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Fire Behavior Computations with the Hewlett-Packard HP-71B Calculator

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RESEARCH SUMMARY

A Custom Read Only Memory (CROM) has been developed for the Hewlett-Packard model 71B handheld calculator for fire behavior computations. The calculator replaces the Texas Instruments TI-59. The CROM programs allow many computations not found in the TI-59 version and implement most of the programs in the BURN subsystem of the BEHAVE fire behavior prediction system. An additional metric mode is included in the programs. A separate CROM was developed for computing the 1978 National Fire-Danger Rating (NFDR) indexes and components, and a separate user's manual has been published: Burgan, Robert E.; Susott, Ronald A. Fire Danger Calculations with the Hewlett-Packard HP-71B Calculator. General Technical Report INT-199. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 16 p.

This report describes the operation of the HP-71B program for fire behavior predictions, the inputs needed, and outputs calculated for each of 13 separate program modules. Sample worksheets are included and worked examples are given for each module of the program.

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INTRODUCTION

The Hewlett-Packard HP-71B has been selected to replace the Texas Instruments TI-59 (Burgan 1979) for field computations of fire danger and fire behavior. This manual describes operation of the fire behavior programs as implemented on the HP-71B. The programs are intended for field use by fire behavior analysts who are familiar with the methods for gathering input data, for interpreting program outputs, and for applying these data to fire problems. Rothermel (1983) has described the methods needed to predict fire behavior. Operation of a separate program written for fire danger rating applications is described in a companion publication (Burgan and Susott 1986). Each program is available as a separate Custom Read Only Memory (CROM).

Separate self-study guides have been prepared for the fire danger and fire behavior programs. These are available through your agency coordinator, who will distribute the guides and help answer questions about the calculator and the course material.

The HP-71B fire behavior program is patterned after the BURN subsystem of the BEHAVE fire behavior prediction and fuel modeling system (FIRE1 and FIRE2 programs). The keywords, program organization, line numbers, and worksheets are similar to those of BEHAVE. The majority of the papers describing the BURN subsystem (Andrews 1986) describe the models used for the calculations, their limitations, and applications. Technical references given there are not repeated here. It is strongly recommended that the reader be familiar with those papers.

CALCULATOR FEATURES

The HP-71B has several features that make it more suitable for field use than the TI-59 it replaces:

- A liquid crystal display (LCD) that is easy to see in daylight.
- The capability to display both alphabetic and numeric characters.

This eliminates the need for keyboard overlays because requests for input and displayed output can be appropriately labeled.

• Use of complementary metal oxide on semiconductor (CMOS) architecture which, because of its very low power requirement, permits many hours of operation between battery changes.

- Use of replaceable, rather than rechargeable, batteries.
- A continuous memory that retains the information stored in the calculator even when the calculator is turned off.
- A capability to be used with optional batteryoperated printers, data cassettes, and disk drives.
- A powerful BASIC programming language that is available for many other user applications.

PROGRAM FEATURES

The fire behavior program for the HP-71B implements much more fire behavior technology than was possible with the TI-59. Program capabilities are indicated by the following list of program modules and their functions:

- FUEL MODEL permits inputting, loading, listing model names or values, saving and deleting models.
- DIRECT calculates spread rate, heat per unit area, fireline intensity, flame length, reaction intensity, effective windspeed, and direction of maximum spread.
- SIZE calculates area, perimeter, length-to-width ratio, forward spread distance, backing spread distance, and maximum fire width.
- CONTAIN calculates length of fireline at containment time, time to containment, and final fire size or required line-building rate.
 - SPOT calculates maximum spotting distance.
 - SCORCH calculates scorch height.
 - IGNITE calculates probability of ignition.
- MOISTURE calculates 1-hour timelag fuel moisture, fuel level temperature and relative humidity, percentage of area shaded, and probability of ignition for either a specific burn time or as hourly calculations.
- MAP calculates fire dimensions, spread distance, and maximum spot distance for plotting on a map.
- SLOPE calculates slope steepness, elevation change, and horizontal distance.
- WIND calculates midflame windspeed from the windspeed measured 20 feet above the general vegetation surface.
 - RH calculates relative humidity and dew point.
- TWO calculates weighted rate of spread for the two-fuel-model concept.
- PRINTER not a module, but provides the option of directing output to a printer.

The 13 standard fire behavior fuel models (Anderson 1982) are included in the CROM. Up to 19 additional user-defined fuel models (numbered 14-99) can also be

entered, and stored in the calculator memory. The fuel modeling subsystem of BEHAVE (Burgan and Rothermel 1984) is strongly advised for the development and testing of user models before their entry into calculator memory.

The program has a metric version that provides for both metric inputs and outputs. Separate data sheets are provided for the English and the metric versions. These data sheets are at the end of this report.

Operation of the fire behavior program will not alter any values assigned to variables created in other programs and saved in continuous memory. Some global flags and system characteristics such as DELAY, OPTION BASE, DEG/RADIANS, Display Format, and Round-off Setting are changed by the program and not reset. User programs that need these system flags or characteristics should be written to correctly initialize them. Refer to the HP-71 Reference Manual for more detailed information.

Operation of the BEHAVIOR program uses a large portion of the HP-71B memory. Large user files or previously defined variables can cause the "Insufficient Memory" error at unpredictable locations in the program. The "DESTROY ALL" statement may reclaim enough memory to run the program, or files can be removed with the "PURGE" statement. Users who frequently have large files in memory should consider obtaining the optional memory expansions available for the HP-71B.

PROGRAM STRUCTURE

When BEHAVIOR is run, the program first enters the MAIN module. The MAIN module's only function is to call other modules that actually perform the desired cal-

culations. Figure 1 shows that the structure of these other modules is divided into three levels. The first level is called directly from MAIN, and the modules in level 1 can be run independent of other modules. Once calculations have been made in a level 1 module, that module can call the next level and pass calculated outputs to it. The called level is said to be "linked" to the calling module through the information passed. For example, a DIRECT-SIZE-CONTAIN run will pass DIRECT outputs to SIZE and both DIRECT and SIZE outputs to CONTAIN. The run outputs from a module can be passed to any of the modules available for linking. For example, level 2 SIZE outputs can be linked to MAP to convert the spread distances to map distances. When MAP is Quit and the program returns to SIZE, a link to CONTAIN uses the same outputs from the last SIZE run to calculate containment times. All outputs of a module Run are valid until new inputs are made or the module is Quit. Modules shown in figure 1 that cannot call other modules cannot pass outputs to any other module. For example, the 1-hour moisture calculated by the MOISTURE module cannot be passed to DIRECT. Of course, such a calculated moisture can be manually entered when running the DIRECT module.

Modules are selected through use of their two-letter keywords—the underlined letters in the module name in figure 1. Additional, generally single letter, keywords are used to perform specific tasks within each module. The large ENDLINE key is used to complete all user entries. Once a module is selected, its keywords are operative and will appear in the display. The Quit keyword is used to move one level to the left in figure 1. Each level must be Quit to return to the MAIN level where you can select another module or Quit the program.

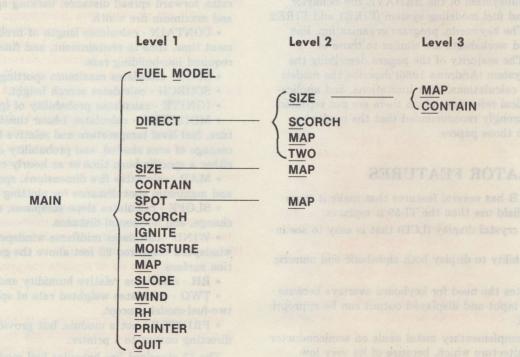


Figure 1.—The HP-71B fire behavior program structure.

GENERAL PROGRAM OPERATION Operation of the MAIN Section

After the HP-71B has been turned on, the fire behavior program can be started in either of two ways:

1. Type in RUN BEHAVIOR and press the END-LINE key. This will always start the program at the beginning.

2. If the fire behavior program was the last program run before the calculator was turned off, just press the RUN key.

When the program starts running, the letters PRGM will appear in the right side of the display, followed immediately by a short display of the words "FIRE BEHAVIOR". The program then asks whether or not you want the metric version and slope in degrees. Entry of No to these questions, or just pressing ENDLINE. gives the defaults of English version and slope in percent. If a printer is attached, and turned on, the message "PRINTER ON" is briefly displayed; otherwise the message "NO PRINTER AVAILABLE" is briefly displayed. Finally, the program indicates you are in the MAIN section by displaying the message "MAIN: FM,DI,SI,SP". This is the MAIN module prompt and the characters following the colon are a menu of keywords for the allowable modules. The remainder of the MAIN section module keywords may be seen by repeatedly pressing the ∧ or the ∨ keys. The other prompts displayed are:

"MAIN: CO,SC,IG,MO";
"MAIN: MA,SL,WI,RH";

"MAIN: P.Q".

The display sequence repeats if the \land or \lor keys are pressed several times. When you are in the MAIN section you can go to one of the modules, set the Printer to on or off, or Quit by entering the appropriate keyword and pressing ENDLINE. The keyword does not have to be currently displayed. Any incorrect entry will just disappear when you press ENDLINE and you can try again.

Normal termination of the fire behavior program is by using the keyword Quit when you are in the MAIN section. You may turn the calculator off any time the program waits for user input, by pressing the gold f ON to invoke the "OFF" command. The calculator will also automatically turn off if there is no activity for about 10 minutes. In these last cases, when the calculator is turned back on, the SUSP annunciator will appear in the display indicating program operation is now suspended. The best way to continue from this point is to press the gold f + for the "CONT" or continue command and a question mark "?" will appear. This indicates the program is still waiting for input of the item being requested when the calculator was turned off. If you do not know what to enter, press the + key (or any nonnumeric), then press ENDLINE, and the display will prompt for the requested input. Pressing the RUN key, or entering "RUN BEHAVIOR", will restart a suspended program from the beginning and previous work will be lost. Failure to end the program by quitting from

MAIN will result in abnormal functioning of some calculator keys.¹ If this happens, enter "RUN BEHAVIOR" and Quit when the display reads "MAIN: FM,DI,SI,SP?". This will return the calculator to normal operation.

Input and Output Procedures

The program will not accept values outside a reasonable range assigned to each item. Although the program does limited checking of the completeness of the inputs, you should be certain the inputs are correct before doing any computations. On the other hand, inputs that do not change from run to run only need to be entered once. If there is any question as to whether or not the inputs are correct, they should be listed before the program is run.

All the modules employ the same techniques for data entry and modification. The inputs for each module have been numbered (see data sheets) and arranged in a specific sequence.

All inputs are initialized to -100 each time you start the program by entering "RUN BEHAVIOR" or by pressing the RUN key. If you do a series of runs, previously defined inputs will remain, thus always list your inputs and check their values before calculating outputs. The program will prompt for those inputs needed by the module being run and check whether or not a value has been entered for all required inputs. Valid inputs are limited to reasonable ranges as shown with the input prompt and listed on the data sheets. If you attempt to enter nonvalid data, it will simply disappear from the display and you may try again. If you have entered an input and it appears that the calculator is not proceeding, the reason is that your input was probably outside the permissible range and you are being asked again for the same input. In general, inputs to one module are not passed to other modules at the same level; exceptions are the fuel model number and map inputs common to MAP and SLOPE.

ENTERING AND LISTING INPUTS

To enter or list input items, you can:

- begin inputting or listing data at the first item in the list by entering I or L, respectively, followed by an ENDLINE. This is the normal procedure for input and will ensure that all needed entries are made.
- begin inputting or listing data at any item number by entering I# or L# respectively, where # is the item number (as shown on the data sheets). A space between L and # is optional. For example, entering I4 when the display reads "DIRECT: I,L,R,Q?" will allow entry of 100H moisture (fourth item in the DIRECT list).

Once you have started entering input data at some point in the input list, the program continues sequentially down the input list. Entry of inputs can be terminated at any time by pressing ENDLINE without first keying in an entry. This will not affect the input parameter whose value is being requested.

¹The program uses key files named KEY0, KEY1, and KEY2. Do not use these names for any other purpose.

The program permits entry of only one value for some input items, but 1, 2, or 3 values may be entered for others. Single value items are indicated in the calculator display, by parentheses () surrounding the valid range. These items also have only one entry line on the data sheets. Multiple value items are indicated in the display by square brackets [] surrounding the valid range. These items have three entry lines on the data sheets. Multiple values are entered by keying in each number, separated by a comma; that is, 4, 6, 8 and pressing ENTER. Thus, depending on the inputs specified, you can obtain:

• a single output value for each output item by entering only one value for each input item

• a list of 2 or 3 output values for each output item by entering 2 or 3 values for one of the input items

• a table of up to 9 output values for any one of the output items by entering 2 or 3 values for two of the input items.

Input listing can be started at any point by entering L#. If no printer is attached, the display pauses after each line is shown. Subsequent items can be listed by pressing the \lor key. Previous items can be listed by pressing the \land key. Terminate the listing by pressing ENDLINE. When a printer is attached, there is no pause between list items; all remaining items will be printed without pressing any keys.

Values can be input with more decimal places than shown on the listings. The values listed are rounded to fit on the display, but the full precision of the numbers entered is used for calculations. Numbers that must be integers, however, are truncated by the program. For example, if a CONTAIN run option of 1.8 is entered, it will be changed to 1.0.

CHANGING INPUTS

The value of individual input items can be changed by entering I# where # is the number of the input parameter to be changed. The display will show that you are to enter the value for the item requested. Enter the value and press ENDLINE. The next input item will then appear in the display, but if you do not want to change its value, just press ENDLINE.

CORRECTING ERRONEOUS INPUTS

Erroneous entries or typing errors can be corrected before the ENDLINE key is pressed by:

- 1. Holding down the gold f key and either pressing the < key repeatedly, or holding the < key down. This invokes the "BACK" command printed in gold letters on the calculator. The last entries are deleted by this operation.
- 2. Pressing or holding the < key to back up the cursor, then deleting the unwanted characters by pressing or holding the gold f key and then the > key. This invokes the "-CHAR" command.
- 3. By using the < key to back up the cursor, then typing in the correct inputs. If extra characters remain,

they can be deleted individually by using the "-CHAR" command or replaced by using spaces.

Refer to the HP-71B Owner's Manual for more detailed line-editing instructions.

OBTAINING OUTPUTS

After you are certain the input values are correct, outputs may be obtained by:

- Entering R (for RUN) to start at the beginning of the output list.
- Entering R# to start at the location of the item number specified. This is normally used to review the value of specific output items after completing a valid run.

At the start of a run, the input list is checked. If the inputs are not complete when a run is attempted, the calculator will beep and display the message "INCOMPLETE INPUT". In this case, list the inputs to discover which inputs still have a value of -100, then enter correct values.

If more than two input items are assigned multiple values, the error message "EXTRA MULTI-INPUTS" is displayed. In this case, list your inputs to find which one can be assigned a single value.

After a valid run, the output listing starts automatically. If you are not using a printer, you may scroll up or down the output list by repeatedly pressing the \wedge or \vee keys, respectively. Output listing is terminated by pressing ENDLINE. If the output is going to a printer, the \wedge , \vee , and ENDLINE keys are deactivated and the list is printed from your starting point to the end of the list.

List output is produced (two or three columns for each output), by assigning two or three values to one input item. The first line displayed is the labeled input line for which multiple values were input. Press the \vee key to display the labeled output line. The output line consists of: the output line number, the mnemonic label, and the two or three output values. After recording the outputs, press the \vee key to continue. At times the output line can contain more than 22 characters and the first few characters will scroll off the display.

A table is produced by assigning two or three values to each of two input items. You must select the table entry item by its output number "TABLE $\#(\emptyset - N)$ " where N is the number for the last output item for the module you are in. The output numbers are given in the data sheets. For example, entry of 4 for table number when you are in the DIRECT module will produce a table of flame lengths—DIRECT output item 4. Entry of \emptyset will terminate the table listing, as will ENDLINE with no entry.

The first line of table output consists of four items that identify the table being produced. These are table number, table item, row item, and column item. Refer to the DIRECT module data sheet for the following example. An example display for a flame length table in DIRECT is: 4 FL 1H * MFWS. This identifies the output item to be displayed in the body of the table as output number 4, which is flame length (FL). Each row will be for a different 1-hour timelag fuel moisture (1H) and

²Only specific input values can be entered into the calculator, rather than the beginning value, ending value, stepsize as in BEHAVE. For the calculator, the values can be entered in any order.

each column for a different midflame windspeed (MFWS). Enter this type of information above the dashed line across the "table" form at the end of the worksheets.

The next display line, obtained by pressing the V key once, is the input values for the column item. An example display is 6 8 11. Enter this type of output on the three lines above the words "Table Values."

The next three output lines are of the form—row number: row value column 1 column 2 column 3 values. An example display of—1:4.0 8.3 10.3 13.2 indicates that for row 1 which has an input value of 4, the table values are 8.3, 10.3, and 13.2 The row number is prerecorded on the data sheet form. Enter the remaining values for each row as you obtain them by pressing the \vee key to scroll down the outputs. You may also scroll up through the outputs by pressing the \wedge key. Continue scrolling until the module label and keywords reappear, for example, "DIRECT: I,L,R,Q?".

If output is being directed to a printer, separator lines (=====) will be printed to help distinguish the input from the output. If a printer is not being used, these lines will only flash briefly on the display. As with other lists, the entire table is printed without using the scroll keys.

The calculator makes as many "RUNS" as necessary for the number of outputs you requested; that is, one run for a single set of outputs, up to nine runs for a 3×3 table containing nine output values. The "RUN" number is displayed as each "RUN" starts. All runs are completed before any outputs are available for listing. Several modules require lengthy calculations and some patience is needed while the runs are being completed.

OPERATING THE MODULES "INDEPENDENTLY" The FUEL MODEL Module

The purpose of this module is to permit entry of a site-specific fire behavior fuel model into calculator memory. It is strongly advised that such models be developed and tested through use of the FUEL subsystem of BEHAVE before entering them into the calculator. (See Burgan and Rothermel [1984] for detailed information on developing fuel models.) Fire behavior cannot be calculated with this module—it is strictly for managing and maintaining a file of user fuel models.

When the calculator display shows—"MODEL: G,I,L,S,Q?"—you are in the fuel model module. Pressing the ∧ key shows an alternate prompt "MODEL: LM,DM" for additional menu selections. While in the fuel model module, you may:

• Get a standard model (numbered 1-13) or a site-specific fire behavior fuel model (numbered 14-99) by entering G and a number. For example, you can get model 14—if it has been previously entered and saved—by keying in G14 and pressing ENDLINE. If the requested model is available, the display will show "MODEL # LOADED", where # is the requested model number. If the model is not available, the message "MODEL # NOT FOUND" is displayed and another

input requested. Alternatively, you can just enter G and the calculator will then request a model number.

• Input all the data for a new model by entering I when the display shows—"MODEL: G,I,L,S,Q?". The program recognizes that some inputs are not always required. For example, if the WOODY LOAD is entered as zero, the WOODY S/V ratio input will not be requested. HERB TYPE and HERB S/V ratio are similarly linked to HERB LOAD. Individual parameters can be input or changed by referring to their line numbers. For example, I3 will cause the calculator to request a value for 1HR LOAD, the third item in the FUEL MODEL input list. This procedure will allow input of herbaceous and WOODY S/V ratios and HERB TYPE even if they are not needed. The values assigned to unneeded inputs are saved in the user fuel model files, but they have no effect on calculations.

• List the current values from the beginning (by entering \overline{L}) or from any other location in the list by entering a line number with the L, for example, L3, and repeatedly pressing the \vee or \wedge keys.

• Save a model in the user model files, which the program automatically creates for you.3 If you just Get an existing model from the file and try to Save it without renumbering it, the calculator will beep, briefly display the fact that the model already exists, then ask if you want to "KILL OLD XX (Y/N)?" where XX is the model number. This gives you the options of replacing the existing fuel model (Y), or not saving the model (N). Entering N avoids replacing an existing fuel model with the same number. The model number can be changed to an unused number before saving. When a model is successfully saved, the display will read "MODEL # SAVED", where # is the model number. Up to 19 models can be filed with any model number from 14 to 99. The order of entry of different model numbers is not important; for example, model 99 can be entered and saved first. An attempt to save more than 19 models will result in an error message "USER FILE IS FULL" and the model will not be saved. The way to save the model at this point is to either change the model number to that of an existing user model (which is no longer needed), or to delete one of the existing models (see below). You can get models 1 to 13 and make changes, but they can only be saved if the model number is changed to 14 to 99. The program prompts for a model number in the correct range and a name before completing the Save operation.

• List Models to obtain a list of all the models in the user model files, by number and name. A message "NO USER MODELS" will be displayed if the file is empty. Scroll up and down through the list with the \land and \lor keys. The contents of the file may be recorded in the form provided after the Fuel Model Module form.

• Delete Models allows you to delete individual fuel models from the file. When the display reads "DELETE MODEL (14-99)?" enter the number of the model to be

³Up to four model files are automatically created in memory, named: USERMODØ, USERMOD1, USERMOD2, and USERMOD3. These names should not be purged or used for other purposes.

deleted. If that model is not in the file, you will get the message "MODEL # NOT FOUND" and another request for the number of the model to be deleted. If the model you want to delete is in the file, the display will read "DELETE # (Y/N)?". If you enter Y, the model will be deleted from the file and another model number requested. Terminate deletions by pressing ENDLINE with no model number entered in the display.

• Quit to exit the fuel model module. If a valid model is not present when Quit is selected, the error message "INCOMPLETE INPUT" is displayed. The program will not Quit the fuel model module until the model has all needed inputs. List will show a -100 for missing inputs. User fuel models should normally be Saved before quitting this section, although a temporary fuel model can be entered and used for calculations in other modules. Any fuel model you Get or build in this module will also be assigned to any other module requiring a fuel model. The normal procedure is to assign fuel models as required by each module you operate.

The DIRECT Module

The prompt "DIRECT: I,L,R,Q" indicates that you are in the DIRECT module. An alternate DIRECT menu

"DIRECT: SI,SC,MA,TW" is displayed by pressing the up arrow, \land , when the module prompt is shown. These modules can be linked to DIRECT after a valid Run is made, as discussed later.

The DIRECT module provides five outputs that describe the general characteristics of the fire (1 through 5). The effective windspeed (6) is for the direction of the spread calculation, whether or not that is the direction of maximum spread rate. If either the slope or windspeed is greater than 0, the input of spread direction (input item 10) is preceded by the question: "PREDICT AT MAX (Y/N)?". If the answer is N, item 10 is requested, but if the answer is Y, item 10 is not entered and all predictions will be in the direction of maximum spread. The direction of maximum spread (7) is output if predictions are in the direction of maximum spread. A list of inputs will show a "MAX" for spread direction whenever the calculations are made in the direction of maximum spread rate. Exhibit 1 shows three runs that provide typical examples of using the DIRECT module. A table of values for any other DIRECT output could also be generated from the input list in exhibit 1c. Exhibit 1e shows a printer list for the above examples: The format for the printer output is the same as display output without a printer.

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LIST NUMBER

		(Keywords: Input, List	, Run, Quit, Size	e, SCorch, MAp, TWo)		
INPUT	(Input, List)				input, Llst)	
1	MODEL #	Fuel model number	(1-99)	Fuel model number	33goM	
2	1H_Q-P_	1-H fuel moisture	[1-60%]	6.0	9.0 Hr	12.0
3	10H	¹ 10-H fuel moisture	[1-60%]	110-H	10H	83
4	100H	¹ 100-H fuel moisture	[1-60%]	enutriom leu-1-001	HOOT	<u> </u>
5	HERB	¹ Live herb moisture	[30-300%]	Live borb moisture	неяв	6
6	WOOD	¹ Live woody moisture	[30-300%]	Live -cody moisture	WOOD	ð
7	MFWS	Midflame windspeed	[0-99 mi/h]	Midil 8 windspeed	MFWS	7
8	SLP	Slope	[0-100% or 0-45 degre		816	8
9	WDIR	² Direction of wind vector, deg. clockwise from uphill	[0-360 deg	rees]	WOIR	9
	PREDICT AT M	1AX	(Y/N)		PREDICT AT M	
10	SDIR	Direction of spread	[0-360 deg	rees] as to assent	& CRIGS	MAX
		calc., deg. clockwise from uphill (or from wind vector if slope is zero)		oals, deg. stockwise from uphili (or from wind vector if stope is zero)		
OUTPUT	(Run)					
0		No more tables				
136	ROS	Rate of spread	ch/h	228	on nextenso	age.
2	H/A	Heat per unit area	Btu/ft²	742	AlH	S
023	FLIZIP	Fireline intensity	Btu/ft/s	3,102	[1]	3
7 481	FL 2.44	Flame length	ft	18.2	.73	4
5 5	RI 324 8	Reaction intensity	Btu/ft²/min	2,900	IR	5
6	EWS	Effective windspeed in direction SDIR	mi/h	8.4	Ews	9
7	MAXD	³ Direction of maximum spread, deg. clockwise from uphill		Spin Plan of maximum spread, deg. clockwill from uphili	MAXD	7

Exhibit 1a.—DIRECT run obtaining a single set of outputs.

¹Input only if corresponding fuel load is not zero. ²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero. ³Output only if calculations are in direction of maximum spread.

LIST NUMBER

(Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo)

INPUT	(Input, List)					
1	MODEL #	Fuel model number	(1-99)	Heet model m	300	
2	1H	1-H fuel moisture	[1-60%]	6.0	9.0	12.0
3	10H	¹ 10-H fuel moisture	[1-60%]	THOU THOU	and spread public	orther _p
4	100H	¹ 100-H fuel moisture	[1-60%]	m harthoans	<u> </u>	<u> </u>
5	HERB	¹ Live herb moisture	[30-300%]		HERR	stitered 2
6	WOOD	¹ Live woody moisture	[30-300%]	Was the same	<u>seenoow</u>	enclarek if
7	MFWS	Midflame windspeed	[0-99 mi/h]	8	CHAFE NA	STEET STEET
8	SLP	Slope	[0-100% or 0-45 degrees]	30%	9/9	See of a see
9	WDIR	² Direction of wind vector, deg. clockwise from uphill	[0-360 degrees]	20	WORLD THE STATE OF	rossich Ic. supples
	PREDICT AT I	MAX	(Y/N)		N	
10	SDIR	Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero)		10 de celoral de company de compa	SUIB	
OUTPUT	(Run)					
0		No more tables		No more table		0
1	ROS	Rate of spread	ch/h	189	155	136
2	H/A	Heat per unit area	Btu/ft²	742	673	648
3	FLI	Fireline intensity	Btu/ft/s	2,574	1,912	1,620
4	FL	Flame length	ft	16.7	14.5	13.5
5	RI	Reaction intensity	Btu/ft²/min	2,900	2,628	2,532
6	EWS	Effective windspeed in direction SDIR	mi/h	7.3	7.3	7.3
7	MAXD	³ Direction of maximum spread, deg. clockwise from uphill	degrees mumican	Spreadlon of spread deg. from uphill	MAXD	-

Exhibit 1b.—DIRECT run obtaining a list of outputs for a range of three 1-hour moisture inputs.

¹Input only if corresponding fuel load is not zero. ²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero. ³Output only if calculations are in direction of maximum spread.

22C

LIST NUMBER

(Keywords: Input, List, Run, Quit, Slze, SCorch, MAp, TWo) INPUT (Input, List) Fuel model number (1-99)MODEL # 1 12.0 2 1H 1-H fuel moisture [1-60%] ¹10-H fuel moisture [1-60%] 3 10H 100H ¹100-H fuel moisture [1-60%] 4 HERB ¹Live herb moisture [30-300%] 5 [30-300%] ¹Live woody moisture 6 WOOD 8 [0-99 mi/h] **MFWS** Midflame windspeed 7 3090 SLP Slope [0-100% or 8 0-45 degrees] 20 9 WDIR ²Direction of wind [0-360 degrees] vector, deg. clockwise from uphill PREDICT AT MAX (Y/N) 110 Direction of spread [0-360 degrees] 10 SDIR calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) See output table 0 No more tables Rate of spread ch/h 1 ROS Btu/ft² Heat per unit area 2 H/A Btu/ft/s FLI Fireline intensity 3 Flame length ft 4 FL Btu/ft²/min 5 RI Reaction intensity mi/h Effective windspeed 6 **EWS** in direction SDIR MAXD ³Direction of maximum degrees 7 spread, deg. clockwise

Exhibit 1c.—DIRECT input list for a range of three values for two inputs.

from uphill

¹Input only if corresponding fuel load is not zero. ²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.

³Output only if calculations are in direction of maximum spread.

OUTPUT TABLES

226	LIST NUMBER NJ MADJEWA)	initial guilt size? 80ord	LIST NUME	BER	Rd
	TABLE ITEM:		ROW ITEM 1 H		SDIR
		Column	Values: 10	60	110
Row No.	Row Value		This woody moisture in	Table Values	
7 159/5	6.0		7.3	3.2	0.6
2	9.0				0.6
3	_12.0_	ab 0.45 degrees]	7.3		0.6
TABLE NO.	TABLE ITEM:	44000	ROW ITEM	COL. ITEM	
DAY SOIRCA	Dan QA of a	P Tesergeb 0880400 d	Bileron to montoerid	SOIR	
			√alues:		
Row No.			T is zero)	able Values	
3	392 000		cers may be feel	1550s	136
TABLE NO	_ TABLE ITEM:	nimi-thute	ROW ITEM	COL. ITEM	18, 5
\$ EWS	Effective vines	spaso numb	Effective windepend	- Ews-	-/g/A
		Column V	alues:	—— GXAM	
input only if careaponding input only if 1 citams winds Output only if calculacions a	low Value			able Values	vine jught'
3	ar ditalang e let g		Bents to bents a for s alt n	udin Toshiq,o	Halitota
	effective windspeed	outputs for the range	of three values for two in	nnute chown in a	vhihit 10

```
des east3 and arbrand beiliong 1 MODEL # 3
                                              Ex. 1a
ton double thing a most gallenge 2 and H of 6.0 am
7 MFWS 8
8 SLP 30
9 WDIR 20
10 SDIR
                                     MAX and districted frames and and are entered to be estant
                                     logwind and beolding sprended histories, end maximum
                       ROS
                            228
                    2
                       H/A
                            742
                       FLI 3102
                    3
                    4
                       FL 18.2
                       R I 2900
EWS 8.4
                    5
                    6
                       MAXD 19
                       MODEL # 3
                                              Ex. 1b
                    2
                       1H 6.0
                                 9.0 12.0
                       MFWS 8
                    7
                    8
                       SLP 30
                       WDIR 20
                    9
                    10 SDIR 10
                       1H 6.0 0.0 12.0
                       -------------
                       ROS 189 155 136
H/A 742 673 648
                    1
                    2
                       FLI
                           2574 1912 1620
                    3
                       FL
                    4
                            16.7 14.5 13.5
                    5
                       RI
                            2900 2628 2532
                        EWS
                            7.3 7.3 7.3
                       MODEL # 3
1H 6.0 9.0 12.0
                    1
                                              Ex. 1c
                    2
                    7
                       MFWS 8
                       SLP 30
WDIR 20
                     8
                    9
                     10 SDIR 10
                                      110
                                 60
                      6 EWS 1H * SDIR
                    10 60 110
                     1:6.0 7.3 2.2
                                      0.6
                                              Ex. 1d
                     2:9.0
                            7.3 2.2
                                      0.6
                                      0 . 6 celder arom of
    3:12.0 7.3 2.2
                    Exhibit 1e.—Printer list for examples
                    of DIRECT module.
```

11

The SIZE Module

The prompt "SIZE: I,L,R,MA,Q" indicates that you are in the SIZE module operating independently (not linked to DIRECT). The SIZE module provides estimates of the fire size, perimeter, length-to-width ratio, forward and backing spread distances, and maximum

width at the end of a specified burning time. These estimates are for a fire originating from a point source, not a line source, and spreading at a constant rate through surface fuels during the elapsed time. The fire shape is assumed to be approximately elliptical. Exhibits 2a, 2b, and 2c illustrate typical runs in the SIZE module.

SIZE MODULE (English Units)							
				LIST NUMBER		23a	
		(Keywords: Input, Lis	t, Run, MAp, 1COnt	ain, Quit)			
INPUT	(Input, List)						
1	ROS	² Rate of spread	[0.1-500 ch/h]	20.0			
2	EWS	² Effective windspeed	[0-99 mi/h]	8.0			
3	ET	Elapsed time	[0.1 - 8 h]	1.0	2.0	4.0	
OUTPUT	(Run)						
0		No more tables					
1	AREA	Area	acres	w //	44	178	
2	PER	Perimeter	ch	46	92	183	
3	L/W	Length-to-width ratio		3.0	3.0	3.0	
4	FSD	Forward spread distance	ch	20.0	40.0	80.0	
5	BSD	Backing spread distance	ch	0.6	1.2	2.4	
6	MXW	Maximum fire width	ch	6.9	13.7	27.5	

¹SIZE can link to CONTAIN only if linked to DIRECT. ²Input only when SIZE is used as an independent module.

0.0
4.0
ble
ble e.
e makilisi

SIZE MODULE (English Units)

¹SIZE can link to CONTAIN only if linked to DIRECT. ²Input only when SIZE is used as an independent module.

Exhibit 2b.—SIZE input list for generating a table of outputs.

OUTPUT TABLES

Rods patenterab Chase 1980), The	distance of a toward and distance of the company of	disense basic manis	LIST NUI	MBER	35
TABLE NO	/ TABLE ITEM:	AREA	ROW ITEM R	OS COL. ITE	EM ET
Calculator read	the from this module may EHAVE outputs because	Column Val	ues: 1.0	2.0	4.0
Row No.	Row Value			Table Values	
1	5.0			3	
2	10.0		3		44
3	20.0			_44	178
TABLE NO	2 TABLE ITEM:	PER	ROW ITEM R		EM ET
	NTTACK OPT Attack option 1 - Dead	Column Val	ues: 1.0	2.0	4.0
Row No.	Row Value			Table Values	46
4 1	5.0			23	
2	10.0		23		
3	20.0	[mino 008-1.0]	46	92	183
TABLE NO	TABLE ITEM:	Line elanisto	ROW ITEM	COL. ITE	M
	Area Breaman &	Column Val	ues:	ol Heli swa swa	
Row No.	Row Value			Table Values	
1			steleptas toposa aprel	pot teptal agus bar	mus = 1
2	or area target too large, cales pullding rate too slow to ceto		Sulfation of wo	potenty rate too state table	e nti e 3 -
3	d stor terror con stor		spie entition of exolo	oci fegnal sera Del	muß = \$-

Exhibit 2c.—SIZE output tables of areas and perimeters calculated from the inputs in exhibit 2b.

The CONTAIN Module

The CONTAIN module is used to estimate fire suppression requirements, providing the following two run options for this purpose:

- Run option 1—estimate the total line-building rate required to contain the fire at a specific size, called the burned area target.
- Run option 2-estimate the final fire size, given a specific line-building capability.

Either run option permits the fire to be attacked at the head or the rear.

The results from CONTAIN are valid only within the basic assumptions that were used in developing the mathematical model. These are:

- The fire has an elliptical shape at the time of attack.
- · The rate of spread is constant during the time required to construct the control line.
- The containment line is constructed at the edge of the fire.
- Work proceeds simultaneously on both sides of the fire at an equal pace.

CONTAIN MODULE (English Units)

		<u>so</u> iti Aiit iiioi	JOLE (Eligibili U	111(3)		
				LIST NUMBE	R	25a
		(Keywords: Ir	nput, List, Run, Quit)			
INPUT	(Input, List)					
1	RUN OPT	Run option	(1 or 2)		1	
ET		1 = calculate total line building rate			D BUBAT	
		2 = calculate burned area				
2	ATTACK OPT	Attack option	(1 or 2)		1	
		1 = head				
		2 = rear				
3	ROS	¹ Rate of spread	[0.1-500 ch/h]	10.0	15-0	20.0
4	AREA	¹ Initial fire area	[0.1-100 acres]	5.0	J-C	f
5	L/W	¹ Length-to-width ratio	[1-5]	3.0	7.07	2
6	BAT	² Burned area target	[0.1-2000 acres]	7.0	20.0	.3
7	TLBR	³ Total line-building rate	[0.1-800 ch/h]	-	IMBER	226
OUTPUT	(Run)					
1 !!	PER	Total length of line	chains	35	35	35
2	TIME	Containment time	hours	1.0	0.7	0.5
3	FFS	⁴ Final fire size	acres	_ 84		Promote
3	TLBR	⁵ Total line-building rate	ch/h	33	50	67
4	MAXA	⁵ Maximum area calculable	acres	8	8	8
5	MINA	⁵ Minimum area calculable	acres	5	5	5

Error Codes:

- -1 = Burned area target too large, cannot calculate slow enough line building rate
- -2 = Line building rate too slow to catch fire
- -3 = L/W ratio too large
- -4 = Burned area target too close to initial fire size
- -5 = Line building rate too fast

¹Input only when CONTAIN is used as an independent module. ²Input only for run option = 1 (calculate total line-building rate). ³Input only for run option = 2 (calculate burned area target). ⁴Output only for run option = 2.

⁵Output only for run option = 1.

Exhibit 3a.—CONTAIN run obtaining a list of outputs using run option 1.

When calculating the final fire size, CONTAIN uses total line-building rate rather than line-building rate per flank as was used in the TI-59 program (Albini and Chase 1980). The program then applies half of the linebuilding rate to each flank. Thus the line-building rate entered must be more than twice the forward rate of spread; otherwise the control forces will never catch the fire.

When calculating the line-building rate required to contain the fire to a specific size, the target fire size must be larger than the initial fire size.

Calculator results from this module may differ somewhat from the BEHAVE outputs because the computa-

tional algorithm is different. To save computation time, the calculator results are based on a table lookup and interpolation process, whereas BEHAVE uses a pure computational method (Andrews and Morris in preparation). Because it is easy for the value of requested outputs to exceed the limits of the table in the calculator. the maximum (MAXA) and minimum (MINA) burned area targets calculable are output (Run option 1). Negative numbers (-1 to -5) indicate error codes as referenced on the data sheet. Exhibits 3a and 3b provide examples of calculating both total line-building rate and final fire size.

CONTAIN MODULE (English Units)

				LIST NUMBER	2	56
		(Keywords: I	nput, <u>L</u> ist, <u>R</u> un, <u>Q</u> uit)			
INPUT	(Input, List)					
1	RUN OPT	Run option	(1 or 2)		2	
		1 = calculate total line building rate		enalis (1.00 sv-ol-enbift	WOS .	
		2 = calculate burned area				
2	ATTACK OPT	Attack option	(1 or 2)	distance	2	
		1 = head				
		2 = rear				
3	ROS	¹ Rate of spread	[0.1-500 ch/h]	10.0	15.0	20.0
4	AREA	¹ Initial fire area	[0.1-100 acres]	5.0		
5	L/W	¹ Length-to-width ratio	[1-5]	3.0	and a second	
6	BAT	² Burned area target	[0.1-2000 acres]	-	19 33011	
7	TLBR	³ Total line building rate	[0.1-800 ch/h]	60.0		
OUTPUT	(Run)			icue impd = 2. amm		
1	PER	Total length of line	chains	47	62	94
2	TIME	Containment time	hours	0.8	1.0	1.6
3	FFS	⁴ Final fire size	acres	10	15	30
3	TLBR	⁵ Total line building rate	ch/h	of patheon 20	HEG	8
4	MAXA	⁵ Maximum area calculable	acres	nt poli-off am	THET	6
5	MINA	⁵ Minimum area calculable	acres	to second	RT's	01
				na voca esta esta esta esta esta esta esta est	THEFT	11

Error Codes:

- -1 = Burned area target too large, cannot calculate slow enough line building rate
- -2 = Line building rate too slow to catch fire
- -3 = L/W ratio too large
- -4 = Burned area target too close to initial fire size
- -5 = Line building rate too fast

Input only when CONTAIN is used as an independent module.

Input only for run option = 1 (calculate total line building rate).
Input only for run option = 2 (calculate burned area target).

Output only for run option = 2 Output only for run option = 1.

Exhibit 3b.—CONTAIN run obtaining a list of outputs using run option 2.

The SPOT Module

The SPOT module predicts the maximum spotting distance from three firebrand sources:

- · torching trees
- · burning piles
- · wind-driven surface fires.

Although spot fires may occur at lesser distances, the purpose of this calculation is to estimate the greatest distance at which spot fires can be expected. The number of spot fires likely to occur is not estimated. None of

the spotting calculations apply in the case of extreme fire behavior such as running crown fires, or any situation in which large fire whirls occur.

The wind-driven surface fire option applies only to fires occurring in surface fuels without timber cover and predicts only intermediate range spotting. Specifically, not included is short-range (a few tens of yards) spotting resulting from low intensity fires, or very long-range (several miles) spotting associated with extreme fire behavior such as crowning and large fire whirls.

Exhibits 4a, 4b, and 4c provide an example of inputs required for each of the three firebrand sources.

		SPOT MODULI	E (English Uni	ts) LIST NUMBER	26	ó a
		(Keywords: Input, I	ist, Run, MAp, Qu			
INPUT	(Input, List)	(11)				
967	BRAND SRC	Firebrand source	(1-3)			
		1 = torching trees 2 = burning piles 3 = wind-driven surface fire				
2	MCHT	Mean cover height	[0-300 ft]	100		1 60501
3	20'W	20-ft windspeed	[0-99 mi/h]	10	20	40
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	1,500		
5	RVHD	Ridge-to-valley horiz.	[0-4 mi]	1.5		DATTA
6	SRC LOC	Spotting source location	(0-3)		3	
		0 = midslope, windward side = valley bottom 2 = midslope, leeward side 3 = ridgetop			NE STATE OF THE ST	
7	TREE SP	¹Tree species	(1-6)		2	
		pole pine 5 = white pine 6 = balsam fir,		in the pullur and tate		
8	DBH	¹Torching tree DBH	[5-40 inches]	20	910 12	REATY
9	TRHT	¹Torching tree height	[10-300 ft]	90	M455	AXAM,
10	#TR	¹ Number of torching trees	[1-30]	4	IME'S	AMUS
11	FLHT	² Continuous flame height	[1-100 ft]			
12	FL	³ Flame length	[0.1-50 ft]			Codes:
13	MODEL #	³ Fuel model	(1-99)		ent tensi	
14	HERB	⁴ Herbaceous moisture	[30-300%]	n dotso ot wol	g rate too g	nibiliud antu i
OUTPUT	(Run)			ciosa (o initial	t oot size	miblind and
1	SPOT	Maximum spotting distance	mi (arter)	0.24	0.47	0.88
¹ Input only	for firebrand source	e = 1 (torching tree option).				

Exhibit 4a.—SPOT run with torching trees as the firebrand source.

Input only for firebrand source = 2 (burning pile option).

Input only for firebrand source = 3 (wind-driven surface fire option).

Input only for dynamic fuel models with a herbaceous fuel load.

			SPOT MODULE	266	266		
			(Keywords: Input, Li	st, Run, MAp, Q	uit)		
INP	UT	(Input, List)				(lubrit Frat)	
	1	BRAND SRC	Firebrand source	(1-3)	C Firebrarefig	2	
	2	MCHT	1 = torching trees 2 = burning piles 3 = wind-driven surface fire Mean cover height	[0-300 ft]	100	THOM	S
	3	20'W	20-ft windspeed	[0-99 mi/h]	10	20	40
	4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	1,500	Java	34
	5	RVHD	Ridge-to-valley horiz.	[0-4 mi]	1.5	OHVS	8
	6	SRC LOC	Spotting source location	(0-3)		3	
			0 = midslope, windward side				
			1 = valley bottom2 = midslope, leewardside3 = ridgetop				
	7	TREE SP	¹ Tree species	(1-6)		95 3381	
			 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodge- pole pine 5 = white pine 				
			6 = balsam fir,				
			grand fir				
	8	DBH	¹ Torching tree DBH	[5-40 inches]	ou galdoto l'	H80	8
	9	TRHT	¹ Torching tree height	[10-300 ft]	nt paintait	THAT	8
	10	#TR	¹ Number of torching trees	[1-30]	to jednitari	ALE.	G)
ahlbif t	11	FLHT	² Continuous flame height	[1-100 ft]	20	FLHT SES	17

13	MODEL #	³ Fuel model	(1-99)		WOLTEN	
14	HERB	⁴ Herbaceous moisture	[30-300%]	Herbaceou	неяв	Ar
OUTPUT	(Run)					
08.0	SPOT	Maximum spotting	mi galling	0.09	0-18	0.35

[0.1-50 ft]

12

FL

Exhibit 4b.—SPOT run with burning piles as the firebrand source.

³Flame length

¹Input only for firebrand source = 1 (torching tree option).

²Input only for firebrand source = 2 (burning pile option).

³Input only for firebrand source = 3 (wind-driven surface fire option).

⁴Input only for dynamic fuel models with a herbaceous fuel load.

		SPOT MODULE	(English Units) LIST NUMBER	26) C
		(Keywords: Input, Lis	st, Run, MAp, Quit)		
INPUT	(Input, List)			0	
1	BRAND SRC	Firebrand source	(1-3)	3	
	MCHT	1 = torching trees 2 = burning piles 3 = wind-driven surface fire Mean cover height	[0-300 ft] /00	ced with our start of large fire with on exercise fire beautiful.	reme first
3	20'W	20-ft windspeed	[0-99 mi/h]	20	40
4	RVEL	Ridge-to-valley elevation difference	[0-4,000 ft]	R. Sava	4
5	RVHD	Ridge-to-valley horiz.	[0-4 mi] 1.5	0	8
6	SRC LOC	Spotting source location	(0-3)	3	
		 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop 	0 = midslope, windward Edide prozen 2 = trippiope, teeward 2 = trippiope, teeward 1 = trippiope, teeward 2 = trippiope 1000		
7	TREE SP	¹ Tree species	(1-6)	NG MMI	
		 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodge- pole pine 5 = white pine 6 = balsam fir, grand fir 			
8	DBH	¹Torching tree DBH	[5-40 inches]	HBO -	8
9	TRHT	¹ Torching tree height	[10-300 ft]	THRE	- 6
10	#TR	¹ Number of torching trees	[1-30]	<u> ATs</u>	10
11	FLHT	² Continuous flame height	[1-100 ft]	THUR	- 17
12	FL * TRAT	³ Flame length	[0.1-50 ft] 20.0		12
13	MODEL #	³ Fuel model	(1-99)	_4	
14	HERB	⁴ Herbaceous moisture	[30-300%]	HERB	5.1
OUTPUT	(Run)				
01.35	SPOT	Maximum spotting	mi 0.33	0.52	0.80

distance

Exhibit 4c.—SPOT run with a wind-driven surface fire as the tirebrand source.

¹Input only for firebrand source = 1 (torching tree option).
²Input only for firebrand source = 2 (burning pile option).
³Input only for firebrand source = 3 (wind-driven surface fire option).
⁴Input only for dynamic fuel models with a herbaceous fuel load.

The SCORCH Module

The SCORCH module can be used to estimate the height to which tree crowns will be scorched by a surface fire burning beneath them. This module must be used with caution because very limited data were used for development of the mathematical scorch height model. Results may also be erroneous if applied to slopes steeper than 30 percent. Exhibit 5 shows a typical example of a SCORCH module run.

SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)			alki input left ovr		
m1d for	TEMP	Ambient air temperature	[33-120 °F]	90	it is particu	larly true with
2	FL	¹ Flame length	[0.1-20 ft]	4.0	CHOCK YOUR DE	pace present a
3	MFWS	¹ Midflame windspeed	[0-10 mi/h]	_0_	_5_	10
OUTPUT	(Run)			for hour cases. Ex	ter the Jupat	
1	SCHT	Scorch height	feet	_30_	21	10
of anade	NO1	ed as an independent module. TABLE ITEM: Scorch heigh	nt ROW	ITEM	COL. ITEM	M
		METI WOM Co	lumn Values:	METE ITEM: Fre	T +	TABLE NO
Row No.	Ro	ow Value		Table	e Values	
	1		_			
	2		Column Vaju			
	3					

Exhibit 5.—SCORCH run obtaining a list of scorch heights for a range of midflame windspeeds.

The IGNITE Module

The IGNITE module can be used to calculate the probability that a firebrand will ignite a fire if it lands on fine dead fuel. Probability is calculated to the nearest 10 percent and does not indicate whether or not the ignition will result in a sustained fire. The probability of ignition is not the same as the ignition component (IC) of the National Fire-Danger Rating System (NFDRS). The NFDRS-IC uses fire spread rate as well as probability of ignition to estimate the likelihood of a sustained fire on which suppression action may be required. The MOISTURE module discussed later also calculates ignition probability.

Exhibit 6 shows an example probability of ignition

IGNITE MODULE (English Units)

(Keywords: Input, List, Run, Quit)

0/		o Quantities and dumin	01-0] beeq	obniw emailbiM		
1 2 3	(Input, List) TEMP 1H SHAD	Ambient air temperature 1-h fuel moisture Shade	[33-120 °F] [1-60%] [0-100%]	90 5.0 30	10.0	15.0
OUTPUT 1	(<u>R</u> un)	Probability of ignition	pct Ingled des	70	30	20
TABLE		TABLE ITEM: Prob. of Ignit			COL. ITE	M M
		Col	lumn Values:			8
Row No.	Row	Value		Tab	le Values	
	FL	*Flame length	10 1-50 to			
	2 _	1 mailes deregal	(1.99)			

Exhibit 6.—IGNITE run obtaining a list of ignition probabilities for a range of 1-hour fuel moistures.

The MOISTURE Module

The MOISTURE module is used to calculate the moisture content of fine dead fuels (Rothermel and others 1986). It has two run options:

- Run option 1.—Calculate the 1-hour fuel moisture, fuel level temperature and relative humidity, percent shade, and probability of ignition for a specific time. This is the burn time option.
- Run option 2.—Calculate the 1-hour fuel moisture and fuel level temperature and relative humidity each hour. This is the hourly option.

The input line numbers have been made to coincide with those used for the MOISTURE and SITE modules of the FIRE2 program of BEHAVE. Thus, missing input line numbers are for FIRE2 line numbers not used for the HP-71.

Although there are numerous inputs, many are not used for specific cases. For example, aspect is not requested if the slope is 0, timber overstory information is not requested if the crown closure is 0, sunset and sunrise weather are not asked if burn time is before sunset, and the various moisture initialization options request different inputs. These examples are not exhaustive, but the program will prompt for the data required for any specific run.

If you do not have estimates of the overstory tree characteristics and think you can estimate the amount of shade caused by the overstory, answer line 15 (crown closure) with 0 percent and line 25 (burn day cloud cover) with your estimate of shade for both the clouds and the overstory. This is recommended only for option 1.

Several input items are requested for the "burn day," which is defined to be the period from 1200 noon to

1200 noon, not from midnight to midnight. "Burn day -1" is the previous period from 1200 to 1200. The amount of weather input required depends on the time of day designated as "burn time."

Fuel moisture must be specified at 1400 on the day before the burn. BEHAVE offers five "Moisture Initialization Options" to assist in specifying this value, but the HP-71B calculator offers only four. Moisture initialization option 2 (complete data for the previous 7 days) is not allowed. Option 1 permits input of fine fuel moisture when it is known for the day before the burn; options 3, 4, and 5 are used when incomplete weather information is available.

Particular care must be exercised when changing the value of specific inputs by entering them individually. You may find that more input is required (the calculator displays "INCOMPLETE INPUTS") or that you are using invalid inputs left over from a previous run. While this is true with all modules, it is particularly true with this one, so always list and check your inputs before a RUN.

Examples of RUN OPTION 1 and RUN OPTION 2 are shown in exhibits 7a and 7b. The other inputs are the same for both cases. Enter the input values shown to get the burn time outputs. Then change the first input (RUN OPTION) to 2, and rerun to get the hourly output table. Multiple inputs are not allowed in the hourly option. The MOISTURE module takes longer to run as burn time approaches the end of the burn day or if multiple inputs are used, so some patience is required to obtain an answer in these cases. The output form for run option 2 has an extra line at the bottom to record burn time data that does not end on an even hour.

MOISTURE MODULE (English Units)

		er Jugal Walladw 16 tenenas o	an helomed the molecule	IST NUMBER	30a-1
		(Keywords: Inp	out, List, Run, Quit)		
INPUT	(Input, List)	HVAH Hel carned salt seeings			evel temperature and
1,00	RUN OPT	Run option	(1 or 2)		to val dedong bine a
		1 = Burn time calculations			
		2 = Hourly calculations			
TIME AN	ID LOCATION				
2	BURN MONTH	Month of burn	(1-12)		7
3	BURN DAY	Day of burn	(1-31)		12
4	LATITUDE	Latitude of fire location	(-90 to 90 degrees)	serous inputs	45
5	BURN TIME	Time of burn	(0-2,359 h)		2,230
FUEL M	ODEL				requestion a tab to as
6	MODEL #	Fuel model number	(1-99)		2
SLOPE,	ELEVATION, ASPE	Manual (RUN OPTION)			
intrae	SLP	Slope steepness	[0-100% or 0-45 degrees]	20	oti do net-have estima. Alla para esta començativa esta
12	ELFL onto on	Elevation of fire location	[0-12,000 ft]	3,000	el with your againste
	RH OBS AT FIR	en option is a that that done	(Y/N)		<u> </u>
13	ELOB	Elevation of T&RH observations	(0-12,000 ft)		versi input items are is defined to be the
14	ASPECT	Aspect of fire location 0 = north 180 = south 90 = east 270 = west	(0-360 degrees)		270
TIMBER	OVERSTORY DES	CRIPTION			
15	CCLO	Crown closure	[0-100%]	20	
16	FOLIAGE	Foliage presence 0 = absent 1 = present	(0 or 1)		
17	SHADE TOL	Shade tolerance 0 = intolerant 1 = tolerant	(0 or 1)		0_
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)		
19	AVHT	Average tree height	[10-300 ft]	80	
20	H/H	Crown height/tree	[0.1-1]	0.50	
20	11/11	height ratio	[0.1-1]	0.00	
21	H/D	Crown height/crown diameter ratio	[0.2-5]	3.00	

Exhibit 7a.—MOISTURE run obtaining just burn time outputs using run option 1.

				LIST NUMBER	30a-2
EARLY	AFTERNOON WE	ATHER			
22	14T	Burn day 1400 temperature	[33-120 °F]	80	-40 EXPOSURE-
23	14RH	Burn day 1400 relative humidity	[1-100%]	20	
24	14W	Burn day 1400 20-ft windspeed	[0-99 mi/h]	_10	
25	14CC	Burn day cloud cover	[0-100%]	20	
26	14HZ	Burn day 1400 haziness	[1-4]	2	
		1 = very clear sky2 = average clear forest atmosphere3 = moderate blue haze			
		4 = dense haze— moderate smoke			
SUNSE	T WEATHER				
27	SST	Sunset temperature	[33-120 °F]	70	
28	SSRH	Sunset relative humidity	[1-100%]	25	
29	SSW	Sunset 20-ft windspeed	[0-99 mi/h]	5	
30	SSCC	Sunset cloud cover	[0-100%]	20	
SUNRIS	SE WEATHER				
31	SRT	Sunrise temperature	[33-120 °F]		F NOITEO 38HT2IOH
32	SRRH	Sunrise relative humidity	[1-100%]	mail 1	
33	SRW	Sunrise 20-ft windspeed	[0-99 mi/h]		
34	SRCC	Sunrise cloud cover	[0-100%]		- e vión ra anureios
BURN 1	TIME WEATHER				
35	ВТТ	Burn time temperature	[33-120 °F]	65	-
36	BTRH	Burn time relative humidity	[1-100%]	28	52 RAIN
37	BTW	Burn time 20-ft windspeed	[0-99 mi/h]		
38	втсс	Burn time cloud cover	[0-100%]	Signs radition done	TON CC
39	BTHZ	Burn time haziness	[1-4]	on nomemon and	3000/1/46 #6
		 1 = very clear sky 2 = average clear forest atmosphere 3 = moderate blue haze 4 = dense haze— moderate smoke 		t = clear 2 = cloudy 3 = parity c	

Exhibit 7a. (Con.)

LIST NUMBER

30a-3

JRN TIME WIND			2	
40 EXPOSU	RE Exposure of fuels to wind	(1-5) Usasagmes COAT vab mull	7	
	1 = exposed 2 = partially sheltered			
	3 = fully sheltered— open stand			
	4 = fully shortered			
	= U L			
41 WAF	I II - I I footor	(0-1) (0-1)		
IOISTURE INITIA	LIZATION OPTION			
43 MOIS O		(1-5) — exad sensb = A		
	1 = fine fuel moisture known for day before			
	burn 2 = not allowed			
	3 = incomplete data; rain			
	the week before burn			
	4 = incomplete data; no ra the week before burn			
	5 = incomplete data; weather pattern char			
MOISTURE OPTIC	N 1 saservations (70 0)			
14 14	Burn day -1 fine fuel moist	ture [1-100%]	SALE DE TE	32.
44 FM-1	Burn day – I fille fuel fillosi		SRW	
MOISTURE OPTIC		M 7 days		
51 RDAY	Number of days before burn	tracet are enutringmed emit mud	TTB	35
10 FOL		f [0-400]	иете	82
52 RAIN	an inch			
53 RDT	1400 temperature on rain da		3016	38
54 SKY C	ODE Sky condition from rain day to burn day		SHIE /	
MOISTURE OPTI	1 = clear 2 = cloudy 3 = partly cloudy			
MOISTURE OPTIO	No additional input.			
Exhibit 7a. (Con.	Orean treightferown			

		raiculation of fire spread	The example ()	IST NUMBER	30a-4
MOISTUE	RE OPTION 5				
55	TD-1	Burn day -1 1400 temperature	[33-120 °F]	-	in surecy requires the
56	RD-1	Burn day -1 1400 relative humidity	[1-100%]	pteristics of link the discussed in	ted MAS rans very con- a a teter section.
57	WD-1	Burn day - 1 1400 20-ft windspeed	[0-99]		dr - to
58	CD-1	Burn day -1 1400 cloud cover	[0-100%]	-	<u>811/44</u>
59	WTHR	Weather condition prior to burn day -1	[1-3]	14 Parties	47
		1 = hot and dry 2 = cool and wet 3 = between 1 and 2			
OUTPUT	(Run)			10	
1_1_	MOIS	1-hour fuel moisture	pct	6.2	COS
2	TEMP	Fuel level temperature	°F	65	A.)
3	%RH	Fuel level relative humidity	pct	28	5.00gz
4	SHAD	Percent of area shaded	pct	100	24 62
5	P(I)	Probability of ignition	pct	50	<u> </u>

Exhibit 7a. (Con.)

306

		LIST NUMBER	306
HOURLY OUTPUT (Run			
TIME	FMOIST	enulated med OFTEMP at must	FRH
	pct [60007-1]	Burn day - 4°1400 relative	pct pct
14	6.1	88.7	15.0
15	5.8	86.8	16.0
16	5.7	19400 buch 0 83.4 mus	17.7
17	5.7	79.0	20.0
18	5.7	74.6	22.6
19	5.8	71.6	24.2
20	10M OPTION 5.9	69.3	25.4
21	6.1	67.5	26.5
22	6.2	65.8	27.5
23	2 Some too	Fue l lovel relative hur nidity	LICEUS A
24	The Scomplete data: (a) log	behada sera la mone9	DAHP A
1	the week before burn	Probability of ignition	5 P(I)
2	the week before burn		Exhibit 7s (Onn.)
3	5 a tenompiate data; wasther pattern changin		
4			
5	the many of the had extended	Travel 10	
6	Selection of the select		
MOISTURE OF 7			
ADAY 8	Number of days before burn	[1-7 chys]	
9	that your occusion	ro-actin	
10	Rain although harrows and an look		
10 ADT 11	100 temperature on sale day	(33-120 · F)	
54 SKY CODE	Sky condition from rate day	(4-3)	
Burn Time 22.5	6.2	65.0	28.0

Exhibit 7b.—MOISTURE outputs using the inputs listed in exhibit 7a but with run option 2 to calculate hourly values.

The MAP Module

The MAP module permits calculation of fire spread distances, or spot distances, with the output expressed in units (inches or centimeters) to enable plotting the fire on a map. Inputs of scale option, representative fraction, and inches per mile are common to both MAP and SLOPE modules. In the metric option, only representative fraction is allowed for scale option. Exact output obtained depends on the UNITS OPTION selected and

whether the run is independent or linked to other modules.

The example shown in exhibit 8 is for an independent MAP run. Note that unit option 2 (spot distance) requires an input in miles while other inputs are in chains. Also, unit option 3 (rate of spread) requires the elapsed time to make the distance calculation. The input and output characteristics of linked MAP runs vary considerably and will be discussed in a later section.

		MAP MODULE	(English	Units)		٥.	
				LIS	T NUMBER	31a	
		(Keywords: Input	List, Run,	Quit)			
INPUT	(Input, List)	20-fi winders of the Point 11-05	5 someth m	1017		0	
² 1	SCL OPT	Scale option 1 = Representative fraction	(1 or 2)			(Input, List)	
		2 = Inches per mile				SCL OPT	
2	RF/1000	¹ Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)			2.00	
3	IN/MI	² Inches per mile	(0.0625-8)			2.00	
4	UNITS OPT	Units option	(1-3)			3	
		1 = Spread distance2 = Spot distance3 = Rate of spread					
5	DIST	³ Spread distance	[0-1000 ch]		nychay0	THI HOO INT	6.0
6	SPOT	⁴ Spot distance	[0.1-10 mi]	5011		O ALTERNA	3
7	ROS	⁵ Rate of spread	[0.1-500 ch	n/h] _	20.0		4.0
8	TIME	⁵ Elapsed time	[0.1-8 h]	-	1.0	2.0	
5	FSD	⁶ Forward spread distance	ch	-		(num)	TURTUO
6	BSD	⁶ Backing spread distance	ch				
7	MXW	⁶ Maximum fire width	ch	epness	Slope ste	- 8f. b. di	
OUTPUT	(Run)						
1	MFSD	Forward spread distance on map (UNITS OPT = 1 or 3)	inches	change I distanç	0.5	1.0	2.0
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	inches			T = mottop alace to	Input only to
2	MBSD	Backing spread distance on map (SIZE linked only)	inches		.elqme	-SLOPE run ex	Exhibit 9.—
3	MMXW	Maximum fire width on map (SIZE linked only)	inches				

Input only for scale option = 1.

²Input only for scale option = 2.

³Input only for units option = 1.

⁴Input only for units option = 2. ⁵Input only for units option = 3. ⁶Passed from SIZE for linked run only. No input is needed.

The SLOPE Module

The purpose of the SLOPE module is to provide a convenient means of calculating slope steepness, which you can then input to another module. Slope is output in both percentage and degrees, and does not depend on slope input units selected at the start of the BEHAVIOR program. All the inputs can be obtained

from a good contour map. Inputs of scale option, representative fraction, and inches per mile are common to both SLOPE and MAP modules. In the metric option, only representative fraction is allowed for scale option. The heading "From Point ____ to ___ Point" on the worksheet is to provide a label that corresponds to similarly labeled points on a map. A typical slope calculation is shown in exhibit 9.

SLOPE MODULE (English Units)

LIST NUMBER 32a

(Keywords: Input, List, Run, Quit)

From Point A to Point B

INPUT	(Input, List)			25.4
1	SCL OPT	Scale option	(1 or 2)	_2
		1 = Representative fraction 2 = Inches per mile		
2	RF/1000	¹ Representative fraction/1,000 e.g., RF of 1/24,000 = 24	(1-500)	THO ETIMO &
3	IN/MI	² Inches per mile	(0.0625-8 in)	2.00
4	CON INT	Contour interval	(10-500 ft)	200
5	MAP DIST	Map distance	(0.1-10 in)	1.0
6	# INTVLS	Number of contour	(1-100)	3
		intervals		
OUTPUT	(Run)			
				030 8
1	SLP %	Slope steepness	pctpct	23
2	SLP DEG	Slope steepness	degrees	13
3 5	EL DIFF	Elevation change	feet o sometel beauting biswood	600
4	HORIZ DIST	Horizontal distance	feet S 10 t = T90 STIMU) gsm	2640

¹Input only for scale option = 1.

Exhibit 9.—SLOPE run example.

²Input only for scale option = 2.

The WIND Module

The WIND adjustment module is used independently to adjust the windspeed, as measured 20 feet above the vegetation, to a windspeed at midflame height. In the metric version, the program assumes the 20-foot windspeed equals the 10-meter windspeed. The midflame windspeed can then be entered manually in other mod-

ules. Four wind exposure options are available for various amounts of sheltering, plus a fifth option to enter the wind adjustment factor directly. The adjustment factor for exposed fuels depends on the fuel model; the adjustment factors for sheltered and partially sheltered fuels do not. A typical midflame windspeed calculation is shown in exhibit 10.

WIND ADJUSTMENT MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)	13-120 °F 10 1 10 10 10 10 10 10 10		and ten in	n of IBMAGNAIN	prend rate.
1	20'W	20-ft windspeed	[0-99 mi/h]	5	10	15
2	EXPOSURE	Exposure to wind	(1-5)		1	
		1 = exposed 2 = partially sheltered 3 = fully sheltered, open stand 4 = fully sheltered, closed stand 5 = enter wind adjust- ment factor				
3	WAF	¹ Wind adjustment factor	(0-1)		ended — enters	
4	MODEL #	² Fuel model number	(1-99)			
OUTPUT 1	(Run) MFWS	Midflame windspeed	mi/h	2.0	4.0	6.0

¹Input only for exposure = 5.

Exhibit 10.-WIND run example.

²Input only for exposure = 1.

The RH Module

The RH module is used to calculate relative humidity and dew point from dry and wet bulb temperatures, and elevation. The output RH is not automatically passed to other modules, but it can be entered manually. The RH calculations assume ice is present on the wet bulb if the

temperature is below 32 °F (0 °C). Dew points below freezing are with respect to liquid water. An error will be generated if you enter a wet bulb temperature greater than the dry bulb temperature or if the dew point temperature is unrealistically low (below -40 °F or -40 °C). A typical humidity calculation is shown in exhibit 11.

RH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

90 66 WETB
E
WETB
ħ.
66
50
39
30
30
WETB
66
60
57 54

OPERATING THE MODULES IN "LINKED" RUNS

"Linked" runs provide the capability to use results from one program module in another program module. Level 2 or 3 modules may be linked to specific level 1 or 2 modules, respectively, as shown in figure 1. Thus SIZE, SCORCH, MAP, and TWO may be linked to DIRECT, while MAP and CONTAIN may be linked to SIZE. MAP may also be linked to SIZE or SPOT when they are run independently.

Remember that multiple values may be entered for a maximum of two input items, including those passed from a linked module. Depending on the number of items for which multiple values are entered, you may

pass to the "linked" module:

• a single value for each output item—one value entered for each input item,

• a list of values for each output item—two or three values entered for one input item,

• a table of values for each output item—two or three values entered for each of two input items.

If a set of single output values is passed forward, a list can be produced from the linked module by entering two or three values for one of the linked module inputs. A table would be produced by the linked module if multiple values were entered for two of the linked module inputs. If a list is passed forward to a linked module, a table may be produced by entering two or three values for one linked module input. If a table is passed forward, multiple values may not be entered for any linked module input.

Output produced by running a module independently will not be passed to another module that is also run independently. For example, if you run the DIRECT module from the MAIN program, then also run the SIZE module from MAIN after quitting DIRECT; the outputs from DIRECT will not be passed to SIZE. This would have to be accomplished by first running DIRECT, then selecting the SIZE module while you are still in the DIRECT module. SIZE output could similarly be passed to MAP or CONTAIN by selecting one of these modules while still in the SIZE module. In addition, you can link to another module only after a successful run using the module you are currently in. Otherwise, the display will briefly show the error message, "NO LINK BEFORE RUN". If any inputs are changed, a new run is necessary.

Linked run forms were considered, but found to be complicated and numerous if they were to be made for all possible combinations. Use the forms for individual modules. If multiple values are entered for one input item, the linked module will list the multiple output values. If a table is passed from one module to the next, then listing the inputs in the linked module will display the range of table values passed. The form of the display is: "ITEM LABEL value TO value". For example, "AREA 65 TO 303". Use the space provided for multiple inputs of this item to write this range on the data sheet for the linked module.

Linked DIRECT-SIZE-CONTAIN Run

An example DIRECT-SIZE-CONTAIN run is shown in exhibits 12a, 12b, and 12c. The rate of spread and effective windspeed, in the direction of maximum spread rate, are passed to SIZE. ROS and EWS passed to SIZE or CONTAIN are always in the direction of maximum spread rate. The ROS and EWS in the output list of DIRECT can be in other directions if that option was selected for input item 10 (SDIR) of DIRECT. Thus, outputs from linked SIZE or CONTAIN runs are independent of the spread direction input in DIRECT. The output from DIRECT is a list of three values for each output item. This is expanded to tabular output by entering three elapsed time (ET) values in SIZE, shown in exhibit 12b. Only single values can be entered in CONTAIN (exhibit 12c) because tables of AREA and L/W were passed to it from SIZE. That is, only one total line-building rate (TLBR) could be entered.

The AREA table produced by SIZE in exhibit 12b shows the size of the fire (acres) if it were to burn unconstrained for the nine combinations of three 1-hour fuel moistures (10, 11, and 12 percent) and three time intervals (1.0, 1.5, and 2.0 hours). These areas become the initial fire area for CONTAIN in exhibit 12c. Note that the SIZE module prompt "SIZE: I,L,R,MA,CO,Q" now gives you the option to go to CONTAIN. This option is only available in linked runs and not available in independent runs.

The final fire size (FFS) table produced by CONTAIN in exhibit 12c shows the size of the fire (acres) for the same nine combinations of 1-hour fuel moisture and burning time, but with suppression action being taken by forces attacking the fire from the rear. These forces have a total line construction rate capability of 100 chains per hour. The TIME table of CONTAIN shows how long it will take to contain the fire at the sizes listed in the FFS table.

LIST NUMBER

(Keywords: Input, List, Run, Quit, Slze, SCorch, MAp, TWo) INPUT (Input, List) (1-99)Fuel model number MODEL # 1 12.0 0.0 [1-60%] 1-H fuel moisture 1H 2 110-H fuel moisture [1-60%] 3 10H 1100-H fuel moisture [1-60%] 100H ¹Live herb moisture [30-300%] 5 HERB [30-300%] ¹Live woody moisture WOOD 6 [0-99 mi/h] Midflame windspeed 7 MFWS 20 [0-100%/ Slope SLP 8 0-45 degrees] [0-360 degrees] ²Direction of wind WDIR 9 vector, deg. clockwise from uphill (Y/N) PREDICT AT MAX [0-360 degrees] Direction of spread 10 SDIR calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) No more tables 0 ch/h Rate of spread ROS 1 Btu/ft² Heat per unit area 2 H/A Btu/ft/s FLI Fireline intensity 3 ft Flame length FL 4 Btu/ft²/min Reaction intensity RI 5 mi/h Effective windspeed **EWS** 6 in direction SDIR degrees ³Direction of maximum MAXD spread, deg. clockwise from uphill

¹Input only if corresponding fuel load is not zero.
²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
³Output only if calculations are in direction of maximum spread.

Exhibit 12a. - DIRECT run obtaining outputs that can be linked to SIZE.

SIZE MODULE (English Units)

274

				LIST NUMBER	310
		(Keywords: Input, Lis	t, Run, MAp, 1COn	tain, <u>Q</u> uit)	
INPUT	(Input, List)				- 1
1	ROS	² Rate of spread	[0.1-500 ch/h]	35	34 32
2	EWS	² Effective windspeed	[0-99 mi/h]	2.3	2.3 2.3
3	ET	Elapsed time	[0.1 - 8 h]	1.0	1.5 2.0
OUTPUT	(Run)				
0		No more tables		see output table	
1,00	AREA	Area	acres	see output table on next page.	
2	PER	Perimeter	ch	1/:0	
3	L/W	Length-to-width ratio			
4	FSD	Forward spread distance	ch	2011177	22 24
5	BSD	Backing spread distance	ch		\$3
6	MXW	Maximum fire width	ch 939	Mail DIBAT	I ON 3 PORT

¹SIZE can link to CONTAIN only if linked to DIRECT. ²Input only when SIZE is used as an independent module.

Exhibit 12b.—Linked SIZE run using DIRECT outputs shown in exhibit 12a.

OUTPUT TABLES

376 LIST NUMBER ROW ITEM IH COL. ITEM ET TABLE NO. 1 TABLE ITEM: AREA 1.5 2.0 1.0 Column Values: Table Values Row Value Row No. 3/6 10.0 290 11:0 268 TABLE NO. 2 TABLE ITEM: PER ROW ITEM IH COL. ITEM ET Column Values: Table Values Row No. Row Value 207 103 155 10.0 198 99 149 11.0 12.0 ROW ITEM IH COL. ITEM ET TABLE NO. 3 TABLE ITEM: L/W Column Values: 1.0 1.5 2.0 Table Values Row Value

Exhibit 12b. (Con.)

1

10.0

12.0

Row No.

1.6

1.6 1.6 1.6

CONTAIN MODULE (English Units)

37c LIST NUMBER

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)	Ambient se terrografure	PER			
1	RUN OPT	Run option	(1 or 2)		2	_
		1 = calculate total line building rate				
		2 = calculate burned area			57	
2	ATTACK OPT	Attack option	(1 or 2)		2	old wor
		1 = head 2 = rear				
3	ROS	¹Rate of spread	[0.1-500 ch/h]	35	34	32
4	AREA	¹ Initial fire area	[0.1-100 acres]	67	to	3/6
5	L/W	¹ Length-to-width ratio	[1-5]	1.6	to	1.6
6	BAT	² Burned area target	[0.1-2000 acres]	_	Later Control	
7	TLBR	³ Total line building rate	[0.1-800 ch/h]	100.0		
OUTPUT 1	(<u>R</u> un)	Total length of line	chains	See on		tables page.
2	TIME	Containment time	hours	ha DIRECT OFF	uta of ext	808 128 _{014 we}
3	FFS	⁴ Final fire size	acres	0_0\		- 1
3	TLBR	⁵ Total line building rate	ch/h	if you halve AA	samble, p	roduged is list
4	MAXA	⁵ Maximum area calculable	acres	2.0.0	ni a centri J eografia	r onepus with
5	MINA	⁵ Minimum area calculable	acres			

Error Codes:

- -1 = Burned area target too large, cannot calculate slow enough line building rate
- -2 = Line building rate too slow to catch fire
- -3 = L/W ratio too large
- -4 = Burned area target too close to initial fire size
- -5 = Line building rate too fast

¹Input only when CONTAIN is used as an independent module. Input only when Contain is used as an independent module.

Input only for run option = 1 (calculate total line building rate).

Input only for run option = 2 (calculate burned area target).

Output only for run option = 2.

Output only for run option = 1.

Exhibit 12c.—Linked CONTAIN run using outputs from DIRECT and SIZE.

OUTPUT TABLES

				LIST NUM	BER <u>3</u>	7c
TABLE NO	,	TABLE ITEM:	PER	ROW ITEM 1H	COL. ITE	M ET
TABLE NO.	7		(\$ or 2)	m option T = calculate total line		
>			Column	Values:		2.0
Row No.	F	Row Value			Table Values	
1		10.0		385	578	77/
2		11.0		334	501	668
3		12.0		296	444	592
TABLE NO.	2	_ TABLE ITEM:	TIME	ROW ITEM 1H	COL. IT	EM ET
		100.0	[0.1-800 oh/h]	efer gnibiliud enil late	ore AB	JT Y
rables.			Column	Values:	1.5	2.0
Row No.					Table Values	
1	ded	10.0		3.9	5.8	7.7
2		11.0		etas ento 3.3	5.0	6.7
3		12.0		3.0	4.4	5.9
TABLE NO.	3	_ TABLE ITEM:	FFS	ROW ITEM		
		ena gridi		slow to catch fire	col eter gribili.	-2 = Line bi
			Column	Values:	1.5	2.0
Row No.		Row Value			Table Values	Input only when Captured to tun
1		10.0		773	1,740	3,093
2		11.0		600	1,351	2,402
3		12.0		484	1,090	1,937
Exhibit 12c. (C	on.)					

SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)			am a kail a nofi bar		
1	TEMP	Ambient air tem	perature [33-120 °F]	80	I zididzą ni nwod	e sa OWT
2	FL	¹ Flame length	[0.1-20 ft]	7.3	7.1	7.0
3	MFWS	¹ Midflame winds	speed [0-10 mi/h]	10311112	3	
OUTPUT	(<u>R</u> un)			32.Q.		
1 ,	SCHT	Scorch height	feet	59	57	55
TABLI	E NO1	TABLE ITEM: Sco		OW ITEM	COL. ITEM	2 2 8 4
		vae to Leas	4.00000001	Live help moisture	anak	- 0
			Column Values:	Live woody moistur	0000	9
Row No.	Roy	w Value		eegabalw emall Tal	ole Values	
10	1 SDIA	Sero sieg. old		Slope (ass)	9.18	/18X_
	2					

Exhibit 13.—Linked SCORCH run obtaining a list of scorch heights from the DIRECT outputs of exhibit 12a.

Linked DIRECT-SCORCH Run

The DIRECT run in the previous example (exhibit 12a) can be linked to SCORCH by entering SC after a valid DIRECT run. The midflame windspeed and flame length in the direction of spread selected by SDIR are passed to SCORCH. Only air temperature needs to be input for SCORCH calculations. The calculations are not corrected for slope; erroneous results may be obtained for slopes steeper than 30 percent. The output of SCORCH linked to DIRECT is shown in exhibit 13.

Linked DIRECT-TWO Run

The TWO module is available only by linking to it through DIRECT. This module is used to weight the spread rate of fire through two very different fuel types that occur as interspersed patches in the same general area.

First, run DIRECT with the fuel model and environmental conditions that describe the situation for one of the vegetation types. Then do a second run for the other fuel model. Except for model number, all other DIRECT inputs common to both models should be equal for both runs. If the second model requires additional moisture inputs for additional fuel classes, these inputs should be made. DIRECT must produce single output, list output, or tabular output for both models. That is, you cannot

link to TWO if you have, for example, produced a list output with the first model and a tabular output with the second. This will produce the message "INPUT ERROR".

After doing both DIRECT runs, enter keyword TW to link to the TWO module. A List at this point will produce a list of five items, the first four of which were values passed to TWO by DIRECT. Items 1 and 2 (MODEL1 and MODEL2, respectively) display the numbers of the fuel models used in the first and second DIRECT runs. Items 3 and 4 list the spread rates produced by the first and second models run by DIRECT. Spread rates are for the direction selected for the calculation in input item 10 (SDIR) of DIRECT.

The spread rates will be presented as single values, lists, or a range of values, depending on how many DIRECT input items were assigned multiple values. All of TWO items 1-4 are passed by DIRECT; you cannot enter any of them independently. You must, however, enter values for input item 5 — COV1. This is the percentage of area covered by the first fuel model run in DIRECT (item MODEL1). No input is needed for area coverage of the second model, as it is assumed to cover the remainder of the area.

The rate of spread calculated by TWO is not passed back to DIRECT, nor can it be used in SIZE or CONTAIN calculations. Once a Run is made in TWO, a



return to DIRECT will not allow subsequent links to other modules until a valid DIRECT Run is made.

An example follows in which two fuel models are run in DIRECT to produce two lists of spread rates (exhibits 14a and 14b). After the second Run a link is made to TWO as shown in exhibit 14c. Both fuel model numbers

and the ROS output from DIRECT are passed to TWO. Only input 5, the area coverage (percent) of the first model (COV1), is needed to complete the input list in TWO. Three percentages of coverage were entered and a table of weighted ROS is output, as shown in the TWO data sheet.

DIRECT MODULE (English Units) LIST NUMBER (Keywords: Input, List, Run, Quit, SIze, SCorch, MAp, TWo) INPUT (Input, List) Fuel model number (1-99)MODEL # 1-H fuel moisture [1-60%] 10 2 1H 3 ¹10-H fuel moisture [1-60%] 10H ¹100-H fuel moisture [1-60%] 4 100H ¹Live herb moisture [30-300%] 5 HERB 6 WOOD ¹Live woody moisture [30-300%] 7 MFWS Midflame windspeed [0-99 mi/h] [0-100%/ 8 SLP Slope 0-45 degrees] ²Direction of wind [0-360 degrees] 9 WDIR vector, deg. clockwise from uphill PREDICT AT MAX (Y/N) Direction of spread [0-360 degrees] 10 SDIR calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) 0 No more tables ch/h ROS Rate of spread 1 Btu/ft² 2 H/A Heat per unit area FLI Fireline intensity Btu/ft/s 3 4 Flame length Btu/ft²/min RI 5 Reaction intensity Effective windspeed mi/h **EWS** 6 in direction SDIR 0 0 0 3Direction of maximum MAXD degrees

³Output only if calculations are in direction of maximum spread.

from uphill

spread, deg. clockwise

¹Input only if corresponding fuel load is not zero.

²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.

DIRECT MODULE (English Units)

LIST NUMBER (Keywords: Input, List, Run, Quit, Slze, SCorch, MAp, TWo) INPUT (Input, List) MODEL # Fuel model number (1-99)1 10.0 2 1H 1-H fuel moisture [1-60%] 3 10H ¹10-H fuel moisture [1-60%] 100H ¹100-H fuel moisture 4 [1-60%] 5 HERB ¹Live herb moisture [30-300%] 90 WOOD ¹Live woody moisture [30-300%] 6 4 7 **MFWS** Midflame windspeed [0-99 mi/h] 8 SLP Slope [0-100%/ 0-45 degrees] 9 WDIR ²Direction of wind [0-360 degrees] vector, deg. clockwise from uphill PREDICT AT MAX (Y/N) 10 Direction of spread [0-360 degrees] SDIR calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) 0 No more tables 1 ROS Rate of spread ch/h Btu/ft² Heat per unit area 2 H/A 3 FLI Fireline intensity Btu/ft/s FL Flame length 4 11,445 Btu/ft²/min 10,893 5 RI Reaction intensity 11.175 Effective windspeed 6 **EWS** mi/h in direction SDIR 7 ³Direction of maximum MAXD degrees spread, deg. clockwise from uphill

Exhibit 14b.—Second DIRECT run for linking to TWO in exhibit 14c.

¹Input only if corresponding fuel load is not zero.
²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
³Output only if calculations are in direction of maximum spread.

TWO MODULE (English Units)

(Keywords: Input, List, Run, Quit)

5	WDTE	Polifection of v vector, deg. c from uphili	Column Va	alues: 30	wind voc	Table Values	70
					ena most		
TABLE	NO1	TABLE ITEM:	Weighted ROS	ROW ITEM	_IH	COL. ITEM	Covi
1	ROS	Rate of spread	[seergeb 098-0] ch/h	n of wind leg. clockwise		AIGW	
OUTPUT	(Run)						
		first model					
5	COV1		verage [20-80	2/6]	30	50	70
NPUT	(Input, List)	Euda Que a					9
4	ROS2	Spread rate for	second model	± molsture	61	_ 59	56
3	ROS1	Spread rate for	first model	moisture	50	39	E
2	MODEL2	Second model re	un by DIRECT		-0	20	^
	MODEL1	First model run	by DIRECT			100	
1							

Exhibit 14c.—Linked TWO run using spread rates calculated for two models in exhibits 14a and 14b.

Linked MAP Runs

Linking to MAP from SIZE, SPOT, and DIRECT results in automatic selection of the MAP units option 1, 2, and 3, respectively. SIZE passes three distances to MAP—forward spread distance, backing spread distance, and maximum fire width. These three distances change the input item names on the independent MAP input

2		40.0	60.0	8 0 . 0 SIZE	<u>L</u> ist
-did-	ROS	40.0	60.0	80.0	
3 4	AREA PER L/W FSD BSD MXW	2 4 9 1 9 9 2 . 3 8 0 . 0 4 . 4 3 7 . 5	559 298 2.3 120.0 6.6 56.3	995 397 2.3 160.0 8.8 75.0	Run
1 3 4 5 6 7	UNITS		2 1. 1 1 2 0 . 0 6 . 6 5 6 . 3	0 0 0 0 1 6 0 . 0 8 . 8 7 5 . 0	<u>L</u> ist
3 4 5 6 7 ==	SCL OF IN/MI UNITS FSD BSD	OPT 80.0 4.4	1 . 1 1 2 0 . 0 6 . 6	160.0 8.8	List

Exhibit 15.—Example of SIZE run followed by link to MAP.

sheets, and result in the three output map distances. SPOT passes a maximum spotting distance in miles. DIRECT passes a rate of spread to MAP where spread time is needed for MAP to calculate forward spread distance. Exhibits 15, 16, and 17 show examples of these different linked runs. A printer was used as a list device, but if no printer is attached, the same output can be seen on the display by stepping through the lists.



Exhibit 16.—Example of SPOT run followed by link to MAP.

1 2 3 4 5 7 8 9	10H 100H HERB MFWS SLP WDIR SDIR	8.0 10.0 12.0 80 5 10 90	7 M	1 0	DIRECT	<u>L</u> ist
	====== MFWS	5	7	10	A S Soond	
1 2 3 4 5 6 7	H / A 4 4 F L I 2 F L 6 R I 3 3	3 5 6 3 9 4 6 . 2 8 5 7 3 6 . 0	6 2 4 6 3 5 2 9 8 . 1 3 5 7 7 . 0 8 9	1 1 8 46 3 9 9 9 1 0 . 8 3 3 5 7 1 0 . 0 9 0	DIRECT	Run
1 3 4 7 8	SCL OF IN/MI UNITS ROS 3 TIME 3	OPT 35 2.0	2 1 3 6 2	. 0 0 0	MAP	<u>L</u> ist
	M F W S	5	7	10	MAR	Dun
1	MFSD		1.6	A A	MAP	Run

Exhibit 17.—Example of DIRECT run followed by link to MAP.

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APPENDIX A: DATA SHEETS, ENGLISH UNITS OF MEASURE



(Keywords: Get, Input, List, Save, Quit, List Models, Delete Models)

INPUT LIST (Input, List)

1	MODEL #	Fuel model number	(14 - 99)
2	NAME	Fuel model name	(22 char. max.)
3	1HR LOAD	1-hour load	(0.01-30 tons/acre)
4	10HR LOAD	10-hour load	(0-30 tons/acre)
5	100HR LOAD	100-hour load	(0-30 tons/acre)
6	HERB LOAD	Live herb load	(0-30 tons/acre)
7	WOOD LOAD	Live woody load	(0-30 tons/acre)
8	1HR S/V	1-hour surface/volume ratio	(1,200-3,500 ft ² /ft ³)
9	HERB S/V	¹ Herb surface/volume ratio	(1,200-3,500 ft ² /ft ³)
10	WOOD S/V	² Woody surface/volume ratio	(1,200-3,500 ft ² /ft ³)
11	DEPTH	Fuel bed depth	(0.1 - 10 ft)
12	HEAT	Fuel heat content	(7,000-12,000 Btu/lb)
13	MOIS EXT	Dead fuel extinction moisture	(10 - 50%)
14	STATIC-DYNAM	Static or dynamic model	(0 or 1)
		0 = static or herb load is zero	
		1 = dynamic	
15	WIND FACTOR	Exposed fuel wind adjustment factor	(0.01 - 1)

¹Input only if herb load is greater than zero. ²Input only if wood load is greater than zero.

APPENDIX A: (Con.)

	Aller and the second se
OKANES!	(14 - 99) Land model numbers (14 - 99)
7.	xxxxx (22 oher max) or
	(experience (6-10.9)
	(e-30 tons/acres) General Beell works (e-30 tons/acres)
33 483	16 (erosiènes (66-9). Bus tais Reportiugnoet au GAGG MATION
2 8 1	(experience 98-0) . Hurgan, Beet that average space 19851 or
0 7.0	(grossenot 00-0) user basi kbgog avid - QAOI GDOW
0.0	Fin's DOS, E-000, 1) Oltan activioristic states and Fine activity
****	HERB SAV Here surface volume ratio (1,200-3,500 ns/pg ===
	City Silv
	Operation of the contract of t
6. 6.2	(dluys 000,51-000,7) Serting rice dead death Forest and Rath, 40 an
	Jacob - Or) enutaiom noticing a leut a self a self leut a self leu
5355XX	The state of the contract of t
100	beot died to tilete = 0 Agriculture, Perest Service
0 0 0 0 0 0 0 0	FREEZE) MAP - Buy Rotherson A C. See to predict the orrest and
	nity of thems that change first. Unitered Texanic

DIRECT MODULE (English Units)

LIST NUMBER (Keywords: Input, List, Run, Quit, Slze, SCorch, MAp, TWo) INPUT (Input, List) 1 MODEL # Fuel model number (1-99)2 1H 1-H fuel moisture [1-60%] 3 10H ¹10-H fuel moisture [1-60%] 100H 1100-H fuel moisture 4 [1-60%] 5 HERB ¹Live herb moisture [30-300%] 6 WOOD ¹Live woody moisture [30-300%] **MFWS** Midflame windspeed [0-99 mi/h] 8 SLP Slope [0-100% or 0-45 degrees] 9 WDIR ²Direction of wind [0-360 degrees] vector, deg. clockwise from uphill PREDICT AT MAX (Y/N) [0-360 degrees] 10 SDIR Direction of spread calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) 0 No more tables ROS ch/h 1 Rate of spread 2 Btu/ft² H/A Heat per unit area Btu/ft/s 3 FLI Fireline intensity ft FL Flame length 4 Btu/ft²/min 5 RI Reaction intensity 6 **EWS** Effective windspeed mi/h in direction SDIR ³Direction of maximum degrees 7 MAXD spread, deg. clockwise from uphill

¹Input only if corresponding fuel load is not zero.
²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero.
³Output only if calculations are in direction of maximum spread.

SIZE MODULE (English Units)

		OIZE INC	10011			
				LIST NUMBER		
		(Keywords: Inpu	ıt, List, Run, M.	Ap, ¹ COntain, Quit)		
INPUT	(Input, List)					
1	ROS	² Rate of spread	[0.1-500	ch/h]	# 3ECRO16	
	EWS	² Effective windspeed	[0-99 m	i/h] enutation leut as-t	HI	S
2		Elapsed time	[0.1 - 8		HOT	4
3	ET	Elapsed time	[6908-1]	100-H fuel moisture	HOOT	
OUTPUT	(<u>R</u> un)					
0		No more tables				
1	AREA	Area	acres	beegebrily smsNbiM	MEWS	¥
2	PER	Perimeter	ch	State	9,18	8
3	L/W	Length-to-width ratio	0-45 degre			
4	FSD	Forward spread dist	ance ch	balw 1 5 - 61 - 610	inter//	- 9
5	BSD	Backing spread dista	ance ch	vector deg. clockwise		
6	MXW	Maximum fire width	ch	Hindu mon	TX TOWNSHIP	

¹SIZE can link to CONTAIN only if linked to DIRECT.
²Input only when SIZE is used as an independent module.



CONTAIN MODULE (English Units)

LIST NUMBER

(Keywords: Input, List, Run, Quit)

		(Keywords: Inc	out, List, F	Somos pusidents		
INPUT	(Input, List)					
1	RUN OPT	Run option	(1 or 2)			
		1 = calculate total line building rate				
		2 = calculate burned				
2	ATTACK OPT	area Attack option	(1 or 2)		AVEL	
		1 = head				
		2 = rear				
3	ROS	¹ Rate of spread	[0.1-500	ch/h] ch/h]	SRC LOC	<u> </u>
4	AREA	¹ Initial fire area	[0.1-100	acres]		
5	L/W	¹ Length-to-width ratio	[1-5]	1 - valley bottom		
6	BAT	² Burned area target	[0.1-2000	acres]		
7	TLBR	³ Total line building rate	[0.1-800		os <u>Values</u>	
OUTPUT	(Run)					
1	PER	Total length of line	chains	rga nhamlagna t		
2	TIME	Containment time	hours	2 × Douglas-lir.		
3	FFS	⁴ Final fire size	acres	subalpine fir		
3	TLBR	⁵ Total line building rate	ch/h	4 = ponderosa, lod	_	
4	MAXA	⁵ Maximum area calculable	acres	poie pine		
5	MINA	⁵ Minimum area calculable	acres	6 = balsam fir,		

Error Codes:

- -1 = Burned area target too large, cannot calculate slow enough line building rate
- -2 = Line building rate too slow to catch fire
- -3 = L/W ratio too large
- -4 = Burned area target too close to initial fire size
- -5 = Line building rate too fast

⁴Output only for run option = 2. ⁵Output only for run option = 1.



¹Input only when CONTAIN is used as an independent module.

²Input only for run option = 1 (calculate total line building rate).

³Input only for run option = 2 (calculate burned area target).

SPOT MODULE (English Units)

LIST NUMBER (Keywords: Input, List, Run, MAp, Quit) (Input, List) INPUT (1-3)Firebrand source BRAND SRC 1 1 = torching trees 2 = burning piles 3 = wind-driven surface fire [0-300 ft] Mean cover height MCHT 2 [0-99 mi/h] 20-ft windspeed 20'W 3 [0-4,000 ft] Ridge-to-valley 1 RVEL elevation difference [0-4 mi] Ridge-to-valley horiz. 5 RVHD distance (0-3)Spotting source location SRC LOC 6 0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward side 3 = ridgetop (1-6)¹Tree species TREE SP 7 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir [5-40 inches] ¹Torching tree DBH DBH 8 [10-300 ft] ¹Torching tree height TRHT 9 [1-30] ¹Number of torching trees 10 #TR [1-100 ft] ²Continuous flame height FLHT 11 [0.1-50 ft] 3Flame length FL 12 (1-99)³Fuel model MODEL # 13 [30-300%] HERB ⁴Herbaceous moisture 14 OUTPUT (Run) mi Maximum spotting SPOT distance

¹Input only for firebrand source = 1 (torching tree option). ²Input only for firebrand source = 2 (burning pile option).

³Input only for firebrand source = 3 (wind-driven surface fire option). ⁴Input only for dynamic fuel models with a herbaceous fuel load.



SCORCH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperatu	ure [33-120 °F	Ambient air temperatu	TEMP	1
2	FL	¹ Flame length	[0.1-20 ft]	t-h tuel moisture	H	2.
3	MFWS	¹ Midflame windspeed	[0-10 mi/h]	Shade*	SHAD	8
OUTPUT	(Run)					
1,1	SCHT	Scorch height	feet	Probability of Ignition	P(1)	T
¹ Input only	if SCORCH is used	as an independent module.				
	BURK DAY	Day or eligi				
TABLE	NO. 1	TABLE ITEM: Scorch he	eight	ROW ITEM	COL. ITEM	
		Time of burn		1		
FUEL	MODEL					
			Column Values:	<u> </u>		
Row No.	Row	Value		Table \	/alues	
	1 -	Slope steephers		BF		
	2	Elevation of Sta		(<u> </u>		
	3	iocatign				

IGNITE MODULE (English Units)

(Keywords: Input, List, Run, Quit)

NPUT					
AF OT	(Input, List)				
1	TEMP	Ambient air temperature	[33-120 °F]	TEMP	*
2	1H	1-h fuel moisture	[1-60%]		2
3	SHAD	Shade	[0-100%]	21/51/4	
UTPUT	(Run)				
1 3	P(I)	Probability of ignition	pct (199 min) justice 1		
TABLE	NO1	TABLE ITEM: Prob. of Igni	ition ROW ITEM	COL. ITEM _	3.10A7
TABLE	NO1	Sporting source locally	ROW ITEM	COL. ITEM _	3.10AT
TABLE	NO1	Sporting source length of a midslope, window side	(0-3)	COL. ITEM _	3JBAT
TABLE	NO1	Sporting source length of a midslope, window side	olumn Values:		310.47
6	SRG LOC	Sporting source length of a midslope, window side	olumn Values:	COL. ITEM	ol/ was
6	SRG LOC	Sporting source lesses or a missione, missione communication communicat	olumn Values:		a roar
TABLE	Row	Sporting source lesses or a missione, missione communication communicat	olumn Values: Tab		old wor



MOISTURE MODULE (English Units)

		AUN TSLI	DET NUMBE		
			LIST NUMBER	W NOOMBEE	EARLY
		(Keywords: Inpo	ut, <u>List, Run, Q</u> uit)		
INPUT	(Input, List)				
1	RUN OPT	Run option	(1 or 2) yabimun -	HAN	
		1 = Burn time calculations 2 = Hourly calculations			
TIME AN	ID LOCATION				
2	BURN MONTH	Month of burn	(1-12) senisari 0047 yab muS		
3	BURN DAY	Day of burn	(1-31) VIE 18910 VIEV = 1		
4	LATITUDE	Latitude of fire	(-90 to 90 degrees)		
5	BURN TIME	Time of burn	(0-2,359 h)		
FUEL M			moderate smoke		
		1 = the tool not see	(4.00)		
6	MODEL #	Fuel model number	(1-99)	TRR	
SLOPE,	ELEVATION, ASPE	<u>CT</u>			
11	SLP	Slope steepness	[0-100% or	SSW	28
12	ELFL	Elevation of fire location	[0-12,000 ft]	8800	- 30
	RH OBS AT FIR	E weather pattern office g	(Y/N)	E WEATHER	
13	ELOB	Elevation of T&RH	(0-12,000 ft)	TRA	
	PM-5	observations	Sunrise relative humidity		
14	ASPECT	Aspect of fire location 0 = north 180 = south	(0-360 degrees)	SR#	
		90 = east 270 = west			
TIMBER	OVERSTORY DES	CRIPTION			
15	CCLO	Crown closure	[0-100%]	TTB	35
16	FOLIAGE	Foliage presence	(0 or 1)	нята	
		0 = absent 1 = present			
17	SHADE TOL	Shade tolerance	(0 or 1) 000 buolo amb mas		
		0 = intolerant 1 = tolerant			
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)		
19	AVHT	Average tree height	[10-300 ft]		
20	H/H	Crown height/tree height ratio	[0.1-1] exioms statebom		
21	H/D	Crown height/crown diameter ratio	[0.2-5]		

MOISTURE MODULE (continued, English Units)

22	14T	Burn day 1400 temperature	[33-120 °F]	-	Tiels (maril)	1994
23	14RH	Burn day 1400 relative humidity	[1-100%]	go nor	— 130 иол	-
24	14W	Burn day 1400 20-ft windspeed	[0-99 mi/h]			
25	14CC	Burn day cloud cover	[0-100%]		ND LOCATION	A BAST
26	14HZ	Burn day 1400 haziness	[1-4] mud to	Month	HTMOM MRUS	5
		1 = very clear sky				
		2 = average clear forest				
		atmosphere 3 = moderate blue haze				
		4 = dense haze— moderate smoke				
SUNSE	T WEATHER					
27	SST	Sunset temperature	[33-120 °F]		ELEVATION, ASP	390.18
28	SSRH	Sunset relative humidity	[1-100%]	je <u>egola</u>	0.10	. 11
29	SSW	Sunset 20-ft windspeed	[0-99 mi/h]			
30	SSCC	Sunset cloud cover	[0-100%]	Elevation	1918	\$1
	SE WEATHER					
31	SRT	Sunrise temperature	[33-120 °F]	Elavation	80.15	13
	SRRH	Sunrise relative humidity	[1-100%]	svisado		
32	SRW	Sunrise 20-ft windspeed	[0-99 mi/h]	Aspect o	ASPECT	MI -
33		Sunrise cloud cover	[0-100%]	90 = eas		
34	SRCC			CRIPTION		
BURN	TIME WEATHER		[33-120 °F]			
35	BTT	Burn time temperature		Foliage p	FOLIAGE	81
36	BTRH	Burn time relative humidity		eda = U	NEW COLUMN	
37	BTW	Burn time 20-ft windspeed	[0-99 mi/h]		HOT BRIADE	51
38	ВТСС	Burn time cloud cover	inerelt	Shade tol	200 00000	
39	BTHZ	Burn time haziness	[1-4]	eloi 		
		1 = very clear sky				

2 = average clear forest atmosphere3 = moderate blue haze4 = dense haze—

moderate smoke

MOISTURE MODULE (continued, English Units)

LIST NUMBER **BURN TIME WIND** (1-5) 40 **EXPOSURE** Exposure of fuels to wind 1 = exposed2 = partially sheltered 3 = fully shelteredopen stand 4 = fully sheltereddense stand 5 = direct entry of wind adjustment factor 41 WAF Wind adjustment factor (0-1)Exposure 5 only MOISTURE INITIALIZATION OPTION MOIS OPT Moisture initialization option 43 (1-5)1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing **MOISTURE OPTION 1** Burn day -1 fine fuel moisture [1-100%] FM-1 44 **MOISTURE OPTION 3** 51 RDAY Number of days before burn [1-7 days] that rain occurred 52 RAIN Rain amount, hundredths of [0-400]an inch [33-120 °F] 53 RDT 1400 temperature on rain day SKY CODE Sky condition from rain day (1-3)54 to burn day 1 = clear 2 = cloudv3 = partly cloudy **MOISTURE OPTION 4** No additional input.

MOISTURE MODULE (continued, English Units)

		LIST NUMB	LIST NUMBER		
	E OF HOR 5	Burn day -1 1400 temperature	[33-120 °F]	EXPOSURE	08
55 56	TD-1	Burn day - 1 1400 relative humidity	[1-100%]		
57	WD-1	Burn day -1 1400 20-ft windspeed	[0-99 mi/h]		
58	CD-1	Burn day -1 1400 cloud cover	[0-100%]	All residence and the second	
59	WTHR	Weather condition prior to burn day -1	[1-3] W to vitne tostib = 2	WAF	14
		1 = hot and dry 2 = cool and wet 3 = between 1 and 2		URE INITIALIZAT	
		3 = Detween Fand 2			
OUTPUT 1	(Run) MOIS	1-hour fuel moisture	pct shallow real engles to		
2	TEMP	Fuel level temperature	135 (20 °F) 0400		
3	%RH	Fuel level relative humidity	3 = incomplete defections		
4	SHAD	Percent of area shaded	pct		
5	P(I)	Probability of ignition	the week before buret 5 = Incomplate data;		
39					

APPENDIX A: (Con.)

MOISTURE MODULE (continued, English Units)

				LIS	ST NUMBE	R	
HOURL	Y OUTPUT (Run)						
	TIME	FM	OIST	FTEMP			FRH
		F	oct (\$ 00 t)	°F			pct
	14			prosentative	1 = Re		
	15	Scale option	(1 or 1				
	16	1 - Represen	(1-50 <u>0)</u>		*Rep <u>resen</u>	RF/1000	2
	17	traction 2 × Inches pa	and the second		fractioni e.g., P.C.		
	18	'Representative	(8.85)0(0)800		Anch <u>es ac</u>	IM\MI	3
	19	e.g., RF of 100	<u> </u>	lon noi	Units opi	UNITS OPT	4
	20	Finches her mile	**************************************	read distance (8.8	1 = 8c		
	21	Contour interval	(10.50	or distance			
	22					DIST	a
	23	Number of cont	ees am or tid 100	sons	Spot dist		
	24	intervala	[0.1-600 chih]	pread	e to staffe	ROS	\$ T
	(Run) 1		[rt 8:1.0]	emi	t beegel3a	TIME	8
	2		nlo	spread distance	Forward	PSD	ð
	3	Slope steephes	rio	spread distance	*Backing		9
	SLP DEG	Slope atonymia	- do Sil	diplw ent i	mumixeM ^a	WXM	- N
	4	Elevatio n shart				(<u>nup</u>)	TURTUC
	5	Hofizor <u>ist fibe</u>	Inches	soread distance on		G8 191	1
	for some one a		inches	spot distance		MSPT	1
	8			JULIES OPT = 2)			
	9		Inches	spread distance SIZE (Inked only)		USAM	7
	10		Inches	no dtblw eni		WXMM	8
	11			E linked only)	map (SIZI		
Burn Ti						r scale option = 2 r scale option = 2 r units option = 1 r units option = 2	



MAP MODULE (English Units)

			LIST	IUMBER
		(Keywords: Inpu	t, <u>L</u> ist, <u>R</u> un, <u>Q</u> uit)	
INPUT	(Input, List)			
Pot F	SCL OPT	Scale option 1 = Representative	(1 or 2)	<u> </u>
		fraction 2 = Inches per mile		
2	RF/1000	¹ Representative	(1-500)	<u>at</u>
		fraction/1,000 e.g., RF of 1/24,000 = 24		
3	IN/MI	² Inches per mile	(0.0625-8)	81
4	UNITS OPT	Units option	(1-3)	81
		1 = Spread distance 2 = Spot distance		
		3 = Rate of spread		
5	DIST	³ Spread distance	[0-1000 ch]	22
6	SPOT	⁴ Spot distance	[0.1-10 mi]	23
7	ROS	⁵ Rate of spread	[0.1-500 ch/h]	24
8	TIME	⁵ Elapsed time	[0.1-8 h]	
5	FSD	⁶ Forward spread distance	ch	
6	BSD	⁶ Backing spread distance	ch	
7	MXW	⁶ Maximum fire width	ch	* **
OUTPUT	(Run)			
1	MFSD	Forward spread distance on map (UNITS OPT = 1 or 3)	inches	0
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	inches	8
2	MBSD	Backing spread distance on map (SIZE linked only)	inches	2
3	MMXW	Maximum fire width on	inches	01

¹Input only for scale option = 1.

²Input only for scale option = 2.

³Input only for units option = 1.

⁴Input only for units option = 2.

⁵Input only for units option = 3.

⁶Passed from SIZE for linked run only. No input is needed.



SLOPE MODULE (English Units)

		OLOI E MODE	JEE (Eligiloti Cinto)		
			LIST NUMBER	٦	
		(Keywords: <u>I</u> r	nput, List, Run, Quit)		
		From Point	to Pointagebuily #1-05		
INPUT	(Input, List)				
CHTPU	SCL OPT	Scale option	(1 or 2) sensitive villatines = S		
		1 = Representative			
		fraction 2 = Inches per mile			
2	RF/1000	¹ Representative	(1-500) tallos briw toine = 6		
		fraction/1,000 e.g., RF of 1/24,000 = 24			
3	IN/MI	² Inches per mile	(0.0625-8)	MODEL #	
4	CON INT	Contour interval	(10-500 ft)	(nuA)	
5	MAP DIST	Map distance	(0.1-10 in)	NMEWS00	
6	# INTVLS	Number of contour intervals	(1-100)	or exposure a 5.	
OUTPUT	(<u>R</u> un)				
1	SLP %	Slope steepness	pct	COLO 9 ENGINEES	
2	SLP DEG	Slope steepness	degrees		
3	EL DIFF	Elevation change	feet		
4	HORIZ DIST	Horizontal distance	feet		

¹Input only for scale option = 1.

 $^{^{2}}$ Input only for scale option = 2.

WIND ADJUSTMENT MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)				
1	20'W	20-ft windspeed [0-99 mi/h]	From		
2	EXPOSURE	Exposure to wind (1-5)			
		1 = exposed			
		2 = partially sheltered 3 = fully sheltered,			
		5 = enter wind adjust- ment factor			
3	WAF	¹ Wind adjustment factor (0-1)	e.g., RF of 1/24,000		
4	MODEL #	² Fuel model number (1-99)	elim req serionis .	188M	
OUTPUT	(Run)				
1	MFWS	Midflame windspeed mi/h	Map distance	MAP DIST	5
	DIST.	Scar distance (00f-k)+10 mil			
¹ Input only	for exposure = 5.				

Input only for exposur

 $^{^{2}}$ Input only for exposure = 1.



RH MODULE (English Units)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1.00	DRYB	Dry bulb tempera	ature	[33-120 °F]	TOBRIO MORS	PASSEG
2	WETB	Wet bulb temper	ature	[0-120 °F]	MODELI	t
3	EL	Elevation		[0-12,000 ft]	MODEL2	2
OUTPUT	(Run)					
1	%RH	Relative humidity	y	pct on broose tol etal osela?	ROSZ	
2	DEWP	Dew point		°F	rab(Jalubulught)	IMPUT
ERROR C	ODES:					
-888 = V	Vet bulb temp	erature greater than				
-999 = D	ew point too	cold for valid calcula	ations			
•			ch/h	Rate of spread	ROS	1
				DOWNTEN	OOL ITEM	
TABLE	NO1			ROW ITEM		
				ARLE ITEM: Weighted ROS		
			C	Column Values:		
Row No.	Ro	ow Value		Colum	Table Values	
now no.		yw vardo				Row No.
	2					
	3				2	
	3				2 2 3	
TABLE	3	TABLE ITEM:	DEWP	ROW ITEM	COL. ITEM	
TABLE	3	TABLE ITEM:		ROW ITEM	COL. ITEM	
TABLE	3 NO2	TABLE ITEM:		Column Values:	COL. ITEM	
	3 NO2			Column Values:		
	3 NO. 2			Column Values:		
	3 NO. 2			Column Values:		



TWO MODULE (English Units)

PASSED F		(110) 1101 401 111	ut, <u>L</u> ist, <u>R</u> un, <u>Q</u> uit)	
	FROM DIRECT	(List) 170 001-88		
1	MODEL1	First model run by DIRECT		
2	MODEL2	Second model run by DIRECT		3 EL
3	ROS1	Spread rate for first model		(muA) TU9TUO
4	ROS2	Spread rate for second model	Relative humidity	HA62 1
INPUT	(Input, List)	4 - fully shellered,		2 DEWP
		stoded stend		
5	COV1		[20-80%]	regmet diud teW = 888 -
OUTPUT	(Run)			
1	ROS	Rate of spread	ch/h	
UTPUT	(Aum)	Thate of spread	- Clari	
4	COEMIEM	MidnemeMQTbW09d	ABLE ITEM: 96RH PL	TABLE NO. 1
		uma Values:	lumn Values:	
			lumin values.	
	Day			
Row No.	HO	w Value		able Values
Row No.	1			
Row No.				
Row No.	1			
Row No.	1 2		BLE ITEM: DEWP	able Values



OUTPUT TABLES

			LIST NUI	MBER	
Model (Control	Number	<u> </u>	ial Bame (9) akeroman maumo	ST (input, List)	LI TUSM
TABLE NO	TABLE ITEM:	(14 - 99)	ROW ITEM	COL. ITEM _	t
	(SINS)	OT M. 01-20.01	DECT SUCTE	GACU TIAT	37
			Column Values:	10HR LOAD	4
Row No.	Row Value			Table Values	
1	(67)		Live woody load	WOOD COAD	
2	70		olten emulovleostnus ruoni i	MS AG	8
3	(911)		ottar emulevelvelume ratto	vic an3ri	W.
	(6)	(AP)	Woody Surface/volume ratio	Als dools	04
74545 NO	TABLEITEM	(mo 00£-t)	ROW ITEM	COL. ITEM	
TABLE NO	TABLE ITEM	(15,000-30,000 joules(g)	Fuel heat content	TASH	12
		(10 - 50%)	Dead fuel extinction moisture	MOIS EXT	13
			Column Values:	STATIO-DYNAM	14
Row No.	Row Value			Table Values	
1			olm anyb r		
2		(110.0)	Expand fuel wind	- VIND EACTOR	- 31
3			adjust man factor		
				COL ITEM	
TABLE NO	TABLE ITEM:		ROW ITEM	COL. ITEM _	
			Column Values:		
			5/6		
Row No.	Row Value			Table Values	
1	-				
2					
3					



APPENDIX B: DATA SHEETS, METRIC UNITS OF MEASURE

FUEL MODEL MODULE (Metric)

(Keywords: Get, Input, List, Save, Quit, List Models, Delete Models)

INPUT LIS	T (Input, List)				
1	MODEL #	Fuel model number	(14 - 99)	1 3.18AT	TABLE NO
2	NAME	Fuel model name	(22 char. max.)		
3	1HR LOAD	1-hour load	(0.02-70 M tons/ha		
4	10HR LOAD	10-hour load	(0-70 M tons/ha)		
5	100HR LOAD	100-hour load	(0-70 M tons/ha)	Row Value	Row No.
6	HERB LOAD	Live herb load	(0-70 M tons/ha)	GOTTO A - M-DET	2000 10000
7	WOOD LOAD	Live woody load	(0-70 M tons/ha)		0
8	1HR S/V	1-hour surface/volume ratio	(40-120 cm ² /cm ³)		
9	HERB S/V	¹ Herb surface/volume ratio	(40-120 cm ² /cm ³)		
10	WOOD S/V	² Woody surface/volume ratio	(40-120 cm ² /cm ³)		
11	DEPTH	Fuel bed depth	(1-300 cm)	BUEAT	JAI SJIÐAT
12	HEAT	Fuel heat content	(15,000-30,000 joules/g)	(66.)	TEM
13	MOIS EXT	Dead fuel extinction moisture	(10 - 50%)		
14	STATIC-DYNAM	Static or dynamic model	(0 or 1)		
		0 = static or herb load is zero			
		1 = dynamic			
15	WIND FACTOR	Exposed fuel wind	(0.01 - 1)		3
		adjustment factor			

¹Input only if herb load is greater than zero. ²Input only if wood load is greater than zero.

APPENDIX B: (Con.)



USER FUEL MODEL FILE CONTENTS (List Models)

Model Number	Model Name	(22 characters maximum)		
£ 000 20	(98-1)	Fuel model number	MODEL	
The state of the s	[8908-1]	TH fuel moisture	HI	-2-
	[6008-1]	enutaion leuf H-01 ⁻¹	HOL	
	[6908-F]	amtalom leut H-0011	H001	
	[30-300%]	'Live nerb moisture	BR3H.	8
V N	[48008-08]	Live woody moisture	MOOB	
A AUGU A)	[0-160 km/h]	beegsbrilw smallbild-	MFW8	
2 200 20	10-10090 10	Slope	918	
3 1784 18	[anargeb. 84-0			
6 anyto as	[0.360 degraps]	Direction of wind vestor, deg. clockwise from ushill	RIGW	
	(MVX)	XAM	PREDICT AT	
d coly when SIZE to used as an in	10-260 decreeb case of	Direction of speed calc., deg. clockwise trom uphilit ou from wind yeater. If slope is zero)	RIDS	
			(auB)	
		No more tables		
	n/m/m	Rate of spread	808	
	Kjouleshm ²	Heat per unit area	Alth	2 .
	kwatts/in	Fireline intensity	UF	
				4.4
				. а
				8.



APPENDIX B: (Con.)

DIRECT MODULE (Metric)

LIST NUMBER (Keywords: Input, List, Run, Quit, Slze, SCorch, MAp, TWo) INPUT (Input, List) Fuel model number (1-99)MODEL # 1 [1-60%] 1-H fuel moisture 1H 2 [1-60%] ¹10-H fuel moisture 3 10H [1-60%] 1100-H fuel moisture 100H 4 [30-300%] ¹Live herb moisture 5 HERB [30-300%] ¹Live woody moisture WOOD 6 [0-160 km/h] Midflame windspeed **MFWS** 7 [0-100% or SLP Slope 8 0-45 degrees] [0-360 degrees] ²Direction of wind WDIR 9 vector, deg. clockwise from uphill (Y/N) PREDICT AT MAX [0-360 degrees] Direction of spread SDIR 10 calc., deg. clockwise from uphill (or from wind vector if slope is zero) OUTPUT (Run) No more tables 0 m/min Rate of spread ROS 1 kjoules/m² Heat per unit area 2 H/A kwatts/m Fireline intensity FLI 3 m Flame length FL 4 kwatts/m² Reaction intensity RI 5 km/h Effective windspeed **EWS** 6 in direction SDIR degrees 3Direction of maximum 7 MAXD

from uphill

spread, deg. clockwise

Input only if corresponding fuel load is not zero.

²Input only if midflame windspeed (MFWS) and slope (SLP) are not zero. ³Output only if calculations are in direction of maximum spread.



SIZE MODULE (Metric)

				LIST NUMB	ER	
		(Keywords: Input, Lis	t, Run, MAp, 1Co	Ontain, Quit)		
INPUT	(Input, List)					
1	ROS	² Rate of spread	[0.03-170 m/m	in]		
2	EWS	² Effective windspeed	[0-160 km/h]	notiqu nun	THO NUA	
3	ET	Elapsed time	[0.1 - 8 h]	s esculate t		
OUTPUT	(Run)		in-ten bemte	f etaluatea - C		
0		No more tables				
1	AREA	Area	ha			
2	PER	Perimeter	m	beed - f		
3	L/W	Length-to-width ratio		2 = rear	P LA LONG	
4	FSD	Forward spread distance	m	Rate of spread	80F	ε
5	BSD	Backing spread distance	m	Unities fire area	AREA	
6	MXW	Maximum fire width	e m	"Length-to-width	Wu	a
				Plannad area ten	TAR	(N)

¹SIZE can link to CONTAIN only if linked to DIRECT.



²Input only when SIZE is used as an independent module.

CONTAIN MODULE (Metric)

				LIST NUMBER		
		(Keywords: Inp	out, List, Run, Qui	it)		
INPUT	(Input, List)					
1	RUN OPT	Run option	(1 or 2)		ow 3	
		1 = calculate total line building rate				
		2 = calculate burned area				
2	ATTACK OPT	Attack option	(1 or 2)		A 255 A	
		1 = head				
		2 = rear				
3	ROS	¹ Rate of spread	[0.03-170 m/min]	Ser go brawnoll	023	<u> </u>
4	AREA	¹ Initial fire area	[0.05-50 ha]	Backlag op 1936	<u></u>	3
5	L/W	¹ Length-to-width ratio	[1-5]	gril mumicett	WYM-	3
6	BAT	² Burned area target	[0.1-1000 ha]	TUESTIC OF GENERAL NO.	CONTRACTOR OF S	nic nico 3300
7	TLBR	³ Total line building rate	[0.1-250 m/min]	ned medependent med	nen SiZE is used a	M Atuo Indise.
ОИТРИТ	(Run)					
1	PER	Total length of line	m			
2	TIME	Containment time	hours			
3	FFS	⁴ Final fire size	ha			
3	TLBR	⁵ Total line building rate	m/min			
4	MAXA	⁵ Maximum area calculable	ha			
5	MINA	⁵ Minimum area calculable	ha			

Error Codes:

- -1 = Burned area target too large, cannot calculate slow enough line building rate
- -2 = Line building rate too slow to catch fire
- -3 = L/W ratio too large
- -4 = Burned area target too close to initial fire size
- -5 = Line building rate too fast

Input only when CONTAIN is used as an independent module. ²Input only for run option = 1 (calculate total line building rate).

³Input only for run option = 2 (calculate burned area target).

⁴Output only for run option = 2.

⁵Output only for run option = 1.



SPOT MODULE (Metric)

LIST NUMBER (Keywords: Input, List, Run, MAp, Quit) INPUT (Input, List) 1 **BRAND SRC** Firebrand source (1-3)1 = torching trees 2 = burning piles 3 = wind-driven surface fire 2 MCHT Mean cover height [0-100 m] **10MW** [0-160 km/h] 3 10-meter windspeed RVEL Ridge-to-valley [0-1,500 m] 4 elevation difference 5 RVHD Ridge-to-valley horiz. [0-6 km] distance 6 SRC LOC Spotting source location (0-3)0 = midslope, windward side 1 = valley bottom 2 = midslope, leeward 3 = ridgetop (1-6)TREE SP ¹Tree species 1 = Engelmann spruce 2 = Douglas-fir, subalpine fir 3 = hemlock 4 = ponderosa, lodgepole pine 5 = white pine 6 = balsam fir, grand fir ¹Torching tree DBH [10-100 cm] 8 DBH [1-100 m] ¹Torching tree height 9 TRHT ¹Number of torching trees 10 #TR [1-30] FLHT ²Continuous flame height [0.1-30 m] 11 [0.03-15 m] 3Flame length 12 FL 13 MODEL# ³Fuel model (1-99)HERB 14 ⁴Herbaceous moisture [30-300%] OUTPUT (Run) km Maximum spotting SPOT



¹Input only for firebrand source = 1 (torching tree option). ²Input only for firebrand source = 2 (burning pile option).

distance

³Input only for firebrand source = 3 (wind-driven surface fire option). ⁴Input only for dynamic fuel models with a herbaceous fuel load.

APPENDIX B: (Con.)

SCORCH MODULE (Metric)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
	TEMP	Ambient air temperature	[0-50 °C]	agent pai <u>rhant = t</u>		
1		¹ Flame length	[0.03-5 m]			
2		¹ Midflame windspeed	[0-16 km/h	navinb-briw = E		
3	MFWS	in our		Mean cover height	THOM	2
OUTPUT	(Run)	Scorch height	0]			
1	SCHT	Scorch neight		Ridge-to-valley	RVEL	4
¹ Input only	if SCORCH is use	ed as an independent module.				
		t trace [mal 6	0)	Ridge to valley hode:	The PURT	7
TABLE	E NO. 1	TABLE ITEM: Scorch height		ROW ITEM	COL. ITEM _	
	ROS	— Trate of spread				
4	AREA	linitial fire area	10:00 dl 1	abla		
			[1-5]			
		EBurned area target Coll	umn Values:	2 = midsiope leews		
Row No.	Ro	ow Value		Table	Values	
	1(250)			selosda estri	TREE SP	1
	2	Total longth of line		or ga nasmlaga2 = 1		
	3	Containment time		2 = Douglas-fir, subsigine fir		
	MIWA •					



IGNITE MODULE (Metric)

(Keywords: Input, List, Run, Quit)

INPUT	(Input, List)					
1	TEMP	Ambient air temperature	[0-50 °C]		(Input, List)	1979
2	1H	1-h fuel moisture	[1-60%]	noilgo nuli	HON OPT	
3	SHAD	Shade	[0-100%]	2 Hours calcula		
OUTPUT	(Run)					
1	P(I)	Probability of ignition	pct	mud to dtnoM	HTHÓM HAUS	2
- 44			80_)	Latitude of fire	TATITUDE	4
		2 w stronge creat forest		noissoi		
TABLE	NO1	TABLE ITEM: Prob. of Ignit	ion	ROW ITEM	COL. ITEM	8
					1900	FUEL M
		Co	lumn Values:	105	ELEVATION, ASP	SLOPE,
Row No.	Pov	1/0/10		geenquete agai?	e Values	
				Table	e values	
	1	Support The event week of the		elevation elecation		
	3	Sunset cloud sover			- RH OBS AT-FIL	
	WEATHER	(m 0		Elevation of T&RH Observations	ELOB \	El.

MOISTURE MODULE (Metric)

			LIST NUMBER	
		(Keywords: Inp	ut, List, Run, Quit)	
INPUT	(Input, List)			
21	RUN OPT	Run option	(1 or 2)	- Z - 1H
		1 = Burn time calculations 2 = Hourly calculations		
TIME AN	ID LOCATION			
2	BURN MONTH	Month of burn	(1-12) nothing to will distort	
3	BURN DAY	Day of burn	(1-31)	
4	LATITUDE	Latitude of fire location	(-90 to 90 degrees)	
5	BURN TIME	Time of burn	(0-2,359 h)	TABLE NOW BURNE
FUEL M	ODEL			
6	MODEL #	Fuel model number	(1-99)	
SLOPE,	ELEVATION, ASPI	ECT 200		
11	SLP	Slope steepness	[0-100% or	3000 - 6/4 s
12	ELFL	Elevation of fire location	[0-4,000 m]	8
	RH OBS AT FIR	E	(Y/N)	<u> </u>
13	ELOB	Elevation of T&RH observations	(0-4,000 m)	
14	ASPECT	Aspect of fire location 0 = north 180 = south 90 = east 270 = west	(0-360 degrees)	
TIMBER	OVERSTORY DES	CRIPTION		
15	CCLO	Crown closure	[0-100%]	
16	FOLIAGE	Foliage presence 0 = absent 1 = present	(0 or 1)	
17	SHADE TOL	Shade tolerance 0 = intolerant 1 = tolerant	(0 or 1)	
18	DOM TYPE	Dominant tree type 1 = coniferous 2 = deciduous	(1 or 2)	
19	AVHT	Average tree height	[3-100 m]	
20	H/H	Crown height/tree height ratio	[0.1-1]	
21	H/D	Crown height/crown	[0.2-5]	



			LIST NUMBER	
ARLY	AFTERNOON WE	ATHER		
22	14T	Burn day 1400 temperature	[0-50 °C]	
23	14RH	Burn day 1400 relative	[1-100%] best-questions	
67	WD-1	humidity	3 = fully shellered - not ga	
24	14W	Burn day 1400 10-meter windspeed	[0-160 km/h] Dasia sego	
25	14CC	Burn day cloud cover	[0-100%]	
26	14HZ	Burn day 1400 haziness	[1-4] Total Inemiaula.	WALME TO
		1 = very clear sky 2 = average clear forest		
		atmosphere 3 = moderate blue haze		
		4 = dense haze—		
		moderate smoke		
UNSET	WEATHER			
27	SST	Sunset temperature	[0-50 °C]	
28	SSRH	Sunset relative humidity	[1-100%]	
29	SSW	Sunset 10-meter windspeed	[0-160 km/h]	
30	SSCC	Sunset cloud cover	[0-100%]	
UNRIS	E WEATHER			
31	SRT	Sunrise temperature	[0-50 °C]	FACT - 64
32	SRRH	Sunrise relative humidity	[1-100%]	
33	SRW	Sunrise 10-meter windspeed	[0-160 km/h]	E MOITTO BRUTEION
34	SRCC	Sunrise cloud cover	[0-100%]	VACIO 12
BURN T	IME WEATHER			
35	BTT	Burn time temperature	[0-50 °C]	. 82 PAIN
36	BTRH	Burn time relative humidity	[1-100%] ST DO STUDIES OF COAT	83 RDT
37	BTW	Burn time 10-meter windspeed	[0-160 km/h] month mod library via	54 SICY CODE
38	втсс	Burn time cloud cover	[0-100%]	
39	BTHZ	Burn time haziness	[1-4] Vhuolo vhuolo = S	
		 1 = very clear sky 2 = average clear forest atmosphere 3 = moderate blue haze 4 = dense haze— 		

			LIST NUMBER		
RIIDN T	IME WIND				
40	EXPOSURE	ID - 09-0	Burn day 1400 temperature	TAT	
		1 = exposed			
	EXPOSURE Exposure of fuels to wind (1-5) 1 = exposed 2 = partially sheltered 3 = fully sheltered— open stand 4 = fully sheltered— dense stand 5 = direct entry of wind adjustment factor WAF Wind adjustment factor Exposure 5 only WRE INITIALIZATION OPTION MOIS OPT Moisture initialization option (1-5) 1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing				
		4 = fully sheltered—			
41	WAF	2 = partially sheltered— open stand 4 = fully sheltered— dense stand 5 = direct entry of wind adjustment factor Wind adjustment factor Exposure 5 only NITIALIZATION OPTION DIS OPT Moisture initialization option (1-5) 1 = fine fuel moisture known for day before burn 2 = not allowed 3 = incomplete data; rain the week before burn 4 = incomplete data; no rain the week before burn 5 = incomplete data; weather pattern changing			
	WHITTON				
	DE INITIALIZAT	TION OPTION			
MOISTU	RE INITIALIZA				
43	MOIS OPT	Moisture initialization option	(1-5) — esan const = 5		
			g revoo buolo seenus		
MOISTU	IRE OPTION 1				
		Day day 4 fine fuel moieture	[1 10006] supplement samula		
44	FM-1	Burn day-1 fine fuel moisture		SRRH ———	32
MOISTU	RE OPTION 3				
51	RDAY	Number of days before burn	[1-7 days]	Jone	96
		that rain occurred			
52	RAIN	Rain amount, millimeters	[0-100 mm]	TTE	ar-
53	RDT	1400 temperature on rain day	[0-50 °C]	ната	ac
		LE DISTANT	(1-3)		
54	SKY CODE	이 보다는 사용하다 가장 그리를 가게 되었다. 그리는 경우를 때문에 되었다면 하는 것이 하는 것이 없었다. 그렇게 하는 것이 없는 것이 없는 것이 없다면 하는 것이 없다면			
MOISTI	IRE OPTION 4	3 = partly cloudy			
WIOIST	THE OF HOR 4	No additional input.			
		140 additional input			

APPENDIX B: (Con.)



			LIST NUMB	BER
MOISTUI	RE OPTION 5			
55	TD-1	Burn day -1 1400 temperature	[0-50 °C]	BMIT
56	RD-1	Burn day - 1 1400 relative humidity	[1-100%]	At the state of th
57	WD-1	Burn day - 1 1400 10-meter windspeed	[0-160 km/h]	
58	CD-1	Burn day -1 1400 cloud cover	[0-100%]	at
59	WTHR	Weather condition prior to burn day -1	[1-3]	17
		1 = hot and dry 2 = cool and wet 3 = between 1 and 2		
OUTPUT	(Run)			
1	MOIS	1-hour fuel moisture	pct	21
2	TEMP	Fuel level temperature	°C	22
3	%RH	Fuel level relative humidity	pct	23
4	SHAD	Percent of area shaded	pct	22
5	P(I)	Probability of ignition	pct	



APPENDIX B: (Con.)

		LIST NUMBER	
HOURLY OUTPUT (Run)			
TIME	FMOIST	FTEMP	FRH
	pct . [50001-7]	evitaler COV oc - Veb mass	pct and
14		thumidity	
15	(0-160 km/s) one s nego	Burn day - 1 1400 10-meter windspeed	T-QW. YG
16	dense stand [80001-0]	Burn day - 1 1400 cloud cover	
17	5 a direct entry of wings-11	Weather condition prior to	RHTW 88
	What adustment factor	mun day -1 - yab mud	
10	Exposure 5 gray	1 = hot and dry	
19	OR OPTION	2 = cool and wet 3 = between 1 and 2	
20	Moisture initialization option	(1-0)	(800) 109100
21	d = fine fluer moisture kdog	1-bour fuel molarie	Siche I
22	for day before burn 3°	Foet temperature	91/07 6
23	2 Iso allowed	Fuel level relative humidity	14 DAD 8
24	the week before buffig	Percent of area shaded	4 SHAD
1	the week before builded	Probability of ignition	5 P(I)
2	5 w incomplete data:	laves	
3			
1			
5	Buch (ay) was too too a cc		
6		To 7 street State Sec.	and the second
51 RDAY 7	that rain pocured	(MA ANNO)	
8 52 AAM	Rain amount, millimotera	(Datt) meg	
9	1400 temperature on reticiday	(050 %)	
10	Sky ex ultion from mires ty	(1-3)	
11	to burn day		
Burn Time	3 - partly cloudy		



MAP MODULE (Metric)

LIST	NUMBER	
	INCINIDEII	

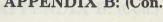
(Keywords: Input, List, Run, Quit)

INPUT LIS	(Input, List)				
1	SCL OPT	¹Scale option		1	
		1 = Representative fraction			
2	RF/1000	Representative	(1-500)	<u> </u>	
		fraction/1,000 e.g., RF of 1/100,000 = 100			
4	UNITS OPT	Units option	(1-3)	TWENT CANA	
		1 = Spread distance 2 = Spot distance 3 = Rate of spread			
5	DIST	² Spread distance	[0-20,000 m]		
6	SPOT	³ Spot distance	[0.1-15 km]	MAP DIST	<u>d</u>
7	ROS	⁴ Rate of spread	[0.03-170 m/min]	WINIAT?	
8	TIME	⁴ Elapsed time	[0.1-8 h]		
5	FSD	⁵ Forward spread distance	m	(unsi)	109100
6	BSD	⁵ Backing spread distance	m		
7	MXW	⁵ Maximum fire width	m m	966 A78	
OUTPUT	(Run)		Slupe steapness des		
1	MFSD	Forward spread distance on	Elevation change mo		
		map (UNITS OPT = 1 or 3)	n distance m		
1	MSPT	Forward spot distance on map (UNITS OPT = 2)	cm (notificant existances good free	esta the scale option	otido olifeM
2	MBSD	Backing spread distance on map (SIZE linked only)	cm		
3	MMXW	Maximum fire width on map (SIZE linked only)	cm		

¹Metric option sets the scale option = 1 (representative fraction).
²Input only for units option = 1.
³Input only for units option = 2.
⁴Input only for units option = 3.
⁵Passed from SIZE for linked run only. No input is needed.

SLOPE MODULE (Metric)

			LIST NUMBE	LIST NUMBER		
		(Keyword	ds: Input, List	t, <u>R</u> un, <u>Q</u> uit)		
		From Po	int to	Point	(Input, List)	
INDIIT I IS	ST (Input, List)					
1	SCL OPT	¹ Scale option 1 = Representative			RF/10001	
2	RF/1000	fraction 1Representative fraction/1,000 e.g., RF of 1/100,000 =	(0-1)		UNITS OPT	
4	CON INT	Contour interval	(1-200 i		Te ig	
5	MAP DIST	Map distance	(0.1-25		10 13	
6	# INTVLS	Number of contour intervals	(1-100)		ROS	
OUTPUT	(Run)					
1	SLP %	Slope steepness	pct			
2	SLP DEG	Slope steepness	degree	Maximum ille width	- VVAN	
3	EL DIFF HORIZ DIST	Elevation change Horizontal distance	m mo no		(nu8) -084M	
¹ Metric optio	n sets the scale option	n = 1 (representative fraction).				



WIND ADJUSTMENT MODULE (Metric)

(Keywords: Input, List, Quit)

INPUT LI	ST (Input, List)	List)			
1	10MW	10-meter windspeed	[0-160 km/h]	8Y80	<u> </u>
2	EXPOSURE	Exposure to wind	(1-5) enuteregment dlud teW.	WETB	
		1 = exposed			
		2 = partially sheltered			
		3 = fully sheltered,			
		open stand 4 = fully sheltered,			
		closed stand 5 = enter wind adjust-			
3	WAF	¹ Wind adjustment factor	(0-1) enclishated allow not bl	ew point too co	
4	MODEL #	² Fuel model number	(1-99)		
OUTPUT	(Run)				
1	MFWS	Midflame windspeed	km/h	T THE LEW	13081
	for exposure = 5.				

 $^{^{2}}$ Input only for exposure = 1.

RH MODULE (Metric)

(Keywords: Input, List, Run, Quit)

NPUI LIS	i (input, Lis	(1)				
1	DRYB	Dry bulb temperature		C] beegsbrilw retem 01		
2	WETB	Wet bulb temperatur		0 50 °C]	EXPOSURE	- 1
3	ELout, List)	Elevation	[0-4,00	[m 0] m		
UTPUT	(Run)					
1	%RH	Relative humidity	pct	3 = fully sheltered,		
2	DEWP	Dew point	°C	A = fully sheltered;		
RROR C	ODES:			closed stand 5 = enter wind adju		
-888 = V	Vet bulb temp	perature greater than dry				
-999 = C	Dew point too	cold for valid calculation	ns (F0) 00 M			
6	MAP DIST	Man distance	(pg/sy 15 c	Disadmun labor, lau?	MODEL & 21	b
	NO1	TABLE ITEM:	%RH	ROW ITEM	COL. ITEM	TURTUO
TPUT	(Run)					dao tuani'
			Column	Values:	it in entreoders sot i	and Evant
Row No.		ow Value			Table Values	
	1					
	2					
	3	St 1 hoosewheres traceer				
TABLE	NO2	TABLE ITEM:	DEWP	ROW ITEM	COL. ITEM	
			Column	Values:		
Row No.	Re	ow Value			Table Values	
	1					
	2					
	_			The second secon	The state of the s	



TWO MODULE (Metric)

(Keywords: Input, List, Run, Quit)

MODEL1				
MODELO	First model run by DIRECT		TABLE ITEM:	TABLE NO.
MODEL2	Second model run by DIRE	CT		
ROS1	Spread rate for first model			
Input, List)				
COV1	Percent area coverage first model	[20-80%]	Row Value	.oV-wo
(Run)				
ROS	Rate of spread	m/min		
		Column Values:		
Rov			Table Values	
1 _				
				iow No.
2 _				iow No.
2 _ 3 _				low No.
				ow No.
((Run) ROS	COV1 Percent area coverage first model (Run) ROS Rate of spread NO. 1 TABLE ITEM: Weighter	COV1 Percent area coverage [20-80%] first model (Run) ROS Rate of spread m/min NO. 1 TABLE ITEM: Weighted ROS ROW IT	COV1 Percent area coverage [20-80%] first model (Run) ROS Rate of spread m/min NO. 1 TABLE ITEM: Weighted ROS ROW ITEM COL. IT

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APPENDIX B: (Con.)

OUTPUT TABLES

		UR desprintakethowyody LIS	ST NUMBER	e service A.A.
TABLE NO T	ABLE ITEM:	ROW ITEM		S S
	Elevation		HOS1 Spread rate	8
OUTPUT (Rum			ROS2 Spread tate	
		Column Values:		TURN
	Value	Coverage : 0° [20-80%]	Table Values	3
- atto - Vo butb temps		belb temperature	(nuE)	TUSTUO
3 3 30111 2	oold for valid palculatio	ns nimin bes	ROS Rate of spr	1
	:8			
Row No. Row	v Value		Table Values	
1 .				
2			2	
3				
TABLE NO	TABLE ITEM:	ROW ITEM	COL. ITEM	
		Column Values:		
Row No. Roy	w Value		Table Values	
1				
2				
3				

Susott, Ronald A.; Burgan, Robert E. Fire behavior computations with the Hewlett-Packard HP-71B calculator. General Technical Report INT-202. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 80 p.

This report describes the operation of the fire behavior prediction program available as a Custom Read Only Memory (CROM) for the Hewlett-Packard model 71B handheld calculater. Worked examples are given for each of the 13 program modules, and the inputs and outputs are described. "Fire danger computations with the Hewlett-Packard HP-71B calculator," by Robert E. Burgan and Ronald A. Susott (1986) is a separate publication describing National Fire-Danger Rating (NFDR) system computations with the HP-71B.

KEYWORDS: fire behavior prediction, calculation aids, metric

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