users must establish a table which defines the normal dispatch priority or order for various types and classes of fire resources. The program first attempts to make a satisfactory dispatch using priority 1 units, then adds successive priority levels as needed. The data for each simulated fire occurrence has the capability to modify dispatch priorities for that particular fire. Agencies or resources other than planning unit initial attack forces can be specified as first priority for a given fire, while the regular initial attack forces can be relegated to a lower priority. This reordering of priorities could occur where fires are within an adjacent protection jurisdiction, such as a fire district within a National Forest.

3.3.2 Program Assumptions

Water exhaustion times for dispatched pumpers are calculated using a rate of 7.5 gallons of water per minute. When available, additional air tankers are dispatched from the simulated fire based on spread rate. One air tanker is added for spread rates over 10 chains per hour; two air tankers for spread rates over 20 chains per hour; and three air tankers if the forward spread rate is over 40 chains per hour.

3.4 Fire Attack Calculations

3.4.1 Planning Assumptions

The calculation of a hypothetical attack on a fire is based on the list of resource arrivals generated by the dispatching part of the FOCUS program. Three modes of attack can be used, as specified on the fire occurrence data for each fire: direct head attack, direct rear and flank attack, indirect or backfiring head attack.

The call for a direct head attack may be overridden by the program logic if sufficient forces are unavailable to ensure a safe head attack. Similarly, in an indirect head attack, the call may be overridden if the combination of forces and time available is not sufficient to construct a backfiring line which will hold the fire under escape size. In either case, the program converts to a direct rear attack mode.

For the direct rear attack, the method for assignments of forces to the fire flanks is an overall (not for individual fires) user option. The ratio of production rates on left and right flanks is the criterion specified. A simple programmed assignment schedule may also be called for. This much-used option attempts to equalize production rates on the two flanks up to a given level, then builds up on one flank to a strong attack, before again equalizing the flank production rates at a higher level. Of course, all of the assignment options are goals to try for, and they are governed by the availabilities of forces along with the necessity of making whole number assignments of personnel and equipment.

Fires are declared *escaped* by the program if user-specified escape parameters are exceeded for burned area or maximum time of engagement. For escaped fires, the program prints out the fire parameters, size at escape, time of escape, and length of fireline constructed. The total list of dispatched resources also is given.

If, in a multiple fire situation, resources are exhausted to the point where nothing is available to send to a fire, the fire is declared "no-dispatch" by the program and the fire parameters are printed out along with a calculation of when and how the fire would reach escape conditions if not attacked. This condition most often occurs either in evening fires when forces are exhausted by an afternoon lightning storm and air attack can no longer be made because of darkness, or in a heavy incendiary outbreak. If 20 consecutive "no-dispatch" fires occur, the program stops execution, assuming a data error exists.

Air tanker drops are assumed to perform a holding function only. Fire will spread around drops but not through them using the direct rear attack mode in the simulation. Drops must be backed up by fireline construction to be secure. The first drop on a fire is always made at the head. Subsequent drops may be tied in on the flanks if made before the fire spreads around the drop ends or made on new fire heads formed when the fire goes around the drops. A complex logic arrangement determines where drops subsequent to the first will be made, depending on previous drop geometry and crew locations and status.

When air tanker dispatch is called for on small, easily contained fires, a limited number of simulated drops may be made but are assumed to have no effect on final fire size. The effectiveness of such drops would be minimal, but they are included for costing purposes.

3.4.2 Program Assumptions

The basic free-spreading fire model used in FOCUS fire attack calculations is a growing ellipse with its origin at a focus (*fig. 9*). This ellipse is determined by three parameters—initial area, forward rate of spread, and length-to-width ratio or elliptical eccentricity. Values for these three parameters are entered as data for each fire in the simulated fire occurrence list. Rate of spread and length-to-width ratio are assumed constant throughout the fire attack calculations. Users are cautioned to consider these assumptions when setting the maximum, or escape, size for fires.

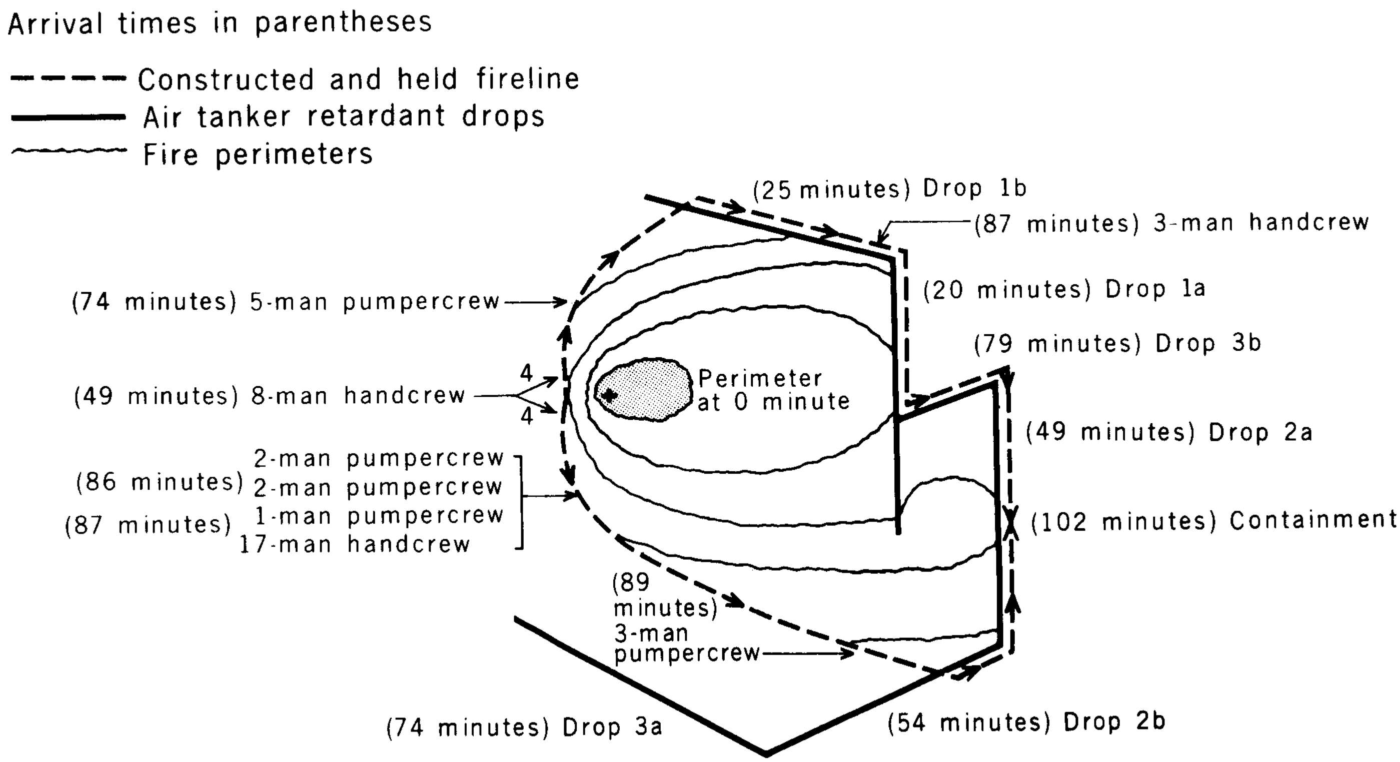


Figure 10—The rates of fireline production change as reinforcements arrive.

The program performs two kinds of attack calculations—a table look-up procedure for easy fires, and more complex attack calculations when the fire cannot be controlled easily. First, an attempt is made to use a table look-up procedure for small, easy fires (Bratten 1978). The look-up tables give the size and time at containment under assumptions of equal assignments to the two fire flanks and no air tanker effectiveness. All line-building resources which arrive within 15 minutes of the first units are used. The fireline construction rate is accumulated for these first arrivals. An average arrival time is calculated by weighting the individual arrival times by the production rates. Production rates for pumpers in the arrival list are weighted by considering their exhaustion times from the arrival list and assuming that the engagement time on the fire is 1 hour. Average production rates are calculated by using production rates with water until exhaustion, and hand crew rates for the remainder of the hour.

The look-up tables are entered using the initial fire area from the fire occurrence data, the average arrival time, and the total production rate. The available production rate is assumed to be split equally between the two fire flanks. If the result is containment at less than 10 acres in less than 2 hours, the size and time are accepted and no further attack calculations are performed.

If the fire cannot be controlled within these limits, the program goes into one of the three attack modes discussed in *section 3.4.1.* The results from part of the table look-up calculations are used to check and perhaps modify the user's designation of head or rear attack mode for each fire. If head attack is specified, the initial production rate for the table look-up calculations must exceed a minimum value. Otherwise, the attack designation is changed to rear. The criterion for head attack is that the ratio of production rate to forward spread rate must exceed (3 + 6 V) where V is the forward spread rate in chains per minute specified in the fire data. This criterion defines a boundary between easy and difficult containment by direct head attack. By this criterion, difficult head attack is assumed hazardous and should not be attempted. (This discussion does not apply to indirect head attack.)

In direct attack calculations, fireline production rates are integrated along the perimeter of the growing fire ellipse with changes in these rates as new arrivals are assigned (*fig. 10*). Fireline production rates may decrease when pumper crews run out of water, at which time they may begin work with handtools, depending on data input. When pumpers are refilled from either local sources or nurse tankers, production rates return to the higher values. When nurse tankers arrive at a fire, the water supply is assumed to be shared equally between all pumper units on the fire.

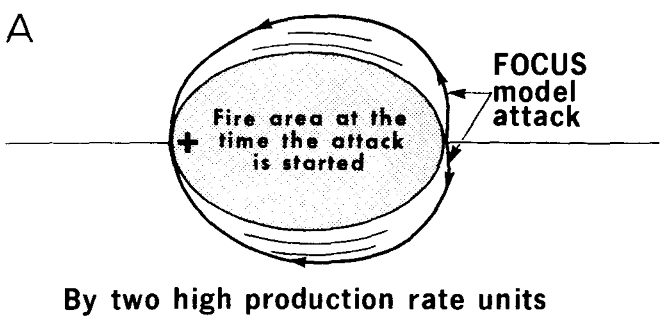
Reassignment of crews may occur as new resources arrive in an attempt to reach or maintain assignment criteria. In extended attack calculations, units are assigned to the two flanks of the fire as they arrive, attempting to give equal production rates for head attacks, or to meet user-specified criteria for rear attacks.

Air tanker drops are treated as fire barriers in FOCUS. Fire will not spread through them; however, to be completely effective, crews must tie the fireline to the drops and complete a backup line behind them before the fire spreads around them.

For direct head attack, retardant drops from air tankers in the arrival list do not affect the calculations, though they are retained in the list for printout and costing. It is assumed that such drops would be used to aid crews in line work, and would have negligible impact on calculated fire area.

The geometry of direct head attack by two high production rate units is similar to the tactics that normally would be employed by actual units. Each direct head attack unit starts from the forward end of the long ellipse axis and produces a fireline until they meet toward the rear of the fire (*fig. 11A*). Note that in this case the forward spread of the fire is entirely stopped.

When the fire is attacked by only one crew, the geometry is somewhat different (*fig. 11B*). In this case the unit starts at the head and circles around behind the fire. The fire continues to spread in the unattacked forward quarter and the control line must be built until it intercepts the long axis of the fire ellipse at the forward edge of the fire. At this point FOCUS departs somewhat from reality since the line is not built back to the starting point; however, at least as much control line is constructed as likely would have occurred in the "real world."



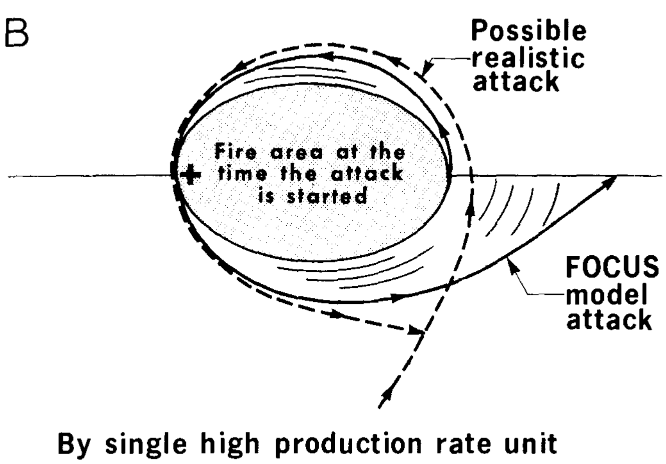


Figure 11—Direct head attack as modeled by FOCUS for two crews (A) and a single crew (B).

With the exception of fires starting along roadsides, FOCUS does not consider natural or manmade barriers to fire spread other than the control line put in during the fire. Although the occurrence of natural forms such as rivers and cliffs may act as barriers to foot and off-road vehicle travel, they do not influence fire size or shape. Roadside fires are the exception and always spread away from or along the road but do not cross it.

In direct rear attack calculations, the first drop is made across the head of the fire, assuming that line construction has not already stopped the fire head (*fig. 10*). Subsequent drops are made using a logic scheme based on the status of crews working on the two flanks of the fire and the events which have occurred since the previous drop. In general, successive drops are made to tie in with drops already made. The drops are oriented to maximize the chances that crews will be able to tie control line to the drops before the drops are bypassed by the fire.

Only in direct rear attack calculations are retardant drops treated as impenetrable fire barriers that can be bypassed only by fire spreading around the ends. Retardant drops associated with an indirect head attack are assumed to be penetrated after a set time.

Indirect head attack calculations assume that backfiring lines are constructed ahead of the fire. The user can specify the number of parallel, adjacent lines judged necessary. This set of line is placed so that it will be completed by a specified time preceding arrival of the fire head. The production units then begin line construction on one or both flanks to complete the line around the fire. The same basic elliptical fire growth model is used for both indirect head attack and direct attack (*fig. 12*). The tactic simulates a section of fireline ahead of the fire which may or may not be fired out or backfired. Line is then constructed from the ends of the backfire line on one or both flanks and tied in for direct attack at the widest part of the fire. Containment is achieved either by tie-in of the two crews, or by a single crew encircling the fire after constructing the line across the head (*fig. 12A and B*).

The geometry of the attack ensures that the attack on at least one flank will be completed. If the attack on the other flank is too weak, any forces tentatively assigned to it are shifted to the strong flank. A one-way encirclement of the fire is attempted back along the strong flank, then forward on the weak flank to tie in with the backfire line on that end (*fig. 12B*).

Another possibility considers that forces will arrive on the weak flank after the fire has hit the backfire line but before it goes around the end. If these forces are strong enough, a direct flank attack is mounted from the backfire line; otherwise, the forces are added to strengthen the attack from the strong side (*fig. 12C*).

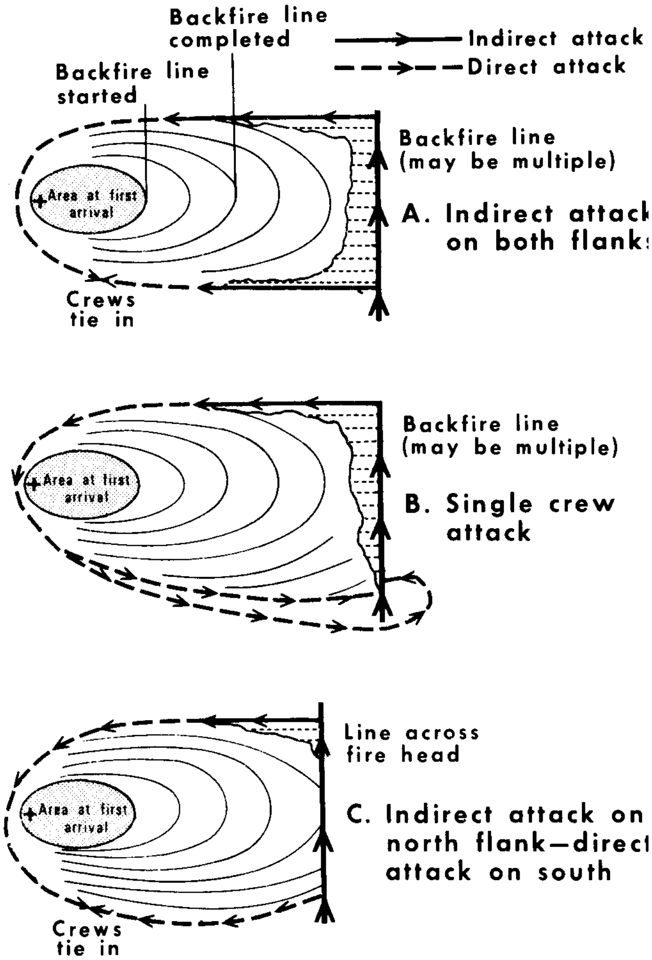


Figure 12—Examples of simulated backfire or indirect head attacks.

Attacks are governed by a set of user data which specifies three attack parameters based on fire rate of spread, fuel type, experience and custom. The parameters are:

- Time from backfiring line completion to arrival at the line of the fire head.
- Ratio of backfiring line length to width of fire at the time of backfiring line completion.
- Multiplicity of backfiring lines, that is, the number of parallel single lines constructed to form the backfiring line.

A maximum of three air tanker retardant drops, made before backfiring line completion, can be used to slow the forward spread, allowing the backfiring line to move in and decrease the final fire size.

The retardant drops are assumed to hold the fire for a maximum of 15 minutes; the fire may spread around the ends before that time. After 15 minutes, the fire can spread through the drop (*fig. 13*).

3.5 Mop-up Calculations

3.5.1 Planning Assumptions

Once a simulated fire is declared contained or escaped in the fire attack calculations, some units are retained on the fire, that is, made unavailable for dispatch, in the mop-up part of the program. Program users provide data giving time spent on mop-up and number of units required, depending on unit type, fire size, and fuel type. The user also indicates a priority order for retaining units on mop-up, based on the resource classes (see *sec. 3.3.*) Those user-supplied data are used for contained fires only. For escaped fires, an internal set of rules applies.

Some experience-based but more or less arbitrary assumptions are made about escaped fires and the time that units will be committed to such fires, since the time of control and the time for mop-up are indeterminate in the program. All primary attack forces will be available for dispatch at 0800 on the morning after the day of the fire. These same forces will be available at noon when committed to fires occurring between midnight and 0800. Secondary forces are held on the fire for 24 hours. Cooperators are held for 8 hours then released, unless they are helitack units which are released 2 hours after escape time. Primary initial attack forces are interpreted to be resource Class 1, secondary forces are Class 2, and cooperators are all higher classes in the program.

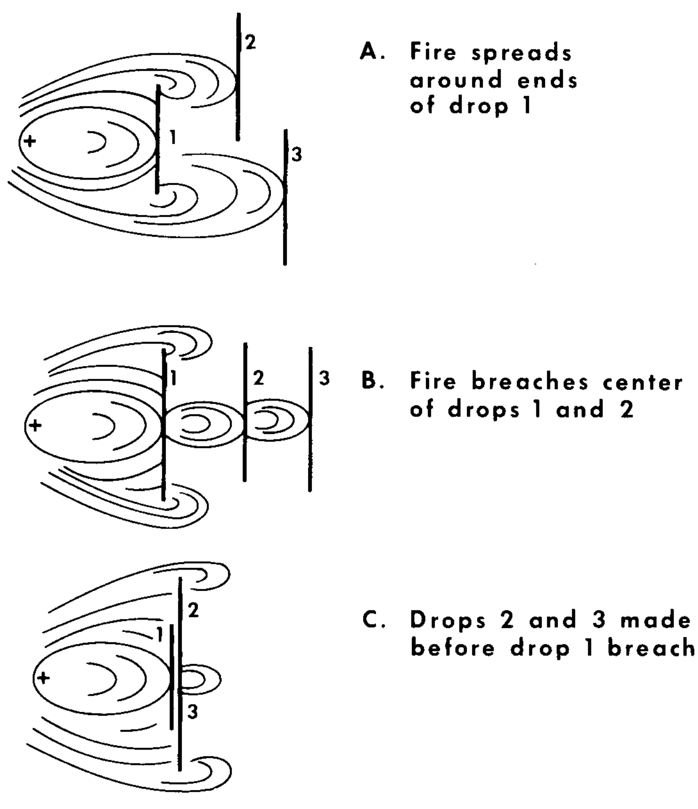


Figure 13—Examples of air tanker drop geometry in backfire attack.

These arbitrary rules obviously would not apply well to campaign fires extending over 2 or more days, and might be overly conservative for fires which are only slightly over escape size—typically 100 acres. The intent is to reflect the impact of large fires on initial attack capabilities without being too severe.

3.5.2 Program Assumptions

Data for contained fires consider three kinds of mop-up resources: hand crews, pumper crews, and bulldozers. Often, these types are not all present on a fire, so other resources must substitute. Strict substitution rules are not adhered to between these resource types, but the presence of one or more bulldozer for mop-up is assumed to reduce the labor requirement by 30 percent. The requirement for hand crew forces is considered first. Where this requirement cannot be filled, any pumper crew is assumed to be "worth" five hand crew members.

When mop-up requirements for hand crews require less than the smallest crew size on the fire, the crew will be split. The part of the crew not needed will be returned to base immediately, if more than one person.

3.6 Suppression Module Output

3.6.1 Planning Assumptions

Examples of printed output were given in *section 3*. Additional printouts available in production runs include the run set-up data and a complete list of the base plan resource unit and base data along with any changes made for a particular alternative run. These printouts are displayed in easily read formats. One example is the run set-up parameters for helitack and air tanker attack (*fig. 14*). Similarly, data printout examples are shown for helitack bases and helicopters (*fig. 15*).

The FOCUS cost module calculates and summarizes the costs of suppression operations of a fire organization. Part of the costs are on-the-fire suppression costs for labor and equipment. The suppression module must supply the computer-based information needed by the cost module to calculate suppression costs on the simulated fires. Such a file is generated on demand by the suppression module.

Special diagnostic printouts from the suppression module provide a method of analyzing the complete operation of the module (*sec. 3*). These printouts are used principally by program maintenance technicians, but are available to knowledgeable users to assess the program's handling of one or a few simulated fires. This type of printout can be quite extensive and impractical for a large number of simulated fires.

3.6.2 Program Assumptions

The quantities which can be printed out or written in the cost module file and the formats used are internal program features. Users can choose only whether to use these capabilities.

```
HELITACK PARAMETERS ARE -

                MAX FIRE TO HELISPOT DISTANCE-------  40 CHAINS
                AVE. NATURAL HSPOT-FIRE WALK DIST.--  40 CHAINS.
                HELISPOT USE DOCTRINE -
                    2 - NATURAL HELISPOTS ALWAYS USED.
                DELIVERY MODE OPTION -
                    2 - USE NEAREST COPTER & BASE. LIFT CREWS TO FIRE AS NEEDED.
                MIN. COPTER LOAD------------------  2 MEN
                MAX. NO. OF COPTERS ON 1 FIRE IS--- 1

AIRTANKER ATTACK PARAMETERS ARE -

                MAX. NO. OF TRIPS PER TANKER--------  4
                INTERVAL BETWEEN DROPS--------- 3 MINUTES
                CRIT. BI CLASS FOR AUTO. DISPATCH---10
                AIR TANKERS RELOAD AT CLOSEST BASE UNLESS EXCLUDED.
                LOCAL WATER USED. PLANNING UNIT QUADRANTS SET BY:
                    LATITUDE = 36.800 DEG.   LONGITUDE = 119.000 DEG.
                AVE. FLYING DIST. TO RELOAD BY QUADRANTS, IN CHAINS:
                    (NW)  30,  (NE)  45,  (SW)  60,  (SE)  75
                AIR TANKER TYPES WHICH USE LOCAL WATER:
                    4     0     0     0     0
```

Figure 14—Example of suppression module output: run set-up parameters for an air attack.

HELITACK BASES

HELI BASE #	NO. OF COPTERS	# MEN STATIONED	# MEN AVAIL.	BASE X-LOC	BASE Y-LOC	# GND BASE SHARES MEN	PRIORITY FOR H-TAK	BASE NAME
1	0	2	2	553	326	3	1	CAMP 4 1/2
2	0	2	2	-734	-458	5	1	BIG MEADOWS
3	1	6	6	810	923	7	2	TRIMMER (FE
4	0	5	5	-415	-38	2	1	HUME LAKE
5	1	4	4	-158	-87	0	1	HALFWAY HEL

HELICOPTER PARAMETERS

PTER NO.	HOME BASE	CRUISE SPEED (CH/MIN)+	LOAD CAP. (MEN)	LOAD + UNLOAD TIME(MINS)	RESOURCE CLASS	DATE ON	DATE OFF	ASSOC. A.T.++ NUMBER	HELI NA
1	3	90	2	10	2	1	365	0	FENCE
2	5	100	4	10	1	1	365	104	HALFWA

100 ADDED TO ASSOC. A.T. NO. IF FIXED WING.

Figure 15—Example of suppression module output: bases and aircraft.

4. COST MODULE

The cost module computes the suppression costs and damages associated with the fire plan and fire workload. Dollar rates are applied to the hourly total of labor and equipment from the suppression module, resulting in total costs. Proper dollar equivalents are also applied to acres burned by damage potential classes which are derived from the suppression module, resulting in total damages. The cost module is an aid to determine total costs and damages whereby alternative plans may be compared. The program is not intended as a precise accounting system for individuals and equipment. Many cost items are too detailed to be simulated and must be entered as estimated averages. The dollar cost and damage summaries should be used to rank the cost elements rather than to achieve a precise dollar difference between plans. Further FOCUS use and analysis of results are needed to determine at what point differences between plans constitute an amount of significance to management.

The cost module consists of two programs: SMOKEY I and SMOKEY II. SMOKEY I requires input which is closely related to the suppression module input. SMOKEY I provides summaries and error checking printouts and stores base and unit costing data. SMOKEY II calculates suppression costs from the combined input of the base and unit costing data of SMOKEY I and the fire suppression history from the suppression module.

The objective of the cost module is to assess dollar values of costs and losses for each initial attack alternative. Costs are separated as fixed or variable (*fig. 16*). Suppression costs represent only the values of equipment and people actually used in on-fire activity (*fig. 17*). Such values may not be comparable to the real world fire budgeting which, under certain circumstances, often permits several Federal agencies and many States to allocate so-called emergency firefighting funds to presuppression activities.

4.1 Assumptions and Limitations

4.1.1 Planning Assumptions

The cost module computes functional summaries based on the suppression module data set of suppression force use and the cost module data set of rates. This modeling assumes the validity and sensitivity of the suppression module estimates, the ability to express user accounting methods to cost labor and equipment in a small number of present options in the cost module, and the deterministic calculation of all costs from these suppression force uses and rates.

Because cost module input is derived from suppression module output, the cost module shares all the appropriate assumptions.

The accuracy of cost module estimates must never be confused with that of accounting printouts. The precision of the required inputs and computerized summaries, which implies more accuracy than is justified, could be misleading to the decisionmaker. FOCUS is a planning tool whose dollar totals are for ranking purposes or paired comparisons only. The cost module is designed to test alternative plans, not to budget differences within or between regions. The cost module is intended to provide information for fire management decisionmaking.

```
                          COST SUMMARY
                          SEASON 1980

INITIAL ATTACK                  1702538
PREVENTION                        23492
DETECTION                         43011
OTHER(FIRE)                        6053
OTHER(NONFIRE)                      989

SUBTOTAL FIXED COSTS                          1776087
-----------------------------------------------------

UNUSED CONTRACTS                 204738
NORMAL MANNING (NON SUPR)       1033219
SUPPRESSION                           0
SUBTOTAL VARIABLE COSTS                       1237957
-----------------------------------------------------

POTENTIAL DAMAGE                                    0
-----------------------------------------------------

COSTS PLUS POT. DAMAGE                                     3014044
------------------------------------------------------------------

* CONSULT PAGE 10-40 IN FOCUS USER MANUAL FOR DEFINITION OF COST TERMS
```

Figure 16—Example of cost module output: summary of fixed and variable costs.

TYPE--GROUND CREWS AND PLOWS / BULLDOZER

FOR SEASON 1970

B	U	NAME	UNUSED CONTRACT MIN	NORMAL MANNING	SUPPRESSION COST	# OF FIRES	MILES TRAVELED	MAN HR SUPR	# OF TRIPS	# OF MEN SENT	# OF RET LOADS
1	1	STOCKTON ENGINE	0.	24705.00	.00	0.	.0	.0			
2	1	MORMON ENGINE	0.	24705.00	.00	0.	.0	.0			
2	2	MORMON ROCK FPT	0.	5307.00	.00	0.	.0	.0			
2	3	MORMON TRACTOR	0.	5845.00	.00	0.	.0	.0			
2	4	MORMON NURSE	0.	4843.00	.00	0.	.0	.0			
3	1	LYTLE CR ENGINE	0.	48756.09	2560.31	17.	881.0	279.8			
3	2	LYTLE CR FPT	0.	21040.47	646.87	12.	672.0	67.7			
3	3	LYTLE CR IRC	0.	11680.00	.00	0.	.0	.0			
4	1	SAN SEVAINE ENG	0.	24705.00	.00	0.	.0	.0			
4	2	SAN SEVAINE HTK	0.	30856.00	.00	0.	.0	.0			
5	1	DAY CANYON ENG	0.	24705.00	.00	0.	.0	.0			
5	2	DAY CANYON FPT	0.	10614.00	.00	0.	.0	.0			
6	1	SYCAMORE ENG	0.	24705.00	.00	0.	.0	.0			
7	1	COTTONWOOD ENG	0.	24705.00	.00	0.	.0	.0			
7	2	COTTONWOOD FPT	0.	10614.00	.00	0.	.0	.0			
7	3	COTTONWOOD NURS	0.	4843.00	.00	0.	.0	.0			
8	1	WATERMAN ENG	0.	24705.00	.00	0.	.0	.0			
8	2	WATERMAN FPT	0.	21036.36	860.23	13.	1260.0	86.5			
9	1	DEVILS CYN ENG	0.	24705.00	.00	0.	.0	.0			
9	2	DEVILS CYN FPT	0.	5307.00	.00	0.	.0	.0			
10	1	ROCK CAMP ENG	0.	24705.00	.00	0.	.0	.0			
10	2	ROCK CAMP FPT	0.	10614.00	.00	0.	.0	.0			
11	1	SKYFOREST ENG	0.	48893.34	1583.53	14.	496.0	209.6			
11	2	SKYFOREST FPT	0.	21134.60	129.95	3.	178.5	14.8			
12	1	CITY CREEK ENG	0.	24705.00	.00	0.	.0	.0			
12	2	CITY CREEK FPT	0.	10614.00	.00	0.	.0	.0			
13	1	CRAB FLATS ENG	0.	24705.00	.00	0.	.0	.0			
14	1	DEER LICK ENG	0.	24705.00	.00	0.	.0	.0			
14	2	DEER LICK FPT	0.	21040.95	772.28	11.	1186.5	75.8			
14	3	DEERLICK TRACT	0.	5845.00	.00	0.	.0	.0			
15	1	BIG PINE FL ENG	0.	24705.00	.00	0.	.0	.0			
15	2	BIG PINE FL NUR	0.	4843.00	.00	0.	.0	.0			
15	3	BIG PINE FL FPT	0.	10614.00	.00	0.	.0	.0			
16	1	SANTA ANA ENG	0.	24705.00	.00	0.	.0	.0			
17	1	FAWNSKIN ENG	0.	49080.37	1632.44	9.	655.0	165.3			
17	2	FAWNSKIN FPT	0.	10585.00	23.49	1.	48.0	1.4			
17	3	FAWNSKIN HTSHOT	0.	96860.00	.00	0.	.0	.0			
18	1	CONVERSE ENG	0.	24705.00	.00	0.	.0	.0			
19	1	HEART BAR ENG	0.	24705.00	.00	0.	.0	.0			
19	2	HEART BAR FPT	0.	5307.00	.00	0.	.0	.0			
20	1	CAMP ANGELUS EN	0.	24705.00	.00	0.	.0	.0			
20	2	BARTON FLTS FPT	0.	10614.00	.00	0.	.0	.0			
20	4	CAMP ANG TRACT	0.	12775.00	.00	0.	.0	.0			
20	5	CAMP ANG NURSE	0.	4843.00	.00	0.	.0	.0			
20	6	CAMP ANG HELISH	0.	67802.00	.00	0.	.0	.0			

Figure 17—Example of cost module output: summary of base and unit costs.

Errors can have a cumulative or biasing effect. For example, if amortization of replacement costs and maintenance are omitted from all owned equipment, the output will be biased against contracted equipment, even though such items are obviously included in corresponding guarantees and rates. Therefore, contracted equipment will appear less cost-effective than owned equipment.

4.1.2 Program Assumptions

The cost module operates under the set of system assumptions and limitations discussed in *section 4.1.* A few of the parameters in the cost module are limited because of the confining amount of real world fire costs which the program could model, and the lack of needed cost data in current Forest Service inputs. Therefore, the cost module inputs are assumed to be averages and estimates. The user may define the values for the seven classes of damage potential. These values are applied to the suppression results to provide a measurement of fire damages. The output should be used only to rank plans, not to reflect dollar values, since no current method exists to base these values on sound economical studies.

The cost module logic is relatively simple, compared to the suppression module. Basically, the suppression module simulates a fire season; the cost module accounts for the results. Therefore, the cost module assumptions discussed below are few.

The damage values for the seven classes may be either positive or negative which allows for a fire that may give a benefit versus a loss. In this case, a negative damage figure is displayed for the fire and subtracted from the seasonal totals. Escape and no-dispatch fires are not accounted for in the cost module, therefore they must be accounted for in the gaming process.

Manning charges are computed differently depending on the pattern and type of staffing. Normal staffing charges (crews not on fire status) are computed as a minimum crew cost plus any additional staffing costs that occur. The minimum crew cost provides a method of lumping different employee grades or pay scales into one figure. Any individuals added to the minimum crew are assumed to be firefighters at a standard pay rate. For example, the first nonzero number in a staffing pattern is assumed to be the minimum crew size (*table 2*). For purposes here, the minimum crew size is assumed to be three persons. If the staffing level for a particular day happens to be very high, then two extra persons are accounted for in the minimum crew cost. However, if the staffing pattern decreases as the staffing level increases (*table 2*), the normal staffing charges are omitted to prevent any negative costs. This change might occur if crew members were shifted to more critical locations as fire danger increases.

Table 2—*Patterns for increasing or decreasing staffing, by staffing levels*

Staffing	Low	Medium	High	Very High	Extreme
	Crew Size				
Increasing	0	3	3	5	5
Decreasing	5	5	3	3	3

The staffing charges for personnel on fire status are computed as normal for an increasing staffing pattern. However, if a decreasing staffing pattern occurs, the number of personnel dispatched are multiplied by the standard cost for an extra person. Therefore, the charge for this particular crew may not be adequately represented because the total personnel on the crew are assumed to be at the same pay scale.

The suppression module has the capability to modify staffing under special conditions, as defined by the user. The cost module adequately accounts for labor under special staffing conditions only for fire status. The cost module does not account for crews on special staffing if they are not on a fire.

Overtime charges are at the rate of time-and-a-half for fire staffing. Overtime is assumed to include the hours after 6:00 p.m. and before 9:00 a.m. The overtime rate is not charged if a crew works on its regular day off. Normal time in the cost module is 7 days a week from 9:00 a.m. to 6:00 p.m. Anything outside the above parameters will be charged to overtime if the overtime option was selected at the beginning of a run.

Crews receive hazard pay only if the appropriate option has been selected, if the crew is currently paid a normal staffing charge, and only if the crews are on fire assignments. The rate is time-and-one-quarter from 9:00 a.m., regardless of the time of the fire. For example, if a crew goes to a fire at 5:00 p.m. and returns home at 10:00 p.m., it will be paid the normal rate from 9:00 a.m. to 5:00 p.m.; hazard pay is accrued from 9:00 a.m. at a rate of one-quarter the normal salary until they return home. Overtime is paid from 6:00 p.m. to 10:00 p.m.

4.2 Input Data Requirements

The SMOKEY I program and related input forms are quite detailed. However, to simplify, the cost input for any unit may be lumped into one or a few cost entries if this level of accuracy is sufficient to produce satisfactory output. The accuracy of the cost input data is related to the differences in the alternative plans tested and the limitations of the program. Per diem costs, lost tools, and related items must be accounted for by averages for salaries and recurring costs. Similarly, operating cost figures such as maintenance of a guard station should be averages rather than a specific year's cost. For example, if the guard station costs are known to have been $50 and $350 for the past 2 years, the average $200 per year is a more usable entry for simulation purposes than either $50 or $350. The cost data should be entered as averages in current dollars.

Damage figures are inherently more problematic than costs and often dominate an economic analysis. Certain fires are viewed as beneficial and therefore their effects are incorrectly calculated by present value classes; at the same time, other fire damages may be underestimated. The SMOKEY programs will accept any resource damage potential classes entered on the suppression module fire data cards and any dollar values (including negative) for the damage values. A maximum of seven damage potential classes and associated dollar values are the only limitations.

Some contention prevails that cost-plus-loss analysis does not provide adequate information for management decisions, in which case the opportunity exists to apply one's ingenuity. For example, hour control standards could be substituted for damage potential class on the fire data cards. The suppression module can print out acreages by classes or hour control standards. Then, within the group of alternate plans that meet some set of hour control criteria, costs may be compared to achieve improved management decisions.

4.3 Output Descriptions

The reliability of the output is related to the validity of the program logic and the reliability of the input data. Judgment in using this management tool is developed along with experience in using FOCUS to evaluate a variety of alternatives with familiar local data.

SMOKEY II, unlike its counterpart SMOKEY I, does not attempt to scan data for errors or insist that errors be corrected before the program runs. Instead, the program considers the possibility that the interface between the suppression and cost modules is not perfect. Rather than demand that data be corrected, the program simply prints a message and assigns a default value. User response to these errors is usually not necessary, therefore their messages are embedded within the listing where detected.

4.3.1 Output Options

In SMOKEY II, users can make optional choices of eight parameters controlling program operation, including printouts. Default values are used for these options when the user does not specify alternatives. The sample computer printout table for the SMOKEY II options (*fig. 18*) lists the default interpretations. Other user choices would be similarly listed.

Printed outputs from SMOKEY I include the base (*fig. 19*) and unit (*fig. 20*) costs which users provide, along with the totals for these costs (*fig. 21*). Simulation results are not included in these costs, so they have no relevance for judging the merits of plans or alternatives. These are provided by SMOKEY II.

4.3.2 Individual Fire Summaries

SMOKEY II provides a transaction printout (*fig. 22*) which summarizes in one line the activities of each unit in the order they were dispatched to the fires and the costs related to the specific suppression action. The first line for each fire contains (on the right) the total acres burned and damages associated with this fire. Each unit is identified by its base, unit, and type numbers, and the crew size dispatched to the fire. Cost item definitions are discussed in the user manual (USDA Forest Service 1977c, ch. 10, sec. B).

```
------------------------------------------------------------------------------------
OPTIONS IN EFFECT FOR PLAN SAN BERNARDINO NF A12 EXISTING REDUCED BY 50 PERCENT
------------------------------------------------------------------------------------



READ IN NEW COST CARDS, PRINT BASE & UNIT RATES

 1 SEASONS TO BE SIMULATED ON THIS RUN

SMOKEJUMPERS WALKOUT TIME IS 36 HRS,(TIME TO BE CHARGED)

PRINT OUT FIRE   SUMMARY

PRINT SUMMARY OF UNIT COSTS BY SEASON

PRINT SUMMARY OF UNIT COSTS BY SEASON

SEASON BEGINS ON JULIAN DATE 137

SEASON ENDS ON JULIAN DATE  319

CALCULATE OVERTIME AND HAZARD PAY
```

Figure 18—Example of cost module output: default options in effect under the Smokey II program.

BASE FORM

BASE NAME	COSTS ANNUAL		COSTS DAILY		COSTS ONE TIME		PERCENT IA	PERCENT PREVENT	PERCENT DETECT	PERCENT OTHER(F)	PERCENT OTHER(NF)	BASE NO.	BASE TYPE	MANNING AREA
DETROIT #1	$	30278	$	5	$	0	70	17	3	10	0	1	1	3
DETROIT #2	$	0	$	10	$	0	95	5	0	0	0	2	1	3
DETROIT #3	$	0	$	0	$	0	100	0	0	0	0	3	1	3
MARION FORKS	$	300	$	3	$	0	60	40	0	0	0	4	1	3
BREITENBUSH	$	300	$	3	$	0	60	40	0	0	0	5	1	3
PEARL	$	0	$	0	$	0	100	0	0	0	0	6	1	3
SHORT MTN	$	0	$	0	$	0	100	0	0	0	0	7	1	3
UNCLE BOB	$	0	$	0	$	0	100	0	0	0	0	8	1	3
PRESLEY LAKE	$	0	$	0	$	0	100	0	0	0	0	9	1	3
ELKHORN	$	0	$	0	$	0	100	0	0	0	0	10	1	3
SWEET HOME #1	$	22165	$	0	$	0	70	17	3	10	0	11	1	3
SWEET HOME #2	$	0	$	0	$	0	100	0	0	0	0	12	1	3
LAVA LAKE	$	0	$	0	$	0	70	30	0	0	0	13	1	3
QUARTZ CREEK	$	0	$	0	$	0	100	0	0	0	0	14	1	3
CANYON CREEK	$	0	$	0	$	0	100	0	0	0	0	15	1	3
HARTER MTN	$	0	$	0	$	0	100	0	0	0	0	16	1	3
MCKENZIE #1	$	20692	$	10	$	0	70	17	3	10	0	17	1	2
MCKENZIE #2	$	0	$	0	$	0	100	0	0	0	0	18	1	2
MCKENZIE #3	$	0	$	0	$	0	100	0	0	0	0	19	1	2
COUGAR #1	$	0	$	0	$	0	100	0	0	0	0	20	1	2
AIRSTRIP	$	500	$	1	$	0	100	0	0	0	0	21	1	2
FISH LAKE	$	300	$	5	$	0	70	30	0	0	0	22	1	2
BLUE RIVER #1	$	21156	$	10	$	0	70	17	3	10	0	23	1	2
BLUE RIVER #2	$	0	$	0	$	0	100	0	0	0	0	24	1	2

Figure 19—Example of cost module output: base costs under the Smokey I program.

```
TOTAL OF COSTS FOR ALL BASES AND UNITS
--------------------------------------

INITIAL ATTACK:
    ONE TIME COST:             $         .00
    YEARLY COST:               $   207841.10
    SEASONAL COST(PER DAY):    $      914.20

PREVENTION:
    ONE TIME COST:             $         .00
    YEARLY COST:               $    35816.89
    SEASONAL COST(PER DAY):    $      132.16

DETECTION
    ONE TIME COST:             $         .00
    YEARLY COST:               $    13207.71
    SEASONAL COST(PER DAY):    $      123.84

OTHER(FIRE):
    ONE TIME COST:             $         .00
    YEARLY COST:               $    24347.30
    SEASONAL COST(PER DAY):    $      125.80

OTHER(NON-FIRE):
    ONE TIME COST:             $         .00
    YEARLY COST:               $         .00
    SEASONAL COST(PER DAY):    $         .00
```

Figure 21—Example of cost module output: total costs under the Smokey I program.

I U N I T   F O R M - 1 I

UNIT NAME	SAL/DAY MNC	1XM	OT CST	A CST	GMN/YR	MXCR VS MNGUAR /YEAR	/DAY	CREDIT C/DAY	C/HR	B	- NO CREDIT - C/DAY	C/HR	B	CST/UNIT	U	CR	B	U#	TP	B#
DETROIT FMO	8	0	0	0	0	0	0	0	0	0	2	0	0	12	1	1	1	1	1	1
DETROIT FMO	8	0	0	136	0	0	0	0	0	0	2	0	0	12	1	1	1	2	1	1
DETROIT AFMO	63	0	0	0	0	0	0	0	0	0	2	0	0	12	1	1	1	3	1	1
DETROIT AFMO	63	0	0	136	0	0	0	0	0	0	2	0	0	12	1	1	1	4	1	1
DET PREV ASST	63	0	0	0	0	0	0	0	0	0	2	0	0	12	1	1	1	5	1	1
DET PREV ASST	63	0	0	136	0	0	0	0	0	0	2	0	0	12	1	1	1	6	1	1
DET TANKER	124	38	0	776	0	0	0	0	0	0	5	0	0	45	1	1	1	7	2	1
DET SUPP CREW	365	33	0	600	0	0	0	0	0	0	3	0	0	16	1	1	1	8	1	1
DET HELO CREW	200	38	0	600	0	0	0	0	0	0	3	0	0	16	1	1	1	9	1	1
DET PROJECT	365	33	0	0	0	0	0	0	0	0	0	0	0	16	1	1	1	1	1	2
RDET SC #1	0	48	0	60	0	0	0	0	0	0	2	0	0	12	1	1	1	2	1	2
DET SC #2	144	48	0	60	0	0	0	0	0	0	2	0	0	12	1	1	1	3	1	2
DET CAT	96	48	0	60	0	0	0	0	0	0	500	5	2	0	0	1	1	4	3	2
DET ENG TANKER	0	48	0	0	0	0	0	0	0	0	0	0	0	45	1	1	1	5	2	2
DETROIT DEPL 1	0	90	0	500	0	0	0	0	0	0	3	0	0	16	1	1	1	1	1	3
DETROIT DEPL 2	0	90	0	500	0	0	0	0	0	0	3	0	0	16	1	1	1	2	1	3
DETROIT DEPL 3	0	90	0	500	0	0	0	0	0	0	3	0	0	16	1	1	1	3	1	3
DETROIT DEPL 4	0	90	0	500	0	0	0	0	0	0	3	0	0	16	1	1	1	4	1	3
MARION FPT	0	38	0	0	0	0	0	0	0	0	0	0	0	16	1	1	1	1	2	4
MARION FPT	38	38	0	263	0	0	0	0	0	0	3	0	0	16	1	1	1	2	2	4
MARION SC #1	0	48	0	30	0	0	0	0	0	0	0	0	0	12	1	1	1	3	1	4
BREITEN FPT	38	38	0	0	0	0	0	0	0	0	0	0	0	16	1	1	1	1	2	5
BREITEN FPT	38	38	0	263	0	0	0	0	0	0	3	0	0	16	1	1	1	2	2	5
PEARL FPT	38	38	0	0	0	0	0	0	0	0	0	0	0	16	1	1	1	1	2	6

Figure 20—Example of cost module output: unit costs under the Smokey I program.

EACH TRANSACTION FOR PLAN: SAN BERNARDINO BASE PLAN YEAR 1970

**** FIRE NO. 1 ****

BASE NO.	UNIT NO.	UNIT TYPE	NO. MEN	FIRE MANNING	OVER TIME	HAZARD PAY	EQUIP COST	MILE COST	MATERIAL COST	TOTAL SUPPRESSION	POTENTIAL DAMAGE	BURNED ACRES
43	1	2	8	.00	.00	.00	.00	.00	.00	.00	.00	.00
43	2	2	8	.00	.00	.00	.00	.00	.00	.00		
42	1	2	5	.00	.00	.00	.00	.00	.00	.00		
21	1	2	5	50.34	.00	12.59	.00	40.25	.00	103.18		
8	2	2	2	26.58	.00	6.65	.00	34.20	.00	67.43		
14	2	2	2	27.07	.00	6.77	.00	36.00	.00	69.83		
3	2	2	2	27.31	.00	6.83	.00	36.90	.00	71.04		
3	1	2	5	64.97	.00	16.24	.00	100.05	.00	181.26		

**** FIRE NO. 2 ****

BASE NO.	UNIT NO.	UNIT TYPE	NO. MEN	FIRE MANNING	OVER TIME	HAZARD PAY	EQUIP COST	MILE COST	MATERIAL COST	TOTAL SUPPRESSION	POTENTIAL DAMAGE	BURNED ACRES
56	1	2	4	.00	.00	.00	.00	.00	.00	.00	2.40	.00
55	1	2	4	.00	.00	.00	.00	.00	.00	.00		
41	1	2	5	.00	.00	.00	.00	.00	.00	.00		
42	1	2	5	.00	.00	.00	.00	.00	.00	.00		
39	1	2	5	.00	.00	.00	.00	.00	.00	.00		
8	2	2	2	.00	36.25	6.04	.00	11.70	.00	53.99		
21	1	2	5	.00	86.91	14.48	.00	36.80	.00	138.19		
3	1	2	5	.00	90.28	15.05	.00	46.00	.00	151.33		

**** FIRE NO. 3 ****

BASE NO.	UNIT NO.	UNIT TYPE	NO. MEN	FIRE MANNING	OVER TIME	HAZARD PAY	EQUIP COST	MILE COST	MATERIAL COST	TOTAL SUPPRESSION	POTENTIAL DAMAGE	BURNED ACRES
59	1	2	5	.00	.00	.00	.00	.00	.00	.00	.00	.00
59	2	2	5	.00	.00	.00	.00	.00	.00	.00		
61	1	2	5	.00	.00	.00	.00	.00	.00	.00		
11	1	2	5	54.28	.00	13.57	.00	27.60	.00	95.45		
35	1	2	5	.00	.00	.00	.00	.00	.00	.00		
41	1	2	5	.00	.00	.00	.00	.00	.00	.00		
42	1	2	5	.00	.00	.00	.00	.00	.00	.00		

Figure 22—Example of cost module output: individual fire printouts.

```
              FIRE SUPPRESSION EXPENDITURES
              -----------------------------
                        FOR 1979
                        --------
------------------------------------------------------------

FIRE MANNING                       2115
OVERTIME                           4342
HAZARD PAY                         1169
SUBTOTAL WAGES                                7626
----------------------------------------------------

EQUIPMENT                             0
MILEAGE                            5115
MATERIALS                             0

SUBTOTAL RESOURCES                            5115
----------------------------------------------------

TOTAL SUPPRESSION                                       12741
-------------------------------------------------------------

TOTAL ACRES BURNED          16.13
-------------------------------------------------------------
```

Figure 23—Example of cost module output: summary of seasonal fire suppression expenditures.

This listing has several characteristics which should be mentioned. What appears to be a discrepancy between the dispatch list of the suppression module and this transaction list occurs when helicopters are deployed. Instead of showing one transaction each time a helicopter is used, two transactions are usually generated to allow separate costing of the crew and helicopter units. All costs related to their suppression activities are accumulated before the helicopter-related costs are considered.

Instead of listing the crew size dispatched under the *MEN* category for an air tanker, the total number of loads carried on this fire is indicated. Thus, the program waits until the last air drop is registered by this air tanker. The air tanker which therefore makes more than one drop does not appear in the transaction list in the same order or as many times as in the dispatch list. A helicopter might also appear fewer times on the transaction list if it is used to shuttle more than one crew to a fire. This results from the method used to keep track of helicopter time and to avoid overcharging flight time on multiple flights.

4.3.3 Fire Suppression Expenditures

Fire suppression expenditures (*fig. 23*) are always printed regardless of the options selected. This printout breaks down the total suppression cost for every season simulated in SMOKEY II. The items listed in the summary are season totals of the fire summary listing.

4.3.4 Base and Unit Summary

The base and unit cost printout (*fig. 21*) groups all units in the plan by base type and lists corresponding data for each season. Besides giving the base and unit numbers and the unit name, the printout indicates any funds from contract agreements which were not used during the season (not subtracted from the minimum guarantee on non-dispatch days.[3] Also displayed are normal staffing costs, suppression costs, and the number of fires the unit was dispatched to. Five other categories are filled in according to unit type: *MILES TRAVELED* and *TIME/MAN HR* by ground crews, *TIME/MAN HR* by plows and dozers, *# OF TRIPS* by helicopters (should be greater than or equal to *# OF FIRES), # OF MEN SENT* by smokejumpers, and *# OF RET LOADS* by air tankers.

4.3.5 Cost Summary

The cost summary (*fig. 16*) appears regardless of the option selected. This summary lists the fixed costs, variable costs, and damage potential for one season. The cost summary is an improper means of comparison if, for the purposes of debugging, only a portion of the fire season is costed. The variable cost and damage potential would then reflect only a portion of the season's fires.

5. LARGE FIRE GAMING

Although FOCUS provides a realistic simulation of fire behavior and suppression forces for small fires, the computer model cannot realistically handle large fires. No computer model is currently available that can reliably simulate the actions of large fires. The reasons are several:

- Large fires burn through drastically different weather, fuel, and topography conditions.
- Fire control strategies differ between fire bosses and are almost impossible to generalize and model.
- Firefighting forces on a large fire may not be part of the fire plan and availability can be unpredictable, particularly when cooperators and military are used.

Large fire simulation is supported by FOCUS but must be gamed by fire experts using local knowledge, experience, and judgment. Moreover, the garners are constrained by a standardized set of procedures.

Despite the expense of gaming large fires (it requires bringing together a team of knowledgeable people for several days), some FOCUS planners have used the procedure as a training exercise for personnel prior to the fire season.

[3]Some equipment is hired on a commitment or minimum guarantee for a day or an entire season from an independent contractor, for example, a contracted bulldozer or helicopter. Depending on the contract, hourly or daily credit is charged against this contract as the equipment is used or in some cases a charge in addition to the guarantee. FOCUS can cost out various combinations of such contracts.

5.1 Input Requirements

FOCUS considers escaped fires to be large or long duration fires, usually 100 acres or more (the actual values are input parameters), that must be handled by the gaming procedures. The escaped fires to be gamed are located and plotted on topographic maps. The FOCUS suppression module output will provide a summary of forces already on the fire and those forces that have been dispatched but not yet arrived. The FOCUS suppression module also provides the fire size at a given time and the amount of held line.

The materials needed for large fire gaming include:

- Topographic maps of the fire area scaled 2 inches to the mile or 4 inches to the mile and aerial photographs of the fire area.
- FOCUS printouts summarizing fire activity by alternative plans.
- Maps or overlays of fuel models, fuel types, or vegetative cover types in the area.
- Maps or overlays of resource damage potential classes, values-at- risk, or other display of potential economic loss from fire.
- Hand-held calculator for fire behavior characteristics, such as the Texas Instrument Model TI-59 with the fire danger/fire behavior Custom Read Only Memory.[4]
- Fireline Notebook or other means of calculating rates-of-spread of fires and fireline construction and holding rates.
- Diurnal weather change information.
- Draftsman's compass, protractor, scale, colored pencils, pens, and planimeter.
- Copies of the FOCUS baseline fire information worksheet (form 43), escape fire calculation sheet (form 44), and perimeter-acreage form (USDA Forest Service 1977c).
- Approved suppression cost figures for the unit, based on average or actual costs which in turn are estimated on a per acre, per chain of held line, per hour, or per mile basis. The Forest Service Morning Report and other sources may be used.
- FOCUS dispatch priorities for the plans or alternatives being evaluated.

5.2 Output Summaries

The gainer's objective is to calculate the final size and shape of the fire(s) that would result under the various proposed alternative plans. The same fire may have to be gamed several times, once for each alternative that results in an escape. One baseline fire must be calculated in order that the results be as objective as possible and the comparisons between alternatives be as realistic as possible. This baseline fire is simply the gainer's recorded (mapped) estimate of what each FOCUS escaped fire would look like over time with no suppression action after the fire reached escape conditions.

Hourly calculation of the baseline fire's perimeter should consider the variations in rates-of-spread (ROS) under causes such as slope, aspect, fuel changes, weather, and natural or manmade barriers. The gamer is free to select the direction and shape of the baseline fire based on his knowledge and experience of the fire area. Once the gamer has plotted the baseline fire perimeters by hour, he can estimate the effectiveness of suppression actions against that fire. Implied in each alternative fire plan are some differences in forces, locations, or other components; therefore, resultant gaming of baseline fires gives some differences in the fire size, forces required for control, and costs.

Worksheets are provided to guide the gaming task. After final perimeters are calculated for all alternatives to be tested, the cost and damage figures are entered on the appropriate forms.

Gainers and planners can prepare a variety of escape fire summaries after gaming results are recorded in order to compare performance of alternatives (*table 3*). These summaries include data from the following sources:

Year/day	Fire workload year and Julian date of escape fire.
Fire number	FOCUS sequential fire number found in suppression module output.
Value class	Resource damage potential class; in this case, 2 means $500/acre (USDA Forest Service 1977c, table 3.1).
Acres burned	Data from large fire gaming process, form 44, item 12 (USDA Forest Service 1977c, sec. 6.7).
Damage potential	Acres burned multipled by value class. An alternative is to use agency's own damage estimation procedures.
Suppression cost	Data from large fire gaming process, form 44, item 11 (USDA Forest Service 1977c, sec. 6.7).
Cost plus loss	Damage and suppression cost columns added (for National Forest only).
State acres burned	Extra information for other agency cooperators.

The sample summary worksheet included here (*table 3*) provides data on five escaped fires which occurred on National Forests and Grasslands during 4 nonconsecutive years (State fires are shown in parentheses). These escaped fires burned a total of 495 acres, inflicted $446,500 in damages, and resulted in suppression costs totaling $69,600. Cost-plus-loss for the planning unit considered in alternative A totaled $516,150.

The unit participated also on six adjacent State escaped fires. In State fires, only the State acres burned are calculated, in this case 580 acres.

[4]Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

Table 3—*Summaries of escape fires, entered on worksheets, alternative*

Year/ Julian day	National Forest and Grassland						State acres burned
	Fire No.[1]	Value Class[1]	Acres burned	Damage potential	Suppression cost	Cost plus loss	
				Dollars			
[2]61-122	(5)	(2)	—	—	—	—	3
61-194	84	2	30	15,000	5,984	20.984	—
61-194	(86)	(1)	—	—	—	—	390
61-273	(308)	(2)	—	—	—	—	2
Subtotal 61 1	(3)	——	30	15,000	5,984	20,984	395
67-169	(15)	(3)	—	—	—	—	45
[2]67-291	230	3	6	6,000	6,830	12,830	—
Subtotal 67 1	(1)	—	6	6,000	6,830	12,830	45
[2]69-047	(1)	—	—	—	—	—	—
[2]69-106	4	3	6	6,200	6,800	13,000	—
69-245	228	3	408	408,100	47,956	456,056	122
Subtotal 69 2	(1)	—	414	414,300	54,756	469,956	122
[2]70-122	(6)	(1)	—	—	—	—	18
70-155	57	1	45	11,250	2,030	13,280	18
Subtotal 70 1	(1)	—	45	11,250	2,030	13,280	18
Total 5	(6)	—	495	446,550	69,600	516,150	580

[1]State fires shown in parentheses; damage not calculated for such fires.
[2] Fire escaped before and after the official fire season.

Four assumptions are important to remember during gaming:

- Gamers are free to use their own expertise and knowledge of fire behavior to predict where and how fast the baseline fire will go.
- Garners are also free to order suppression resources not included in the fire plan being evaluated, provided that such forces are traditionally used in real life, and their orders would be considered reasonable under actual conditions.
- Garners should not materially change tactics or strategies when attacking the same baseline fire with forces from alternative proposals. General strategy should be decided for the first exercise just as though the gamer were on the scene of a real fire. That same general strategy should be followed every time the fire is gamed. The temptation is to change strategies after completing the first exercise and to apply the learning in the next tactic, but that defeats the purpose of objectively testing plan against plan.
- Garners can use two methods for determining suppression costs: Direct calculations using the workup forms provided and instructions given in the User Manual (USDA Forest Service 1977c). Generalized fire size-cost curves that have been developed by various regions (*fig. 24*).

5.3 Deviating from Established Procedure

Care and quality work is essential in large fire gaming because 75 to 90 percent of the costs and damages incurred by agencies are for fires that exceed escape parameters. Careless work or bias toward a particular

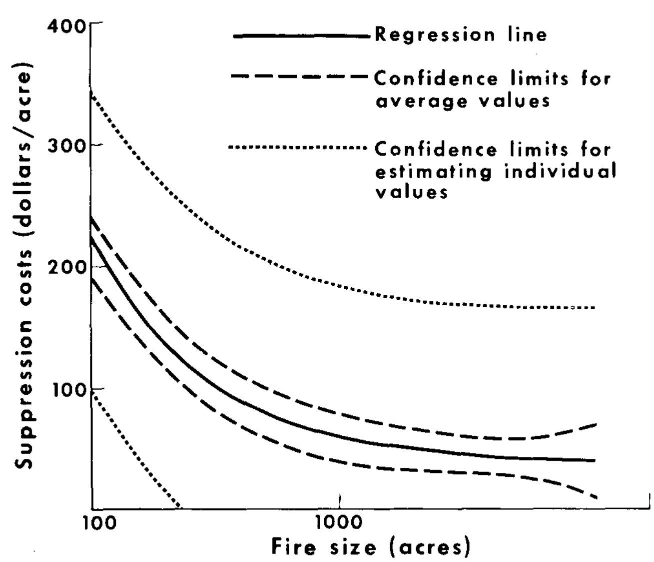


Figure 24—By relating suppression cost to fire size, as in this California Department of Forestry example, generalized curves can be developed.

Table 4-FOCUS Support programs and applications

FORTRAN programs	Input data set	Data source	Output	Remarks
CONVERT	Road network Fire occurrence Off-road barrier	Node map Fire location map Barrier location map	Node number, X, Y value Fire number, X, Y value Barrier number, X, Y value	Use optional; requires minor modification by each data set.
COMBINE	Road network Fire occurrence Off-road barrier	Convert output, coded data Convert output, FORMS output Convert output, coded data	Complete road network 80 pct. of fire occurrence Complete off-road barriers	Use optional; requires minor modification by each data set.
CHECKNET	Road network	Combine output	Consistency errors	Required
PLOTROAD	Road network	Verified data	100 pct. verified road net	Required
SORT	Fire occurrence	Combine output	Chronologically sorted fires	Use optional
FIRECARD	Fire occurrence	Sort output	Verified fire occurrence	Required
ZEDIT	All suppression module data sets	All suppression input	Verified suppression input	Required
SMOKEY I	All cost module data sets	All cost input	Fixed cost and verified	Required

alternative can result in erroneous conclusions. A major concern of all FOCUS system users must be impartiality during the gaming process.

If an unbiased team applies the gaming techniques outlined in the User Manual, each alternative should be tested against the same set of assumptions and the outcome of the alternatives minimally should be ordered according to their relative effectiveness.

Another concern is that FOCUS uses the seven damage potential classes developed for the 1972 Fire Plan. The acres burned in each damage potential class are multiplied by the appropriate class value, the sum of which gives the total damage for the fire. General agreement in the Forest Service is that these values are too high; yet this system is a national standard and at present no other damage calculation procedure is accepted. Large fire damage tends to be so great that it masks variations in costs and damage in small fires and suppression costs in large fires. To retain its currency, the FOCUS system should continually update its fire damage data as new information is learned or made available.

Most users have tended to date to use generalized cost-fire size curves (*fig. 24*) rather than the FOCUS worksheets when the former are available. Regarding the accuracy of this technique, Flatman and Storey state, "Based on the size of the calculated confidence intervals for average costs, one would conclude that the cost-fire size curve is an acceptably accurate source for costing gamed fires."[5]

[5]Flatman, George T., and Theodore G. Storey. 1977. Are generalized cost-fire size curves adequate for costing escape fires in FOCUS simulation? Unpublished manuscript. U.S. Dep. Agric. Forest Serv., Pacific Southwest Forest and Range Exp. Stn., Riverside, Calif.

The authors point out that such accuracy is only available when several years of large fires are gamed and average costs for large fires are used. FOCUS simulation results are interpreted as averages. FOCUS simulates and games fires individually, but it claims to match the real world fire situation only on the average.

6. SYSTEM SUPPORT PROGRAMS

The FOCUS system requires a specific data base which is a compilation of information such as road network, fire occurrence, fire resources, dispatch plans, and cost data. The FOCUS data base relies on a variety of sources, and applies a variety of methods to collect and process these data, depending on the particular planning unit. The FOCUS support programs provide for one method to process and verify the needed data (USDA Forest Service 1977c).

The support programs consist of eight small FORTRAN programs (*table 4*). Five of these programs are editing routines and must be used by all FOCUS users. Suppression module data are checked using programs FIRECARD, CHECKNET, PLOTROAD, and ZEDIT. Program SMOKEY I lists cost data for manual verification. The remaining three support programs convert source data into the FOCUS data specifications and may have to be modified to meet specific needs, depending on data sources.

7. APPLICATION

7.1 User Requirements

FOCUS is an operationally tested, computer-based simulation which enables planners to compare one initial attack system against another in cost-effective terms. The level of effort involved in transferring this technology to the user has been impressive, including training sessions, seminars, management briefings, and personal conferences. Also, research has published a user and technical documentation series designed to assist the user in applying the FOCUS technology at the operations level:

Documentation	***Audience***
Executive Brochure	Policy and legislative level
Fire Manager's Guide	Fire managers
User Manual	Fire specialist and computer specialist at planning unit level
Forms Guide	Fire specialist and computer specialist at planning unit level
Documentation System	Communications at overhead levels
Documentation Control and Software Maintenance Manual	National user support staff level

The Fire Manager's Guide (USDA Forest Service 1977a) explains who should use FOCUS and addresses decisionmaking concerns of the prospective user relating to FOCUS impact on budget, staff, and project objectives. Chapter 2 of the Fire Manager's Guide discusses general considerations, a decisionmaking checklist, and estimates operational start-up costs.

In operational tests to date, the FOCUS system has accommodated all planning unit sizes, large geographical units (Bureau of Land Management, Alaska), heavy fire occurrence units (Rome Unit, Georgia), State Forestry Commission and high density road network units (San Bernardino National Forest, Pacific Southwest Region, Forest Service).

FOCUS is a complex, expensive, and demanding tool. Three ingredients must be present to make FOCUS a worthwhile undertaking—need, motivation, capability:

- Need. The costs of initiating FOCUS are largely dependent on the size—particularly of the transportation system and fire organization—and fire workload of the unit. Some agencies probably do not have sufficient fires to make it worthwhile.
- Motivation. Persons at all levels of the FOCUS effort must be motivated. This is particularly true of high level management within the planning unit. The FOCUS effort will surely fail if an unmotivated employee is given the task to "fit it in" as best he can.
- Capability. FOCUS demands availability of a computer system with a high-speed line printer and card reader. Ideally, these should be available without undue travel time. A computer specialist and a fire specialist are needed. The fire specialist (or whoever is assigned the principal data collection job) should be analytically oriented, with a strong interest in systems analysis. The computer specialist should be familiar with the FORTRAN programming language and data handling techniques.

7.1.1 Developing In-House Experience and Hardware

Successfully introducing FOCUS technology into user organizations depends heavily on recruitment of quality specialist personnel and establishing a compatible organizational environment. Of 23 operational tests to date, five have been relative failures. In every case, the inability to achieve targets can be attributed directly to management breakdowns or recruitment of unqualified personnel. Testing experience indicates that about one-fourth person-year of computer specialist time is needed to start up FOCUS for a planning unit. About one-half to three-fourths user-year of fire specialist time is required. Most of the fire specialist time should be expended at the planning unit level, with some staff time invested at higher levels for purposes of policy direction and training.

FOCUS staffing requirements are defined in the Fire Manager's Guide (USDA Forest Service 1977a, ch. 3). The fire specialist and computer specialist operate as a team under the technical direction of the top level fire managers at the planning unit and higher levels. Users generally have not established the technology at most organizational levels, therefore a FOCUS technical support staff has been made available to provide user support and interpret system documentation. During operational testing, this support service was provided by research at the Forest Fire Laboratory, Riverside, Calif. FOCUS is currently maintained by a systems support staff at the Boise Interagency Fire Center, in Idaho. Until the technology is sufficiently established at regional levels, such support will be necessary. Once the resident technical capability at regional and local levels is established, users may want to reduce national technical support to a level which permits only system maintenance and policy control.

The local fire specialist performs several functions that are essential to the success of FOCUS under management policy and direction. First, he guides the selection of historical fire seasons to be simulated. Second, he helps shape fire management strategies for the alternatives to be studied. Third, he directs the tasks of gaming and estimating large fire costs. These tasks exceed FOCUS computer modeling capability but are nevertheless essential to establishing comparisons of initial attack combinations in terms of total cost effectiveness.

The computer specialist should have recent training in FORTRAN programming. He will supervise data entry, develop small-scale data manipulation programs, control computer runs, correct computer files, cooperate with regional or national technical support groups, and assist in interpreting results.

The largest FOCUS task often is road network data collection. Field technicians are responsible for collecting most of these data. The extraction of fire data from individual fire reports, normally done by dispatcher personnel, is also a major task. These two technician level jobs total about 95 percent of the data collection effort.

In-house hardware capability is now available in the Forest Service systemwide. The computer specialist who represents the planning unit needs a high-speed terminal for access to the Fort Collins Computer Center. States and other agencies can arrange to use these facilities through USDA contracts.

7.1.2 External Maintenance and Support

The FOCUS Maintenance Manual (USDA Forest Service 1978a) is part of the technical documentation provided by research. This manual was mostly prepared by program authors of the suppression and cost modules to provide detailed explanations of computer programs for use by FOCUS computer support personnel.

Continued, close technical liaison was required between program authors and the Forest Service operational support group during the first year of implementation. Production-oriented program modifications and debugging problems are not direct research problems; however, minimum consulting time between research and operations was anticipated and programmed during the first operational year.

7.2 Implementing FOCUS: Principal Tasks

The successful use of FOCUS depends on the joint efforts of technicians, specially trained FOCUS specialists, fire managers, and land management unit decisionmakers. These leadership positions are charged with the responsibility of developing within the user organization the technical expertise required for FOCUS performance. The organization also needs a dynamic fire planning policy which permits consistent and flexible application of the new technology on either the state or national levels.

The principal FOCUS tasks are:

- Planning
- Data collection, entry, and verification
- Storing travel times
- Running and validating the base plan
- Running the cost module
- Running alternatives
- Escape fire gaming
- Analysis and interpretation of results
- Presentation to management.

7.2.1 Planning

The FOCUS User Manual states, "Planning for the use of FOCUS is as critical to success as is planning for the suppression and control of actual fires." This advice is no doubt true since failure to plan can result in unnecessary expense amounting to thousands of dollars. Prior to implementation, the fire specialist should spend several days planning and scheduling the FOCUS operation, with particular attention to the following points.

The planning unit may be the agency's or organization's administrative unit, but can also include cooperators, agency personnel not normally assigned to fires, and joint planning areas such as parts of several National Forests. The FOCUS approach will differ depending on organizational objectives: to analyze and fine tune the agency's organization, or to participate in a national policy or economic analysis. Where national objectives are concerned, both time and requirements may be rigidly structured.

Certain considerations pertain to all levels of effort, specifically, selecting an appropriate fire workload, maximizing utilization of agency personnel and resources, and effecting a productive relationship with cooperators. Program alternatives may be freely selected within this framework, except in the case of budget analysis which operates under more rigidly established guidelines.

Selecting, training, and managing personnel is the key to FOCUS success and efficiency. Personnel must be analytical, motivated, experienced in the planning unit operations, and provided with adequate blocks of time without interruption.

FOCUS requires considerable historical information, the generation of new data such as travel times, and conjecture based on past performance. To this end, the planner needs to assess available resources in light of program objectives and thereby determine how to maximize system performance and achieve reasonable levels of accuracy.

Understanding how an organization works poses a major challenge to some planners. Despite policy guidelines, many unwritten procedures contribute importantly to the philosophy governing an organization's policy and practices. For example, dispatch procedures to high value areas, use of cooperators, and delay factors are all important, but written procedures in these areas do not always determine what is practiced. Many such items make up the general run parameters that are crucial to FOCUS (USDA Forest Service 1977c). For this reason, the planner should devote considerable effort in determining run parameters which respond to an agency's specific requirements.

Large fires may comprise 95 percent of an agency's damage and suppression costs, making it imperative that escaped fire be gamed. Such gaming may entail considerable planning since a team of experts have to be assembled for several days. Budgeting money and time is also required. The planner may be able to offset gaming expenses if the gaming effort is conducted as a training session.

7.2.2 Data Collection and Entry

Data collection is at once the single largest task in setting up the FOCUS planning unit and the most underestimated by management. Transportation network data represents the most comprehensive area of the data collection effort. Travel times between nodes are recorded for three weight classes of vehicles and for foot travel on trails. Fire history data collection is the second major job and can be compiled from individual fire reports.

Agency procedures and rules governing actions such as dispatching and staffing under various conditions need to be translated into decision tables and entered into the FOCUS data bank. For example, these rules describe the use of secondary forces (such as an engineering crew or rural fire department engine), availability, application to specific types of fire, and dispatching requirements.

The Fire Manager's Guide for FOCUS (USDA Forest Service 1977a) estimates time commitments for these tasks. The FOCUS User Manual (USDA Forest Service 1977c) provides step-by-step instructions.

Three methods are used to assemble computer data:

- Transportation node and fire locations are usually converted to data files in either tape or keypunch card form using digitizing equipment.
- Some of the fire occurrence data may be retrieved from computer files of individual fire reports.
- All other data are entered on special data coding forms that are then used to prepare keypunch cards. The digitizing and keypunch operations can normally be contracted for on an as-needed basis.

The data is put on keypunch cards or some form readable by the computer which can then be verified by the fire editing programs. These programs check for missing data and for incorrect values or numbers. The ZEDIT and the SMOKEY I programs help ensure that the data is correct for the suppression and cost modules.

7.2.3 Storing Travel Times

The travel times of all ground units to the fires need to be calculated only once. The STORETT program uses the road network, fire occurrence, and ground base location data to calculate and store the travel times from all bases to all fires. These data are computer stored for further use on alternative runs. The travel times must be recalculated if a base location is moved, a road segment is modified, or a fire location is repositioned. This step is expensive and time consuming; therefore, the user should plan ahead for any changes and include potential base locations and road segments in the data. These potential data items can then be used or omitted for any particular plan alternative.

7.2.4 Running and Validating the Base Plan

Running and validating the base plan is perhaps the most critical step in FOCUS. This procedure verifies that the simulation model data are correct and that the user understands the simulation model operation. Validation is a two-step process. First, the data are verified before running the simulation model. Second, a limited simulation run is made using only a limited number of the historical fires.

Data validation, the first step, uses edit routines to check data for accuracy, consistency, and conformance to FOCUS program requirements. The intent is to isolate discrepancies caused by a variety of human errors during the data collection phase.

Simulation validation, the second step, involves running a base plan to test all operational rules programmed for a specific run, including dispatching rules, staffing rules, and use of secondary resources. The base plan must be tested for data errors and accuracy of planning assumptions prior to running alternatives. Two computer reports must be considered: the resource arrival sequence for each fire, which list the sequence of actions taken to fight each fire, and the use tally for equipment and crews at each base during each fire season. This task is usually more difficult than data validation. The users need to ascertain that the FOCUS model is appropriately deploying resources and fighting fires which have recently occurred.

A FOCUS team usually consists of a computer specialist, a fire specialist, and several planning unit personnel. This team runs the suppression module using their input data and reviews the output fire by fire in order to validate the base plan.

These validation teams inspect output to determine the reasonableness of model responses as compared to historical events. Differences must be explainable or correctable to ensure validation of the simulation; however, not every model fire replicates a historical event. For example, in real life, a dispatcher may erroneously have sent the wrong resource; or' a given historical fire may have benefited from the fortuitous initial attack of a passing forest worker. FOCUS does not make mistakes, nor does it perform providential acts. The model simply processes a scenario based on defined assumptions and given input data. For that reason, the overall summary output of the model should be compared to an overall historical performance. The validation requires many hours of work and reruns on the computer. Mistakes in coding or interpretation of data often lead to false starts. However, this validation is a critical step that leads to success.

7.2.5 Running the Cost Module

The cost module may be variously run. In one method, all suppression module alternatives are run and analyzed prior to executing the cost module. The user is thus allowed to run the base plan and other plans of interest, then eliminate any alternatives that will not be considered for implementation before running the cost module.

In another approach, the cost module is run on the base plan and all alternatives, a method preferred for some planning units and alternatives.

7.2.6 Running Alternatives

Most fire organizations are adaptable: small changes relative to the size of the organization usually will not make much difference to overall damages or costs. Substantial differences normally show up only when alternative plans are significantly different. In FOCUS, alternatives were produced by adjusting several variables:

- Location of bases
- Mix of fire resource types
- Suppression objectives
- Dispatching plans and policies
- Mix of primary and secondary forces
- Use of cooperating agency forces
- Equipment and labor financing.

Summary outputs for alternative plans (number of escaped fires or total costs and damages) may not deviate dramatically from each other. These summaries need careful examination, whether or not they agree with the planners' initial bias and best guess. Data such as the fire workload assumption and variance in fire resources efficiency should be looked at in detail. An output with little or no change may simply mean that the alternative appears insensitive because the fire organization is already overstaffed; yet a closer look at internal utilization summaries may show a wide fluctuation in the use of key suppression resources.

A good set of alternatives requires both careful thought and bold imagination. And more than one attempt has been required in almost all tests to date to arrive at good alternatives. In other words, FOCUS is not an optimizing modeling system: a best choice is not discovered simply by selecting two or three alternatives for analysis and choosing the one that reflects the lowest cost. Studies of how the computer uses fire suppression resources to arrive at the results have led' to substantial improvements in the original organization.

7.2.7 Escaped Fire Gaming

As pointed out in the large fire gaming section, the computer simulation process stops when a fire exceeds the escape parameters. The planning team determines the final suppression costs and resource damages by manual gaming. Gaming is required because the FOCUS computer model would not simulate reality accurately for large fires.

Undisciplined planners and managers sometimes oversimplify and de-emphasize the gaming process. Yet the gaming process, in addition to obtaining the needed large fire costs and losses, apprises a fire organization of the rationale and applicability of FOCUS to their planning unit. Garners have learned why some fires escape and others do not, for example, why the perimeter of a given fire may be almost 100 percent contained at escape, yet the same fire in another alternative may escape with little or no line constructed.

7.2.8 Analyzing and Interpreting Results

Analyzing FOCUS output depends on the objectives of the study and the needs of the decisionmakers. Preliminary analyses should determine which of the alternatives show promise. Other alternatives may arise from these initial efforts. Results which appear anomolous must be investigated. Data or run setup errors and assumptions are always possible.

FOCUS analysts must remember that basic trade-offs exist between resource use and other results, such as acres burned or damage potential. Alternatives which show little change in costs and damages may show significant changes in resource use patterns. If these changes are not acceptable as in overuse of cooperator resources, a new alternative may have to be designed within the realm of acceptability while all other factors remain constant.

Although FOCUS provides several summary tables, specific analyses of resource use require extracting data from the individual fire printouts which are available from both the suppression and cost modules. For example, a detailed list of substitutions can be obtained for a resource unit which was removed in an alternative procedure.

The FOCUS analyst should become sufficiently familiar with the results of alternative plans that he can confidently explain any reasonable questions which might arise.

7.2.9 Management Presentation

The interaction between FOCUS technical efforts and agency management is crucial. Operational testing is most effective where decisionmakers are continually involved. Decisionmakers provide land management input and require accomplishment of specific attainable objectives.

Therefore, how fire managers summarize and display FOCUS output to decisionmakers is important. The system can be a tremendous aid to managers and planners but only if the results are comprehensible. Top management—such as a State land management director, National Forest supervisor, or State region administrator—will have had far less time to understand FOCUS output than the team members who are working with FOCUS daily. The output must be as free as possible from jargon peculiar to FOCUS, and the information presented must have some direct bearing on relevant management issues.

Meetings with top management are in three stages: initial planning, alternative evaluation, and final review. In initial planning, a variety of topics is discussed, including objectives, organizational requirements, base plan review, historical fire workload selection, planning unit

Table 5—*Cost-plus-loss comparison for planning alternatives*

Alternative	Cost	Loss	Total
	Millions of dollars		
A	3.083	0.153	3.236
B	1.862	.461	2.323
C	1.031	.654	1.685
D	0.625	.955	1.580
E	.740	.802	1.542

selection, and alternative plans. This loosely structured meeting should address all pertinent issues and ramifications. Salient issues must be clearly defined and documented. Agreement on program objectives is foremost: the success of various planning unit alternatives are measured against these objectives. Acceptable individual, variable, or cumulative fire losses and economic objectives are determined at this time.

In alternative evaluation, the second stage, initial FOCUS results are presented and evaluated. These results should include a base plan and related alternatives. Evaluation results should be supported by well-developed summary and fact sheets and illustrations as necessary. Agreement must be reached on changing and adding alternative plans and on constraints in the further design and testing of alternatives. Planning objectives are clarified and modified.

Final review is the third and final stage. Here, one of the alternatives, if acceptable, can be selected for implementation; however, if further work is required, additional second stage evaluation can be made. The presentation of a rough-draft final report is recommended, which will provide information for management policy and program changes. Despite the critical nature and urgency of the final review, very few users have availed themselves of this management tool. Heavy reliance has been put on informal communications and briefings. Agency leaders must enforce adherence to report standards and policy to achieve conformance by individual planning units in this area.

7.3 FOCUS Cost-Effectiveness Evaluations

FOCUS output summarizes fixed costs, variable costs, and potential damages for each season and for the total fire occurrence workload for all seasons simulated, as requested.

Each fire is assigned to one of seven or less damage classes representing dollar value per acre with a positive or negative dollar value for each class. Negative values are used when fire effects are benefits; positive values when damages.

Fixed costs consist of presuppression charges related to initial attack preparation, prevention, detection, and capital improvement depreciation. Variable costs in the FOCUS cost module consist of suppression charges, normal staffing, and unused contracts. The cost and losses from large fire gaming must be added manually to these summaries for overall totals.

The bottom lines of the seasonal or total workload summary report permit an overall cost-plus-loss amount to be derived. To date, this information has been interpreted in three ways: to compare one alternative to another on the basis of total cost-plus-loss (*table 5*), to compare alternatives to the costs and losses of the current base plan to derive differences from the base plan (*table 6*)—this will give the same results as the above—or to compare alternatives of equal incurred damages on the basis of economic efficiency or minimum cost.

In the comparison of cost-plus-loss, the lowest overall total would represent to some managers the best alternative. This traditional method of identifying the best decision usually requires a wide range of alternatives. During FOCUS testing, this comparative method was widely applied in evaluating alternatives. Most professional fire managers are wary of these results because the input damage potential resource values used to compute fire damages are regarded as unrealistic and oversimplified.

The comparison of current base plan costs and damages to other alternatives (*table 6*) is a form of

Table 6—*Differences in cost and loss for alternatives from base plan*

Plan	Cost (Millions of dollars)	Difference		Loss (Millions of dollars)	Difference	
		(Millions of dollars)	(Pct.)		(Millions of dollars)	(Pct.)
Base Plan:						
B	1.862	0	0	0.461	0	0
Alternatives:						
A	3.083	+ 1.221	+ 66	.153	– .308	– 67
C	1.031	– .831	– 45	.654	+ .193	+ 42
D	.625	– 1.237	– 66	.955	+ .494	+ 107
E	.740	– 1.122	– 60	.802	+ .341	+ 74

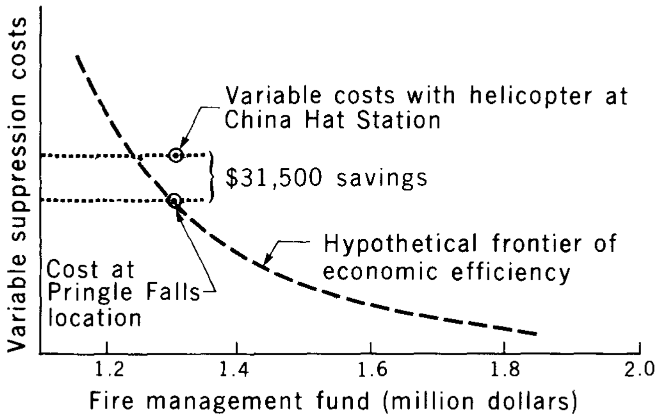


Figure 25— FOCUS can analyze variable cost savings. The Deschutes National Forest, in Oregon, compared the suppression costs of basing a helicopter at two different locations, with effectiveness kept constant for the two alternative locations.

Table 7—*FOCUS first-time planning costs, organizational effort, and return*

National Forest	Planning costs	Fire management fund (78)	Technical efficiency savings (1st year)	Organizational effort[1]
	Thousands of dollars			
Francis Marion	34	367	0	Medium
Huron-Manistee	26	340	([2])	Low
Sawtooth	35	650	31	Medium
Clearwater	14	930	25	Low
Deschutes	35	1,330	189	High
Tonto	25	2,292	([3])	Medium
Cleveland	83	4,120	154	Very high
Average	34			

[1] A judgment based on relative size and expenditure of funds at regional and planning unit staff levels.
[2] Still testing.
[3] Not sampled.

benefit-cost analysis. Here, the loss (or benefit) difference can be compared with the cost (or savings) difference. This cost-effectiveness summary indicates where the biggest decreases can be made in damages per unit of additional cost or where the smallest increases in damage would result from given reductions in cost. This method has been attractive in those states where public cash-flow problems are of increased concern to legislators.

FOCUS cost output and diagnostic resource summaries can identify the most economic variable cost proposal (*fig. 25*). During a period of arbitrary funding constraints, an evaluation which emphasizes cost reduction due primarily to new technology becomes increasingly popular.

Experience has shown that during the operational testing phase those planning units which use a variety of the discussed analytical techniques also provide the best overall performance in developing new protection systems. A more indepth explanation, with examples, of how the various analytic techniques can be applied to evaluate FOCUS output is given by Flatman and Storey (1979).

A survey of FOCUS test planning units at the end of the operational test period listed the experienced costs (*table 7*, under planning costs). The average cost to implement a planning unit (salary, travel, per diem, computer, and overhead) is $34,000. Except for the Cleveland Unit, all managers stated that the historical fire planning process would cost as much or more than the costs experienced by using the new FOCUS system.

This limited sample reveals several apparent cost correlations. Very little relationship exists between the size of the fire problem (as represented by the fixed fire management fund) and planning costs. Planning costs apparently seem more dependent on organizational and overhead complexities. On the other hand, cost savings due to the use of FOCUS relate somewhat to the size of the fire workload and fire budget.

LITERATURE CITED

Bjornsen, Robert L., and Richard A. Chase.
1971. **Computer simulates fire planning problem.** Fire Control Notes 32(4):12-13.

Bratten, F. W.
1978. **Containment tables for initial attack on forest fires.** Fire Technol. 14(4):297-303.

Davis, James B., and Robert L. Irwin.
1976. **FOCUS: a computer approach to fire management planning.** J. For. 74(9):875-881.

Drake, A. W., R. L. Keeney, and P. M. Morse.
1972. **Analyses of public systems.** M.I.T. Press, Cambridge, Mass. 532 p.

Flatman, George T., and Theodore G. Storey.
1979. **Decision techniques for evaluating fire plans using FOCUS simulation.** Res. Note PSW-338, 6 p., Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Gibson, H. P., L. F. Hodgin, and J. L. Rich.
1976. **Evaluating national fire planning methods and measuring effectiveness of presuppression expenditures.** Forest Serv., U.S. Dep. Agric., Washington, D.C.

Hillier, F. S., and G. J. Lieberman.
1968. **Introduction to operations research.** Holden-Day, Inc., San Francisco. 632 p.

Lowry, I. S.
1965. **A short course in model design.** J. Amer. Inst. of Planners 31(5):158-165.

McMillan, Claude, and Richard F. Gonzalez.
1968. **Systems analysis: a computer approach to decision models.** Richard D. Irwin Inc., Homewood, Ill. 520 p.

Naylor, T. H., J. L. Balintfy, D. S. Burdick, and K. Chu.
1966. **Computer simulation techniques.** John Wiley and Sons, Inc., New York. 352 p.

Pirsko, Arthur R.
1961. **An alignment chart for perimeter increases of fires.** Fire Control Notes 22(l):104, illus.

Podufaly, E. T.
1969. **The Army's new TOPOCOM.** Photogramm. Eng. 35(1):75-82.
Storey, Theodore G.
1972. **FOCUS: a computer simulation model for fire control planning.** Fire Technol. 8(2):91-103.
USDA Forest Service.
1972. **Forest Service manual,** section 5122.24, amendment 41, Washington, D.C.
USDA Forest Service.
1977a. **Fire manager's guide for FOCUS.** Pacific Southwest Forest and Range Experiment Station, Riverside, Calif. 37 p.
USDA Forest Service.
1977b. **Evaluation of fire management activities on the National Forests.** Policy Analysis Staff Report, Washington, D.C. 127 p.
USDA Forest Service.
1977c. **FOCUS user manual.** Pacific Southwest Forest and Range Experiment Station, Riverside, Calif. 400 p.
USDA Forest Service.
1978a. **FOCUS maintenance manual.** Pacific Southwest Forest and Range Experiment Station, Riverside, Calif. 538 p.
USDA Forest Service.
1978b. **FOCUS national training program.** Aviation and Fire Management Staff, Washington, D.C. 90 p.

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Bratten, Frederick W., James B. Davis, George T. Flatman, Jerold W. Keith, Stanley R. Rapp, and Theodore G. Storey.

1981. **FOCUS: a fire management planning system—final report.** Gen. Tech. Rep. PSW-49, 34 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

FOCUS (Fire Operational Characteristics Using Simulation) is a computer simulation model for evaluating alternative fire management plans. This final report provides a broad overview of the FOCUS system, describes two major modules-fire suppression and cost, explains the role in the system of gaming large fires, and outlines the support programs and ways of implementing the system.

Retrieval Terms: fire management planning, fire suppression cost, simulation, mathematical models, FOCUS (computer program)