J2.1 BehavePlus FIRE MODELING SYSTEM: PAST, PRESENT, AND FUTURE

Patricia L. Andrews *
US Forest Service, Rocky Mountain Research Station, Missoula, Montana

1. INTRODUCTION

Use of mathematical fire models to predict fire behavior and fire effects plays an important supporting role in wildland fire management. When used in conjunction with personal fire experience and a basic understanding of the fire models, predictions can be successfully applied to a range of fire management activities including wildfire behavior prediction, prescribed fire planning, and fuel hazard assessment.

The BEHAVE fire behavior prediction and fuel modeling system was among the early computer systems developed for wildland fire management. It has been updated and expanded and is now called the BehavePlus fire modeling system to reflect its expanded scope. BehavePlus provides a means of modeling fire behavior (such as rate of spread and spotting distance), fire effects (such as scorch height and tree mortality), and the fire environment (such as fuel moisture and wind adjustment factor). Input is entered directly by the user, and graphs (Figure 1), tables (Figure 2) and simple diagrams (Figure 3) are produced. Each calculation is based on the assumption that conditions are uniform and constant for the projection period; but rarely is a single calculation done. In most cases, the effect of a range of values is examined. For example, potential rate of spread and flame length for several fuel models and a range of live fuel moisture values is shown in Figure 1. The potential for a surface fire to transition to crown fire for various wind speeds is shown in Figure 2.

BehavePlus is part of a suite of fire behavior systems that includes FlamMap, FARSITE, and FSPro (Table 1). Spatial fire behavior systems incorporate the effects of temporal and spatial variation of conditions in various ways. The FlamMap fire mapping and analysis system (Finney 2006) does fire behavior calculations for each point on the landscape with fuel moisture and wind constant in time. For the basic FlamMap operation, each calculation is independent of its neighbors. FlamMap also includes the ability to calculate minimum travel times for fire spread, which is useful in determining effective fuel treatment locations. The FARSITE fire area simulator (Finney 1998) models fire growth under conditions that vary in both space and time. The fire behavior at a point (pixel) depends on the fire spreading from adjoining pixels and the conditions at the time it burned. The FSPro fire spread probability system performs hundreds or thousands of separate fire

Corresponding author address: Patricia L. Andrews, Fire Sciences Lab, 5775 Highway 10 W, Missoula, MT 59808; e-mail: pandrews@fs.fed.us

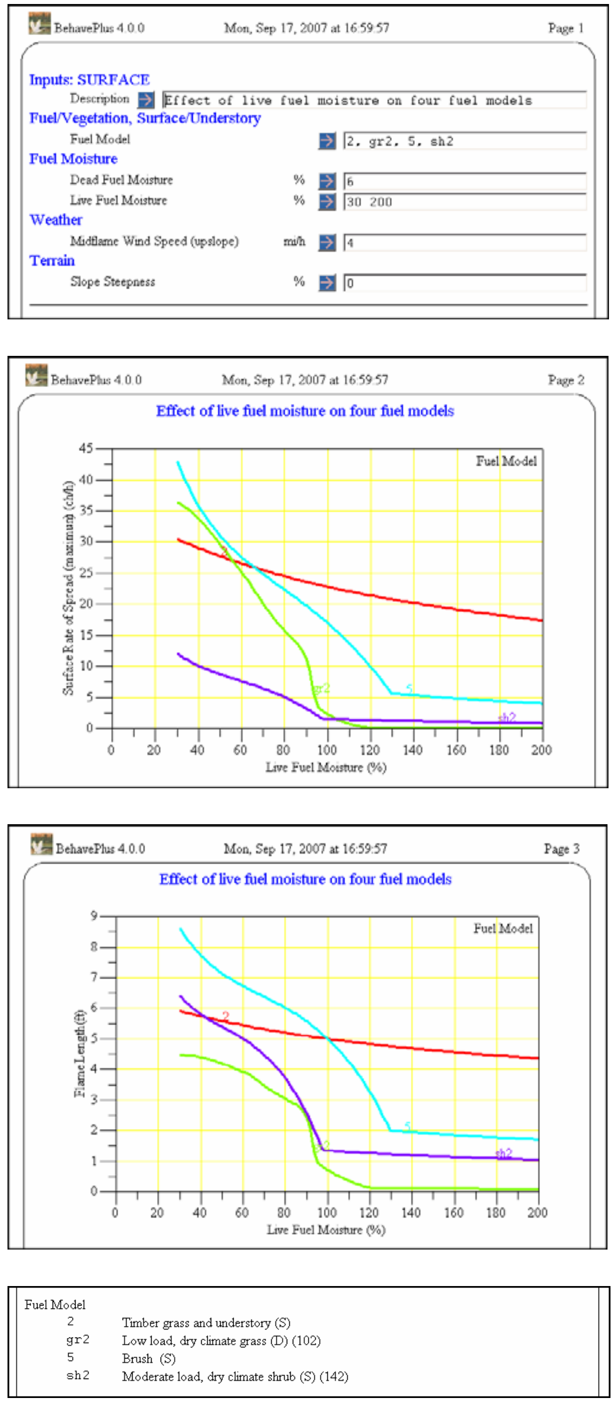
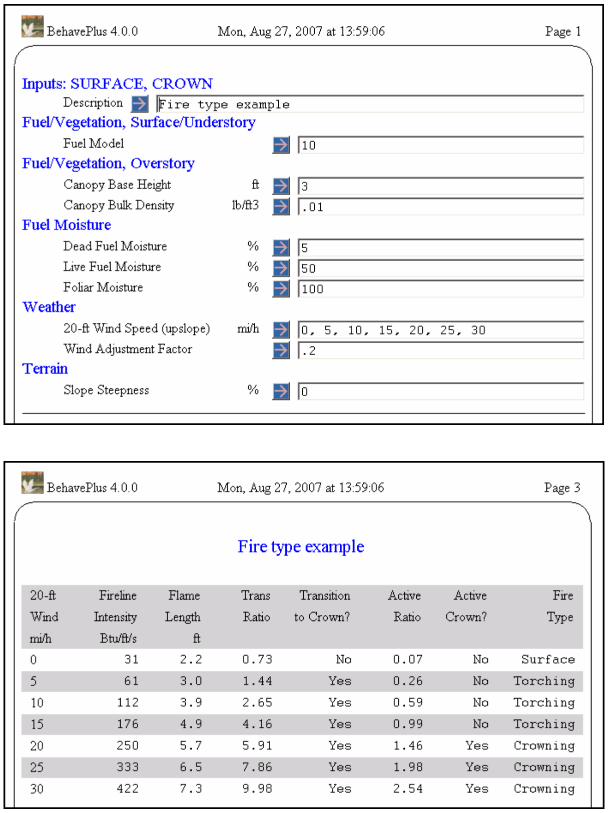


Figure 1--BehavePlus plot comparing predicted rate of spread and flame length for four fuel models, live fuel moisture from 30% to 200%, dead fuel moisture 6%, midflame wind speed 4 mi/h, and 0% slope.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Inputs: SURFACE, CROWN
Description: Fire type example
Fuel/Vegetation, Surface/Understory
Fuel Model: 10
Fuel/Vegetation, Overstory
Canopy Base Height (ft): 3
Canopy Bulk Density (lb/ft3): .01
Fuel Moisture
Dead Fuel Moisture (%): 5
Live Fuel Moisture (%): 50
Foliar Moisture (%): 100
Weather
20-ft Wind Speed (upslope) (mi/h): 0, 5, 10, 15, 20, 25, 30
Wind Adjustment Factor: .2
Terrain
Slope Steepness (%): 0

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Fire type example

20-ft Wind mi/h	Fireline Intensity Btu/ft/s	Flame Length ft	Trans Ratio	Transition to Crown?	Active Ratio	Active Crown?	Fire Type
0	31	2.2	0.73	No	0.07	No	Surface
5	61	3.0	1.44	Yes	0.26	No	Torching
10	112	3.9	2.65	Yes	0.59	No	Torching
15	176	4.9	4.16	Yes	0.99	No	Torching
20	250	5.7	5.91	Yes	1.46	Yes	Crowning
25	333	6.5	7.86	Yes	1.98	Yes	Crowning
30	422	7.3	9.98	Yes	2.54	Yes	Crowning

Figure 2--BehavePlus table showing the effect of 20-ft wind on fire type (surface, torching, crowning)

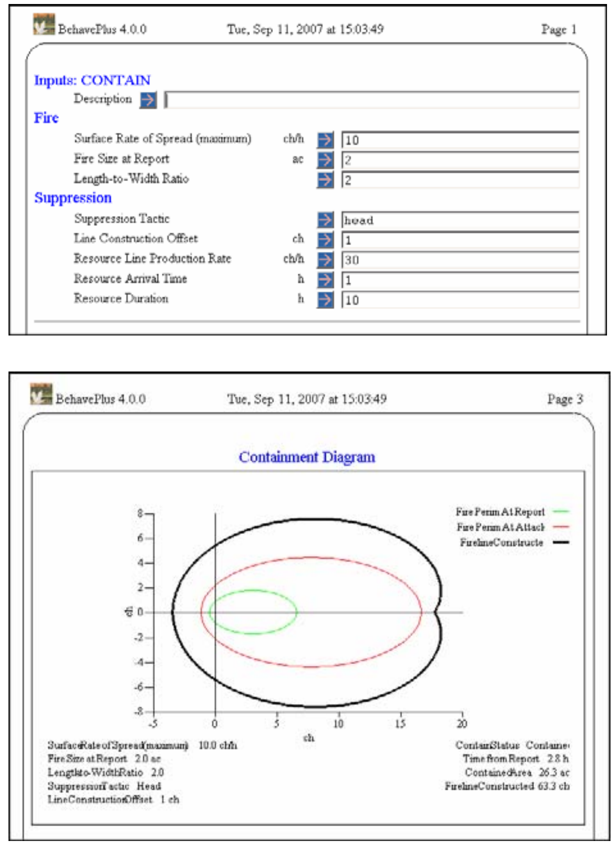


Figure 3--BehavePlus diagram showing fire perimeter at time of report and at initial attack, and the fireline constructed to contain the fire.

growth simulations from weather sequences based on climatology. While FARSITE predicts a fire perimeter location, FSPro produces the probability of the fire reaching each point from the known fire perimeter during the specified simulation duration (such as 2 weeks).

Spatial systems don't eliminate the need for the 'point' calculations in BehavePlus. In some cases BehavePlus is the best tool for an application. For example, tables of calculated scorch height for ranges of wind and fuel moisture values can be used for prescribed fire planning. BehavePlus can also be effectively used in support of the spatial systems, since all of them are based on the same fire models (e.g. spread rate, spotting distance). A person who learns about the models using BehavePlus is then better able to interpret the results of the spatial systems, where the modeling that occurs at each pixel is less evident. Plots such as Figure 1 show the implications of fuel model assignments.

The future of BehavePlus is being examined in conjunction with other fire behavior and fire danger systems. The goal is to strengthen the links among them and ensure that the expanding needs of fire and land managers are met.

In this paper I give a brief review of the original BEHAVE fire behavior prediction and fuel modeling system, describe the capabilities of the current BehavePlus fire modeling system, and discuss points of consideration in moving to the next stage.

2. PAST

The initial BEHAVE computer program was developed by Pat Andrews at the suggestion of Dick Rothermel after the 1976 S-590 'Fire Behavior Officer' course. He thought that a computer program could automate the nomograms (Albini 1976b) and tables taught in the course and also offer options that were too tedious with manual methods. (The prediction methods taught in S-590 are described by Rothermel (1983)).

While the FIREMOD program (Albini 1976a) was designed for research application and ran in batch mode from card decks, BEHAVE was designed for the practitioner, and was available in both batch and interactive mode. At that time, however, an interactive runs could be done only at night when the Missoula Fire Sciences Laboratory had access to the LBL (Lawrence Berkeley Laboratory) computer in California. The first presentation of BEHAVE was given at the Missoula Fire Lab in September 1977.

The TI-59 handheld calculator was programmed for a custom chip for field use of the fire model (Burgan 1979b). With the eventual availability of computer access, BEHAVE was offered for broad application. The option of producing tables and of linking models was added and BEHAVE was expanded to include Burgan and Rothermel's fuel modeling research. In August 1984, BEHAVE was formally transferred from the fire behavior research work unit to the Forest Service Washington Office as a nationally supported system.

Table 1—Comparison of BehavePlus and the spatial fire behavior systems: FlamMap, FARSITE, and FSPro.

System	Condition variation in time	Condition variation In space	Duration specifica-tion	Input	Modeling	Output	Computer access
BehavePlus fire modeling system	Constant	Uniform	Elapsed time for size or spread distance	Interactive user input; generally ranges of values	Separate, independent calculation for each cell of a table or point on a graph	Tables, graphs, simple diagrams	Personal computer
FlamMap fire mapping and analysis system— Basic fire behavior option	Constant	Variable across the landscape	No time duration in the modeling	Spatial (GIS) fuel and terrain data User-defined fuel moisture and wind	Separate, independent calculation for each point (pixel) on the landscape	Map of potential fire behavior for every point on the landscape	Personal computer
FlamMap fire mapping and analysis system— Minimum travel time and fuel treatment optimization options	Constant	Variable across the landscape	Total burning time (minutes)	Spatial (GIS) fuel and terrain data User-defined fuel moisture and wind Percentage of the landscape to treat and maximum treatment size	Minimum travel time based on numerous fire spread pathways	Map of minimum travel time pathways, arrival time contours. Fuel treatment placement recommen-dation	Personal computer
FARSITE fire area simulator	Vary diurnally and by day	Variable across the landscape	Hours/day of active burning. Number of days for the simulation	Spatial (GIS) fuel, terrain, etc. data User-defined fuel moisture and wind	Fire growth simulation	Maps of fire growth, perimeter, intensity, etc.	Personal computer
FSPro fire spread probabilities	Vary by day	Variable across the landscape	Hours/day of active burning by fire danger class Number of days for the simulation	Spatial (GIS) fuel and terrain data Current fire perimeter Weather stations for fire danger and wind climatology	Fuel moisture and wind sequences from climatology Hundreds or thousands of fire growth simulations	Map of probability of the fire reaching each point by the end of the simulation period	'High end' computers with internet access by authorized analysts

The BEHAVE fire behavior prediction and fuel modeling system eventually consisted of five FORTRAN programs that ran under the DOS operating system. The fire modeling portion of the BEHAVE system was the BURN subsystem (FIRE1 and FIRE2 programs). Custom fuel models were developed and tested using the FUEL subsystem (NEWMDL and TSTMDL programs). The RXWINDOW program was designed for prescribed fire planning; the user specified acceptable fire behavior and effects and the program found the associated fuel moisture and wind speed. Publications describe the operation, modeling foundation, and application of BEHAVE (Burgan and Rothermel 1984, Andrews 1986, Burgan 1987, Andrews and Chase 1989, Andrews and Bradshaw 1990).

A 3-day BEHAVE course was developed by the system developers (Andrews, Burgan, and Rothermel) as part of the original technology transfer effort. The developers taught the initial 'train the trainer' courses.

BEHAVE (now BehavePlus) has been formally integrated into fire behavior and prescribed fire courses in the NWCG fire curriculum.

3. PRESENT

The much needed update from BEHAVE to BehavePlus was funded by the Joint Fire Science Program. BehavePlus version 1.0 offered the same fire modeling capabilities as BEHAVE, but the program had a new look and feel as well as a new internal structure. BehavePlus Version 1.0 was released in 2002, Versions 2.0 and 3.0 added modeling capabilities and features in 2003 and 2005. Version 4.0 is being developed at the time of this writing. Following is a summary of modeling capabilities, features, and supporting material for BehavePlus version 4.0.

3.1 Modeling Capabilities

The fire modeling capabilities of BehavePlus are grouped according to modules as shown in Table 2. The term 'model' refers to mathematical relationships that describe a specific aspect of the fire or fire environment, such as rate of spread, scorch height, spotting distance, and wind adjustment factor (Andrews and Queen 2001). The models in each module are given with a source reference in Table 3. There are approximately 35 models in BehavePlus, described in 42 publications, one of which is the Rothermel (1972) surface fire spread model. (Occasionally 'BEHAVE' has inappropriately been used as a synonym for the Rothermel fire spread model.) A 'fuel model' is a set of values that describe the surface fuel as required by the Rothermel surface fire spread model. For this tally, I count the 53 standard fuel models as only one 'model'.

The CROWN module is made up of several models as listed in Table 3. The relationship among them is illustrated in Figure 4. This flow chart also illustrates that the surface fire fireline intensity (or flame length) can either be calculated in the SURFACE module or specified directly by the user.

There are several other cases where the user has the option of linking modules. Indentation in the module selection screen indicates that linkage is possible (Figure 5). Notes on linkages are included in Table 2.

Every 'model' is a representation of reality. Models are always based on simplifying assumptions, and all models have limitations. The user is responsible for proper application, which often requires judgment and adjustments. The structure of BehavePlus facilitates comparison of model results in order to examine relationships.

As an example, Figure 6 shows calculated rate of spread for the dynamic fuel model GR4 (moderate load, dry climate grass) for a range of live herbaceous fuel moisture values. The live herbaceous fuel moisture is used to determine the amount of fuel that is transferred from the live to the dead category to model the curing process (Scott and Burgan 2005). The live moisture also affects rate of spread according to Rothermel's fire spread model. In order for information on curing level to be used if it is available, version 4.0 of BehavePlus offers the option of entering curing (load transfer) as shown in Figure 7. A comparison of these runs shows the significant role that live herbaceous fuel moisture plays for dynamic fuel models. For live fuel moisture of 120% and an automatic calculation of load transfer, the rate of spread is 1 ch/h (flame length is 0.4 ft). If live moisture is 120% and the load transfer portion is specified as 40%, the rate of spread is 30 ch/h (flame length is 5.3 ft). BehavePlus plots can be effectively used to evaluate the implications of choices that are made in modeling fire behavior.

The simple output diagrams provide another means of understanding the models. For example, Figure 3 shows a CONTAIN diagram that illustrates the relationship among fire perimeter at report and at initial attack, and the fireline constructed to contain the fire.

3.2 Features

BehavePlus is designed so that a person can do simple runs using default selections for output variables and input options. It also includes options useful to a person who is doing more complex analyses. Version 4.0 includes additional intermediate values, a feature useful to a person interested in understanding the model foundation. This is especially applicable to Rothermel's surface fire spread model. One of these intermediate values is characteristic dead fuel moisture, which has not previously been available for analysis. Figure 8 shows the characteristic dead fuel moisture for ranges of 1-h and 10-h moisture. The plot for fuel model 4 shows that the characteristic dead fuel moisture is determined primarily by the 1-h fuel moisture. The implication is that if specific values are not known for 1-h and 10-h moisture content, then it is appropriate to use the same dead fuel moisture value for all size classes.

Many aspects of the graphs can be changed. For Figure 8 the defaults were changed for graph size, graph title, curve colors, axis width, and gridline color. If a person wants to format graphs or tables in a manner different from the available program options, results can be exported to a spreadsheet or other software. BehavePlus plots, for example, are generated only for a single variable. A spreadsheet can be used to plot two variables such as rate of spread and flame length on the same graph. Similarly an analyst might want to plot the surface fire spread rate results from BehavePlus compared to a new spread model being developed. BehavePlus automatically adjusts tables to fit onto a page for printing; large tables continue from one page to the next. An exported table can be reformatted to suit specific needs.

Table 2--Modules in BehavePlus, the calculations for each module, and notes on linkage options among modules

Module	Calculations	Linkages
SURFACE	• Surface fire rate of spread • Fireline intensity and flame length • Reaction intensity and heat per unit area • Intermediate values: heat source, heat sink, characteristic dead fuel moisture, relative packing ratio, etc. • Standard, custom, and special case fuel models • Wind adjustment factor	
CROWN	• Transition from surface to crown fire • Crown fire rate of spread • Crown fire area and perimeter • Fire type: surface, torching, conditional crown, crowning	• Surface fireline intensity or flame length can come from SURFACE
SAFETY	• Safety zone size based on flame length • Area, perimeter, separation distance	• Head fire flame length can come from SURFACE
SIZE	• Elliptically shaped point source fire • Area, perimeter, shape	• Head fire rate of spread and effective wind speed can come from SURFACE
CONTAIN	• Fire containment success for single or multiple resources given line construction rate, arrival time, resource duration, head or rear attack, direct or parallel attack • Final area and perimeter, fire size at initial attack, fireline constructed	• Head fire rate of spread can come from SURFACE • Length-to-width ratio and fire size at report can come from SIZE
SPOT	• Maximum spotting distance from torching trees, burning piles, or wind-driven surface fire	• Head fire flame length can come from SURFACE
SCORCH	• Crown scorch height from surface fire flame length	• Surface fireline intensity or flame length can come from SURFACE
MORTALITY	• Probability of mortality from bark thickness and crown scorch	• Scorch height can come from SCORCH
IGNITE	• Probability of ignition by firebrands or by lightning strikes	

Table 3--Models that are included in each of the BehavePlus modules with citations and notes.

BehavePlus Module	Model	Reference and Notes
SURFACE	Surface head fire rate of spread Reaction intensity, heat per unit area Intermediate values: characteristic dead fuel moisture, live fuel moisture of extinction, relative packing ratio, etc.	(Rothermel 1972) With minor adjustments by (Albini 1976a)
	Fireline intensity Flame length	(Byram 1959) with adjustments to work with Rothermel's surface fire spread model by (Albini 1976b)
	Surface fire flame residence time (used to calculate fireline intensity)	(Anderson 1969)
	Direction of maximum spread	(Rothermel 1983) using manual vectoring (Andrews 1986) (Finney 1998) calculations based on Rothermel's wind and slope factors
	Fire characteristics chart, relationship among rate of spread, heat per unit area, fireline intensity, and flame length	(Andrews and Rothermel 1982)
	Spread in direction from ignition point from a point source fire	(Andrews 1986)
	Effective wind speed	(Albini 1976b)
	Wind adjustment factor	(Albini and Baughman 1979, Baughman and Albini 1980, Rothermel 1983)
	Wind speed at 10 m adjusted to 20 ft	(Turner and Lawson 1978)
	13 standard fire behavior fuel models	(Rothermel 1972) (11 fuel models) (Albini 1976b) (slight revision of the 11 plus two more fuel models) (Anderson 1982) (fuel model selection guide)
	40 standard fire behavior fuel models	(Scott and Burgan 2005)
	Custom fire behavior fuel models	(Burgan and Rothermel 1984, Burgan 1987)
	Dynamic fuel load transfer	(Burgan 1979a) (Burgan and Rothermel 1984, Andrews 1986) as used in BEHAVE (Scott and Burgan 2005) as used in the 2005 standard fire behavior fuel models
	Two fuel models weighted rate of spread	(Rothermel 1983)
	Two fuel models, harmonic mean	(Fujioka 1985)
	Two fuel models, 2-dimensional expected spread	(Finney 2003)
	Palmetto gallberry special case fire behavior fuel model	(Hough and Albini 1978)

Table 3 (continued)

BehavePlus Module	Model	Reference and Notes
CROWN	Critical surface intensity needed for transition from surface to crown fire	(Van Wagner 1977)
	Transition to crown fire, relationship of surface fire intensity and critical surface fire intensity	(Finney 1998) (Scott and Reinhardt 2001)
	Crown fire rate of spread, area, and perimeter	(Rothermel 1991)
	Critical crown fire rate of spread, needed for an active crown fire	(Van Wagner 1993)
	Active crown fire, relationship of crown fire rate of spread and critical crown fire rate of spread	(Finney 1998) (Scott and Reinhardt 2001)
	Fire type: surface, torching, conditional crown, crowning	(Finney 1998) (Scott and Reinhardt 2001)
SAFETY	Safety zone size, separation distance, radius	(Butler and Cohen 1996, 1998b, 1998a)
SIZE	Elliptical fire size and shape, area, perimeter, length-to-width ratio	(Anderson 1983) double ellipse Simplified to simple ellipse by (Andrews 1986)
CONTAIN	Fire containment	(Albini et al. 1978) in the old BEHAVE (Fried and Fried 1996) in BehavePlus
SPOT	Spotting distance from torching trees	(Albini 1979, Chase 1981)
	Spotting distance from a burning pile	(Albini 1981)
	Spotting distance from a wind-driven surface fire	(Albini 1983a, Albini 1983b, Chase 1984)
SCORCH	Crown scorch height	(Van Wagner 1973)
MORTAILTY	Tree mortality	(Ryan and Reinhardt 1988, Reinhardt and Crookston 2003)
	Bark thickness	(Ryan and Reinhardt 1988, Reinhardt and Crookston 2003)
IGNITE	Probability of ignition from firebrand	(Schroeder 1969)
	Probability of ignition from lightning	(Latham and Schlieter 1989)
Fine dead fuel moisture Tool	Fine dead fuel moisture tables	(Rothermel 1983)

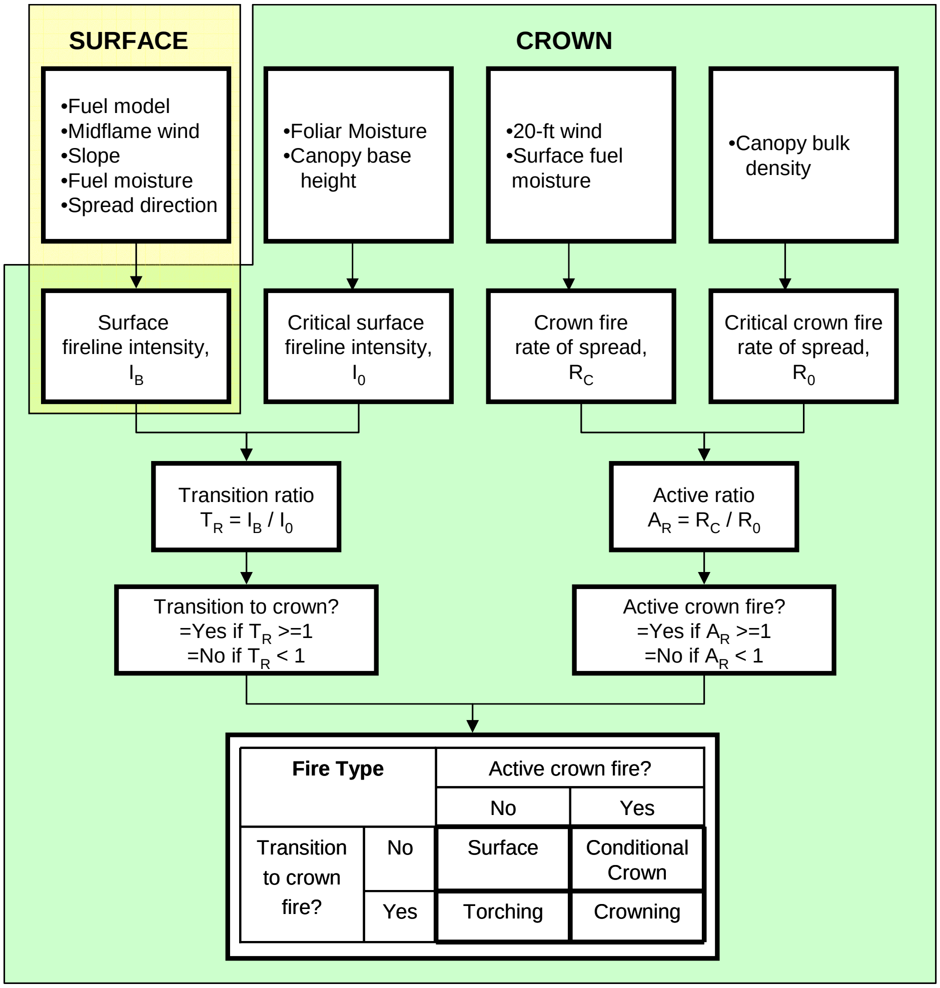


Figure 4-- Information flow for the CROWN module. Surface fireline intensity (or flame length) can either be calculated in the SURFACE module or specified by the user

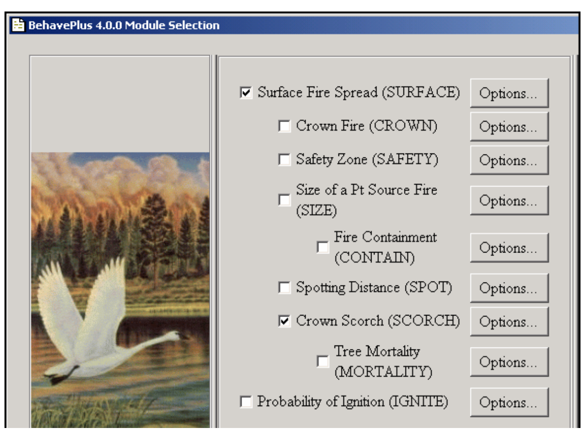


Figure 5--Module selection for BehavePlus. Indentation indicates that modules can be linked, with output from one being used as input to the other. For example, flame length calculated in SURFACE can be used to calculate scorch height in SCORCH. If SURFACE is not selected, the user enters values for flame length.

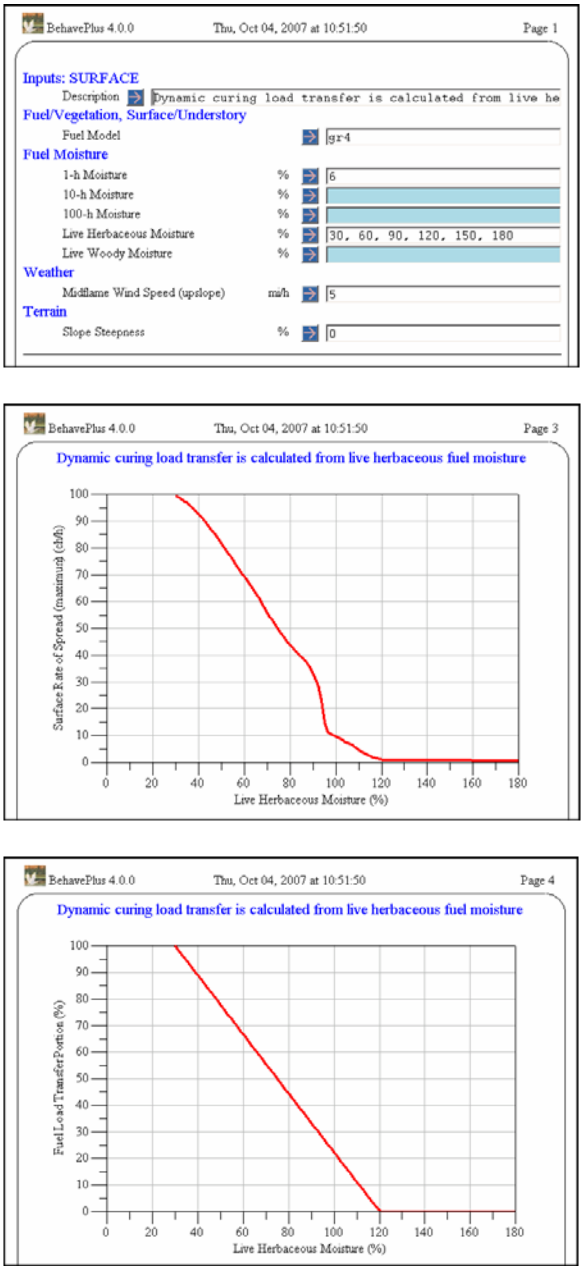


Figure 6--Rate of spread calculated for dynamic fuel model GR4 (moderate load, dry climate grass) for live herbaceous moisture from 30% to 180%. Fuel load is transferred from the live to the dead fuel class as a function of live herbaceous fuel moisture

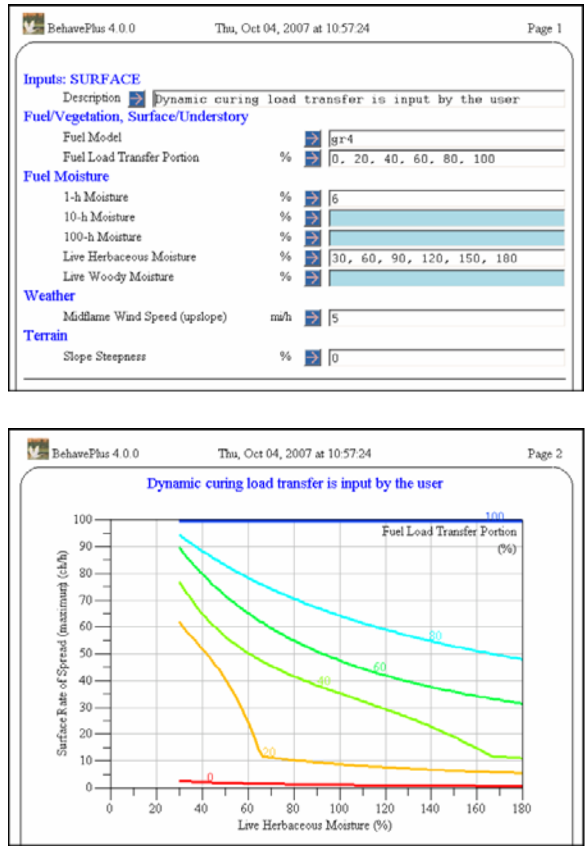


Figure 7--Rate of spread calculated for dynamic fuel model GR4 (moderate load, dry climate grass) for live herbaceous moisture from 30% to 180%. The fuel load transfer portion (curing) is entered by the user rather than being calculated from live fuel moisture.

Full pages of BehavePlus input and output can be printed and attached to a report. There is often a need to insert a table or graph in a report (such as in this paper). Although this can be done with the capture feature in BehavePlus, this is not the most efficient approach. One possible method, using only the standard Windows operating system, is to use Alt-PrintScreen, which captures the current window. That window can be pasted into an MS Word document and cropped using features from the Picture toolbar.

In addition to printed pages and insertions in reports, it is a good practice to save BehavePlus runs in an electronic project documentation package. The BehavePlus workspace feature facilitates file management.

BehavePlus includes a feature that is especially useful for prescribed fire planning. The acceptable limits of fire behavior and fire effects variables can be specified and the associated environmental values can be examined. Figure 9 shows combinations of midflame wind speed and dead fuel moisture that result in flame lengths of 2 to 6 feet. The option of blank cells on the table has been added to version 4.0 in addition to the option of crossed out values.

Other features of BehavePlus 4.0 include:

- Multiple values can be entered for input variables to produce tables and graphs.
- Units of measure and the number of decimal points displayed can be changed.
- Distances can be output as map distances.
- Paintings (with permission from Monte Dolack; www.dolack.com) are inserted throughout the program. These pictures can be turned off for the current window or for the entire run.
- Rows and columns of tables can be transposed.
- X-axis variable and curve variable can be switched.
- The worksheet header can include more lines for additional documentation (see Figure 9).
- The size of the notes section on the worksheet can be increased to allow room for additional user notes for documentation.
- User preferences for defaults can be saved in a user-defined startup worksheet.
- Worksheets, runs, custom fuel models, and moisture scenarios can be saved for documentation or for later use.

3.3 Documentation and Training

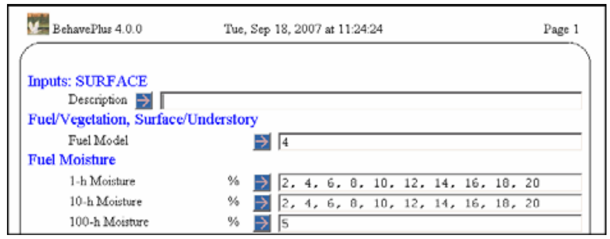
Documentation and training material for BehavePlus fall into three categories:

- Program operation—for details on how to run the program to generate desired outputs
- Modeling concepts—for understanding of the fire model foundation of the system; limitations and assumptions of the models; relationships among models; and sensitivity of calculations to input choices
- Applications—for specific fire management needs such as wildfire prediction, prescribed fire planning, and fuel hazard assessment.

The BehavePlus program, supporting documentation, and training material can be found on www.firemodels.org. This web site also includes information about other fire behavior and fire danger systems.

The User's Guide only addresses operation of the program (Andrews et al. 2005). In addition to being a printable publication, it can be opened as a PDF document through the Help system. Desired information can be found using a search or the detailed table of contents.

BehavePlus also includes a help window that describes each of the input and output variables. There is a short description, a table that shows where the variable is used as input and/or output, and other information such as fuel model photos and line construction rate tables. The input/output variable information will also be available as a PDF document suitable for printing. The many internal links from input and output tables and among variables make that document especially useful when viewed on a computer.



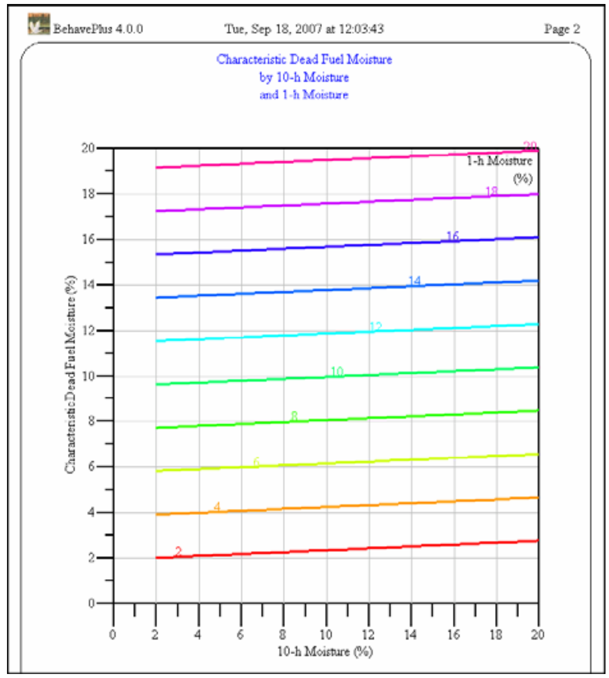


Figure 8--Characteristic dead fuel moisture is an intermediate value available in version 4.0. The plot shows that the characteristic dead fuel moisture is determined primarily by 1-h fuel moisture. Results, while similar, vary by fuel model.

A set of tutorial lessons is available. Some describe program operation (such as worksheets development) and others address modeling concepts (such as crown fire). The tutorials are being updated and expanded. Additional exercises are being added and more lessons are being developed. Development of lessons as building blocks will allow application training to utilize only the needed components. For example, a modeling lesson on scorch height would be needed for the prescribed fire application, but not for wildfire prediction.

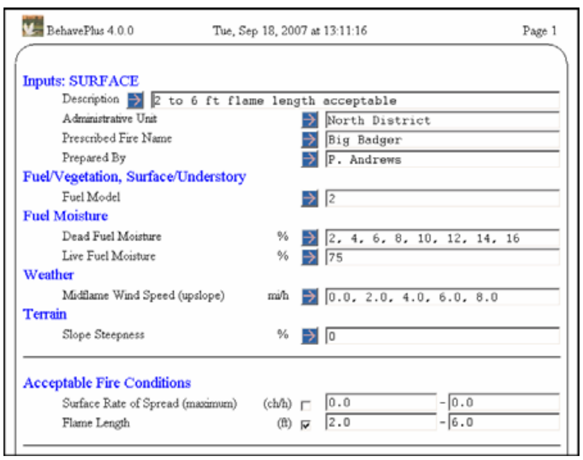
In recognition of the fact that people learn differently, training material will be available in several forms. Some people are comfortable learning to run a program without formal training and just need reference material on available features. Some prefer to be guided through interactive exercises. Travel and time are expensive, so self-study training will be available. Training material can also be presented in a classroom to satisfy those who prefer instructor-led training.

Ideally, the basics will be learned through self-study with classroom and one-on-one training focused to applications in order to generate valuable interaction among participants.

4. FUTURE

Just as BehavePlus was a major step beyond BEHAVE, it is time for another similar step forward, to what I will call 'Behave++'. Design decisions that were made in 1999 need to be revisited, and advances in software, hardware, and communications can be utilized. The platform can go beyond personal computers to include handheld computers and web-based applications.

It is becoming increasingly more difficult to add features and fire modeling capabilities to BehavePlus because of its size and complexity. It is important for a fire modeling system to be readily changed as new research becomes available. The basic internal structure of the program code could be improved to facilitate updates.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Inputs: SURFACE

Description: 2 to 6 ft flame length acceptable
Administrative Unit: North District
Prescribed Fire Name: Big Badger
Prepared By: P. Andrews

Fuel/Vegetation, Surface/Understory

Fuel Model: 2

Fuel Moisture

Dead Fuel Moisture (%): 2, 4, 6, 8, 10, 12, 14, 16
Live Fuel Moisture (%): 75

Weather

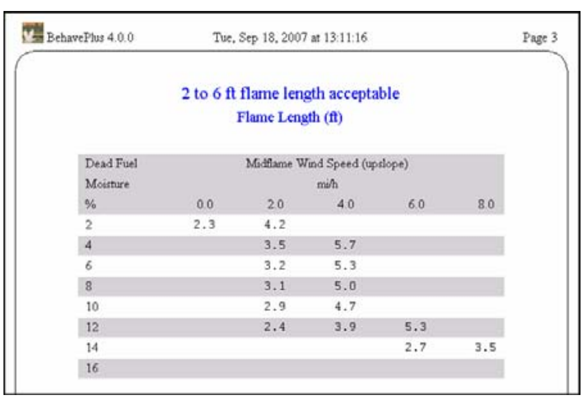
Midflame Wind Speed (upslope) (mi/h): 0.0, 2.0, 4.0, 6.0, 8.0

Terrain

Slope Steepness (%): 0

Acceptable Fire Conditions

Surface Rate of Spread (maximum) (ch/h): 0.0 - 0.0
Flame Length (ft): 2.0 - 6.0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2 to 6 ft flame length acceptable

Flame Length (ft)

Dead Fuel Moisture %	Midflame Wind Speed (upslope) mi/h 0.0	2.0	4.0	6.0	8.0
2	2.3	4.2			
4		3.5	5.7		
6		3.2	5.3		
8		3.1	5.0		
10		2.9	4.7		
12		2.4	3.9	5.3	
14				2.7	3.5
16					

Figure 9— The option 'table shading for acceptable fire conditions' produces a table that shows results for only the specified acceptable conditions (flame length of 2 to 6 feet). This is useful for prescribed fire planning.

BehavePlus currently accepts input only through interactive user entry (although runs can be saved for later use). Expansions could include use of data files such as weather and fuel moisture data from FireFamily Plus (Bradshaw and McCormick 2000). Another source of input might be a click on a pixel in FlamMap or FARSITE.

In addition to direct data linkages among fire behavior and fire danger systems, all of the systems could be revamped to have a common user-interface. This would address the current situation of users having many different systems to learn and use. The systems would not be distinct, separate applications, but rather perform as a common tool.

A redesign will have to address the challenge of satisfying users who want a quick and easy way to model fire as well as those who want features that support advanced analysis needs.

In developing the next generation of systems, care will be taken to avoid 'black box' modeling. An educated user will continue to be an important part of the modeling process. Effective training and supporting documentation is an important part of the package.

I feel confident in saying that there is a continuing need for the 'point-based' fire modeling approach of BehavePlus, and that the more sophisticated spatial systems won't replace it. BehavePlus provides a quick and easy way to do initial fire behavior assessments without the spatial data that is required by FARSITE and FlamMap. It allows easier 'what if' gaming and comparison of the effect of changing conditions, such as 10 mi/h vs. 5 mi/h wind. BehavePlus runs can be used to calibrate landscape models. Effective use of the spatial modeling systems is facilitated through use of BehavePlus.

Building on the long history of BEHAVE and BehavePlus will lead to a 'Behave++' which is an integrated part of the next generation of fire behavior and fire danger systems.

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