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BehavePlus fire modeling system, version 5.0: Design and Features

Faith Ann Heinsch
Patricia L. Andrews



BehavePlus 5.0.1 Select A Worksheet

Worksheet Files Description

- ExampleWorksheets 6 Examples that can't
- Default bpw Blank worksheet, d
- BasicStart bpw Surface fire spread
- FuelModeling bpw Surface fire, fuel mo
- FuelModelingMetric bpw Surface fire, fuel mo
- SurfaceCrown bpw Max surface spread

BehavePlus 5.0.1 Wed, May 05, 2010 at 10:34:51

Fuel Model (16, 0% slope)

Flame Length (ft) Dead Fuel Moisture (%)

Midflame Wind Speed (upslope) (m/h)

BehavePlus 5.0.1 Input Guide

From Thru Step

Picture Help

Ok Clear Cancel

Less Than 1 MPH CALM SMOKE RISES VERTICALLY; NO MOVEMENT OF LEAVES OF BUSHES OR TREES.

1 TO 3 MPH VERY LIGHT LEAVES OF QUAKING ASPEN IN CONSTANT MOTION; SMALL BUSHES SWAY; SLENDER BRANCHLETS AND TWIGS OF TREES MOVE GENTLY; TALL GRASSES AND WEEDS SWAY AND BEND WITH WIND; WIND VANE BARELY MOVES.

4 TO 7 MPH LIGHT TREES OF POLE SIZE IN THE OPEN SWAY GENTLY; WIND FELT

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Abstract

The BehavePlus fire modeling system is a computer program that is based on mathematical models that describe wildland fire behavior and effects and the fire environment. It is a flexible system that produces tables, graphs, and simple diagrams. It can be used for a host of fire management applications, including projecting the behavior of an ongoing fire, planning prescribed fire, assessing fuel hazard, and training. This report documents the BehavePlus design and features to help users better understand the system and use it more effectively. It is based in part on material in a series of self-study lessons that were developed to provide a detailed, step-by-step description of various aspects of BehavePlus. This report supplements two reference guides on BehavePlus: a User's Guide describes operation of the program and can be accessed at http://www.fs.fed.us/rm/pubs/rmrs_gtr106.html, and a Variables paper describes the more than 180 variables in BehavePlus and can be accessed at http://www.fs.fed.us/rm/pubs/rmrs_gtr213.html.

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Preface

The BehavePlus fire modeling system, Version 5.0 began as a DOS program for fire behavior prediction in the 1970s. The original BEHAVE was later combined with fuel modeling programs to make it the BEHAVE fire behavior prediction and fuel modeling system. When computers developed to the point that it was possible, BEHAVE was made available in the field in 1984. A major update began in 1999 with a complete redesign and a change from FORTRAN to C. BehavePlus, Version 1.0 was released in 2001. Modeling capabilities and features have been added with each version.

Some of the design described in this report is based on decisions made more than 10 years ago. We recognize that there are deficiencies, but we also know that BehavePlus is a successful system and, in most ways, is a useful tool for fire managers. Hopefully, there will be a next generation system (BehavePlusPlus?)—another major update possibly done in combination with other fire behavior and fire danger systems. We hope that strengths as well as deficiencies of BehavePlus will be considered as future systems are developed. In addition to helping users get the most out of the BehavePlus system, this report can be a reference for designers of the next generation of fire modeling systems.

Information

Information about the BehavePlus fire modeling system, related publications, and training material are available at the BehavePlus web site: <http://www.FireModels.org>.

Cover Art

“WILDFIRE” © 1992, an original acrylic painting by Monte Dolack. Trumpeter swans take refuge in the air as a threatening wildfire rages through the forest habitat. This image is from a 29- by 24-inch poster commissioned by the National Wildfire Foundation and used here by permission of the artist. All artistic images used in BehavePlus and its associated manuals and training materials are from original works by Monte Dolack and appear by permission of the artist.

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Table of Contents

| | | |
|-------|--|----|
| 1 | Introduction | 1 |
| 2 | Fire Modeling Capabilities | 2 |
| 3 | Worksheets and Runs | 6 |
| 3.1 | Worksheet Components and Output Pages | 6 |
| 3.1.1 | Window Components | 7 |
| 3.1.2 | Page Layout | 8 |
| 3.1.3 | Worksheet Components | 9 |
| 3.1.4 | Output Pages | 12 |
| 3.2 | Designing Worksheets | 14 |
| 3.2.1 | Module Selection | 14 |
| 3.2.2 | Map Distances and Table Shading Options | 15 |
| 3.2.3 | Input Options | 15 |
| 3.2.4 | Output Variables | 16 |
| 3.2.5 | Appearance Preferences | 16 |
| 3.2.6 | Custom Units Preferences and Units Set Selection | 18 |
| 3.3 | Saving and Using a Worksheet | 18 |
| 3.3.1 | Example Worksheets | 18 |
| 3.3.2 | 0Default.bpw and BasicStart.bpw Worksheets | 19 |
| 3.3.3 | Startup Worksheet | 19 |
| 3.3.4 | Your Worksheets | 20 |
| 3.4 | Saving and Using a Run | 20 |
| 3.4.1 | Calculate Options | 21 |
| 3.4.2 | Example Runs | 21 |
| 3.4.3 | Your Runs | 23 |
| 4 | Display and View Features | 23 |
| 4.1 | Window and Page Size | 23 |
| 4.2 | Multiple Windows | 24 |
| 4.3 | Page View | 24 |
| 4.4 | Graph Size | 25 |
| 4.5 | Help Window | 27 |
| 4.6 | PDF Documents | 27 |
| 5 | Units and Decimals | 29 |
| 5.1 | Input Variable Decimals | 30 |
| 5.2 | Fuel Model Parameter Decimals | 31 |
| 5.3 | Units Set Selection | 33 |
| 5.4 | Custom Units Preferences | 34 |
| 5.5 | Units Converter Tool | 35 |
| 6 | Methods of Input | 36 |
| 6.1 | Direct Input | 37 |
| 6.2 | Discrete Variable Selection | 37 |
| 6.3 | Ranges for Continuous Variables | 38 |
| 6.4 | Choices for Continuous Variables | 39 |
| 6.5 | Additional Guidance | 41 |
| 7 | Form of the Output | 42 |
| 7.1 | List | 42 |
| 7.2 | Tables | 43 |
| 7.3 | Graphs | 48 |

| | |
|--|------|
| 7.3.1 Appearance Change | .51 |
| 7.3.2 Axis Change | .52 |
| 7.3.3 Scale Change..... | .54 |
| 7.4 Diagrams | .57 |
| 8 Using Outputs Elsewhere | .60 |
| 8.1 Print Output..... | .60 |
| 8.2 Save as PDF | .60 |
| 8.3 Save as Image | .61 |
| 8.4 Capture, Insert, and Crop | .61 |
| 8.5 Export as HTML..... | .62 |
| 8.6 Export to Spreadsheet | .64 |
| 9 File Management and Workspaces | .68 |
| 9.1 BehavePlus File Structure..... | .68 |
| 9.2 Workspaces | .70 |
| 10 Fuel Models | .71 |
| 10.1 Custom Fuel Models | .72 |
| 10.2 Selecting a Fuel Model | .73 |
| 11 Moisture Scenarios | .75 |
| 11.1 Custom Moisture Scenarios | .75 |
| 11.2 Selecting Moisture Scenarios | .76 |
| 12 Table Shading for Acceptable Fire Conditions | .76 |
| 13 Tools | .79 |
| 14 Map Applications | .79 |
| 14.1 Map distances | .79 |
| 14.2 Slope vs. Horizontal Map Distance..... | .80 |
| 14.3 Slope from Map Measurements | .80 |
| 14.4 Map Scale | .82 |
| 14.5 Slope Tool | .83 |
| 15 Help | .84 |
| 15.1 User's Guide | .84 |
| 15.2 Variables Paper | .84 |
| 15.3 Help Window | .85 |
| 15.4 Master Index | .87 |
| 15.5 Web site | .88 |
| 15.6 Installation Information..... | .89 |
| 15.7 Technical Support | .90 |
| 16 Program Updates | .90 |
| 17 Summary | .90 |
| 18 References | .90 |
| Appendix A. Tricks and Tips List | .93 |
| Appendix B. BehavePlus Lessons List | .96 |
| Appendix C. Comparison of BehavePlus to Spatial Fire Behavior Systems..... | .97 |
| Appendix D. Input Options | .98 |
| Appendix E. Output Variables | .99 |
| Appendix F. Menu Items and Options | .102 |
| Appendix G. Units and Decimals | .103 |
| Appendix H. Appearance Preferences | .107 |
| Appendix I. Glossary | .109 |

1 Introduction

The BehavePlus fire modeling system is a computer program that is based on mathematical models that describe wildland fire and the fire environment. It is a flexible system that produces tables, graphs, and simple diagrams. It can be used for any fire management application that involves modeling fire behavior and effects, including projecting the behavior of an ongoing fire, planning prescribed fire, assessing fuel hazard, and training (Andrews 2007). Successful application of the system is dependent upon decisions made by the user. Those educated in fire behavior understand the fire modeling foundation with the associated assumptions and limitations as well as the influence of various input variables on calculated values. An effective fire modeler has a basis of fire and fuel experience to use in recognizing whether values are reasonable and in making appropriate adjustments.

BehavePlus is designed to balance ease of use with options and features that users want and need. A user who is satisfied with the “default” selections can quickly run the program to get results. If the user has other needs, the program can probably meet them. If the user is not satisfied with the form of a table or graph produced directly by BehavePlus, results can be exported and reformatted using other software.

BehavePlus offers many features and options to enhance its application. Units and decimal display and the form of the output tables and plots can be changed. The header on the worksheet can be expanded to include lines for prescribed fire planning. Wind speed can be entered for midflame height or for 20-ft or 10-m height with a wind adjustment factor that is either specified or calculated. A user who is aware of the features offered in the program can make the most effective use of BehavePlus. A summary list of tips and tricks with reference to the relevant section of this paper is provided in Appendix A, and Appendices D through H provide reference tables previously available only in the **Help** system: Input Options, Output Variables, Menu Items and Options, Units and Decimals, and Appearance Preferences.

This document supplements other published material that describes BehavePlus. The User’s Guide (Andrews and others 2008) addresses operation of the program in the form of a reference guide. Because additions in Version 5.0 did not change basic operation of the program, the Version 4.0 User’s Guide was not updated and remains valid for Version 5.0. (See the version comparison PDF on the BehavePlus web site.) The Variables paper (Andrews 2009), which was updated for Version 5.0, is a reference guide that describes the more than 180 input and output variables in BehavePlus. The document is most useful when viewed on a computer, utilizing the numerous links and bookmarks. Both the User’s Guide and the Variables paper are bundled with the BehavePlus program as part of the **Help** system.

This publication is not a reference guide like the User’s Guide and Variables paper, which are designed to help you find information on a specific topic. Nor is it a step-by-step description of operation as presented in the lessons (Appendix B) or a manual that teaches you how to do fire modeling. This publication’s focus is on program operation, design, and features. Even experienced users might not be aware of all of the features described in this paper. We explain the program’s design to help the user understand why the program behaves the way it does. In some cases, we state that something can be done but

do not give you all the details on how to do it because that information is available in the lessons or other BehavePlus guides.

This publication is based in part on material in a series of self-study lessons that were developed to provide a detailed step-by-step description of various aspects of BehavePlus. A list of available and planned lessons at the time of this writing is provided in Appendix B. The lessons are organized into units and provide detailed, step-by-step instructions and explanation. The Overview Unit describes what BehavePlus is and what it can do. The Introduction Unit consists of four lessons that explain basic operation of the program. The Operation Unit provides additional lessons on more advanced aspects of operation. The Modeling Unit describes the fire modeling capabilities of BehavePlus. This publication primarily covers material in the Introduction and Operation Units, with some from the Modeling Unit. Again, the focus of this paper is program design, not the fire models.

In addition to BehavePlus lessons, there are formal U.S. interagency training courses that include fire modeling concepts (<http://training.nwcg.gov>): S290—Intermediate Wildland Fire Behavior; S390—Introduction to Wildland Fire Behavior Calculations; S490—Advanced Fire Behavior Calculations; S495—Geospatial Fire Analysis, Interpretation, and Application; and S590—Advanced Fire Behavior Interpretation.

2 Fire Modeling Capabilities

The term *model* is used in this report for mathematical relationships that describe an aspect of wildland fire (Andrews and Queen 2001). Models are generally equations that are published in scientific literature. Among the 40 or so mathematical models in BehavePlus are flame length, spotting distance, wind adjustment factor, and bark thickness (Table 1). BehavePlus (or the old BEHAVE) has sometimes incorrectly been equated with Rothermel's surface fire spread model. While that model (Rothermel 1972) does form the foundation of the SURFACE module in BehavePlus, it is only one of the many fire models that comprise the system. Fuel models are not equations but are lists of values needed by the surface fire spread model. Therefore, the 53 standard fuel models are considered to be one “model.”

BehavePlus models are grouped into logical groups called *modules*. Included among the nine modules are SURFACE for surface fire behavior, CROWN for crown fire, and MORTALITY for tree mortality. Table 2 gives a short description of each module with notes on relationships among them. The **Module Selection** window is shown in Figure 1. Indentations indicate where linkages between modules are possible, with output from one module used as input to the other. If both modules are selected, the linkage is in effect. For example, if both SURFACE and SCORCH are selected, they are “linked.” The flame length that is calculated in SURFACE is used as input to the scorch height model in SCORCH. If SURFACE is not selected, the user must enter a flame length value into SCORCH. Using SCORCH without SURFACE can aid understanding of the scorch height model. It also allows a person to use observed flame length rather than calculated values.

The term *system* is used for a computer program, nomogram, or some other packaging of models, interface, and data into a form that fire managers can use. BehavePlus, FARSITE (Finney 1998), FlamMap (Finney 2006), and FSPro (Finney and others, in press) can be considered a suite of fire behavior systems. A table showing the relationship among those

systems (taken from Andrews 2007) is given in Appendix C. These systems are based on many of the same core fire models but are designed for different applications. One of the important uses of BehavePlus is for improved model understanding. It is difficult to see relationships among variables of interest in the maps produced by spatial systems. BehavePlus can be used to exercise the models and systematically examine relationships such as the effect of a choice of a given fuel model or a live fuel moisture value on surface fire rate of spread and flame length. While many examples in this paper use the SURFACE module, remember that modeling surface fire behavior is just one component of the BehavePlus fire modeling system (Table 1).

Table 1—Models that are included in each of the BehavePlus modules with citations (from Andrews 2007).

| BehavePlus module | Model | Reference and notes |
|-------------------|---|--|
| SURFACE | Surface head fire rate of spread, reaction intensity, characteristic dead fuel moisture, live fuel moisture of extinction, etc. | (Rothermel 1972) (Albini 1976a) minor adjustments |
| | 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 (Finney 1998; Rothermel 1983) 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 of 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 Rothermel's 11 plus 2 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 1987; Burgan and Rothermel 1984) |
| | Dynamic fuel load transfer | (Burgan 1979) (Andrews 1986; Burgan and Rothermel 1984) 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, two-dimensional expected spread | (Finney 2003) |
| | Palmetto gallberry special case fuel model | (Hough and Albini 1978) |
| | Western aspen special case fuel model | (Brown and Simmerman 1986) (Brown and Debyle 1987) for mortality |

(continued)

Table 1 (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 | (Van Wagner 1989; 1993) (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 1977) |
| | Active crown fire, relationship of crown fire rate of spread and critical crown fire rate of spread | (Van Wagner 1989; 1993) (Finney 1998; Scott and Reinhardt 2001) |
| | Fire type: surface, torching, conditional crown, or crowning | (Van Wagner 1993) (Finney 1998; Scott and Reinhardt 2001) |
| | Crown fire flame length | (Thomas 1963) |
| | Crown fire intensity | (Rothermel 1991) |
| | Power of the fire, power of the wind | (Byram 1959) |
| SAFETY | Safety zone size, separation distance, radius | (Butler and Cohen 1996; 1998a; 1998b) |
| SIZE | Elliptical fire size and shape, area, perimeter, length-to-width ratio | (Anderson 1983) double ellipse (Andrews 1986) simplified to simple ellipse |
| CONTAIN | Fire containment | (Albini and others 1978) in the old BEHAVE (Fried and Fried 1996) in BehavePlus |
| SPOT | Spotting distance from torching trees | (Albini and Baughman 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) |
| MORTALITY | Tree mortality | (Reinhardt and Crookston 2003; Ryan and Reinhardt 1988) (Hood and others 2008) updates for version 5.0 |
| | Bark thickness | (Hood and others 2008; Reinhardt and Crookston 2003; Ryan and Reinhardt 1988) |
| 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) |

Table 2—Modules in BehavePlus are groupings of related mathematical fire models.

| Module | Calculations | Linkages |
|-----------|---|---|
| SURFACE | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Transition from surface to crown fire • Crown fire rate of spread • Crown fire area and perimeter • Fire type: surface, torching, conditional crown, or crowning • Crown fire intensity and flame length • Power of the fire, power of the wind | <ul style="list-style-type: none"> • Surface fireline intensity or flame length can come from SURFACE • Surface fire heat per unit area can come from SURFACE |
| SAFETY | <ul style="list-style-type: none"> • Safety zone size based on flame length • Area, perimeter, and separation distance | <ul style="list-style-type: none"> • Head fire flame length can come from SURFACE |
| SIZE | <ul style="list-style-type: none"> • Elliptically shaped point source fire • Area, perimeter, and shape | <ul style="list-style-type: none"> • Head fire rate of spread and effective wind speed can come from SURFACE |
| CONTAIN | <ul style="list-style-type: none"> • Fire containment success for single or multiple resources given line construction rate, arrival time, resource duration, head or rear attack, and direct or parallel attack • Final area and perimeter, fire size at initial attack, and fireline constructed | <ul style="list-style-type: none"> • Head fire rate of spread can come from SURFACE • Length-to-width ratio and fire size at report can come from SIZE |
| SPOT | <ul style="list-style-type: none"> • Maximum spotting distance from torching trees, burning piles, or wind-driven surface fire | <ul style="list-style-type: none"> • Head fire flame length can come from SURFACE for wind-driven surface fire |
| SCORCH | <ul style="list-style-type: none"> • Crown scorch height from surface fire flame length | <ul style="list-style-type: none"> • Surface fireline intensity or flame length can come from SURFACE |
| MORTALITY | <ul style="list-style-type: none"> • Probability of mortality from bark thickness and crown scorch | <ul style="list-style-type: none"> • Scorch height can come from SCORCH |
| IGNITE | <ul style="list-style-type: none"> • Probability of ignition by firebrands • Probability of ignition from lightning strikes | |



Figure 1—Fire models are organized according to calculation modules. In this example, SURFACE and SCORCH are selected. The indentation of the selected modules, SCORCH under SURFACE, indicates that the modules are linked with outputs from SURFACE providing input to SCORCH.

3 Worksheets and Runs

A *worksheet* is a form that guides user input to BehavePlus. It is built automatically by the BehavePlus program based on user selection of modules, input options, and output variables so that only the required input values are included on the worksheet. The term *run* is used for a worksheet in which values have been assigned to the required input categories. **Calculate** is the menu selection that produces the output pages for a run.

The worksheet is the foundation of the BehavePlus design. What you see is only part of what you get. Worksheet and run files include not only what is visible on your monitor but an entire suite of selections. We start with a description of the visible parts of a worksheet and related output pages, followed by an explanation of the selections that define all aspects of a worksheet. We then discuss using and saving worksheets and runs.

3.1 Worksheet Components and Output Pages

In the following sections, we describe components of the larger BehavePlus window, the worksheet, and output pages. Items are numbered in the figures to correlate with the descriptions.

3.1.1 Window Components

The BehavePlus window header and footer (Figure 2) give information about the program, the current run and workspace, and the operation menu and icons. The body of the window is the worksheet and results pages, as described in following sections.

1—Window Label

The window label shows the program name and version number (BehavePlus 5.0.1) and the name of the run (not of the worksheet). The name is initially **unnamed01.bpr**, increasing sequentially with each worksheet that is opened. When a run is saved, the run name changes to the file name used when saving. When a run is opened, the name in the window header is the file name of that run. More than one worksheet and/or run can be open at a time; the header helps you keep track of which file you are viewing. You can switch among worksheets or cascade or tile their display using the **Windows** drop-down menu.

2—Menu Items

The menu items located in the toolbar at the top of the BehavePlus window provide access to all of the BehavePlus commands.

3—Command Icons

Icons are available below the menu items for commonly used commands, especially the **Module Selection** icon and the **Calculate** icon (circled in green). The arrows let you view first, last, next, and previous pages. Hovering the cursor over the icon shows its function.

4—Window Footer

The window footer provides the location of the current workspace (Section 9.2). In addition, the current page number and the total number of pages are given in the footer.

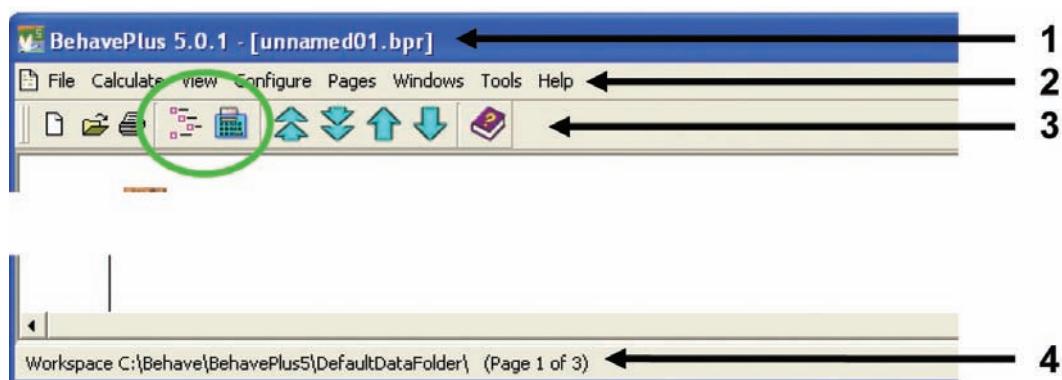


Figure 2—BehavePlus window components, header, and footer. Reference numbers (1-4) refer to description in the text.

3.1.2 Page Layout

A basic design feature of BehavePlus is the page format of 8½- by 11-inch that is suitable for printing. The worksheet may carry over from one page to the next. Each output table or graph begins at the top of a new page. Wide or long tables may span several pages. A run exported to HTML format does not have page breaks, and the exported file can be reformatted using a spreadsheet (Section 8.6). The general layout is similar for all BehavePlus pages (Figure 3).

5—Page Header

The header line on each BehavePlus page includes the program name, version number (BehavePlus 5.0.1), and page number. When calculations are made, the date and time are added. The program version number is useful for future reference. A change log for the program is available on the BehavePlus web site that lists bug fixes and also provides a summary of updates made with each major version. The date and time in the header change each time you **Calculate** a run, providing a means of matching input and output pages if they are separated after being printed. Each worksheet and results page is numbered. If portions of BehavePlus input and output pages are included in a report, it is important to include the page header for complete documentation.

6—Tabs

Tabs can be added to the page layout as an additional means of organization and documentation using **Configure > Appearance preferences > Page Tabs** (Appendix H). An identical tab is placed on every page of the run. You can create a tab for a related run in the next position on the page.

7—Page Border

The page border color and width can be changed using **Configure > Appearance preferences > Application** (Appendix H). A border width of zero eliminates the border surrounding the page. This setting applies to all worksheets in the current BehavePlus session. Any change made using **Configure > Appearance preferences > Application** is preserved between BehavePlus sessions.

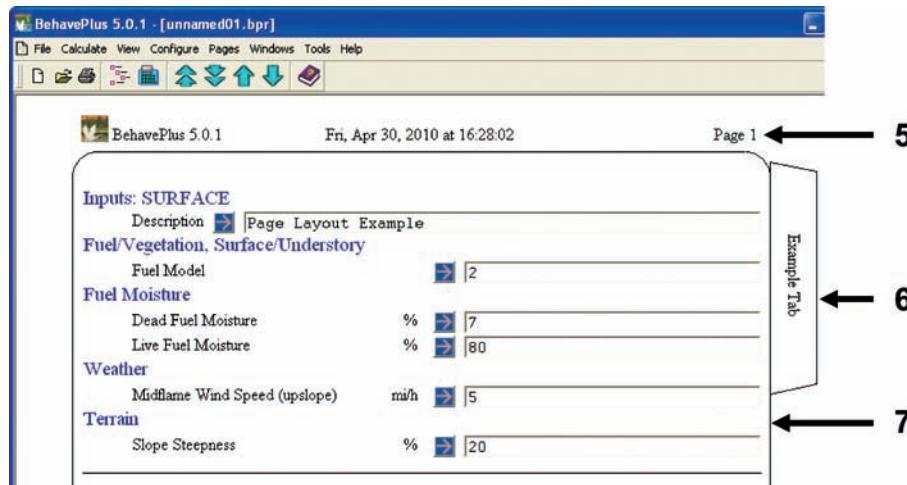


Figure 3—BehavePlus page layout showing page header, tabs, and border. Reference numbers (5-7) refer to description in the text.

3.1.3 Worksheet Components

Items on the worksheet are determined by user selections (Figure 4). The first component of the worksheet is the **Inputs** section. The **Acceptable Fire Conditions** section is included if that option is selected on the **Module Selection** window. The **Run Option Notes** section includes important reminders of selections that were made to develop the current worksheet. The **Output Variables** section can be included or omitted. The **Notes** section is also optional.

8—*Inputs: Selected Modules*

The selected modules are listed at the top of the input section. In this case, both SURFACE and SIZE are selected. The indentation of SIZE under SURFACE in the **Module Selection** window (Figure 1) indicates that the two modules are linked. In this case, the head fire surface rate of spread and effective wind speed that are calculated in SURFACE are used in SIZE (Table 2).

9—*Description*

A description of the run helps you keep track of the purpose of the run, although it is not necessary to enter something in this field. The text typed here is used as a header line on all output pages and as the default description if you save a worksheet or a run. It is also used as the description of a saved custom fuel model or moisture scenario, although you can easily change it when you save the file. Other description lines can be added using **Configure > Appearance preferences > Worksheet**. In this example, three additional lines were added since the **Prescribed fire plan worksheet header** was selected.

10—*Input Variables by Category*

Input variables are organized by category such as **Fuel Moisture** and **Weather** rather than by module such as SURFACE or SIZE since the same input variable may be used by more than one module. The Variables paper (Andrews 2009) includes a table of all input variables arranged by category with an indication of the modules in which they are used.

11—*Guide Button*

The **Guide** button feature of BehavePlus makes it a much more powerful system. A click on the **Guide** button opens a window with three panes. The left pane is a picture, included with permission of the artist to add visual interest to an otherwise grey interface. However, if you prefer, the picture can be eliminated on all windows using **Configure > Appearance preferences > Application**, or it can be closed temporarily on the current window to enlarge the right-hand **Help** pane by removing the **Picture** check mark located at the bottom of the window. The center pane provides guidance on entering input values (Sections 6.2, 6.3, and 6.4). The right-hand pane is a *context-sensitive Help* window with a description of the variable (Section 15.3).

12—Input Values

The worksheet includes lines or input fields for all required input variables. Values must be entered for all lines unless they are shaded in blue. Values entered on a blue line are ignored because they are not needed for current calculations. In some cases, an input value for one variable (for example, fuel model) determines whether an input is required for another (for example, live fuel moisture). In Figure 4, none of the selected fuel models contains a live fuel moisture component, and that line is blue.

13—Acceptable Fire Conditions

This section of the worksheet is added when **Table shading for acceptable fire conditions** is selected on the **Module Selection** window (Figure 1; Section 12).

14—Run Option Notes

Notes are automatically generated for select run options (Appendix D). In this example, note that the maximum reliable wind limit IS imposed. A **Run Option** selection is not listed, however, when it is obvious. For example, if fuel moisture is selected to be entered by individual size class rather than by dead and live category or by moisture scenario, the worksheet requests those values, and an additional note is not needed.

15—Output Variables

The output variable selections are optionally listed in the **Output Variables** section and can be removed using **Configure > Appearance preferences > Worksheet**. Although the output tables and graphs clearly show the output variables, the list in this section is a useful summary with units and the associated module name.

16—Notes

The **Notes** section provides a space for user comments and is helpful in documenting a run. This section can be eliminated from the worksheet or the viewing area can be changed to as many as 10 lines long using **Configure > Appearance preferences > Worksheet**.



Inputs: SURFACE, SIZE ← 8

Description → Example Worksheet and Results ← 9

Administrative Unit → Timber District

Prescribed Fire Name → Blue Burn

Prepared By → FMO

Fuel/Vegetation, Surface/Understory ← 10

Fuel Model → 11, 12, 13, sb1, sb2, sb3

Fuel Moisture

Dead Fuel Moisture % → 2 4 6 8 10 12 ← 11

Live Fuel Moisture % →

Weather

Midflame Wind Speed (upslope) mi/h → 4 ← 12

Terrain

Slope Steepness % → 20

Fire

Elapsed Time h → 1

Acceptable Fire Conditions ← 13

Surface Rate of Spread (maximum) (ch/h) ↗ [0.0] - [0.0]

Flame Length (ft) ↗ [0.0] - [5.0]

Area (ac) ↗ [0.0] - [0.0]

Run Option Notes ← 14

Maximum reliable effective wind speed limit IS imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always
for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Output Variables ← 15

Surface Rate of Spread (maximum) (ch/h) [SURFACE]
Flame Length (ft) [SURFACE]
Area (ac) [SIZE]
Perimeter (ch) [SIZE]

(continued on next page)



Notes ← 16

The Notes section can be deleted or increased to 10 lines.
It provides a means of adding documentation of a run.

Figure 4—Example worksheet with input values. Reference numbers (8-16) refer to description in the text.

3.1.4 Output Pages

Once a run has been calculated, results (output) pages will be appended to the worksheet (Figure 5). When an input value is changed, results pages are deleted until another **Calculate** is performed. Saving a run saves the worksheet *and* the values entered into the various fields. To save computer file storage space, output pages are not saved with the run, but they can be quickly recreated via the **Calculate** command.

17—Table Output

Both table and graph outputs were selected for this example. Each output page begins at the top of a new page. In this example, multiple values have been supplied for two input variables (fuel model and 1-h fuel moisture), so a table is produced for each of the selected output variables (surface rate of spread, flame length, area, and perimeter). The tabular data for surface rate of spread is located on p. 3 of the run. Pages 4 to 6 (not shown) are table output for the other three variables. Note that the table header includes the description from the worksheet as well as the name of the output variable.

18—Graph Output

A graph is also produced for each output variable. This example shows p. 7 of the output for surface rate of spread. Pages 8 to 10 (not shown) are graphical output for the other three variables. The text entered on the **Description** line of the worksheet is part of the title. Additional lines are added to the heading because the **Long** version was selected as an option for the title using **Configure > Appearance preferences > Graph Size**.

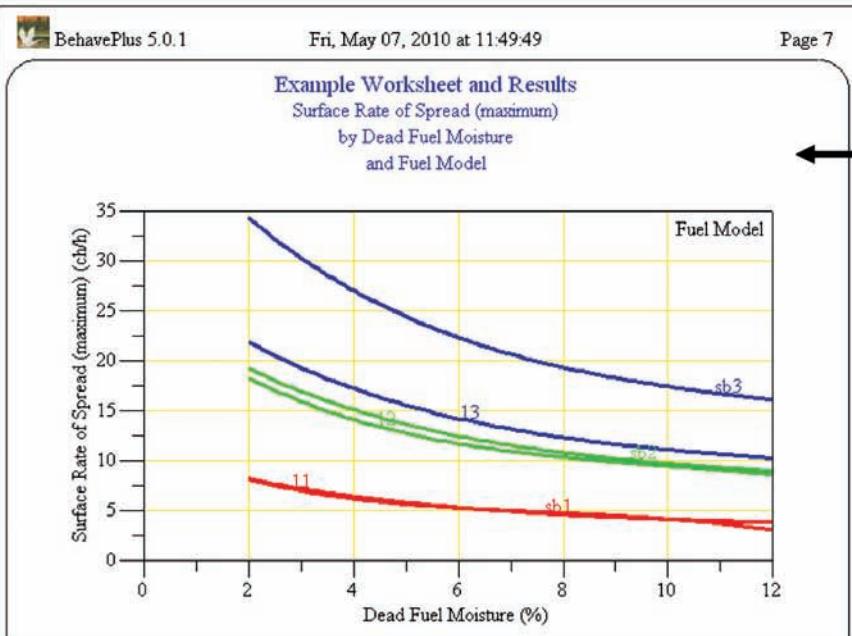
19—Variable Code Definitions

The last page of the run provides a list of definitions for discrete variable codes. The codes listed on this page are only for the values entered on the worksheet. The other available option is **Show descriptions for all discrete variable codes (Configure > Appearance preferences > Worksheet)**. In that case, *all* of the available codes are listed on the worksheet under the input line for that variable. It makes sense to show all of the codes for some variables such as spotting source location with only four options, but it is unreasonable to show all of the codes for the 53 standard fuel models on the input worksheet.

BehavePlus 5.0.1 Fri, May 07, 2010 at 11:49:49 Page 3

Example Worksheet and Results
Surface Rate of Spread (maximum) (ch/h)

| Fuel Model | Dead Fuel Moisture % | | | | | |
|------------|----------------------|------|------|------|------|------|
| | 2 | 4 | 6 | 8 | 10 | 12 |
| 11 | 8.2 | 6.2 | 5.3 | 4.8 | 4.2 | 3.1 |
| 12 | 18.3 | 14.1 | 11.7 | 10.4 | 9.5 | 8.6 |
| 13 | 21.9 | 17.2 | 14.2 | 12.3 | 11.1 | 10.3 |
| sb1 | 8.2 | 6.5 | 5.3 | 4.6 | 4.2 | 3.9 |
| sb2 | 19.2 | 15.1 | 12.5 | 10.8 | 9.8 | 9.0 |
| sb3 | 34.3 | 27.0 | 22.3 | 19.3 | 17.4 | 16.1 |



BehavePlus 5.0.1 Fri, May 07, 2010 at 11:49:49 Page 11

Discrete Variable Codes Used
Example Worksheet and Results

| Fuel Model | Description |
|------------|---|
| 11 | Light logging slash (S) |
| 12 | Medium logging slash (S) |
| 13 | Heavy logging slash (S) |
| sb1 | Low load activity fuel (S) (201) |
| sb2 | Moderate load activity or low load blowdown (S) (202) |
| sb3 | High load activity fuel or moderate load blowdown (S) (203) |

Figure 5—Example output pages. Reference numbers (17-19) refer to description in the text.

3.2 Designing Worksheets

In the previous section, we looked at the visible components of a BehavePlus worksheet. In this section, we describe the selections that define a worksheet. *All* of the selections are stored with a saved worksheet or run, not just those that are visible. There is more to a worksheet than users might realize. In addition to the selection of modules and output variables, the worksheet and run files save your selections for graph size, gridline color, curve width, and so on. An overview is provided below, and more detail is given in following sections.

A worksheet is defined by selections, which are applied to the currently open worksheet and are saved with the worksheet or run.

- Module selection (**Configure > Module selection** menu item or icon; Figure 1)
- Input options (**Options...** button associated with the module; Appendix D)
- Output variables (**Options...** button associated with the module; Appendix E)
- Units and decimal selections (**Configure > Units set selection** and **Configure > Custom units preferences**; Appendix G)
- Appearance of graphs, tables, and worksheets (**Configure > Appearance preferences**; Appendix H)

In addition to selections made for the current worksheet, several selections are preserved between sessions, specifically those available on the **Configure > Appearance preferences > Application** tab. These selections include whether the **Help** and **Picture** panes are displayed in the pop-up windows and the worksheet border color and width. A change will be applied to all worksheets in the current session and selections are maintained between sessions.

Selections that are saved with a run are all of those included with the worksheet as well as selections that are offered with the **Calculate** command: display of table and/or graph results, selection of the table row variable and of the X-axis variable, and whether the Y-axis limits are specified.

Technically, BehavePlus does not have default selections, which are settings automatically assigned by the program. We have, however, made selections and saved them in **0Default.bpw**, **BasicStart.bpw**, and other worksheets available in the **Example-Worksheets** folder (Section 3.3.1). All of the available options as well as our selections are listed in Appendices D through H. These selections are what we mean when we use the word default in this paper. If these settings do not meet your needs, you can save your own selections with a worksheet that you can then define as your startup worksheet (Sections 3.3.2 and 3.3.3). BehavePlus defaults are not assigned by the program, but by users through selections in the current worksheet.

We discuss below selections that are saved with a worksheet or run, again emphasizing that *all* selections are saved, not just those that appear on the current view.

3.2.1 Module Selection

The **Module Selection** window is shown in Figure 1. The associated mathematical models for each BehavePlus module are given in Table 1. Indentation indicates that the models can be linked, with output from one being used as input to the other. Notes on linkages are given in Table 2.

3.2.2 Map Distances and Table Shading Options

The **Module Selection** window includes two additional selections (Figure 1). Checking **Display output distances in map units** adds map distances for distance calculations such as spread distance in SURFACE (Section 14.1) that do not need to be explicitly selected as output variables by the user. Checking **Table shading for acceptable fire conditions** adds an additional section to the worksheet (Figure 4). Table shading is described in Section 12.

3.2.3 Input Options

Input options available for each module are accessed via the **Options...** button associated with the module (Figure 1). All of the available input options are given in Appendix D. The SURFACE module offers the greatest number of input options, which are separated onto several tabs (Figure 6). Navigation arrows at the right (circled in green) allow you to see all of the tabs if they do not appear on your screen.

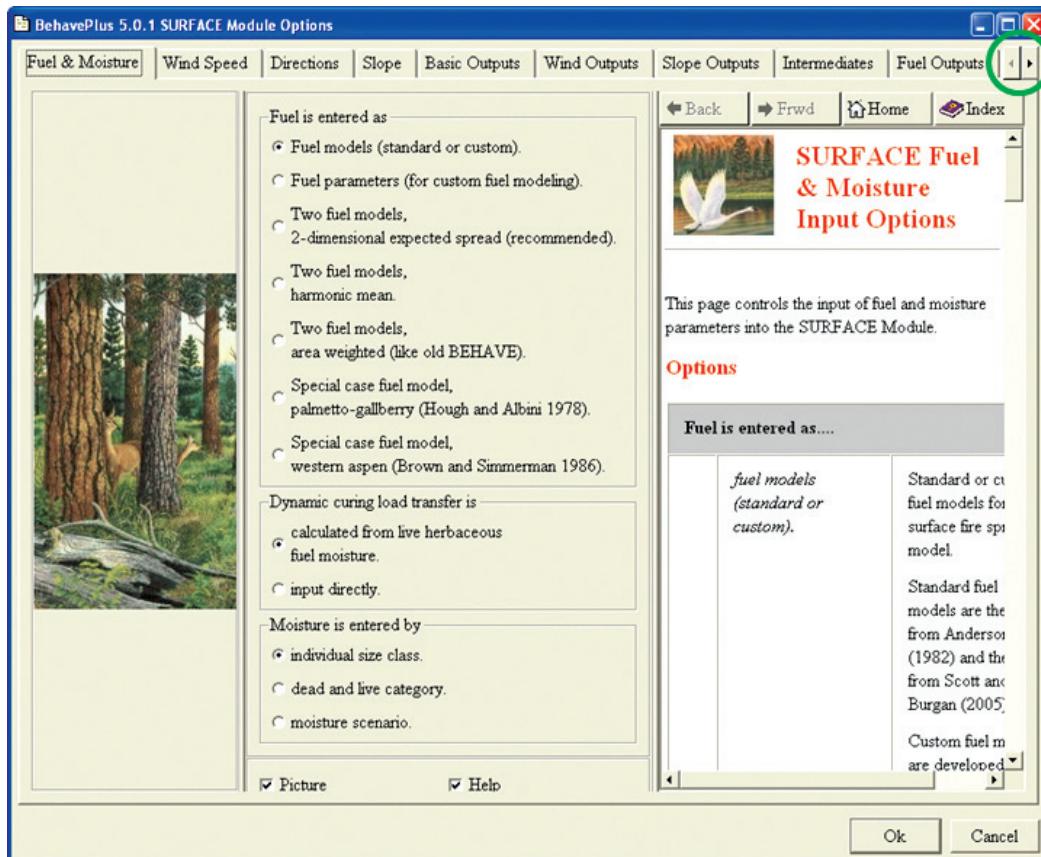


Figure 6—The input options for the SURFACE module are available on the tabs labeled **Fuel & Moisture**, **Wind Speed**, **Directions**, and **Slope**. Other tabs are for output variable selection. If you do not see all of the tabs, use the navigation arrows at the right.

3.2.4 Output Variables

Each module has a list of output variables available via the **Options...** button. Appendix E lists the outputs and default selections associated with each module. The Variables paper (Andrews 2009) includes a table of output variables with units and an indication of whether they are available as map distances or as table shading variables. The SURFACE module includes the most output variables, separated on several tabs (Figure 6). Figure 7 shows the output variables available for the SIZE module.



Figure 7—Eight possible output variables are available for the SIZE module. Area and perimeter are selected in this example.

3.2.5 Appearance Preferences

The menu item **Configure > Appearance preferences** opens a window with several tabs that contain options for customization (Figure 8). The **Graph Size** and **Graph Elements** tabs offer selections that affect graph output (Section 7.3). **Page Tabs** allows you to add tabs to the worksheet as shown in Figure 3. The **Tables** tab gives you options for table format (Section 7.2), including the option of either crossing out values or showing blank cells for the table shading option (Section 12). The **Worksheet** tab lets you modify the worksheet (Figure 8). Again, all selections are saved with a worksheet or run.

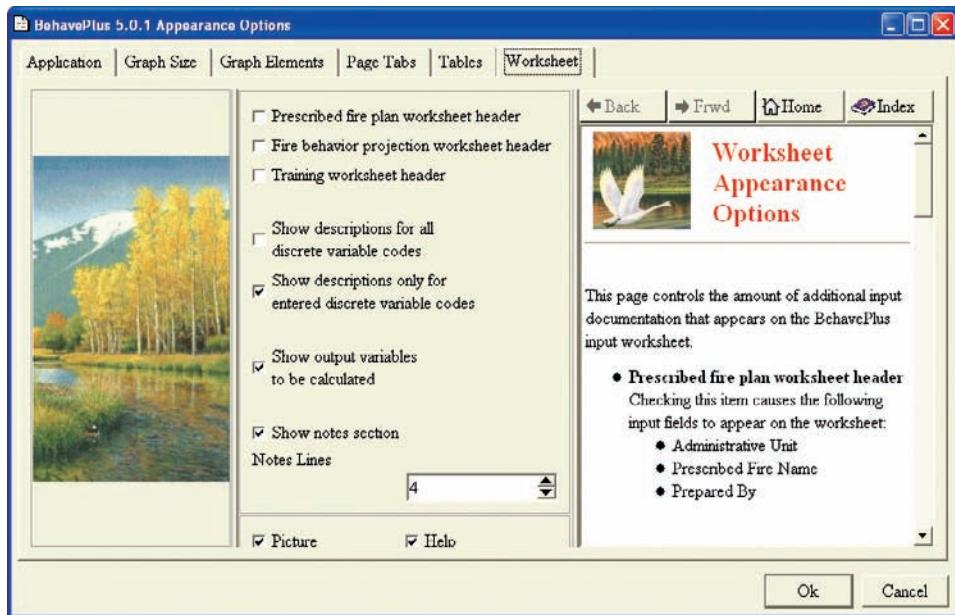


Figure 8—**Appearance options** are saved with a worksheet or run. This figure shows selections on the **Worksheet** tab. Selections on the **Application** tab are applied to the current session and will remain in effect the next time the program is opened.

Selections on the **Application** tab (Figure 9) are a special case because they are preserved between BehavePlus sessions. We see no reason for you to ever remove the check mark from **Show help pane**. However, if you want to eliminate the pictures from all windows, you can remove the check mark by **Show picture pane**. Alternatively, you can remove and restore the picture from the current view using the **Picture** check box at the bottom of each window.

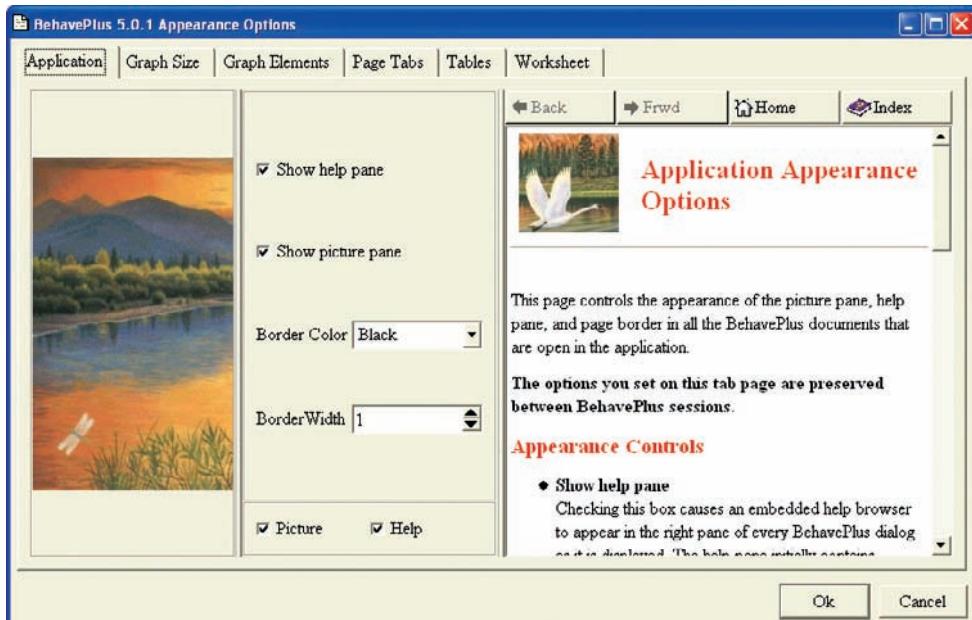


Figure 9—Selections made on the **Application** tab apply to all worksheets and runs in the current session and will remain in effect for future sessions.

3.2.6 Custom Units Preferences and Units Set Selection

Units are assigned to each of the more than 180 variables in BehavePlus for the worksheet and run files even though your visible worksheet shows only a few of them. The units set also includes the number of decimal places displayed for *output* variables. A discussion of units and decimal display options is provided in Section 5.

Configure > Custom units preferences lets you define and save your own set of units and decimals. **Configure > Units set selection** lets you select from our choices for English or metric units as well as your *saved* custom sets. In addition, you have the option of changing units or decimals for the current worksheet without saving a custom set. These changes are saved with the worksheet.

3.3 Saving and Using a Worksheet

As noted, the worksheet concept is at the core of the BehavePlus design. The form of the worksheet depends on user selections. You can change module selections, output variables, and input options to adapt a worksheet to your current needs. You can use one of the example worksheets that come with the program, or you can use one that you previously developed and saved. All BehavePlus worksheets have the extension **.bpw**. More than one worksheet can be open at the same time.

3.3.1 Example Worksheets

A few worksheets are packaged with the program in the folder named **ExampleWorksheets** (Figure 10). This folder is write-protected, so you cannot save other worksheets there. If you make a change to an example worksheet, you must save it elsewhere. The *example* worksheets were called *standard* worksheets in earlier versions of BehavePlus. But “standard” is a misnomer; they are merely examples that we have developed.

The most important example worksheets are **FuelModeling.bpw** and **FuelModeling-Metric.bpw** because they are set up specifically to handle decimal display for fuel load values defined with the **Initialize from a Fuel Model** option (a change in Version 5.0). Explanation is given in Section 5.2.

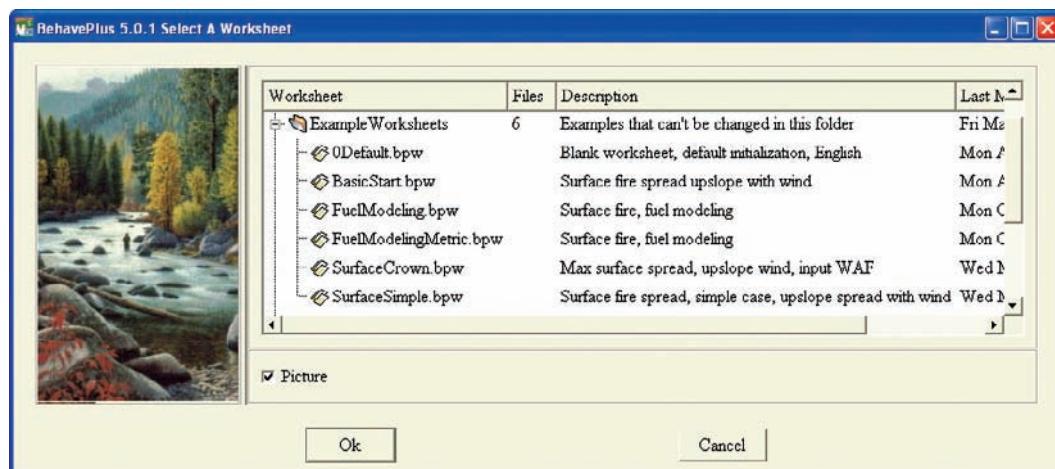


Figure 10—Several example worksheets come with the program. The **ExampleWorksheets** folder is write-protected. Worksheets in this folder cannot be changed and new ones cannot be added.

3.3.2 0Default.bpw and BasicStart.bpw Worksheets

If you open the **0Default.bpw** worksheet, it looks blank (Figure 11). But as we have explained, it includes the full set of selections (Appendices D through H). The only difference between **0Default.bpw** and **BasicStart.bpw** is the selection of the SURFACE module. The **0** in the file name forces it to show up at the top of the list. If you open **0Default.bpw** and select a module, then the default input options, output variables, appearance options, and so forth will appear.

Recall that the defaults are simply our selections. You may want to develop your own set of defaults and name it something like **0MyDefault.bpw**. For example, you may prefer to use more than three colors on the graphs. Rather than making the change every time you open a worksheet, you can make the change in your own default worksheet and in other saved worksheets.



Figure 11—The **0Default.bpw** worksheet appears blank when it is opened, but it includes all of the selections for input options, output variables, etc., in the default settings.

3.3.3 Startup Worksheet

The **BasicStart.bpw** worksheet opens when you first start BehavePlus. You can, however, change the startup worksheet (**File > Set startup worksheet**) to another example worksheet or to any worksheet that you have saved. If you generally use metric units, this saves the steps of starting with **BasicStart.bpw** and then changing the units set. It is also helpful to be able to change your startup worksheet based on your current work effort.

When working as a Fire Behavior Analyst on a wildfire, you would use a different startup worksheet than the one you would use when you are working on prescribed fire planning in the office. If you are working on a report, you might have a startup worksheet that produces graphs in black and white rather than in color.

3.3.4 Your Worksheets

A folder called **MyWorksheets** is available for worksheets that you develop and save. BehavePlus allows the user to create additional folders to facilitate file organization. For example, if you often use metric units, you may decide to open each example worksheet, change the units to metric ones, and then save the files. By creating a new folder with a meaningful name, such as **MetricExampleWorksheets**, you can keep the metric worksheets in this separate folder to prevent confusion.

When you save a worksheet, the entry in the **Description** line of the worksheet is saved with the file name. (Note the Description column in Figure 10.) You have the option of changing the description at the time you save the worksheet. To create a new folder for worksheets, simply enter a new folder name in the **Worksheet Folder** field.

You can give a folder of worksheets to someone else who can use his or her computer's file management program (such as Windows® Explorer) to put it in their **Worksheet-Folder** (Section 9.1). In Figure 12, example worksheets were saved in a folder named **BugTest** and were given to the programmer.

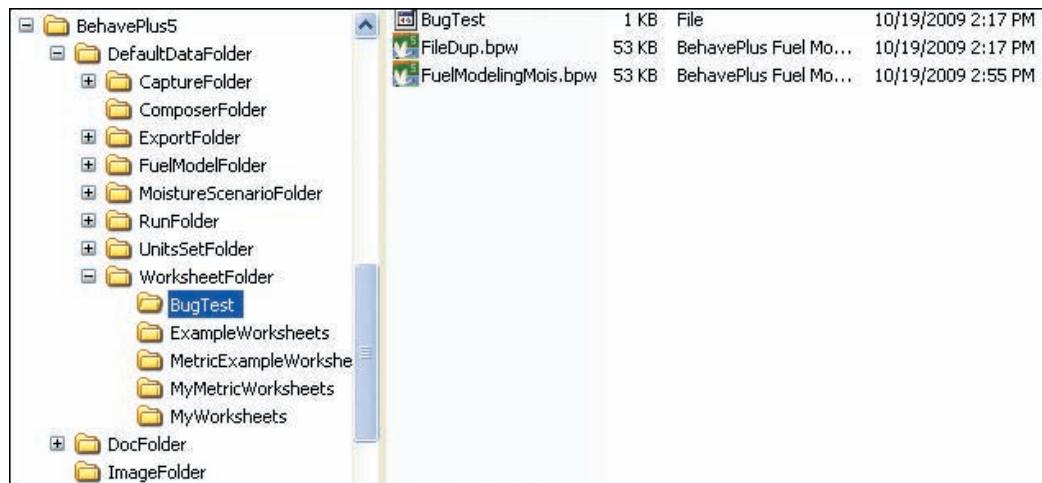


Figure 12—A folder of worksheets can be given to someone else to put in their **WorksheetFolder**. The folder includes the **.bpw** worksheet files and a small file with the description of the folder.

3.4 Saving and Using a Run

Recall that the difference between a worksheet and a run is that a run has values entered on the worksheet. All worksheet selections are saved with a run. In addition, a saved run includes selections made on table and graph outputs following a **Calculate** command. When a run is saved, the results are not saved. Results can be recreated by simply opening the run and recalculating the results. All BehavePlus runs have the extension **.bpr**.

3.4.1 Calculate Options

When you calculate a run, you specify whether you want table and/or graph output and make selections on the table row variable and the X-axis variable. You can either let the program scale the graph to the maximum calculated value or you can specify other Y-axis limits (Section 7.3.3). Selections in the **Calculate Results** window are saved with a run, but not with a worksheet (Figure 13).

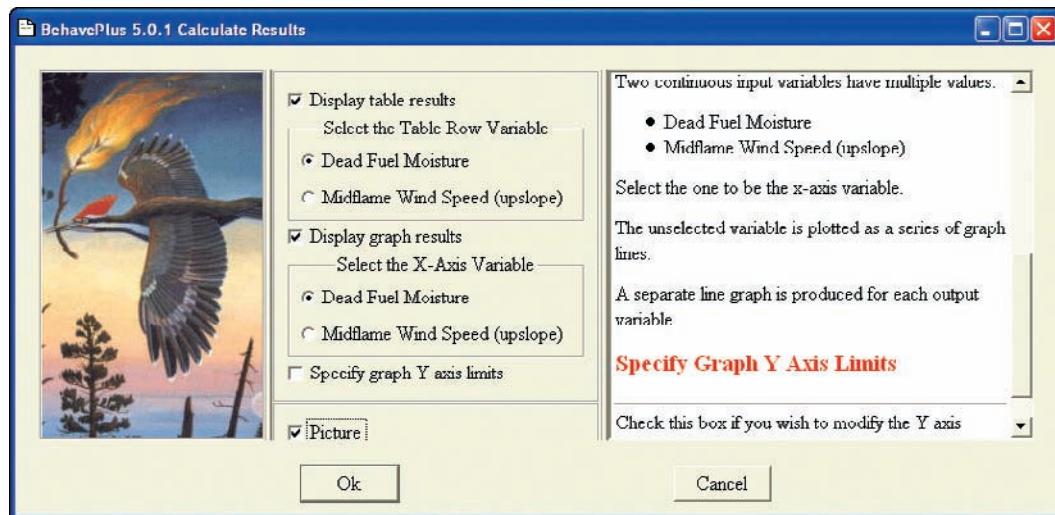


Figure 13—Selections in the **Calculate Results** window are saved with a run.

3.4.2 Example Runs

Similar to **Example Worksheets**, the write-protected folder named **ExampleRuns** provides several sample runs with the BehavePlus program. For example, the **FuelHerb-Mois.bpr** run produces plots of surface rate of spread and flame length for several fuel models for a range of live herbaceous fuel moisture values (Figure 14). You can quickly open this run and change the fuel models to produce another comparison plot.

**Inputs: SURFACE**

Description → Compare fuel models, range of live herb. mois.

Fuel/Vegetation, Surface/Understory

Fuel Model → 1, 2, gr1, gr2

Fuel Moisture

1-h Moisture % → 3

10-h Moisture % → 4

100-h Moisture % → 5

Live Herbaceous Moisture % → 30, 300

Live Woody Moisture % → 120

Weather

Midflame Wind Speed (upslope) mi/h → 5

Terrain

Slope Steepness % → 0



Compare fuel models, range of live herb. mois.

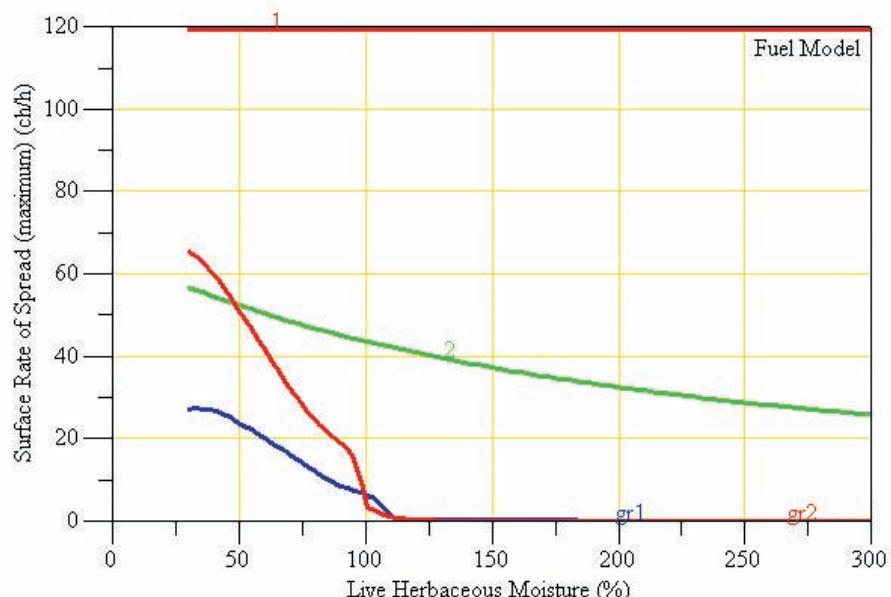


Figure 14—The example run **FuelHerbMois.bpr** reveals the impact of fuel model selection on surface rate of spread for a range of herbaceous fuel moisture.

3.4.3 Your Runs

A folder called **MyRuns** is available for runs that you develop and save, but you can create additional folders and give them meaningful names. You can give a folder of runs to someone else, as described for worksheets (Section 3.3.4).

BehavePlus runs prepared for a project such as prescribed fire planning or wildfire prediction should be saved in a separate documentation file for future reference. The workspace feature of BehavePlus is useful for this purpose (Section 9.2).

4 Display and View Features

In this section, we group a discussion of several topics related to display:

- changing the size of the displayed BehavePlus page (Section 4.1),
- viewing multiple runs simultaneously (Section 4.2),
- moving quickly between BehavePlus pages (Section 4.3),
- changing graph size (Section 4.4),
- expanding the **Help** window for better viewing (Section 4.5), and
- exploring **Help** system PDF documents using bookmarks and links (Section 4.6).

4.1 Window and Page Size

When BehavePlus opens, the window is sized to fit the worksheet. The window size can be changed by dragging the sides, but the BehavePlus page size doesn't change. To change the worksheet display size, use **View**, located on the toolbar (Figure 15). A check mark highlights the current display size. Reducing the view percentage is useful for displaying an entire page on a small monitor or for screen captures. Increasing the percentage will make the text easier to see in presentations.

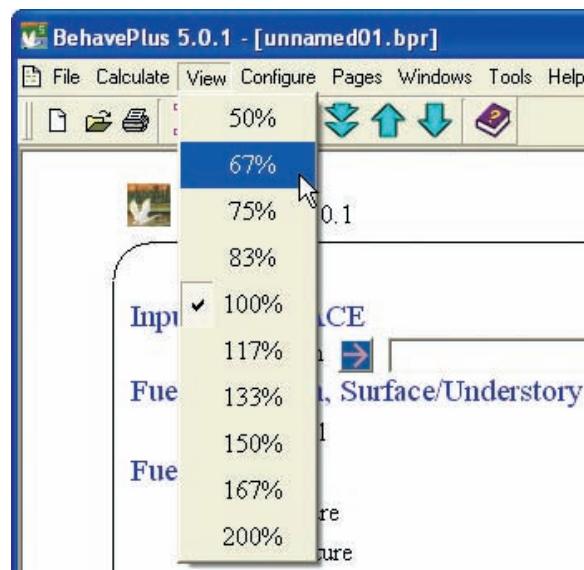


Figure 15—The **View** item in the toolbar allows you to change the size of the display on your monitor.

4.2 Multiple Windows

The Windows menu option allows a switch from one worksheet/run to another or for simultaneous display of multiple runs (Figure 16). The active run is marked with a check mark. This option is useful when doing comparison runs.

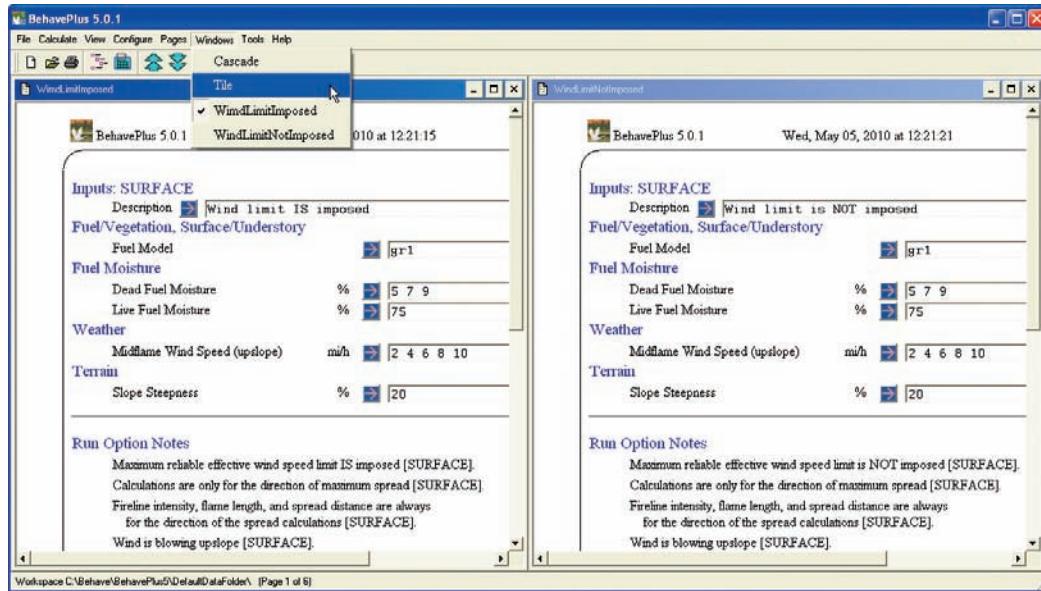


Figure 16—The **Windows** drop-down menu allows a switch between runs or simultaneous display of multiple runs.

4.3 Page View

As previously noted, BehavePlus is designed around producing pages suitable for printing. To view the next or previous page or to go to the first or last page, use the vertical blue arrows located on the toolbar. To jump directly to the page you want to see, use **Pages** on the toolbar (Figure 17). In this example, there are 11 pages: 2 input pages, 4 pages of tables, 4 pages of graphs, and 1 page for discrete variable codes. In addition to a specific description of the page, the icons in the list help you quickly jump to the first graph, for example.

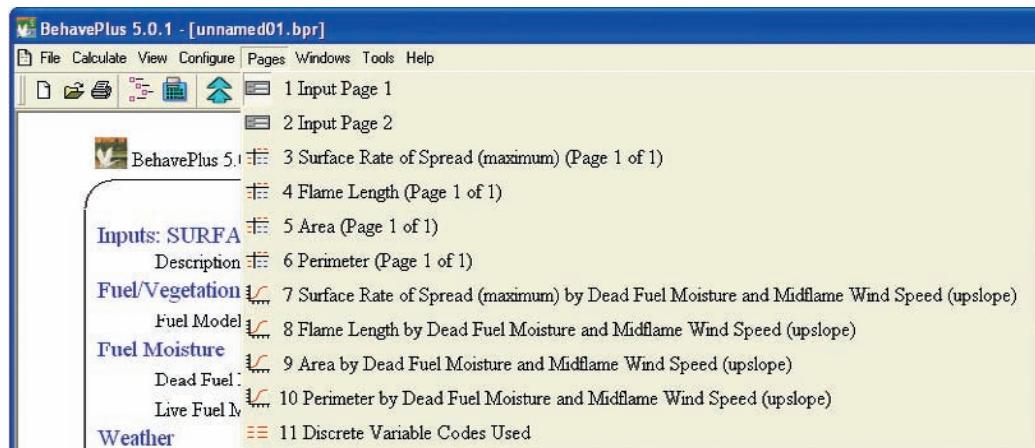


Figure 17—The **Pages** command on the toolbar lets you jump to the page you wish to view. In this example, there are two input pages, four table pages, four graph pages, and one codes page.

4.4 Graph Size

The size of the graphs with respect to an output page can be changed from the default of 50% using **Configure > Appearance preferences > Graph Size** (Figure 18). A change to 100% fills the page. A change to 75% is shown in Figure 18. When you change any **Appearance preferences**, run outputs disappear; click **Calculate** to recreate the run using the new preferences.



Compare fuel models, range of live herb. mois.

Surface Rate of Spread (maximum)
by Live Herbaceous Moisture
and Fuel Model

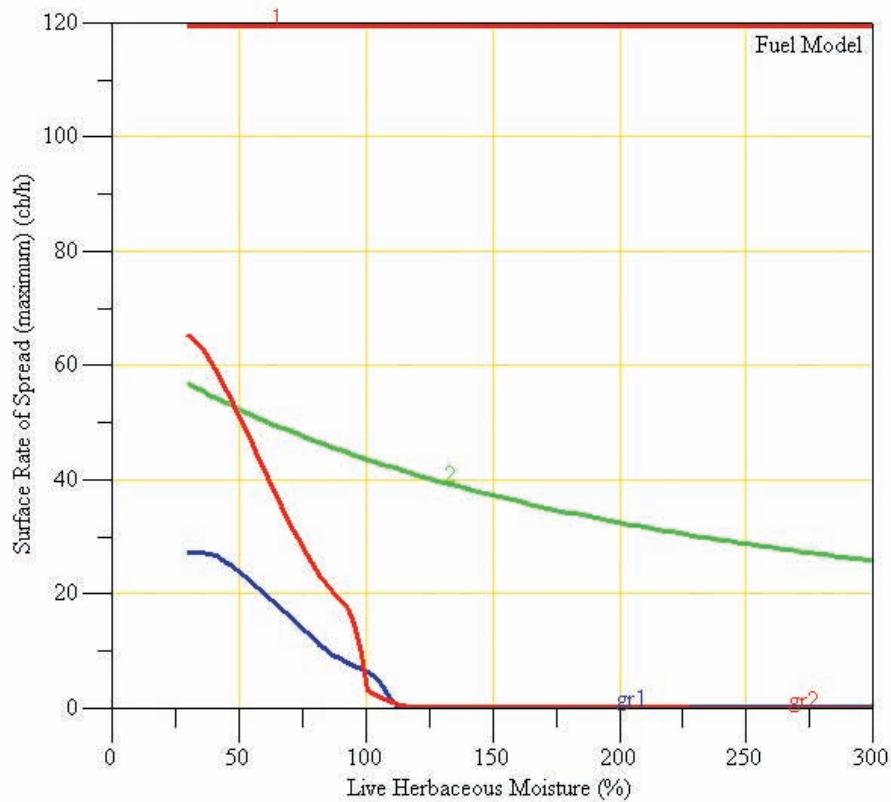


Figure 18—The graph in Figure 14 was changed from 50% to 75% using **Configure > Appearance preferences > Graph Size**.

4.5 Help Window

The **Help** window is a major feature of BehavePlus. *Context-sensitive Help* information is provided in the right-hand pane of every pop-up window (Figure 19). The **Index** button in the pop-up window provides access to other help topics. The **Help** system is discussed in more detail in Section 15.

It can be useful to maximize an **Input Guide** window to see tables and graphs included in the **Help** window. You can also show more of the **Help** window by temporarily turning off the **Picture** using the check box at the bottom of each **Help** window. You can turn off all pictures using **Configure > Appearance preferences > Application** (Section 3.2.5).

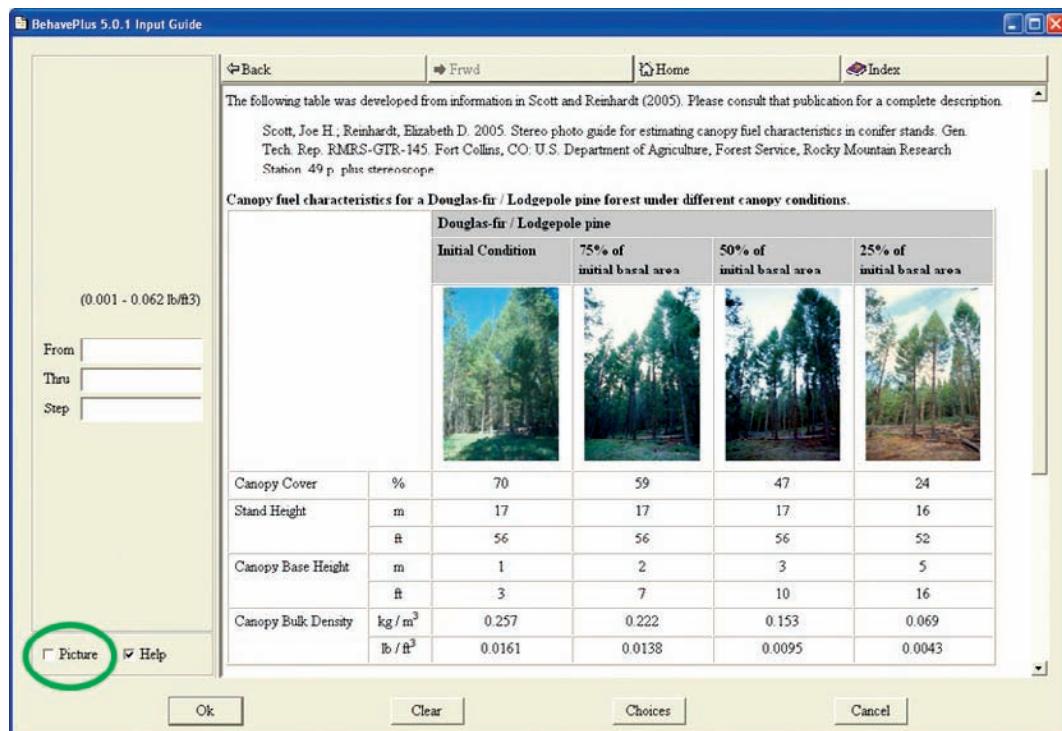


Figure 19—*Context-sensitive Help* information is provided in the right-hand pane of every window. Uncheck **Picture** to remove the picture on the current window to give more room to the **Help** pane. Guidance is given on canopy bulk density for Douglas-fir/Lodgepole pine in this **Help** window.

4.6 PDF Documents

The User's Guide and Variables papers are included as PDF documents available from **Help** on the main menu (Figure 20; Sections 15.1 and 15.2).

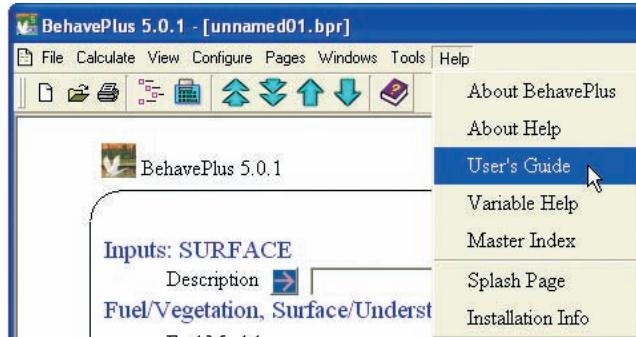


Figure 20—The User’s Guide and Variables paper (“Variable Help”) PDF documents can be opened through **Help** on the toolbar.

Bookmarks and links in the documents help you find what you need (Figure 21). You may need to change settings in Adobe® Acrobat or Reader to take full advantage of the documents. If the bookmarks in the left-hand column do not appear in Adobe® Acrobat, place a check mark next to **View > Navigation Panels > Bookmarks**. The bookmark icon should then appear on the left side of the window. You can expand the bookmarks by clicking on the + sign. In addition, a **Page Navigation Toolbar** allows you to move easily from link to link through the paper. If the right- and left-hand arrows do not appear, click on **View > Toolbars > More Tools...** and scroll down to the options for **Page Navigation Toolbar**. Select **First Page**, **Previous Page**, **Next Page**, **Last Page**, **Previous View**, and **Next View**.

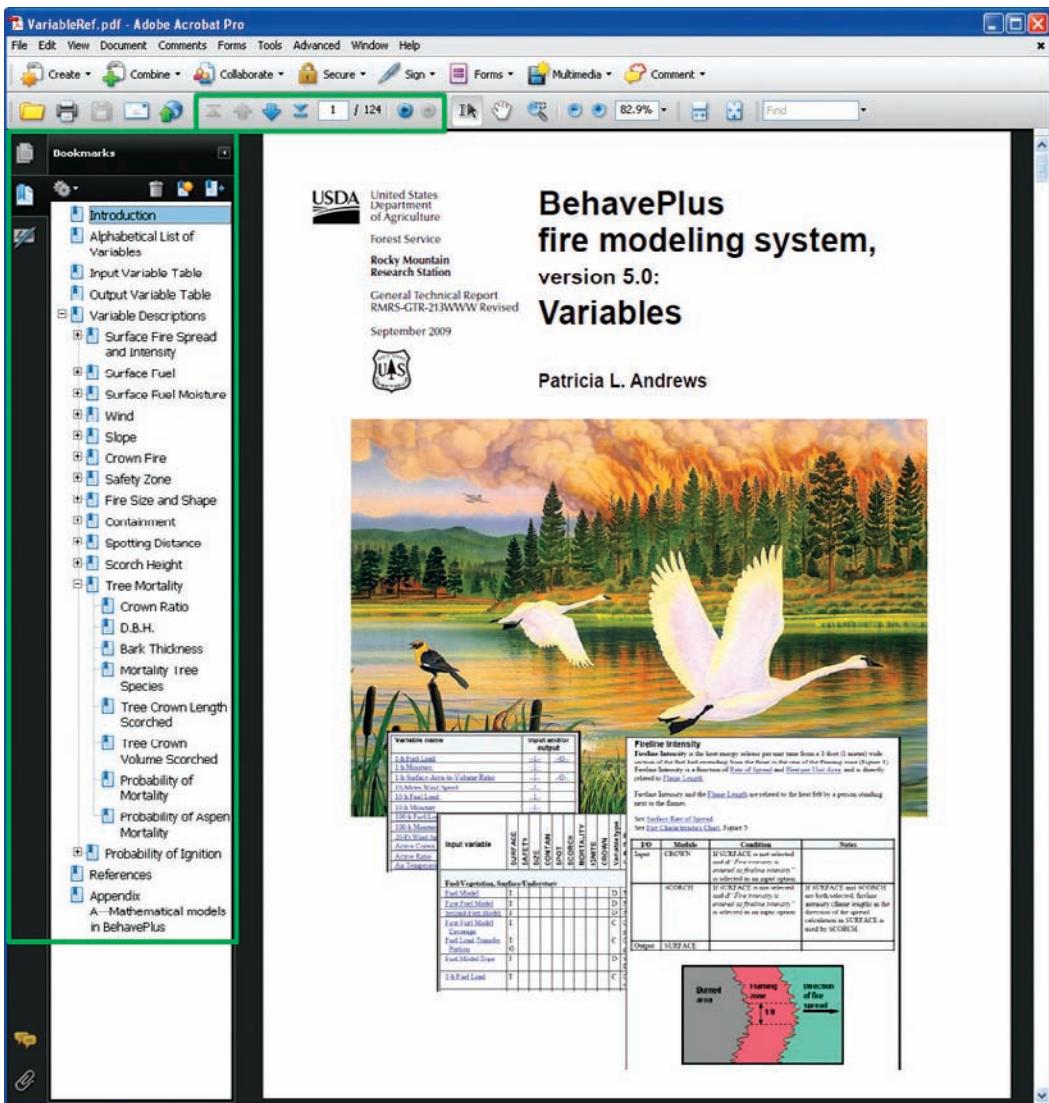


Figure 21—If a PDF document has bookmarks, they can be accessed via the **Bookmarks** toolbar. There is also a **Page Navigation Toolbar** to aid in moving quickly through a document.

5 Units and Decimals

One of the design objectives of BehavePlus was to give the user control over units and decimal display. As with many options, this flexibility comes with a responsibility to understand how the program works. Of course, as with other options in BehavePlus, you can avoid the issue by accepting the default settings.

BehavePlus offers a simple switch between English and metric units (**Configure > Units set selection**). Alternatively, units can be changed for individual input and output variables, and the number of decimal places displayed can be changed for output variables. The number of decimal places for input variables is determined by the values entered on the worksheet. Custom units sets, which include decimal display for output variables,

can be saved for later use. It is also possible to change units and decimals on a worksheet without saving a custom units set; changes to units and decimals are always included in saved worksheets and runs. In addition, BehavePlus includes a helpful **Units converter** tool (Section 5.5). Specifics of units and decimal features are described in the following sections.

Because of issues that can arise due to round off and unit conversions, some basic changes have been made to decimal handling in Version 5.0. We recognize that there is some awkward behavior in decimal display resulting from program design decisions that were made years ago, but this cannot be changed without a major redesign.

BehavePlus calculations are performed in what we call *native units*, the units of the publication that describes the mathematical model. This explains some of the behavior that might seem odd. For example, Rothermel's model uses fuel load in lb/ft² and fuel model parameters are stored in those units. The default display units are tons/ac. The 1-h fuel load for fuel model 5 is stored internally as 0.046 lb/ft², which is equivalent to 1.00188 ton/ac.

Most users will use the same units set (our English or metric or their custom set) for all of their runs and will not switch back and forth between units sets. We have attempted to make the units and decimal handling easiest for the largest user group.

5.1 Input Variable Decimals

Prior to Version 5.0, decimal display of input variables was determined by the setting in the English, metric, or custom units set. Because the program uses values that are visible on the worksheet to make the calculations, there were occasional problems with round off and misinterpretation. Decimal display of input variables is now determined by the values entered by the user. The greatest number of decimal places (precision) entered for a variable determines the decimal display on output tables. In the example in Figure 22, one of the values entered for dead fuel moisture was 9.25% (two decimal places) so all of the dead fuel moisture values on the output table are shown with two decimal places. (This example simply demonstrates the way that the program handles decimal display; a moisture value to that precision is not meaningful.) Similarly, a value of 6.5 mi/h was entered for midflame wind speed, so all of the wind values are shown on the table to one decimal place.

**Inputs: SURFACE**

Description ➔ Demonstrate input decimal display

Fuel/Vegetation, Surface/Understory

Fuel Model ➔ 2

Fuel Moisture

Dead Fuel Moisture % ➔ 4 6.6 9.25

Live Fuel Moisture % ➔ 90

Weather

Midflame Wind Speed (upslope) mi/h ➔ 0 3 6.5 9

Terrain

Slope Steepness % ➔ 0

Demonstrate input decimal display
Surface Rate of Spread (maximum) (ch/h)

| Dead Fuel Moisture % | Midflame Wind Speed (upslope) mi/h | | | |
|----------------------------|---------------------------------------|------|------|-------|
| 4.00 | 0.0 | 3.0 | 6.5 | 9.0 |
| 6.60 | 2.6 | 17.8 | 65.2 | 116.1 |
| 9.25 | 2.0 | 13.6 | 49.6 | 88.4 |

Figure 22—The number of decimal places for input variables that are displayed as rows or columns on table output is determined by the greatest number of decimal places entered as input for that variable.

5.2 Fuel Model Parameter Decimals

Assigning values for fuel parameters is a special case because of the way that input values are assigned using the worksheet option to **Initialize from a Fuel Model**. If you are developing custom fuel models, it is best to use the **FuelModeling.bpw** or **FuelModelingMetric.bpw** worksheets from the **ExampleWorksheets** folder. These worksheets have been designed to display six decimal places for fuel load values to avoid round off problems (Figure 23).

If you prefer to use fewer decimal places, you can develop a similar custom fuel model worksheet by starting with the **BasicStart.bpw** worksheet and changing the input option to **Fuel is entered as Fuel parameters**. In this case, the initialized fuel load values will show two decimal places (Figure 24). In both examples (Figures 23 and 24), the values are obtained using **Initialize from a Fuel Model** and fuel model 2.

The screenshot shows the BehavePlus 5.0.1 software interface with the following details:

- Title Bar:** BehavePlus 5.0.1
- Page Number:** Page 1
- Section Header:** Inputs: SURFACE
- Description:** FuelModeling.bpw; Initialize with fuel model 2
- Table:** Fuel/Vegetation, Surface/Understory
- Columns:** Fuel Model Type, Unit, Value
- Data Rows:**

| | | Initialize from a Fuel Model |
|----------------------------------|------------------------------------|------------------------------|
| Fuel Model Type | → S | |
| 1-h Fuel Load | ton/ac → | 2.003760 |
| 10-h Fuel Load | ton/ac → | 1.001880 |
| 100-h Fuel Load | ton/ac → | 0.500940 |
| Live Herbaceous Fuel Load | ton/ac → | 0.500940 |
| Live Woody Fuel Load | ton/ac → | 0.000000 |
| 1-h SA/V | ft ² /ft ³ → | 3000 |
| Live Herbaceous SA/V | ft ² /ft ³ → | 1500 |
| Live Woody SA/V | ft ² /ft ³ → | 1500 |
| Fuel Bed Depth | ft → | 1.00 |
| Dead Fuel Moisture of Extinction | % → | 15 |
| Dead Fuel Heat Content | Btu/lb → | 8000 |
| Live Fuel Heat Content | Btu/lb → | 8000 |

Figure 23—**FuelModeling.bpw** and **FuelModelingMetric.bpw** worksheets are special case worksheets developed to avoid round off problems when creating custom fuel models. Six decimals are shown for fuel load values when **Initialize from a Fuel Model** is used in these two worksheets.

BehavePlus 5.0.1

Page 1

Inputs: SURFACE

| | |
|--|--|
| Description | → BasicStart.bpw; Initialize with fuel model 2 |
| Fuel/Vegetation, Surface/Understory | |
| Fuel Model Type | |
| 1-h Fuel Load | ton/ac → 2.00 |
| 10-h Fuel Load | ton/ac → 1.00 |
| 100-h Fuel Load | ton/ac → 0.50 |
| Live Herbaceous Fuel Load | ton/ac → 0.50 |
| Live Woody Fuel Load | ton/ac → 0.00 |
| 1-h SAV | ft ² /ft ³ → 3000 |
| Live Herbaceous SAV | ft ² /ft ³ → 1500 |
| Live Woody SAV | ft ² /ft ³ → 1500 |
| Fuel Bed Depth | ft → 1.00 |
| Dead Fuel Moisture of Extinction | % → 15 |
| Dead Fuel Heat Content | Btu/lb → 8000 |
| Live Fuel Heat Content | Btu/lb → 8000 |

Figure 24—When a worksheet is set up by starting with the **BasicStart.bpw** worksheet and the input option is changed to **Fuel is entered as Fuel parameters**, only two decimal places are shown when **Initialize from a Fuel Model** is used.

5.3 Units Set Selection

You can quickly use **Configure > Units set selection** to change among the default English, metric, or custom units sets that you have previously developed and saved (Figure 25). Decimal display for output variables is part of the units set.

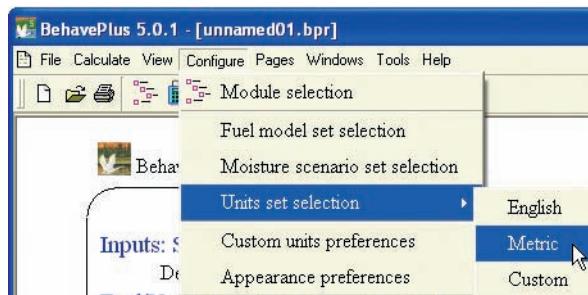


Figure 25—You can change the units set (which includes output decimal display) to English, metric, or a custom set using **Configure > Units set selection**.

If you enter values on the worksheet and then change the units set, six decimal places are displayed for the converted values, although trailing zeros are suppressed. This is a change in Version 5.0. It resolves a problem with round off that sometimes occurred in previous versions. This solution is awkward in some cases, but won't affect most users who generally do not switch back and forth between units sets.

5.4 Custom Units Preferences

A custom units set defines units for all variables in BehavePlus and the decimal display for output variables. Changes may be made using **Configure > Custom units preferences** (Figure 26), which are then applied to the current worksheet. Changes can be saved for future use, if desired. You may want to create a custom units set if, for example, you prefer to use ft/min for rate of spread rather than ch/h. Or you might create a units set with English units for everything except canopy bulk density, which is commonly expressed in kg/m³.

There are over 180 variables in BehavePlus, which are divided into groups for purposes of assigning units and decimal display (Appendix G). The units are assigned by category. Units for all variables in that group will be changed. The **Help** window lists the variables assigned to each group (Figure 26).

You do not have to save a custom units set to apply changes to the current worksheet. You have the option of saving changes in a custom units set or only applying changes to the current worksheet (Figure 27). In either case, the changes will be saved with the current worksheet or run. Figure 28 shows the output table from Figure 22 after reducing the number of decimals for Surface ROS from **1** to **0**. If you are going to use different units and decimals often, you will want to save them as a custom units set, which can be accessed by clicking on **Configure > Units set selection > Custom**.



Figure 26—The decimal display for output variables is changed by **Configure > Custom units preferences**. Variable grouping is given in the **Help** window and is in Appendix G. Variables that only serve as input do not have the option to change decimals.

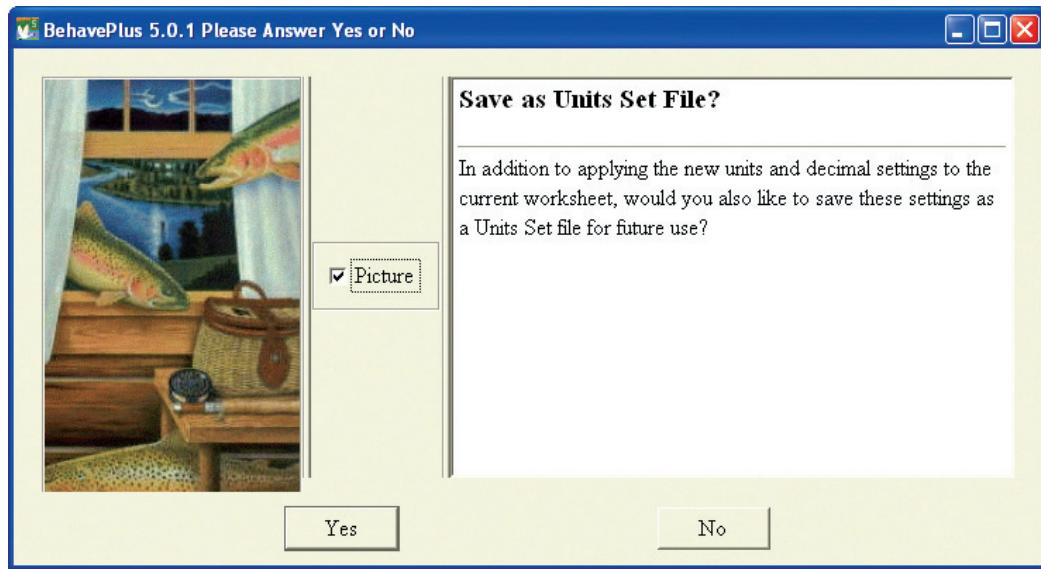


Figure 27—Changes to units and decimals are always applied to the current worksheet. A custom units set file can be saved for future use or used only in the current worksheet/run.

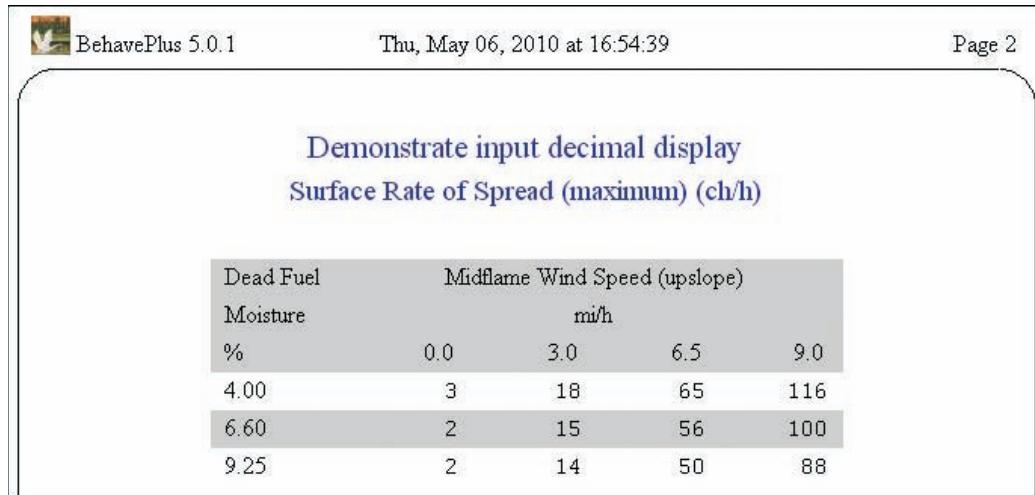


Figure 28—The results from the run in Figure 22 after a change in the number of decimal places from 1 to 0 for Surface ROS (Figure 26).

5.5 Units Converter Tool

The units conversion tool (**Tools > Units converter**) is a flexible tool for converting a quantity between any two related but arbitrary units of measure (Figure 29). The quantity to be converted can be an integer or a real value in either decimal or scientific notation (for example, 0.0005 or 5e-4). Units can be entered as common abbreviations (for example, pounds per foot², lb/ft², lb ft⁻², or lb per ft²). An error message will describe a problem with an entry such as an attempt to convert from feet to kilograms. A long list of units of measure can be found in the **Help** window.

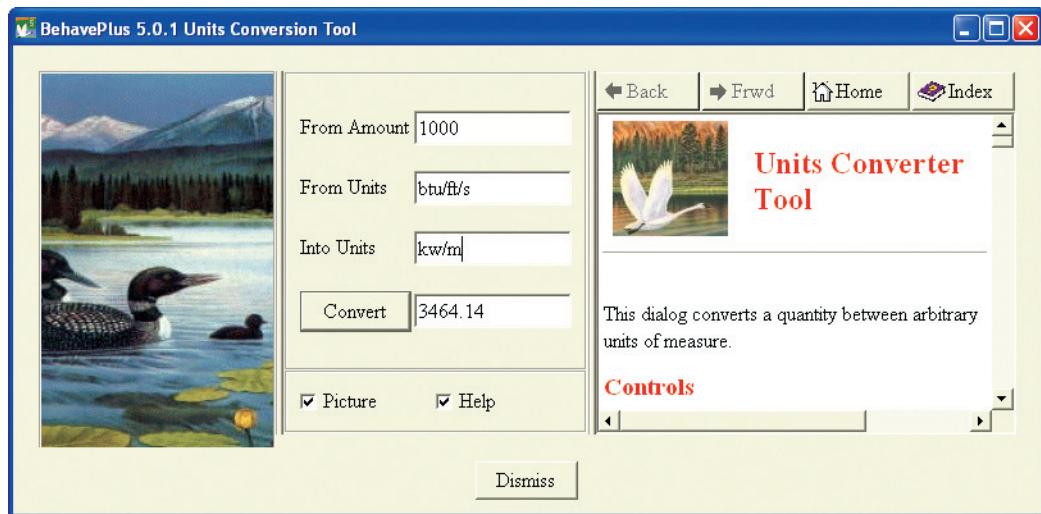


Figure 29—The **Units Converter** tool quickly converts a value from one unit of measure to another.

6 Methods of Input

There are various ways to specify input values to BehavePlus. A particular strength of BehavePlus is the ability to display the influence of inputs on calculated fire behavior (such as the effect of increasing wind speed on rate of spread). Ranges of values are entered to produce tables and graphs. Rarely should a user only enter a single value for each input variable and accept the results. You will most often enter multiple values for input variables before settling on selections.

There are no traditional data files for BehavePlus. Data are entered into a worksheet interactively by the user. Once data have been entered in BehavePlus, however, the worksheet can be saved as a run. Fuel parameter values can be saved as a custom fuel model (Section 10.1), and surface fuel moisture values can be saved as a custom moisture scenario (Section 11.1).

Input variables are categorized as either continuous or discrete. *Continuous variables* are assigned numerical values. Any value in the valid range can be entered. For example, dead fuel moisture percentage can have a value of 4, 4.5, or 5. *Discrete variables*, on the other hand, can have only specific values or codes. For example, a fuel model can be entered as 4, 5, or GR2, but 4.5 is not a valid fuel model code. A table in the Variables paper (Andrews 2009) describes which variables are discrete and which are continuous, but BehavePlus handles the input options for each variable type appropriately and will provide a warning if inputs are entered incorrectly.

In all cases, values can be directly typed into the worksheet. Alternatively, a click on the **Guide** button associated with each input variable offers a list of valid values for discrete variables. The **Guide** button gives a means of entering one, two, or a range of values for continuous variables. For some continuous variables, there is also a **Choices** button that

displays some common values. Additional guidance on input values is available for some variables in the associated **Help** window. Following is a description of the various methods of input.

6.1 Direct Input

A common method of inputting data is to type them into the input field on the worksheet. Values can be separated by commas, spaces, or any combination of the two (Figure 30). Values can be typed in any order in the box; however, the order of entry determines the order of values on output tables and the order that labels are put on graphs.

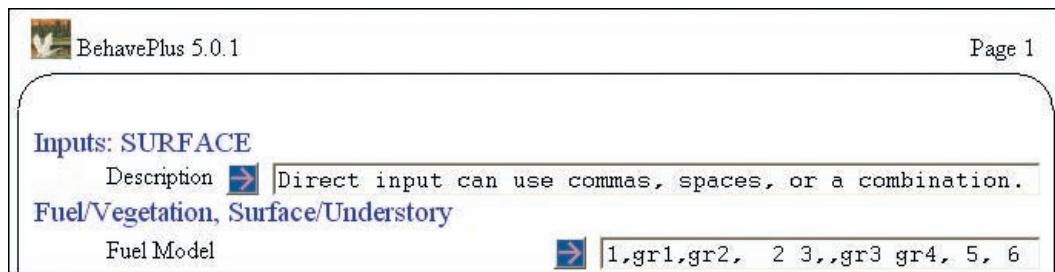


Figure 30—Data can be input directly and separated by commas, spaces, or a combination of the two.

6.2 Discrete Variable Selection

Discrete variables are those for which only specific values are meaningful. As an alternative to typing a value, a click on the **Guide** button gives you a list of all possible values (Figure 31). Items in the **Value** column are those entered in the input box. The **Description** column provides information about the item. If you click on a line, it will turn blue, indicating selection. You can select multiple values by clicking on several lines; you do *not* need to hold down the control (**Ctrl**) key. Clicking on a selection again will remove the blue indicator, and the value is no longer selected.

As an example, if you click on the fuel model **Guide** button, the 53 available standard fuel models are shown. Custom fuel models are added to the list when they are first developed and, in future sessions, when their folder is attached (Section 10.2). The list can be sorted by a click on the column headers, if desired.

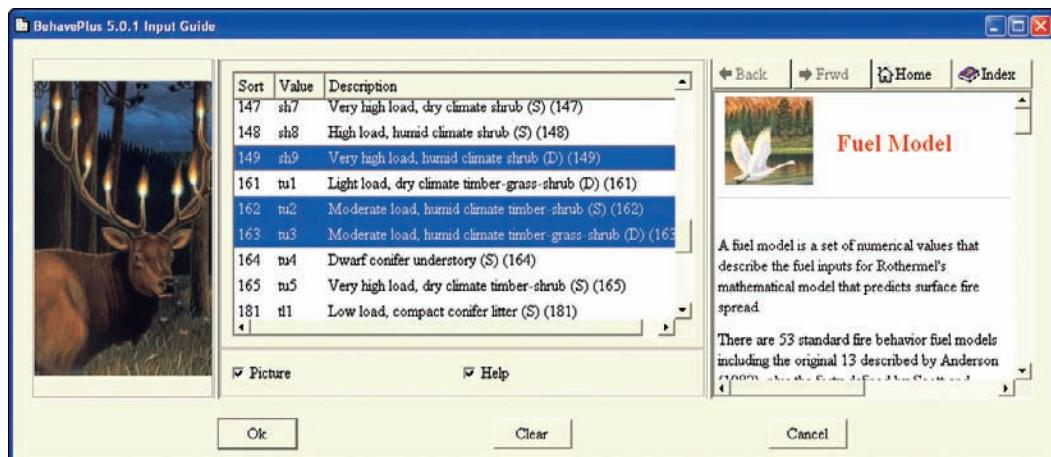


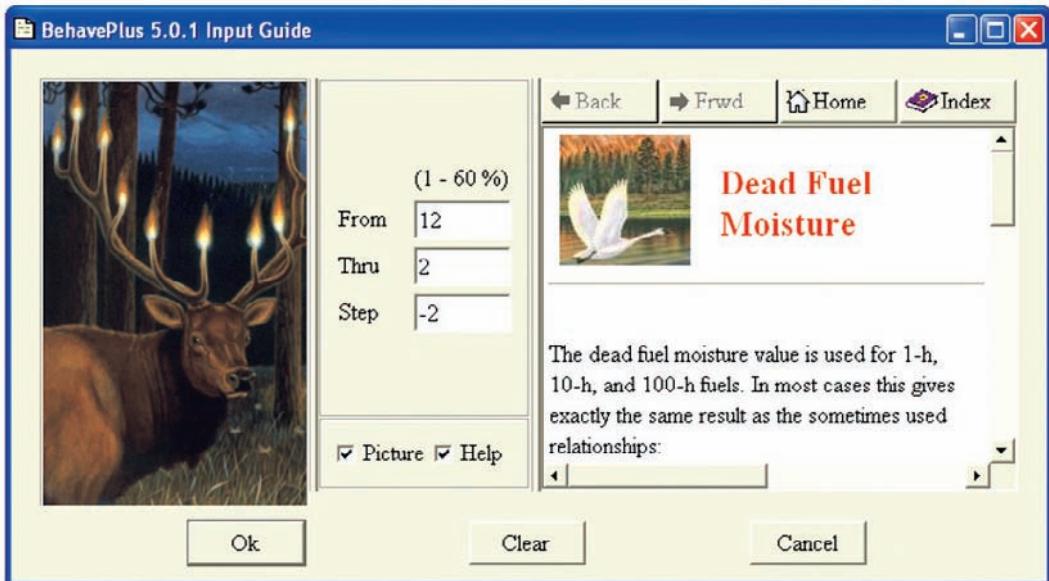
Figure 31—The **Guide** button provides access to a list of available selections for discrete variables such as fuel model. Select and deselect values by clicking on them.

6.3 Ranges for Continuous Variables

Any value within a range of valid values can be entered for a continuous variable. A table in the Variables paper (Andrews 2009) provides valid ranges and default English and metric units for each input variable.

If you click on the **Guide** button beside a continuous variable, an **Input Guide** window will appear (Figure 32). The valid range and units of the variable are shown above the input boxes. You might use the **Guide** button to enter a single value when you want to check the valid range. You might enter only starting and ending values when you are producing a plot. Typically, a range of values is entered: the start value (**From**), the ending value (**Thru**), and the **Step**.

You can enter values in reverse order by putting the highest value in **From**, the lowest value in **Thru**, and entering a negative **Step** size. This has no effect on graphs but can be useful in formatting tables. For example, a table of dead fuel moisture versus wind speed can be organized as increasing wind and decreasing moisture, showing changes in the direction of higher flame length values.



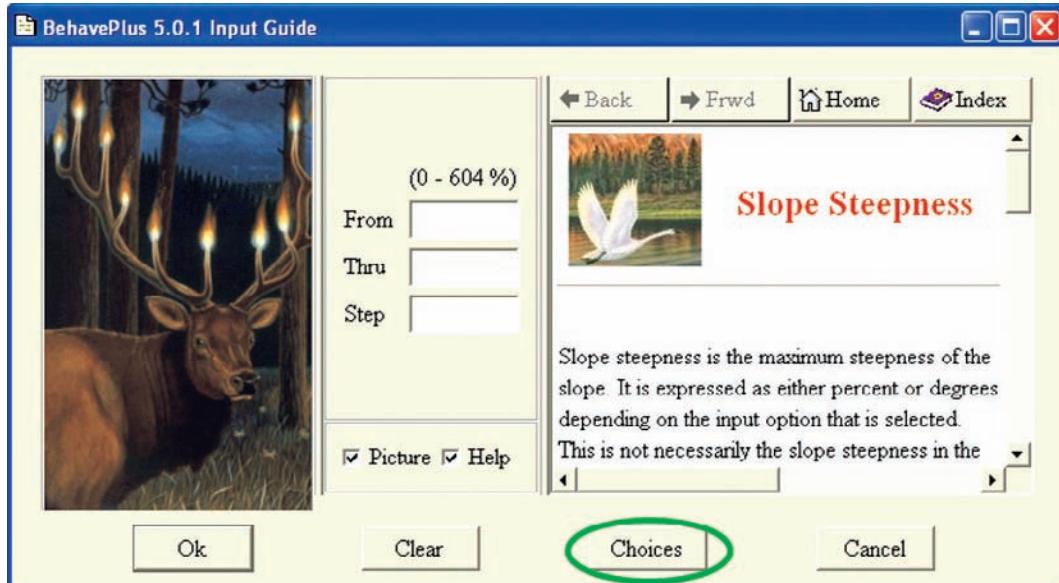
| Fuel Moisture | |
|--------------------|---|
| Dead Fuel Moisture | % <input type="button" value="→"/> 12, 10, 8, 6, 4, 2 |

Figure 32—Continuous data can be input as a range of values. The valid range and units are shown above the input boxes. Use a negative step size to organize a table from larger to smaller values (for example, fuel moisture).

6.4 Choices for Continuous Variables

There is a **Choices** button at the bottom of the **Input Guide** window for some continuous variables. A list of selected input values is given. This is different from the list for all possible discrete variables. It is meant to provide some help and guidance. For example, choices for 1-h fuel load gives values for the 13 fuel models. Map scale gives values in several forms (such as 1:x, in/mi, cm/km, and km/cm) for commonly used map scales. Crown bulk density values are listed in units of both lb/ft³ and kg/m³. Slope steepness choices are provided in both percent and degrees, giving a quick reminder that a slope of 550% is equivalent to a slope of 80° (Figure 33).

(a)



(b)

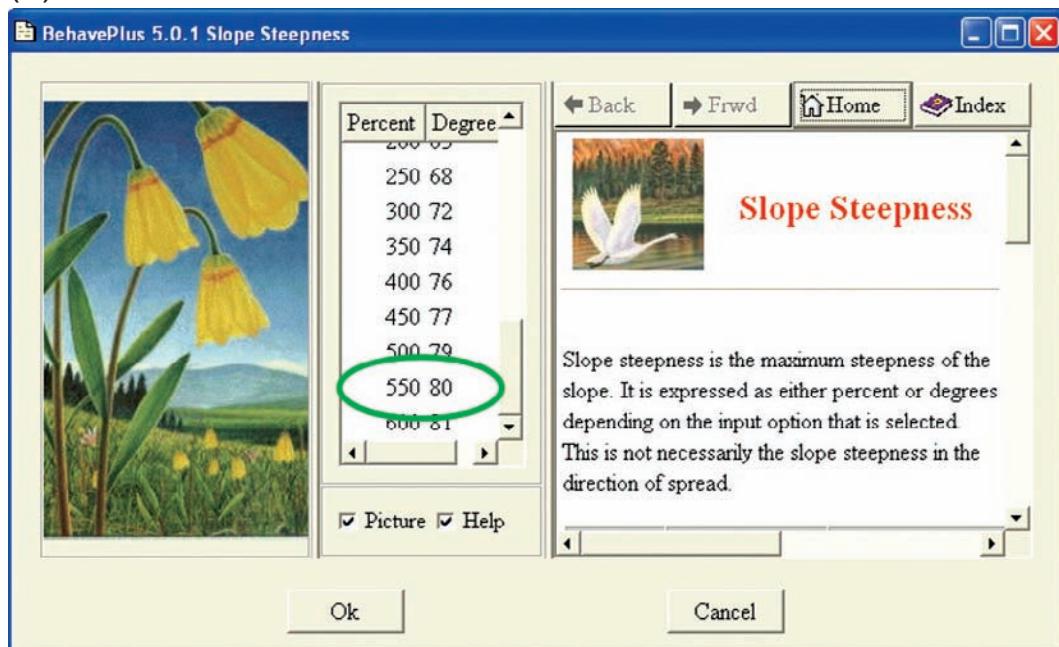


Figure 33—For some continuous variables, the **Choices** button gives a list of selected (not all) values for guidance (a). For example, slope steepness values are given in both percent and degrees (b).

6.5 Additional Guidance

In addition to the values that might be in a **Choices** list, there is additional guidance for some input values in the **Help** window. For example, canopy bulk density photos and data are given for several forest types (Figure 19). Line construction rate tables from the *Fireline Handbook* (National Wildfire Coordinating Group 2004) are included. Wind adjustment factor diagrams and tables are provided (Figure 34).

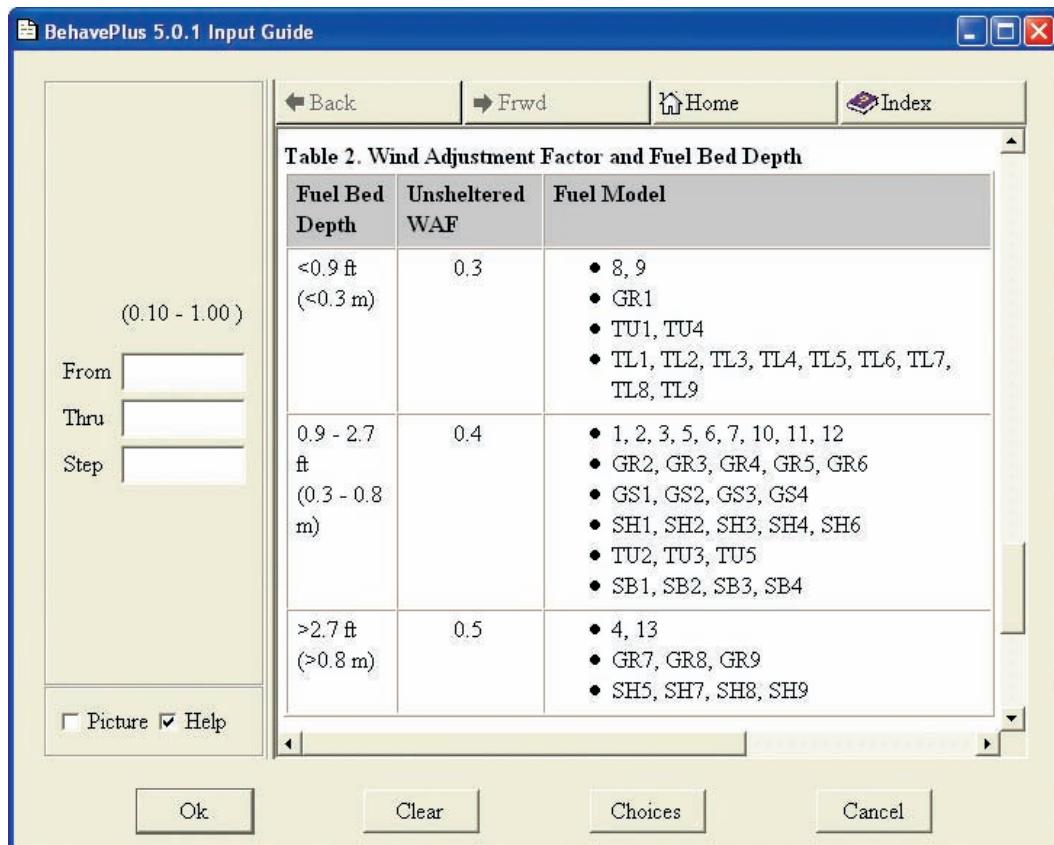


Figure 34—The **Help** window includes guidance for selecting values from some input variables, such as wind adjustment factor.

7 Form of the Output

BehavePlus can produce calculated values in the form of simple lists, tables, graphs, and simple diagrams. Default selections can be accepted, and a user need not be concerned about making choices because the program will generate standard outputs. There are, however, many options that can be used to produce output in a form desired for a given application.

The form of tables and graphs depends on the variable type (continuous or discrete) and number (zero, one, or two) of input variables that are assigned ranges. If input variables are each assigned a single value, an output page will be produced as a simple list of results. If one or two variables are assigned multiple values, tables and graphs can be created. Simple diagrams are produced by selecting a diagram variable from the list of output variables. Various aspects of tables, graphs, and diagrams are described below to help you make best use of BehavePlus.

An important consideration in all cases is that the input worksheet, including the program version number and assigned values, should *always* accompany the results. Model output is meaningless unless all of the information used to produce it is clearly documented.

7.1 List

If a single value is entered for each input variable, a simple list of output is produced (Figure 35). We encourage you to look at tables and graphs with ranges of values before you settle on the single values.

BehavePlus 5.0.1 Fri, May 07, 2010 at 12:11:51 Page 1

Inputs: SURFACE, CROWN

Description → Simple List Output Example

Fuel/Vegetation, Surface/Understory

Fuel Model → 5

Fuel/Vegetation, Overstory

Canopy Base Height ft → 4

Canopy Bulk Density lb/ft³ → 0.012

Fuel Moisture

Dead Fuel Moisture % → 5

Live Fuel Moisture % → 75

Foliar Moisture % → 100

Weather

20-ft Wind Speed (upslope) mi/h → 20

Wind Adjustment Factor → .2

Terrain

Slope Steepness % → 30

BehavePlus 5.0.1 Fri, May 07, 2010 at 12:11:51 Page 3

Simple List Output Example

| | |
|----------------------------------|-----------|
| Surface Rate of Spread (maximum) | 28.7 ch/h |
| Flame Length | 6.9 ft |
| Transition to Crown Fire ? | Yes |
| Crown ROS | 67.2 ch/h |
| Active Crown Fire? | Yes |
| Fire Type | Crowning |

Figure 35—If a single value is entered for each input variable, a simple list of output values is produced. However, we strongly suggest looking at ranges of input values before deciding upon the best values to use.

7.2 Tables

The form of the table depends on whether multiple values are entered for one or two variables, selections on row and column variables, and appearance preferences. If multiple values are entered for more than two variables, an error statement is produced.

If multiple values are entered for one input variable, that variable defines the table rows and each selected output variable is given as a table column (Figure 36). If the number of output variables requires that the table continue onto another page, the input column and values are repeated on each page.

BehavePlus 5.0.1 Fri, May 07, 2010 at 12:13:43 Page 1

Inputs: SURFACE

Description → Effect of Wind

Fuel/Vegetation, Surface/Understory

| | |
|------------|-----|
| Fuel Model | → 9 |
|------------|-----|

Fuel Moisture

| | |
|--------------------------|--------|
| 1-h Moisture | % → 7 |
| 10-h Moisture | % → 8 |
| 100-h Moisture | % → 10 |
| Live Herbaceous Moisture | % → 10 |
| Live Woody Moisture | % → 10 |

Weather

| | |
|-------------------------------|------------------|
| Midflame Wind Speed (upslope) | mi/h → 0 5 10 15 |
|-------------------------------|------------------|

Terrain

| | |
|-----------------|--------|
| Slope Steepness | % → 10 |
|-----------------|--------|

BehavePlus 5.0.1 Fri, May 07, 2010 at 12:13:43 Page 2

Effect of Wind

| Midflame Wind Speed mi/h | ROS (max) ch/h | Flame Length ft |
|--------------------------------|----------------------|-----------------------|
| 0 | 0.9 | 1.0 |
| 5 | 8.2 | 2.8 |
| 10 | 25.1 | 4.7 |
| 15 | 49.4 | 6.4 |

Figure 36—When one variable has a range of values (for example, midflame wind speed), a table is produced, with that variable defining the rows of the table and the outputs in the columns.

If multiple values are entered for two input variables, a separate table is produced for each of the selected output variables. Consider a table of calculated surface rate of spread for two fuel models and several midflame wind speed values. In this case, 2 rows and 10 columns carry over to a second page (Figure 37). The diagram in the upper left-hand corner and arrows on table column heading illustrate this fact.

**Inputs: SURFACE**

Description ➔ Dead mois 7%, Live mois 75%, slope 10%

Fuel/Vegetation, Surface/Understory

Fuel Model ➔ 9 10

Fuel Moisture

Dead Fuel Moisture % ➔ 7

Live Fuel Moisture % ➔ 75

Weather

Midflame Wind Speed (upslope) mi/h ➔ 0, 2, 4, 6, 8, 10, 12, 14, 16,

Terrain

Slope Steepness % ➔ 10



Dead mois 7%, Live mois 75%, slope 10%

Surface Rate of Spread (maximum) (ch/h)

| Fuel Model | Midflame Wind Speed (upslope) mi/h | | | | | | |
|------------|------------------------------------|-----|-----|------|------|------|---|
| | 0 | 2 | 4 | 6 | 8 | 10 | > |
| 9 | 0.9 | 2.4 | 5.9 | 10.9 | 17.4 | 25.1 | > |
| 10 | 1.1 | 3.5 | 7.5 | 12.6 | 18.5 | 25.0 | > |



Dead mois 7%, Live mois 75%, slope 10%

Surface Rate of Spread (maximum) (ch/h)

| < Fuel Model | Midflame Wind Speed (upslope) mi/h | | | | |
|--------------|------------------------------------|------|------|------|------|
| | 12 | 14 | 16 | 18 | 20 |
| 9 | 34.0 | 44.0 | 55.2 | 67.3 | 80.6 |
| 10 | 32.2 | 39.8 | 48.0 | 56.6 | 65.7 |

Figure 37—When multiple values are entered for two input variables, a table is produced for each output variable. If a table extends beyond a page, it is indicated by the diagram in the upper left corner and by the arrows on either side of the table.

By default, the first input variable on the worksheet with multiple values is selected as the row variable and the second as the column. A switch in the **Calculate Results** box to using midflame wind speed as the **Table Row Variable** (Figure 38) produces a more appropriately formatted one-page table (Figure 39).

Note that the entry in the worksheet's **Description** line is repeated at the top of each table. In this simple example, it was possible to include all of the relevant input values in the heading.

The look of the table can be changed via **Configure > Appearance preferences > Tables**. The color used to shade alternate lines for readability can be changed (as in Figure 39), or the shading can be removed (Figure 40).

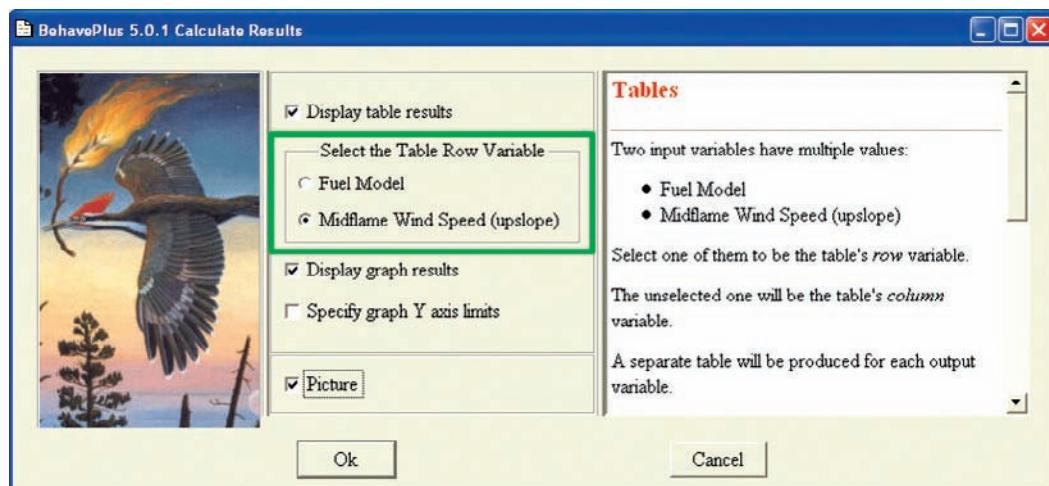


Figure 38—The table format can be changed after the **Calculate** command by selecting the table row variable.



Dead mois 7%, Live mois 75%, slope 10%
Surface Rate of Spread (maximum) (ch/h)

| Midflame Wind Speed mi/h | Fuel Model | |
|--------------------------------|------------|------|
| | 9 | 10 |
| 0 | 0.9 | 1.1 |
| 2 | 2.4 | 3.5 |
| 4 | 5.9 | 7.5 |
| 6 | 10.9 | 12.6 |
| 8 | 17.4 | 18.5 |
| 10 | 25.1 | 25.0 |
| 12 | 34.0 | 32.2 |
| 14 | 44.0 | 39.8 |
| 16 | 55.2 | 48.0 |
| 18 | 67.3 | 56.6 |
| 20 | 80.6 | 65.7 |

Figure 39—This is the table in Figure 37 with switched row and column variables. The color of the line shading was changed using **Configure > Appearance preferences > Tables**.



Dead mois 7%, Live mois 75%, slope 10%
Surface Rate of Spread (maximum) (ch/h)

| Midflame Wind Speed mi/h | Fuel Model 9 | Fuel Model 10 |
|--------------------------------|-----------------|------------------|
| 0 | 0.9 | 1.1 |
| 2 | 2.4 | 3.5 |
| 4 | 5.9 | 7.5 |
| 6 | 10.9 | 12.6 |
| 8 | 17.4 | 18.5 |
| 10 | 25.1 | 25.0 |
| 12 | 34.0 | 32.2 |
| 14 | 44.0 | 39.8 |
| 16 | 55.2 | 48.0 |
| 18 | 67.3 | 56.6 |
| 20 | 80.6 | 65.7 |

Figure 40—Alternate line shading in Figures 37 and 39 can be eliminated using **Configure > Appearance preferences > Tables**.

7.3 Graphs

It is sometimes easier to see relationships in graphs than in tables. Graphs are especially useful in examining model sensitivity and making comparisons. BehavePlus produces line graphs and bar graphs. The type of variable (continuous or discrete) determines the form of the graph (line or bar); it is not a user selection. The user has control of many aspects of graph appearance, including selection of the X-axis variable, line colors, graph size, and grid. All of the graph options and default selections are given in Appendix H. Examples of graphs of one or two continuous or discrete variables, some appearance options, and axis and scale change options are given below.

Figure 41 shows a bar chart of flame length for multiple values entered for the discrete variable, fuel model. We compare the 12 litter fuel models for constant moisture, wind, and slope conditions.

BehavePlus 5.0.1 Thu, May 13, 2010 at 16:20:30 Page 1

Inputs: SURFACE

Description → Dead mois 6%, live mois 75%, midflame wind 5 mi/h, 0% s

Fuel/Vegetation, Surface/Understory

Fuel Model → 8, 9, 10, tl1, tl2, tl3, tl4, t

Fuel Moisture

Dead Fuel Moisture % → 6

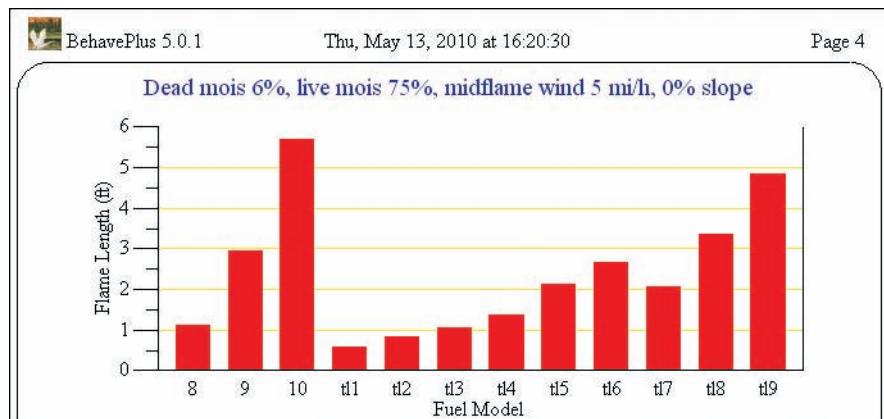
Live Fuel Moisture % → 75

Weather

Midflame Wind Speed (upslope) mi/h → 5

Terrain

Slope Steepness % → 0



BehavePlus 5.0.1 Thu, May 13, 2010 at 16:20:30 Page 5

Discrete Variable Codes Used

Dead mois 6%, live mois 75%, midflame wind 5 mi/h, 0% slope

| Fuel Model | Description |
|------------|--|
| 8 | Short needle litter (S) |
| 9 | Long needle or hardwood litter (S) |
| 10 | Timber litter and understory (S) |
| tl1 | Low load, compact conifer litter (S) (181) |
| tl2 | Low load broadleaf litter (S) (182) |
| tl3 | Moderate load conifer litter (S) (183) |
| tl4 | Small downed logs (S) (184) |
| tl5 | High load conifer litter (S) (185) |
| tl6 | Moderate load broadleaf litter (S) (186) |
| tl7 | Large downed logs (S) (187) |
| tl8 | Long-needle litter (S) (188) |
| tl9 | Very high load broadleaf litter (S) (189) |

Figure 41—A bar graph (middle) is produced for multiple values of a single discrete variable. In the graph, flame length is compared for litter fuel models for constant conditions. The last page of output (bottom) is a list of code definitions for the fuel models used in the run.

When we change the run shown in Figure 41 by assigning a range of values to the continuous variable midflame wind speed, a curve is produced for each fuel model (Figure 42). Multiple points are calculated for each curve using the maximum and minimum values that you entered, not the intermediate values that are used to produce a table. The number of points calculated to produce each line on the graph is determined by the **Curve points** setting under **Configure > Appearance preferences > Graph Elements**. There is little reason to change from the default of 100. Values between curve points are connected by straight lines.

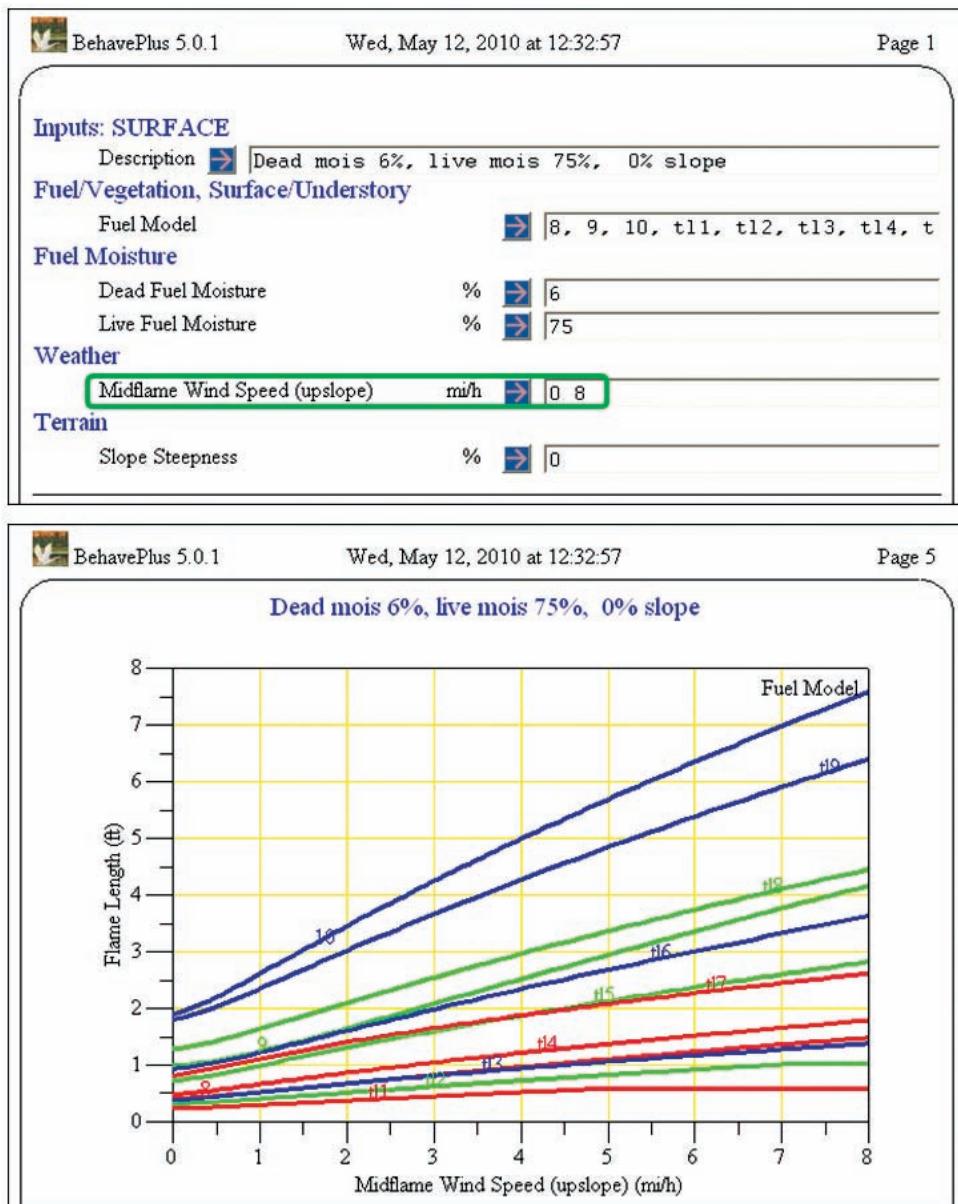


Figure 42—The wind speed of 5 mi/h used for Figure 41 was changed to 0 and 8 mi/h. A range of midflame wind speed values produces a curve for each fuel model.

7.3.1 Appearance Change

Figure 43 uses the same input values as Figure 42, but changes were made to make the graph easier to read. We moved fuel models 8, 9, and 10 on the worksheet to fit better with the fuel models TL1 through TL9 to improve curve labeling. The fuel model order was revised to become “tl1, tl2, tl3, 8, tl4, tl5, tl6, tl7, 9, tl8, tl9, 10.” We also changed the number of colors from 3 to 12 and the gridline color from yellow to grey (both in **Configure > Appearance preferences > Graph elements**), and we changed the graph size from 50% to 70% (**Configure > Appearance preferences > Graph Size**).

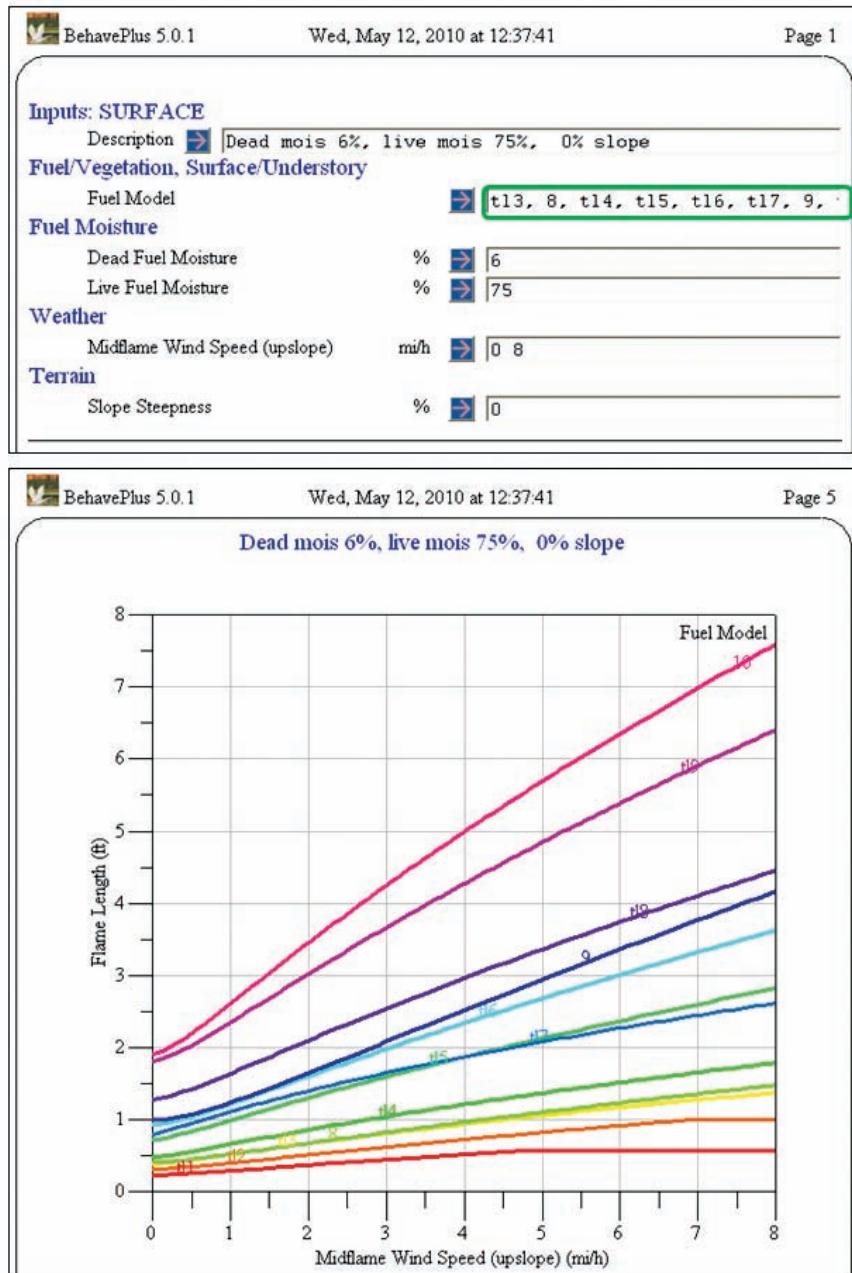


Figure 43—Changes were made to the graph in Figure 42. The number of colors was changed from 3 to 12. Grid color was changed from yellow to grey. Graph size was changed from 50% to 70%. The order of the fuel models on the worksheet was changed to improve curve labeling.

Figure 44 is another example of changing graph appearance. Curves for four of the fuel models from Figure 42 are plotted. The curve color was changed to black.

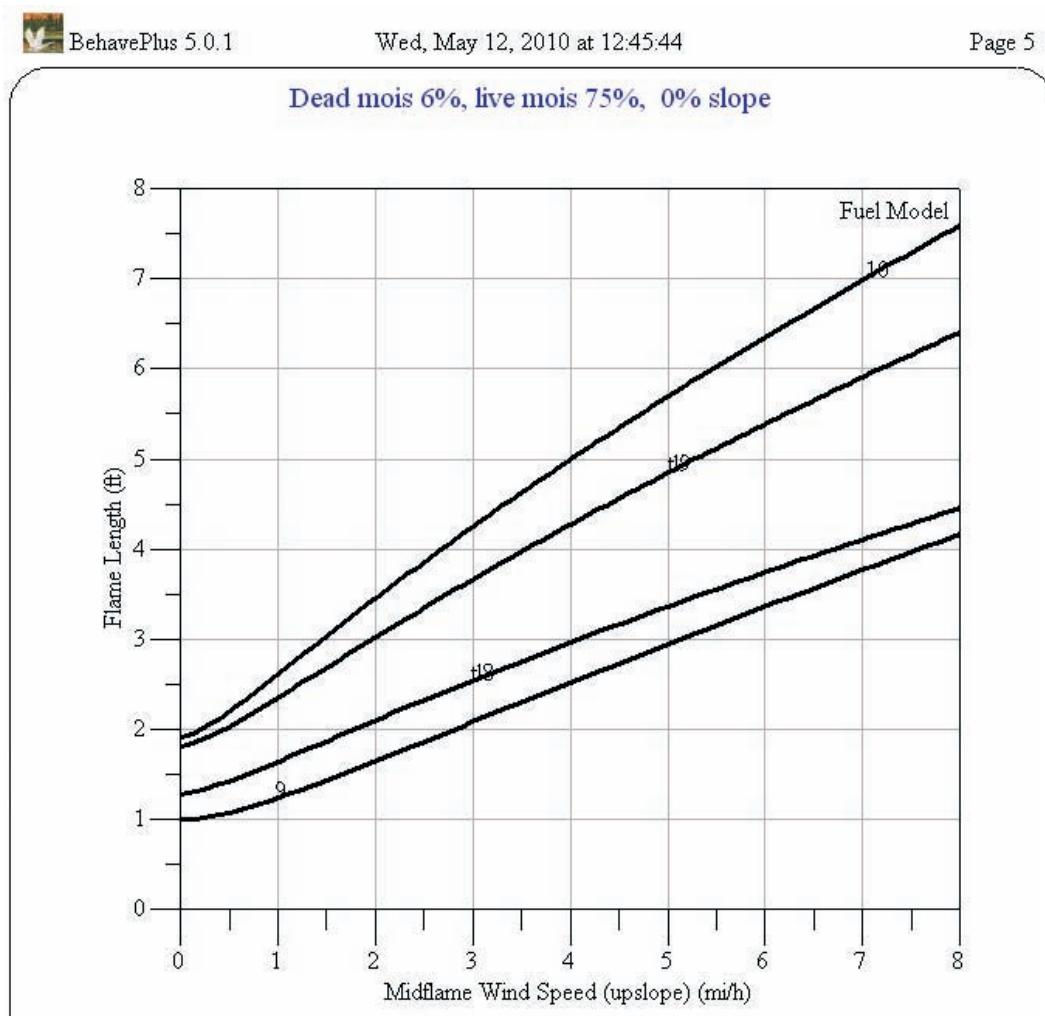
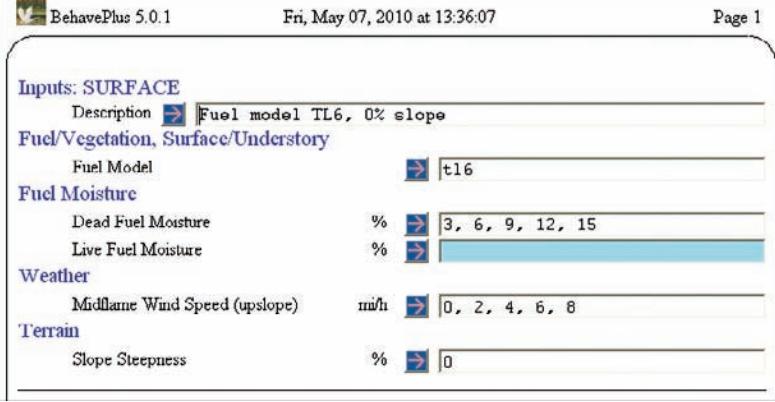
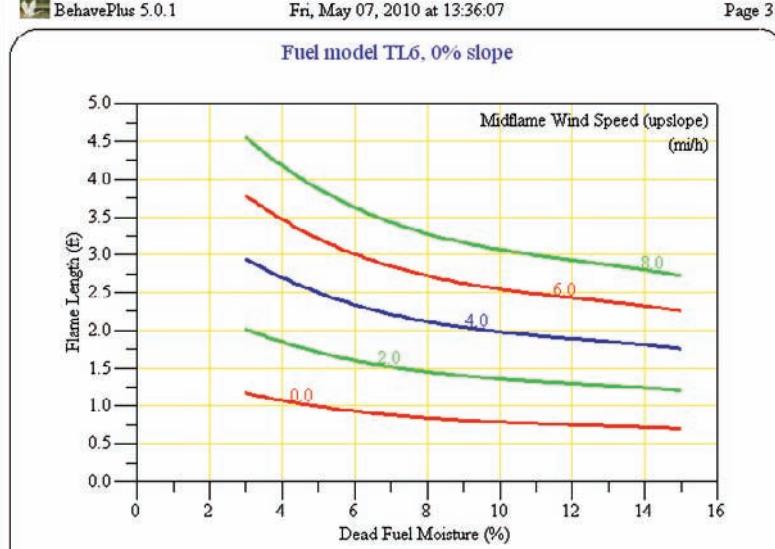


Figure 44—Four fuel models from Figure 43 were plotted with line color changed to black.

7.3.2 Axis Change

If multiple values are entered for two continuous variables, the X-axis variable can be defined as either one of them, and the selection can produce quite different results. The calculations are the same, but the form of the graph can convey different information. The X-axis variable is initially selected as the first one on the worksheet. Figure 45 shows graphs first with dead fuel moisture as the X-axis variable with a curve for several midflame wind speed values and then with midflame wind speed selected as the X-axis variable.

(a) 

(b) 

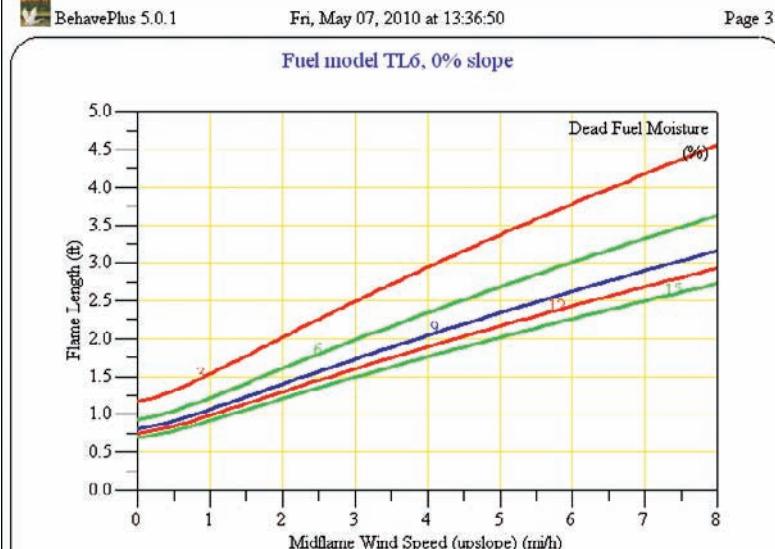
(c) 

Figure 45—When a graph is produced for ranges of two continuous variables (a), either one can be designated as the X-axis variable. Both graphs (b) and (c) are from the same input values. The only difference is in the selection of the X-axis variable.

7.3.3 Scale Change

In the default settings, the minimum value for both axes is zero, the maximum for the X-axis is based on the maximum value that was entered, and the maximum for the Y-axis is based on the maximum calculated value.

While it is generally best to keep the graph origin as (0, 0) to avoid misinterpretation, it can be changed to the minimum entered value for the X-axis and the minimum calculated value for the Y-axis (**Configure > Appearance preferences > Graph size**). In Figure 46, the X-axis origin is changed from zero to the minimum value to better examine live fuel moisture from 75% to 125%.

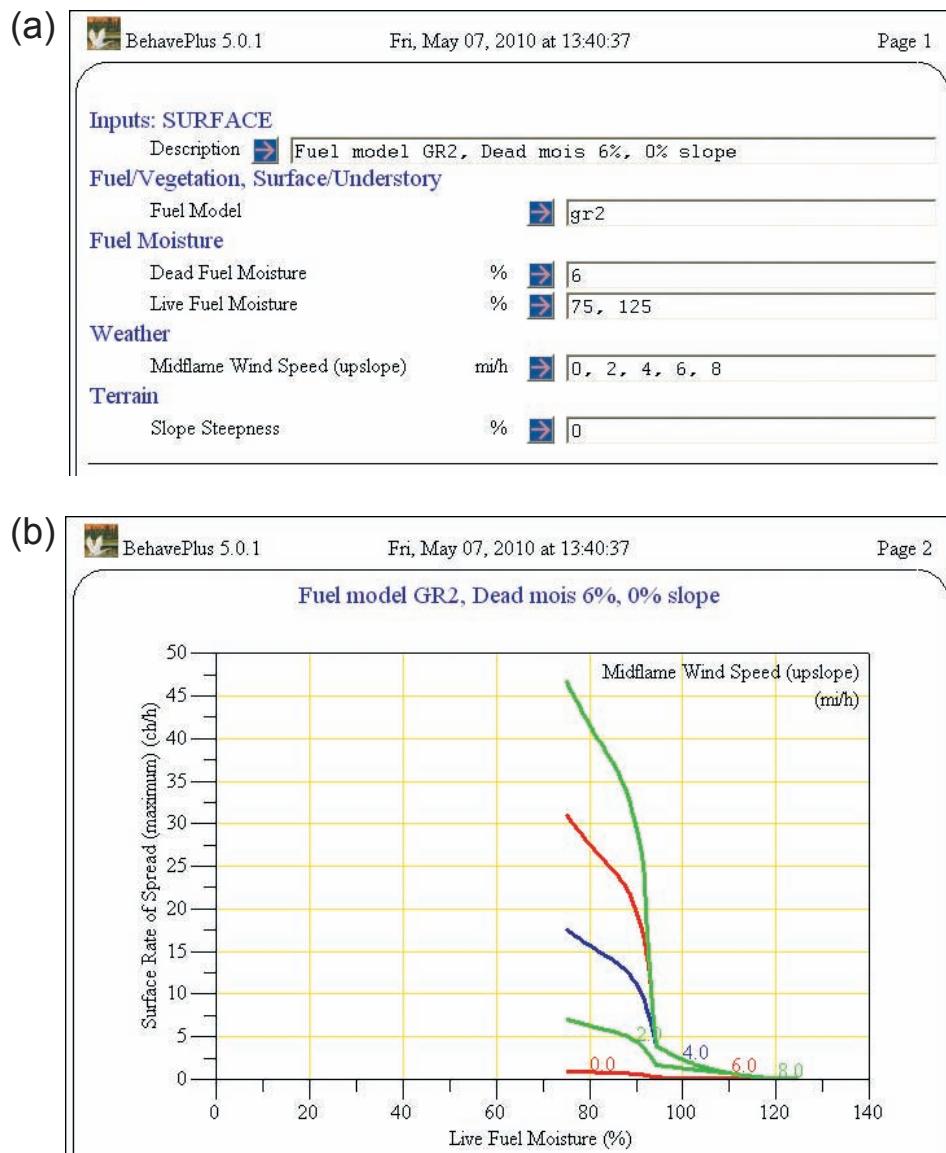


Figure 46—Using the inputs in (a), the graph with the origin at (0,0) in (b) was changed to the minimum X-axis value in (c) using **Configure > Appearance preferences > Graph Size**.

(continued)

(c)

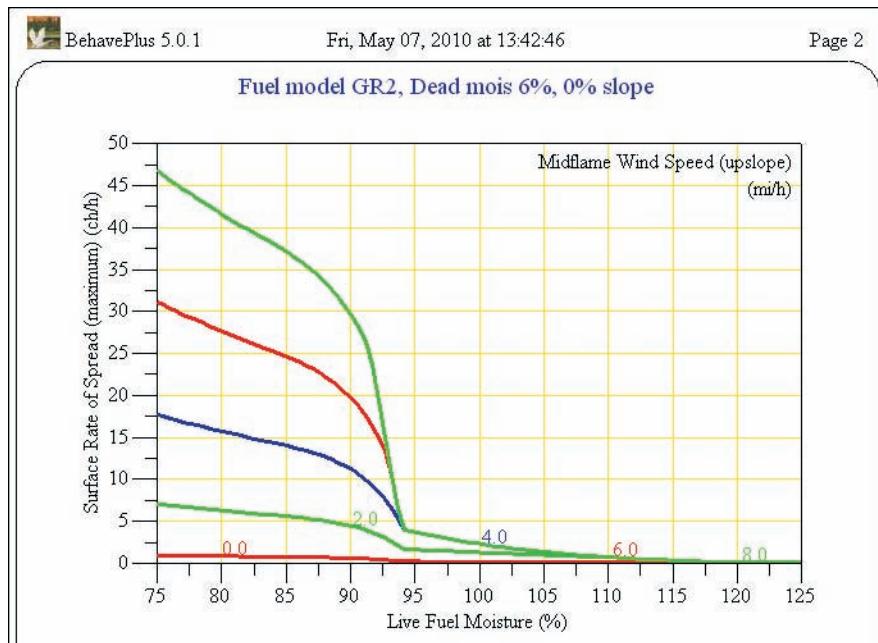


Figure 46—Continued from previous page.

Comparing two graphs is easiest when they have the same scale for the Y-axis. A change from fuel model GR2 in Figure 46 to GR1 produces the graph in Figure 47. In order to better compare surface rate of spread for the two fuel models, the maximum value for the surface rate of spread axis was changed from 10 to 50 ch/h to produce the graph in Figure 48. This was accomplished by checking **Specify graph Y axis limits** in the window that appears after performing the **Calculate** command. The maximum calculated value is shown for reference in the following window where it can be changed (Figure 49).

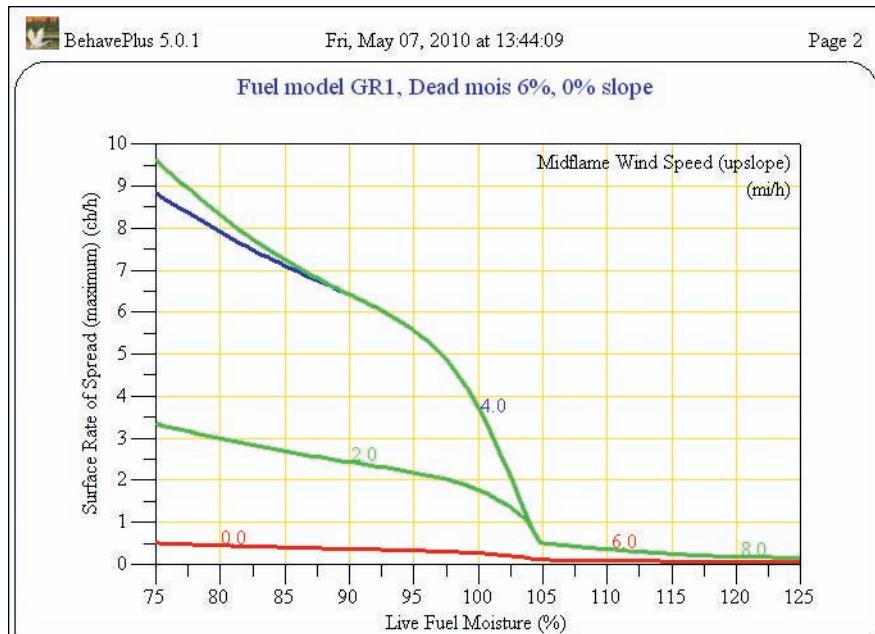


Figure 47—Fuel model GR2 in Figure 46 was changed to GR1. The Y-axis (surface rate of spread) is automatically scaled to the maximum calculated value for GR1.

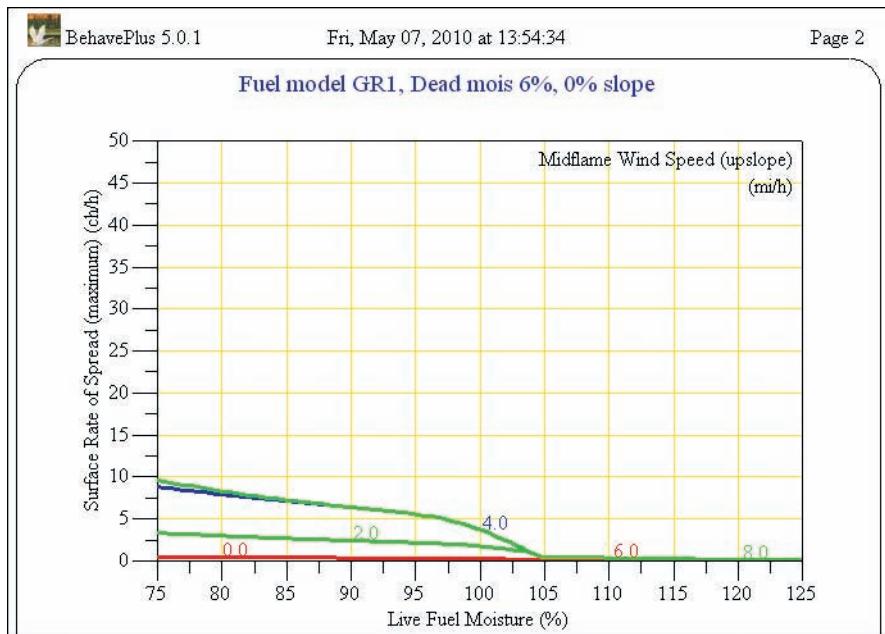


Figure 48—The scale for surface rate of spread in Figure 47 was changed from a maximum of 10 ch/h to 50 ch/h to better compare outputs from fuel model GR1 to the similar plot for fuel model GR2 (Figure 46). The method for changing the Y-axis scale is shown in Figure 49.

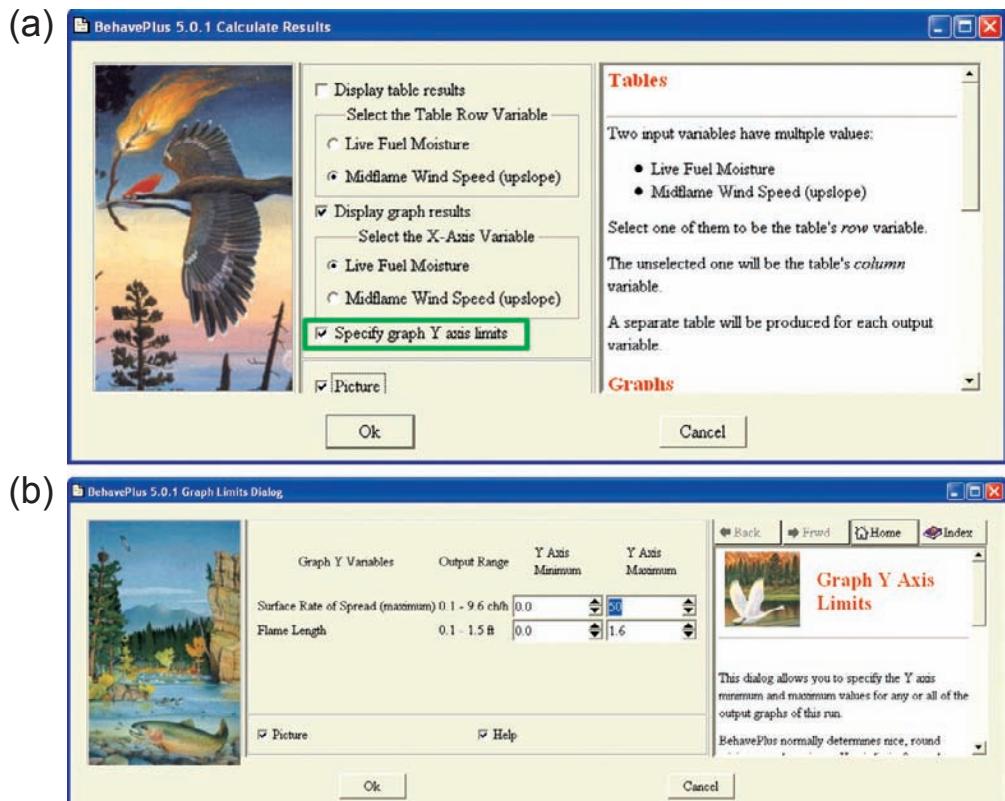


Figure 49—Selecting the **Specify graph Y axis limits** in the **Calculate Results** window (a) will bring up a **Graph Limits Dialog** window (b), allowing a change to Y-axis minimum and/or maximum values.

7.4 Diagrams

In addition to tables and graphs, BehavePlus will create diagrams for four variables: fire characteristics chart in SURFACE, wind/slope/fire spread directions in SURFACE, point source fire shape in SIZE, and the shape of a fire after suppression action (successful or not) in CONTAIN. Diagrams are generated by selecting them from the list of output variables for the module. Diagrams can aid model understanding and interpretation.

Diagrams are produced for values in the output tables. Therefore, if only graph output is selected, diagrams will not be produced. All of the diagrams for a single run use the same scale. It is generally not good practice to request too many diagrams in a single run. Figure 50 shows table output and four associated diagrams. In this case, fire shape diagram was chosen as an output from the SIZE module.

BehavePlus 5.0.1 Fri, May 07, 2010 at 13:59:31 Page 1

Inputs: SURFACE, SIZE

Description → Sample Fire Shape Diagram

Fuel/Vegetation, Surface/Understory

| | |
|------------|-------|
| Fuel Model | → [2] |
|------------|-------|

Fuel Moisture

| | |
|--------------------|----------|
| Dead Fuel Moisture | % → [6] |
| Live Fuel Moisture | % → [75] |

Weather

| | |
|---|--------------|
| Midflame Wind Speed | mi/h → [2 8] |
| Direction of Wind Vector (from upslope) | deg → [90] |

Terrain

| | |
|-----------------|-------------|
| Slope Steepness | % → [10 50] |
|-----------------|-------------|

Fire

| | |
|--------------|---------|
| Elapsed Time | h → [1] |
|--------------|---------|

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always
for the direction of the spread calculations [SURFACE].
Wind and spread directions are degrees clockwise from upslope [SURFACE].
Direction of the wind vector is the direction the wind is pushing the fire [SURFACE].

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]
Flame Length (ft) [SURFACE]
Direction of Maximum Spread (from upslope) (deg) [SURFACE]
Area (ac) [SIZE]
Fire Shape Diagram [SIZE]

Figure 50—Fire shape diagram was selected as an output variable for the SIZE module. A diagram is produced for each value in the table output.

(continued)



Sample Fire Shape Diagram
Surface Rate of Spread (maximum) (ch/h)

| Midflame Wind Speed mi/h | Slope Steepness % | |
|--------------------------------|----------------------|------|
| 2 | 10 | 50 |
| 8 | 9.2 | 19.2 |
| | 87.8 | 89.2 |



Sample Fire Shape Diagram
Direction of Maximum Spread (from upslope) (deg)

| Midflame Wind Speed mi/h | Slope Steepness % | |
|--------------------------------|----------------------|----|
| 2 | 85 | 24 |
| 8 | 90 | 80 |



Sample Fire Shape Diagram
Area (ac)

| Midflame Wind Speed mi/h | Slope Steepness % | |
|--------------------------------|----------------------|-------|
| 2 | 10 | 50 |
| 8 | 5.9 | 18.8 |
| | 214.0 | 219.2 |

Figure 50—Continued from previous page.

(continued)



Sample Fire Shape Diagram

Fire Shape

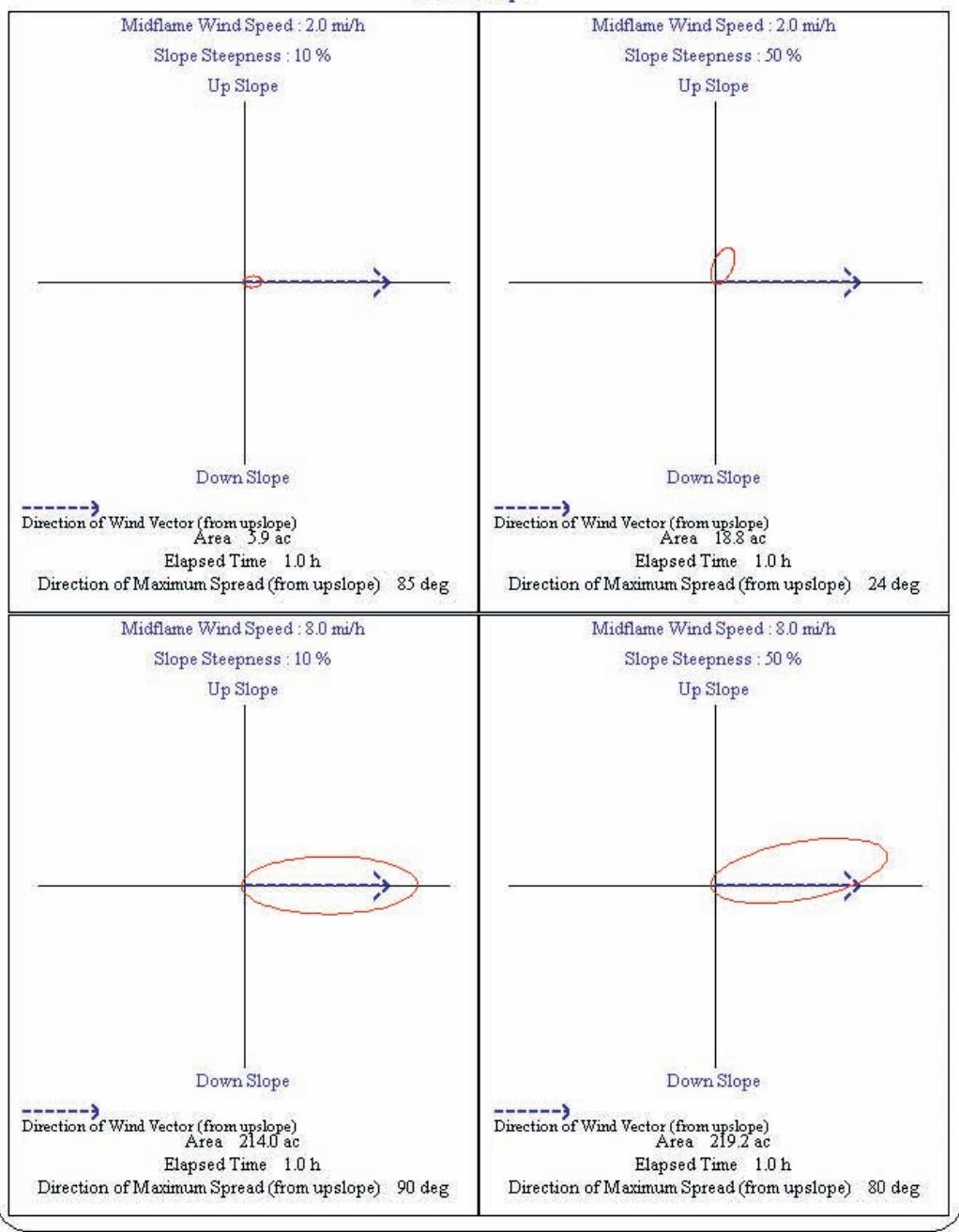


Figure 50—Continued from previous page.

8 Using Outputs Elsewhere

Fire modeling results from BehavePlus are often included in documents. This can be accomplished in various ways, most simply by attaching BehavePlus printed pages to a report. Portions of BehavePlus pages might be captured and inserted into a document (such as this one). Table results can be exported as an HTML file, which does not have the BehavePlus page layout. Spreadsheet or other software can then be used to produce graphs in ways that are not possible within the BehavePlus program.

It is worth repeating that complete information (program version number, input values, selected options, etc.)—in other words, enough information to re-create the run—must *always* be included with results. Tables of flame length or plots of spotting distance are useless if the information used to obtain those values is not provided.

8.1 Print Output

File > Print allows you to print all BehavePlus pages or a range of pages. There is no option for two-sided printing.

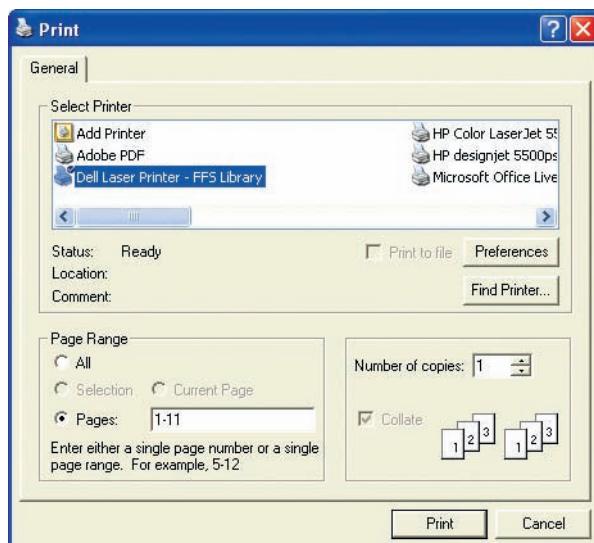


Figure 51—**File > Print** gives the option of printing selected pages. The Adobe PDF option, however, creates one page at a time, allowing you to change the name of the file as each page is saved.

8.2 Save as PDF

If you have the ability to create PDF documents on your computer using Adobe® Acrobat, the BehavePlus command **File > Print** will give **Adobe PDF** as an option (Figure 51). Although it does not behave as you might hope, it does give you the option of converting pages to PDF. Rather than saving all pages in the listed page range, it converts one page at a time, triggering a pop-up window that allows you to change the file name for each page. You can name each page and later combine them into a single document. Although

the BehavePlus window view does not change from page to page, repeated saves of the PDF file move from page to page, starting with the first. Following are the steps to save all pages in a PDF document in Adobe® Acrobat:

- **File > Print > Adobe PDF > Print**
- **Save in:** (create a folder for the document)
- **File name:** (change the default BehavePlus5.pdf to p1) > **Save**
- **File name:** (change the default BehavePlus5.pdf to p2) > **Save**
- (Repeat for all pages)
- When all pages are saved, the **Print** window closes. If you wish to save fewer pages, click **Cancel** multiple times to close the print window.
- Open p1.pdf
- **Document > Insert Pages > From File**
- Highlight p2.pdf through the last page > **Select**
- **Location: > After > Last > OK**
- **File > Save as >** (name your document)
- Delete intermediate files and folder.

8.3 Save as Image

BehavePlus includes the option of saving each page as an image with **File > Save as an image**. A file is created for the currently viewed page in BMP, JPG, or PNG format (BMP files may be very large). Each page has to be captured separately. The saved file can then be inserted into a document and cropped as in the method described below.

8.4 Capture, Insert, and Crop

The BehavePlus **Save as an image** option is awkward and limited. We therefore recommend alternate methods. Commercial software can easily be used to capture portions of input and output for reports and publications. (We used FullShot® for the figures in this paper, although there are a number of commercial and freeware products available.)

Following is a capture method that is commonly available on Windows®-based computers.

- Open a Microsoft® Word document.
- Click on the BehavePlus screen to make it the active screen.
- Simultaneously press the two keys **Alt** and **PrintScrn** to capture only the BehavePlus window. (**PrintScrn** alone captures the entire computer screen.)
- Click on the Word document where you want the image.
- Simultaneously press **Ctrl** and the letter **v** (**Ctrl-v**), use **File > Paste** (Word 2000 or 2003), or use **Paste** on the **Home > Clipboard Task Pane** (Word 2007) to insert the window into the open Word document.
- Click on the inserted BehavePlus image in the Word document.
- To use the crop feature in Word 2000 or 2003, make sure the **Picture Toolbar** is available. If it is not, click on **View > Toolbars > Picture**. In Word 2007, the crop tool is found under the **Picture Tools > Format** tab.
- Crop the image to the desired portion by clicking on the image, using the Word crop feature, and dragging the cursor to the appropriate location.

8.5 Export as HTML

BehavePlus offers the option using **File > Export results** to export input and table output (not graphs or diagrams) as an HTML file, which can be viewed with an Internet browser (Figure 52). You can choose to save the file in the BehavePlus folder **MyExports**, or you can navigate to another location on your computer. BehavePlus page formatting is not carried over to the HTML file. For example, long and wide tables are not split onto multiple pages.

In some cases, the report may look nice in the browser but may not print correctly. To change the settings in Internet Explorer (Version 8.0):

- Select **Tools > Internet Options**.
- Select the **Advanced** tab.
- Scroll down to the **Printing** header.
- Enable the check box titled **Print background colors and images**.

To change the settings in Mozilla Firefox (Version 3.5):

- Select **File > Page Setup**.
- Select the **Format & Options** tab.
- Enable the check box titled **Print Background (colors and images)**.

BehavePlus 5.0.1 (Build 297)
Example of File > Export results
Fri, May 07, 2010 at 14:10:13

Input Worksheet

Inputs: SURFACE

| Input Variables | Units | Input Value(s) |
|-------------------------------------|-------|--------------------|
| Fuel/Vegetation, Surface/Understory | | |
| Fuel Model | 2 | |
| Fuel Moisture | | |
| Dead Fuel Moisture | % | 12, 10, 8, 6, 4, 2 |
| Live Fuel Moisture | % | 75 |
| Weather | | |
| Midflame Wind Speed (upslope) | mi/h | 3 4 5 |
| Terrain | | |
| Slope Steepness | % | 0 |
| Notes | | |

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind is blowing upslope [SURFACE].

Results for: Flame Length (ft)

| Dead Fuel | Midflame Wind Speed (upslope) | | |
|-----------|-------------------------------|-----|-----|
| Moisture | mi/h | | |
| % | 3 | 4 | 5 |
| 12 | 3.1 | 3.9 | 4.6 |
| 10 | 3.9 | 4.8 | 5.7 |
| 8 | 4.2 | 5.2 | 6.2 |
| 6 | 4.5 | 5.5 | 6.6 |
| 4 | 4.9 | 6.1 | 7.2 |
| 2 | 5.8 | 7.1 | 8.5 |

Figure 52—File > Export results saves BehavePlus input and table output (not graphs or diagrams) in HTML format, which can be viewed with a web browser. BehavePlus page formatting that splits long and wide tables is not exported.

8.6 Export to Spreadsheet

You may want to perform additional analysis of results from BehavePlus, such as making comparisons to a new fire model under development. Or you might wish to plot results in a way not offered by BehavePlus, such as plotting two variables on the same graph. The HTML file can be opened with spreadsheet software where additional calculations and formatting can be done. In this description, we use Microsoft® Excel 2007 as the example spreadsheet program. When you save a file using **File > Export results**, you will get a reminder message that you can open the HTML file with Excel.

To graph results, BehavePlus calculates multiple points for each graph using the maximum and minimum values that you entered but not the intermediate values. The number of calculations for each curve is determined by the appearance option (likely 100 points). However, the export function only applies to the values in the tables produced by BehavePlus, so there must be enough data in the table to create an accurate graph in a spreadsheet. You might not need 100 values. For example, if you are interested in flame length values associated with wind speeds from 0 mi/h to 20 mi/h, BehavePlus will create a plot based on those two values. For export, you must input intermediate values between 0 and 20 mi/h (for example, from 0 to 20 in steps of 1) to produce a table suitable for graphing in a different program.

To open the HTML file as a spreadsheet, locate the file on your computer, right-click on the file name, and select **Open With > Choose Program....** Select Microsoft® Excel (or any desired program that can interpret HTML files). Once the values are loaded into a spreadsheet, you can work with them as you see fit. It is *essential* that you save the document in spreadsheet format (**File > Save As...**) and change the file extension from .html to the appropriate extension (.xlsx in our example), so that any changes will be properly saved. It is best to save the file as a spreadsheet as soon as the file is opened and before any additional work is done.

Once the file has been saved as a spreadsheet, a good approach is to leave the imported page as it is and copy the relevant output to a new worksheet. You can then work on this new worksheet to add calculations and/or create graphs.

In BehavePlus, only one variable can be plotted on a graph. A spreadsheet can be used to plot two variables on a graph. The BehavePlus run in Figure 53 examines the effect of changing the 1-h fuel load in fuel model 2 to values higher and lower than its value of 2 tons/ac. A range of values from 0.5 to 5.0 ton/ac are used to calculate ROS and FL. For this example, we are not concerned with round off, so we developed a worksheet using the SURFACE input option **Fuel is entered as Fuel parameters** rather than opening the **FuelModeling.bpw** worksheet from the **ExampleWorksheets** folder (Sections 5.2 and 10.1).

(a) BehavePlus 5.0.1 Fri, May 07, 2010 at 14:15:43 Page 1

Inputs: SURFACE

Description → Fuel model 2 (1-h load = 2 ton/ac)

| Fuel/Vegetation, Surface/Understory | | Initialize from a Fuel Model |
|-------------------------------------|----------------------------------|---------------------------------|
| Fuel Model Type | ton/ac | S |
| 1-h Fuel Load | ton/ac | 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, |
| 10-h Fuel Load | ton/ac | 1.00 |
| 100-h Fuel Load | ton/ac | 0.50 |
| Live Herbaceous Fuel Load | ton/ac | 0.50 |
| Live Woody Fuel Load | ton/ac | 0.00 |
| 1-h SAV | ft ² /ft ³ | 3000 |
| Live Herbaceous SAV | ft ² /ft ³ | 1500 |
| Live Woody SAV | ft ² /ft ³ | 1500 |
| Fuel Bed Depth | ft | 1.00 |
| Dead Fuel Moisture of Extinction | % | 15 |
| Dead Fuel Heat Content | Btu/lb | 8000 |
| Live Fuel Heat Content | Btu/lb | 8000 |

Fuel Moisture

| | | |
|--------------------|---|----|
| Dead Fuel Moisture | % | 5 |
| Live Fuel Moisture | % | 75 |

Weather

| | | |
|-------------------------------|------|---|
| Midflame Wind Speed (upslope) | mi/h | 6 |
|-------------------------------|------|---|

Terrain

| | | |
|-----------------|---|---|
| Slope Steepness | % | 0 |
|-----------------|---|---|

(b) BehavePlus 5.0.1 Fri, May 07, 2010 at 14:15:43 Page 3

Fuel model 2 (1-h load = 2 ton/ac)

| 1-h Load ton/ac | ROS (max) ch/h | Flame Length ft |
|--------------------|----------------------|-----------------------|
| 0.5 | 22.2 | 3.6 |
| 1.0 | 36.9 | 5.3 |
| 1.5 | 47.7 | 6.7 |
| 2.0 | 55.8 | 7.9 |
| 2.5 | 61.8 | 8.9 |
| 3.0 | 66.5 | 9.8 |
| 3.5 | 70.1 | 10.5 |
| 4.0 | 73.0 | 11.2 |
| 4.5 | 75.3 | 11.8 |
| 5.0 | 77.2 | 12.3 |

Figure 53—Using the input in (a), a table and graphs (b) show the effect of a change in 1-h load for fuel model 2 on calculated surface rate of spread (c) and flame length (d).

(continued)

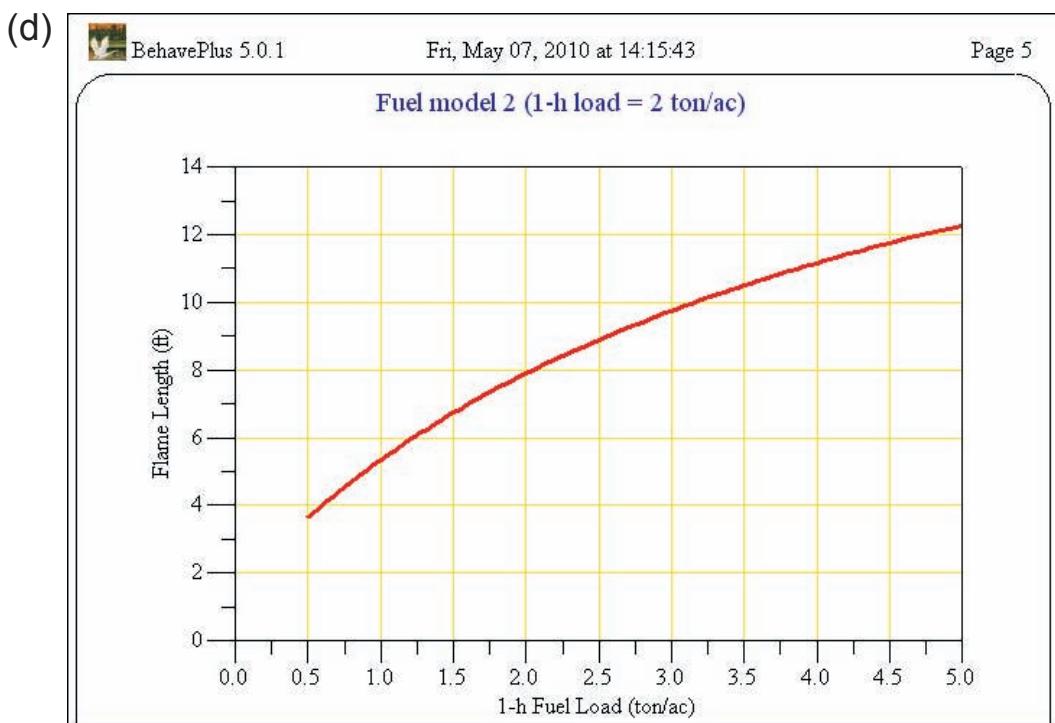
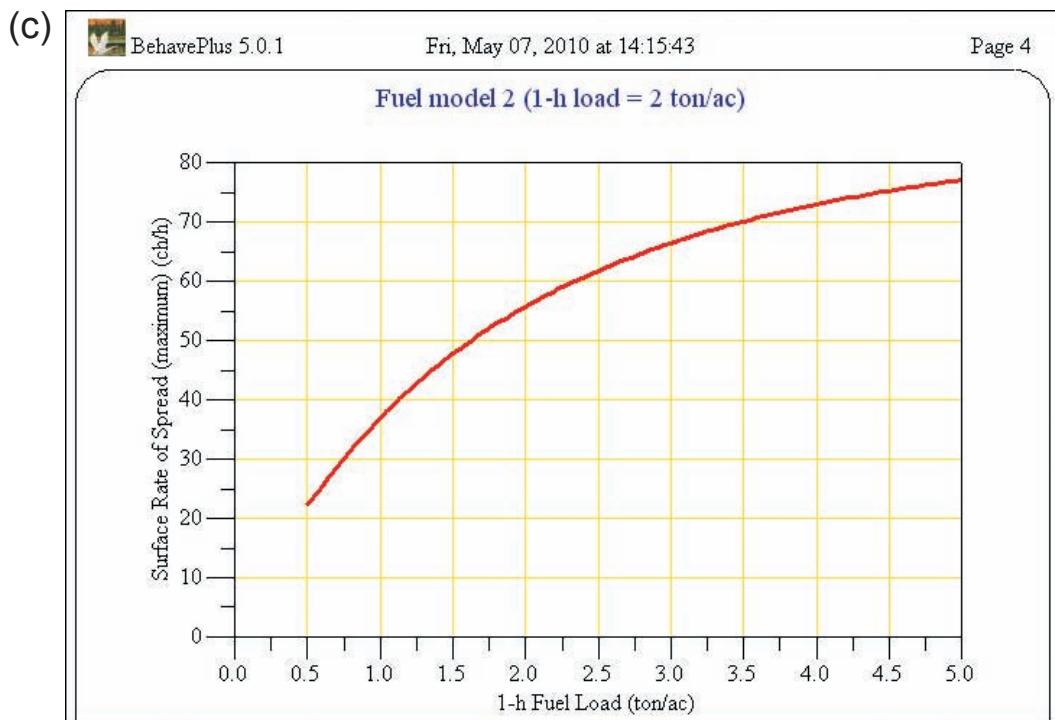


Figure 53—Continued from previous page.

File > Export results was used to save the table results in HTML format. The HTML file was opened with the spreadsheet program and saved as a spreadsheet file. The table output (a section of the complete HTML file) was then copied to another worksheet, and surface rate of spread and flame length were plotted on the same graph with the rate of spread axis on the left and the flame length axis on the right. A dashed line was added to show the initial fuel loading value (Figure 54).

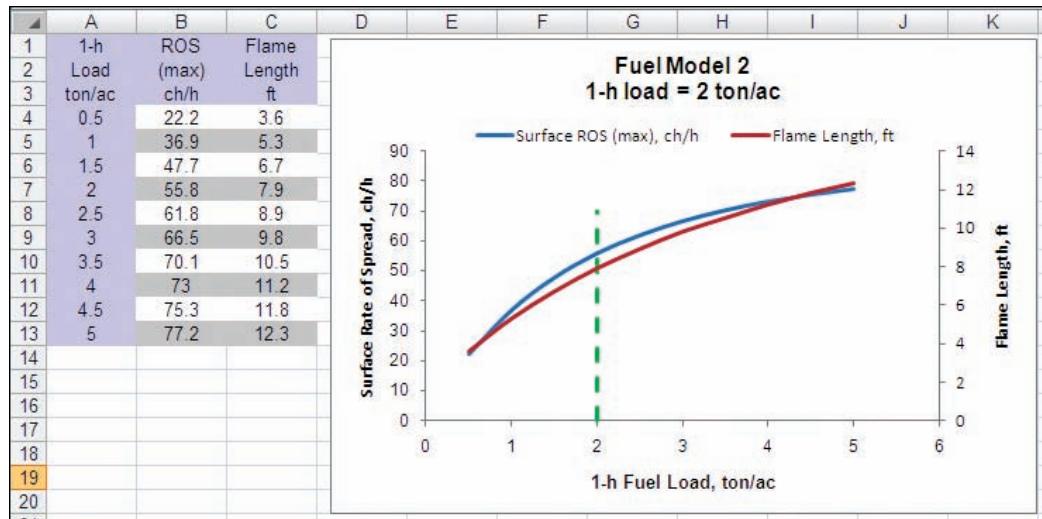


Figure 54—With a spreadsheet program, multiple variables can be plotted on the same graph. The inputs that create these data came from Figure 53a.

A spreadsheet can also be used to perform additional calculations. For this example, we calculate the ratio of surface rate of spread to flame length (Figure 55). This calculation was suggested for custom fuel model development by Burgan and Rothermel (1984) to deal with the common problem of generating approximately the right spread rate but having the flame length too low or vice versa. The plot shows whether spread rate will increase faster than flame length (rising curve) or slower (decreasing curve) as the value of the selected parameter changes. (We converted the surface rate of spread from ch/h to ft/min in the spreadsheet although the unit conversion could have been done in BehavePlus before export.)

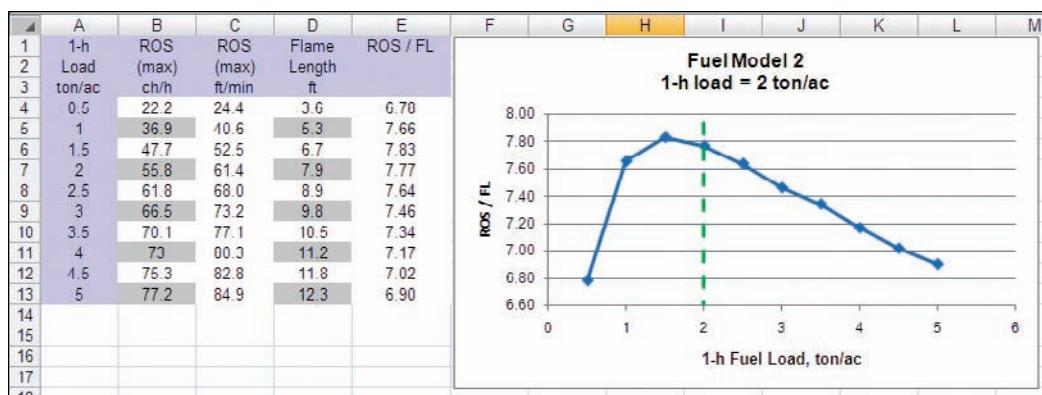


Figure 55—With a spreadsheet program, the ratio of surface rate of spread to flame length was calculated and plotted.

9 File Management and Workspaces

File management and documentation are key components of any fire behavior prediction. You can use BehavePlus' default file structure and create subfolders to organize your files. The use of workspaces, however, will help you keep track of your work and will aid in documenting and sharing results. BehavePlus workspaces store all BehavePlus files in a single, portable format.

9.1 BehavePlus File Structure

BehavePlus has a prescribed file structure, and all BehavePlus files must be located in specific subdirectories (Figure 56). Because they are installed in different folders, BehavePlus, Version 5.0 and earlier versions of the program can be installed on your computer at the same time. Some subfolders are created with program installation (Table 3). When files are saved, the appropriate BehavePlus folder is opened; new subfolders can then be created (Figure 57). Because exported HTML files and fuel models in FARSITE format are not used by BehavePlus, they can be saved anywhere on your computer.

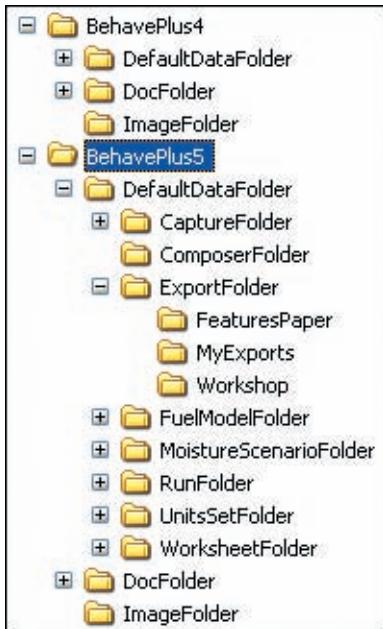


Figure 56—The BehavePlus file structure is prescribed. BehavePlus, Versions 4.0 and 5.0 (as well as earlier versions) can be installed on the same computer. Subfolders can be created using **File > Save as...** (in this case, **ExportFolders: FeaturesPaper** and **Workshop**).

Table 3—BehavePlus folders produced when a new workspace is created (Section 9.2).

| Folder name | Subfolders at installation | Command to create subfolders and save files | File extension |
|------------------------|---|--|----------------------|
| CaptureFolder | MyScreenCaptures | File > Save as an image | .png .jpg .bmp |
| ComposerFolder | | Temporary files | |
| ExportFolder | MyExports | File > Export results | .html |
| FuelModelFolder | MyFuelModels SoCalifornia | File > Save as a fuel model > BehavePlus format | .bpf |
| MoistureScenarioFolder | MyMoistureScenarios FuelModeling Tstmdl | File > Save as a moisture scenario | .bpm |
| RunFolder | MyRuns ExampleRuns | File > Save as a run | .bpr |
| UnitsSetFolder | MyUnitsSets | Configure > Custom units preferences | .bpu |
| WorksheetFolder | MyWorksheets ExampleWorksheets | File > Save as a worksheet | .bpw |

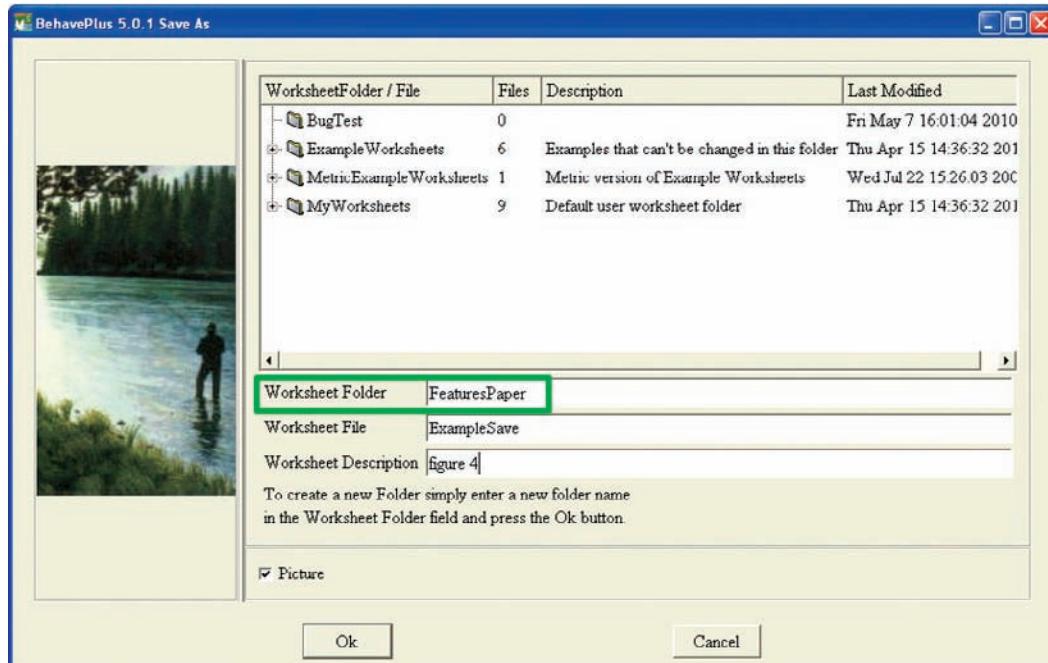


Figure 57—When a file is saved, the appropriate BehavePlus folder is accessed. New subfolders can be created for organization.

9.2 Workspaces

The workspace feature allows users to build a custom configuration for an application such as a prescribed fire burn plan or a wildfire prediction. All the relevant information to recreate analyses performed is included in a single folder for documentation and file-sharing.

The parent directory for the BehavePlus file structure and all its subdirectories and files is known collectively as a *workspace*. The **DefaultDataFolder** could have been named “DefaultWorkspace” because that is exactly what it is. The workspace includes all files in the parent directory, including any user-created folders and files.

To create a new workspace, you can clone an existing workspace to obtain an *identical* version of the workspace under a new name (**File > Workspaces > Clone current workspace**) that contains *all* files in that workspace (including any files you have created). Alternatively, to create a new workspace with the initial BehavePlus folders and files but with no user-created folders and files use the command **File > Workspaces > New workspace**.

Whether you clone a workspace or create a new workspace, it is always best to use the **Make New Folder** option (Figure 58). When naming your workspaces, we recommend using a folder name that indicates that a particular directory is a BehavePlus Workspace. For example, use the name **BPWS_<FireName>** or some equivalent naming scheme, where BPWS denotes that it is a **BehavePlus WorkSpace**. The name that you choose is equivalent to **DefaultDataFolder** in the default file structure.



Figure 58—Use the **Make New Folder** option when cloning a workspace or creating a new one.

When you clone a workspace or create a new one, the location is given for confirmation and you have the option of making the new workspace your current workspace. To change your current workspace, go to **File > Workspaces > Open workspace** and navigate to the folder containing the workspace you wish to use. If you select a folder that is not a workspace, you will get a number of error messages. Each time you restart the program, BehavePlus will start with the default workspace—the one that was created when the program was installed. Make sure you are using the correct workspace by checking the bottom bar of the BehavePlus window (Figure 2).

10 Fuel Models

A fuel model is a set of numerical values that provides the fuel inputs for Rothermel's (1972) mathematical model used to predict surface fire spread. When a fuel model code such as 10 or GS3 is specified, the appropriate set of fuel model parameters is defined for the calculations. The 53 standard fuel models (Anderson 1982; Scott and Burgan 2005) are available with BehavePlus, and you can create and use custom fuel models. While fuel models are generally used in modeling surface fire behavior, BehavePlus also offers the option of specifying two fuel models along with their percent cover as a way to deal with horizontal fuel nonuniformity. As an alternative to using fuel model codes, fuel parameters can be entered. There are also special case fuel models for palmetto-gallberry and for western aspen, which include intermediate calculations to define the fuel input parameters (Figure 59).

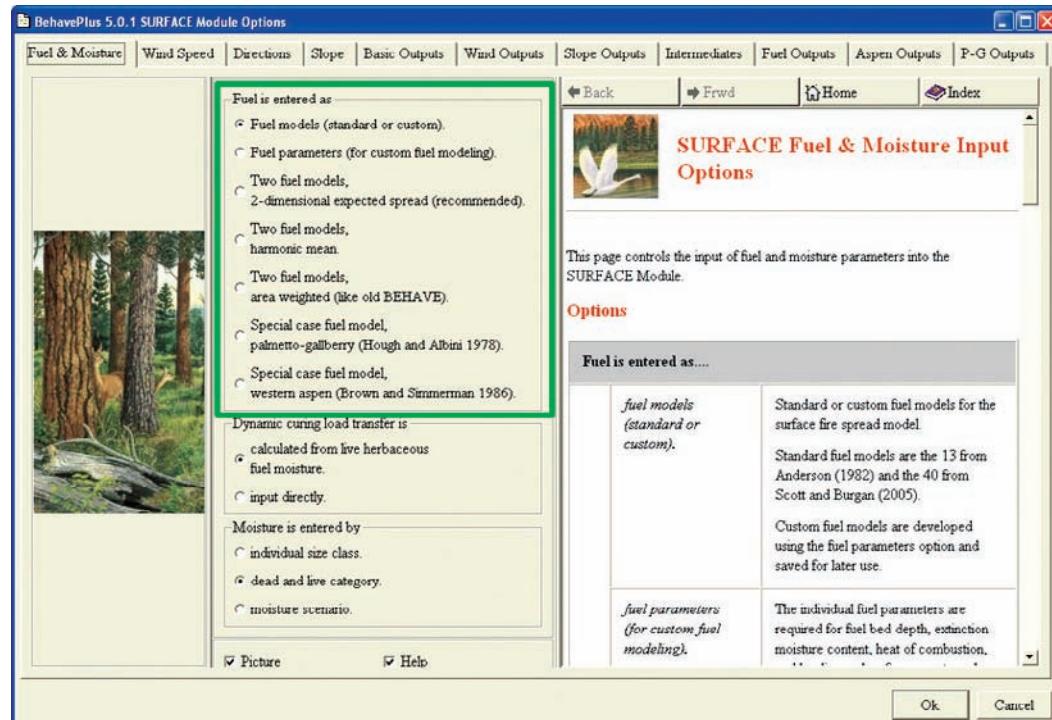


Figure 59—Options for specifying surface fuel for the SURFACE module are available on the **Fuel & Moisture** tab.

10.1 Custom Fuel Models

Developing a custom fuel model is an exercise in modeling. It is not possible to directly use field data to define a custom fuel model. A person who is developing a custom fuel model should have a basic understanding of Rothermel's model (Burgan 1987; Burgan and Rothermel 1984). The **Intermediates** tab of SURFACE includes fire model intermediate values such as relative packing ratio, heat source, heat sink, etc. (Figure 60).

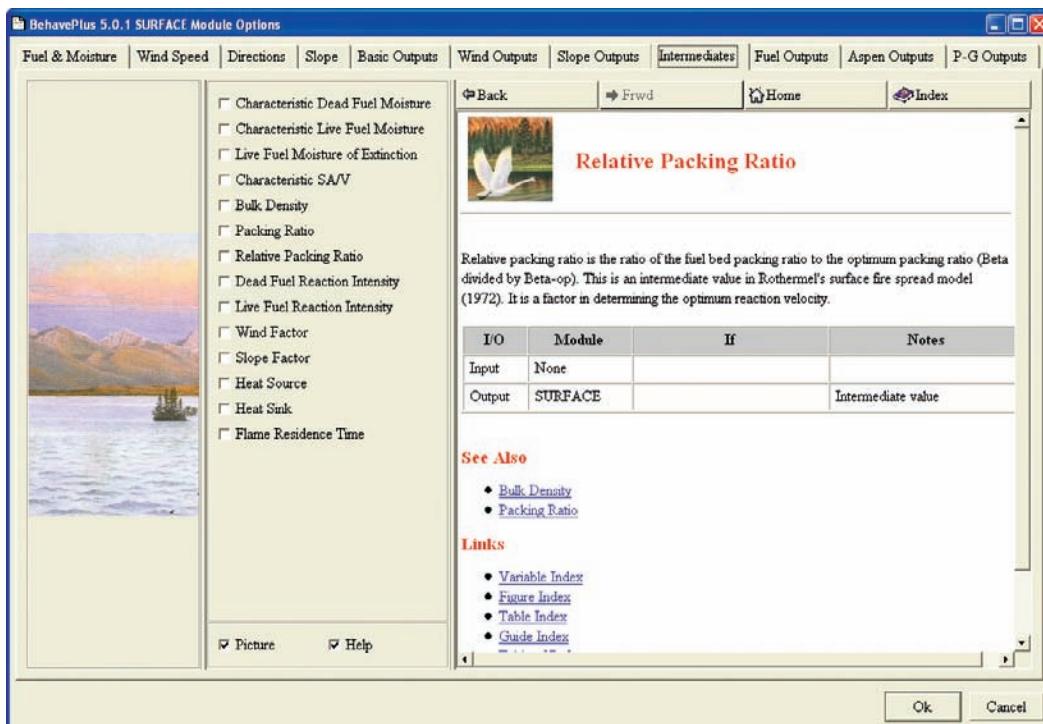


Figure 60—Intermediate values help you understand the fire model for use in developing custom fuel models.

Once it has been determined that none of the standard 53 fuel models is appropriate, a common way to develop a custom fuel model is to make adjustments to an existing fuel model. Rather than selecting the option **Fuel is entered as Fuel parameters** (Figure 59), it is best to open the example worksheet **FuelModeling.bpw** or **FuelModelingMetric.bpw**, both of which are designed with six decimal places for fuel load values to avoid possible issues with round off (Section 5.2). Click on the **Initialize from a Fuel Model** button on the worksheet and select one of the fuel models in the list to fill in values on the worksheet (Figure 61). Fuel model 1 (short grass) has only fine (1-h) dead fuel. A related custom fuel model might be developed by adding some live herbaceous fuel and reducing the 1-h load. Fuel modeling will involve producing tables and graphs to examine influence of changes on calculated surface rate of spread and flame length. It is also helpful to look at the intermediate values (Figure 60).



Inputs: SURFACE

Description → Initialize fuel parameters with fuel model 1

| Fuel/Vegetation, Surface/Understory | |
|-------------------------------------|---|
| Fuel Model Type | → S |
| 1-h Fuel Load | ton/ac → 0.740520 |
| 10-h Fuel Load | ton/ac → 0.000000 |
| 100-h Fuel Load | ton/ac → 0.000000 |
| Live Herbaceous Fuel Load | ton/ac → 0.000000 |
| Live Woody Fuel Load | ton/ac → 0.000000 |
| 1-h SA/V | ft ² /ft ³ → 3500 |
| Live Herbaceous SA/V | ft ² /ft ³ → 1500 |
| Live Woody SA/V | ft ² /ft ³ → 1500 |
| Fuel Bed Depth | ft → 1.00 |
| Dead Fuel Moisture of Extinction | % → 12 |
| Dead Fuel Heat Content | Btu/lb → 8000 |
| Live Fuel Heat Content | Btu/lb → 8000 |

Figure 61—Using the **FuelModeling.bpw** worksheet, a click on **Initialize from a Fuel Model** fills in values (fuel load values contain six decimal places) from an existing fuel model to use as a starting point in developing a custom fuel model.

Once fuel parameters have been determined, the custom fuel model can be saved for later use in BehavePlus using **File > Save as a fuel model > BehavePlus format**. You can use the **MyFuelModels** folder or create one that will meet your needs. The entry in the **Description** line of the worksheet becomes the fuel model description. You can change it to a meaningful name for the fuel model before it is saved. BehavePlus fuel model files have the extension **.bpf**.

Fuel models that have been saved for BehavePlus can also be exported in the format required by the FARSITE, FlamMap, and Nexus systems using **File > Save as a fuel model > FARSITE format**. These files will have the extension **.fmd**. The **Help** window gives guidance on naming conventions. You will probably want to save fuel models formatted for FARSITE somewhere other than in the BehavePlus folder to avoid confusion.

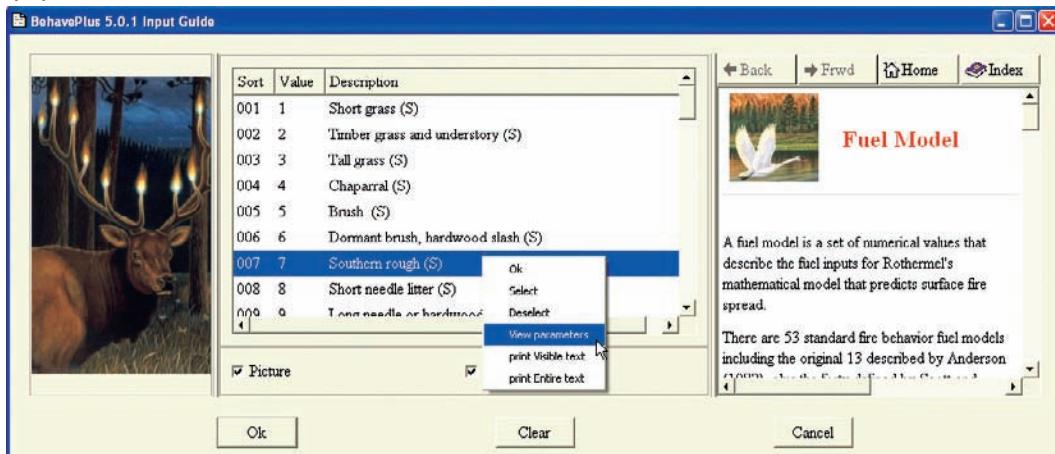
10.2 Selecting a Fuel Model

Clicking on the **Guide** button next to **Fuel Model** on the worksheet will bring up the fuel model **Input Guide** window. The 53 standard fuel models are always available (the original 13 in Anderson 1982 and 40 more in Scott and Burgan 2005). Custom fuel models will appear at the end of the list during the session in which they are created. In future sessions, the custom fuel model folder must be attached using **Configure > Fuel model set selection**. Individual fuel model files are attached by selecting the folder in which they reside. It is not possible to select and attach individual fuel model files; the entire

folder must be attached. Once a folder is attached, the new fuel models appear in the selection window. Several fuel model folders can be attached at one time.

A right-click on a fuel model in the selection window gives the option to **View parameters** (Figure 62). This is a quick way to check, for example, moisture of extinction or fuel bed depth of a fuel model.

(a)



(b)

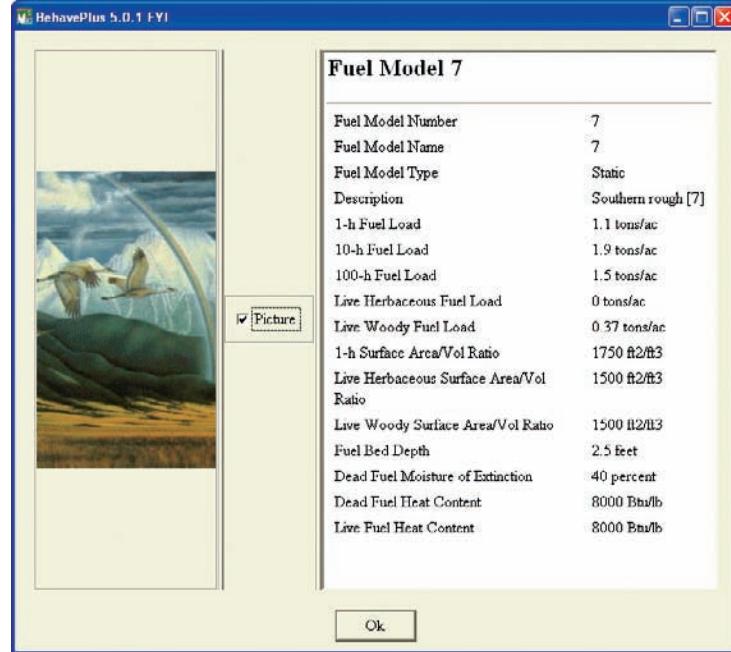


Figure 62—Right-click on a fuel model in the **Input Guide** list (a) to view its parameters (b).

11 Moisture Scenarios

A fuel moisture scenario is a set of fuel moisture values that represent moisture conditions of surface fuel: 1-h, 10-h, 100-h, live herbaceous, and live woody fuel moisture. Fuel moisture scenarios are analogous to fuel models—they package a number of values into a labeled set. The option of using moisture scenarios is available in **SURFACE Options...** on the **Fuel & Moisture** tab (Figure 59). The moisture scenarios used by Scott and Burgan (2005) to develop the set of 40 fuel models are provided with the program. Moisture scenario D2L1, for example, represents low dead, fully cured herbaceous fuel (1-h = 6%, 10-h = 7%, 100-h = 8%, live herbaceous = 30%, and live woody = 60%). Similar to fuel models, a right-click on a moisture scenario code in the selection list gives the option to **View parameters**. A window will open that shows the moisture values associated with each class of fuel (Figure 63).

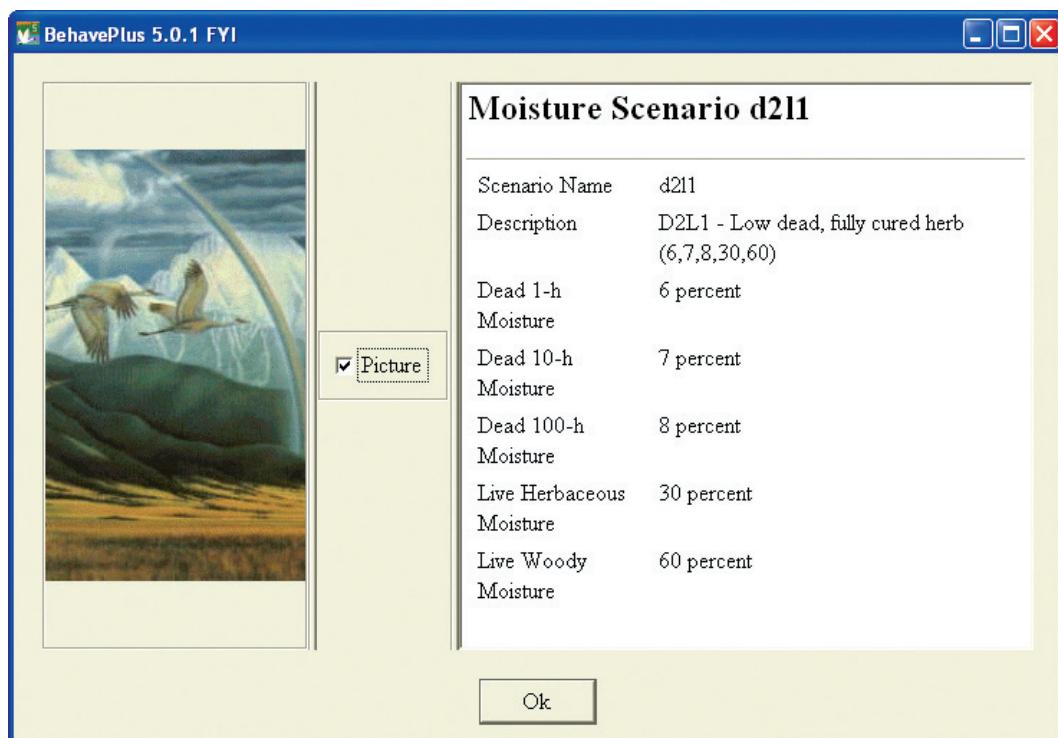


Figure 63—Right-click the moisture scenario code in the selection list and select **View parameters** to view values of the moisture scenario.

11.1 Custom Moisture Scenarios

As a user, you can also define and save your own moisture scenarios. For example, you might want to define moisture values for the 90th and 97th percentile fire weather conditions for a prescribed fire site. To create a custom moisture scenario, use a BehavePlus worksheet that includes the SURFACE input option of **Moisture is entered by individual size class**. You need only to fill in the fuel moisture values on the worksheet and then click **File > Save as a moisture scenario**. When naming a custom moisture scenario, it is a good practice to include the values in the name for easy reference.

11.2 Selecting Moisture Scenarios

As with fuel models, custom moisture scenarios are available during the session in which they were created. In future sessions, you must attach the folder in which they reside. It is not possible to select and attach individual moisture scenario files; the entire folder must be attached.

Moisture scenarios are useful when developing custom fuel models. That option is selected for the **FuelModeling.bpw** and **FuelModelingMetric.bpw** worksheets.

12 Table Shading for Acceptable Fire Conditions

A primary use of the BehavePlus option of **Table shading for acceptable fire conditions** is for prescribed fire planning. Acceptable conditions (such as 2- to 8-ft flame length) can be specified; unacceptable conditions are then “shaded” on output tables. (They are actually crossed off or left blank.) In this way, conditions such as wind speed and dead fuel moisture that result in acceptable conditions can be identified.

The approach used in BehavePlus is different from that in the RXWINDOW program of the old BEHAVE system (Andrews and Bradshaw 1990). RXWINDOW reversed the calculations to determine environmental conditions that corresponded to specified fire conditions. That approach is not feasible given the additional fire models (such as crown fire) that are available in BehavePlus.

To add acceptable fire conditions to your worksheet, check the box next to **Table shading for acceptable fire conditions** in the **Module Selection** window (Figure 1). Output variables available for table shading are given in a table in the BehavePlus Variables paper (Andrews 2009).

The added section of the worksheet lists output variables that allow input fields for minimum and maximum acceptable values (Figure 64). Entered values only affect results if the associated box is checked. If acceptable conditions are specified for flame length, values outside of that range on the flame length output table are crossed off. Associated table entries are also crossed off on any other table that is produced (in this example, surface rate of spread and reaction intensity).

It is a good practice to first show the values that are crossed out (unacceptable values) so that you see what is happening. Once you create the table that you want, you can produce a nicely formatted table with blank cells using **Configure > Appearance preferences > Tables**, checking the box next to **Show only acceptable conditions when table shading**, and recalculating the run.

(a)  BehavePlus 5.0.1 Thu, May 13, 2010 at 16:41:12 Page 1

| | |
|--|------------------------------------|
| Inputs: SURFACE | |
| Description <input checked="" type="checkbox"/> | Example: Acceptable FL = 2 to 8 ft |
| Administrative Unit <input checked="" type="checkbox"/> | North End |
| Prescribed Fire Name <input checked="" type="checkbox"/> | Blue Bird |
| Prepared By <input checked="" type="checkbox"/> | Mr. Smith |
| Fuel/Vegetation, Surface/Understory | |
| Fuel Model <input checked="" type="checkbox"/> | [2] |
| Fuel Moisture | |
| Dead Fuel Moisture % <input checked="" type="checkbox"/> | [14, 13, 12, 11, 10, 9, 8, 7, 6] |
| Live Fuel Moisture % <input checked="" type="checkbox"/> | [120] |
| Weather | |
| Midflame Wind Speed (upslope) mi/h <input checked="" type="checkbox"/> | [0, 2, 4, 6, 8, 10] |
| Terrain | |
| Slope Steepness % <input checked="" type="checkbox"/> | [0] |
| Acceptable Fire Conditions | |
| Surface Rate of Spread (maximum) (ch/h) <input type="checkbox"/> | [0.0] - [0.0] |
| Flame Length (ft) <input checked="" type="checkbox"/> | [2.0] - [8.0] |
| Run Option Notes | |
| Maximum reliable effective wind speed limit IS imposed [SURFACE]. | |
| Calculations are only for the direction of maximum spread [SURFACE]. | |
| Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE]. | |
| Wind is blowing upslope [SURFACE]. | |
| Output Variables | |
| Surface Rate of Spread (maximum) (ch/h) [SURFACE] | |
| Flame Length (ft) [SURFACE] | |
| Reaction Intensity (Btu/ft ² /min) [SURFACE] | |

Figure 64—Unacceptable conditions resulting from the inputs in (a) can be either crossed out (b) or left blank (c).

(continued)

(b)



BehavePlus 5.0.1

Thu, May 13, 2010 at 16:41:12

Page 4

Example: Acceptable FL = 2 to 8 ft

Flame Length (ft)

| Dead Fuel Moisture % | Midflame Wind Speed (upslope) mi/h | | | | | |
|----------------------------|---------------------------------------|-----|-----|-----|------|------|
| | 0 | 2 | 4 | 6 | 8 | 10 |
| 14 | 0.4 | 0.8 | 1.2 | 1.7 | 2.1 | 2.1 |
| 13 | 1.0 | 1.8 | 2.9 | 4.0 | 5.1 | 6.1 |
| 12 | 1.2 | 2.2 | 3.6 | 4.9 | 6.2 | 7.4 |
| 11 | 1.4 | 2.5 | 4.1 | 5.6 | 7.0 | 8.5 |
| 10 | 1.5 | 2.7 | 4.4 | 6.1 | 7.7 | 9.2 |
| 9 | 1.6 | 2.9 | 4.7 | 6.4 | 8.1 | 9.7 |
| 8 | 1.6 | 3.0 | 4.8 | 6.6 | 8.4 | 10.1 |
| 7 | 1.7 | 3.1 | 5.0 | 6.8 | 8.6 | 10.4 |
| 6 | 1.7 | 3.1 | 5.1 | 7.0 | 8.9 | 10.7 |
| 5 | 1.8 | 3.3 | 5.3 | 7.3 | 9.2 | 11.1 |
| 4 | 1.9 | 3.4 | 5.6 | 7.7 | 9.7 | 11.7 |
| 3 | 2.0 | 3.7 | 6.0 | 8.3 | 10.4 | 12.5 |
| 2 | 2.2 | 4.1 | 6.6 | 9.1 | 11.5 | 13.8 |

(c)



BehavePlus 5.0.1

Thu, May 13, 2010 at 16:42:57

Page 4

Example: Acceptable FL = 2 to 8 ft

Flame Length (ft)

| Dead Fuel Moisture % | Midflame Wind Speed (upslope) mi/h | | | | | |
|----------------------------|---------------------------------------|-----|-----|-----|-----|-----|
| | 0 | 2 | 4 | 6 | 8 | 10 |
| 14 | | | | | 2.1 | 2.1 |
| 13 | | | 2.9 | 4.0 | 5.1 | 6.1 |
| 12 | | 2.2 | 3.6 | 4.9 | 6.2 | 7.4 |
| 11 | | 2.5 | 4.1 | 5.6 | 7.0 | |
| 10 | | 2.7 | 4.4 | 6.1 | 7.7 | |
| 9 | | 2.9 | 4.7 | 6.4 | | |
| 8 | | 3.0 | 4.8 | 6.6 | | |
| 7 | | 3.1 | 5.0 | 6.8 | | |
| 6 | | 3.1 | 5.1 | 7.0 | | |
| 5 | | 3.3 | 5.3 | 7.3 | | |
| 4 | | 3.4 | 5.6 | 7.7 | | |
| 3 | 2.0 | 3.7 | 6.0 | | | |
| 2 | 2.2 | 4.1 | 6.6 | | | |

Figure 64—Continued from previous page.

13 Tools

The BehavePlus fire modeling system provides a number of tools that are stand-alone utilities, meaning they are not linked with any of the calculation modules. They are available via **Tools** on the main menu (Figure 65).

- **Fine dead fuel moisture** is a means of reading values from moisture tables, which are in the **Help** window. Results can be exported in HTML format for documentation (Section 8.5).
- **Relative humidity** provides a means for determining relative humidity from tables.
- **Units converter** is a quick way to make conversions between related units of measure (Section 5.5).
- **Slope from map measurements** calculates slope steepness in percent and degrees from map measurements. Results can be exported in HTML format for documentation. The tool provides the same outputs as the SURFACE module when the input option **Slope steepness is calculated from map measurements** is selected.
- **Slope vs horizontal map distance** converts calculated map distances to horizontal map distances.
- **Sun-moon calendar** allows you to generate sunrise, sunset, civil dawn and dusk, moonrise, and moonset in table or calendar format. The tool also displays a table of equinox, solstice, and moon phases for the year chosen.

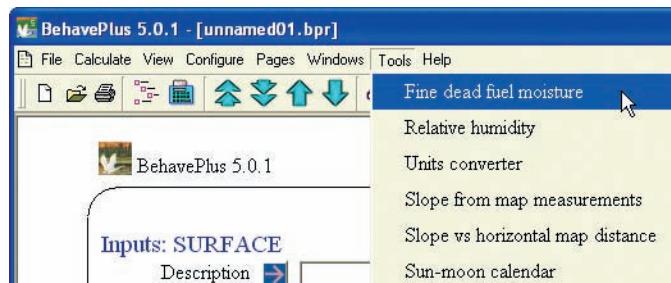


Figure 65—Several stand-alone tools are available via the **Tools** drop-down menu on the toolbar. There is guidance for each tool in its **Help** window.

14 Map Applications

BehavePlus includes several features related to map applications. Calculated distances can be converted to map distances, distance along the ground can be converted to a horizontal map distance, and slope steepness can be calculated from map measurements.

14.1 Map distances

The **Module Selection** window includes a check box to **Display output distances in map units** (Figure 1). This is a quick way to add map distance outputs from several modules with one click. Variables that are converted to map distances include surface spread distance in SPREAD; crown spread distance in CROWN; spotting distance in SPOT; and forward spread distance, backing spread distance, fire length, and maximum fire width in SIZE.

14.2 Slope versus Horizontal Map Distance

Map distance is found by multiplying slope distance by the map scale. This is not technically correct, but because of the many variables that exist in the real world, the difference between slope distance and horizontal distance is not critical. The **Slope vs horizontal map distance** tool (Figure 66) is provided to make a conversion of slope map distance to horizontal map distance in case you want to make the correction before you plot a distance on a map. (The tool requires slope input as a percentage and gives the associated value in degrees.)

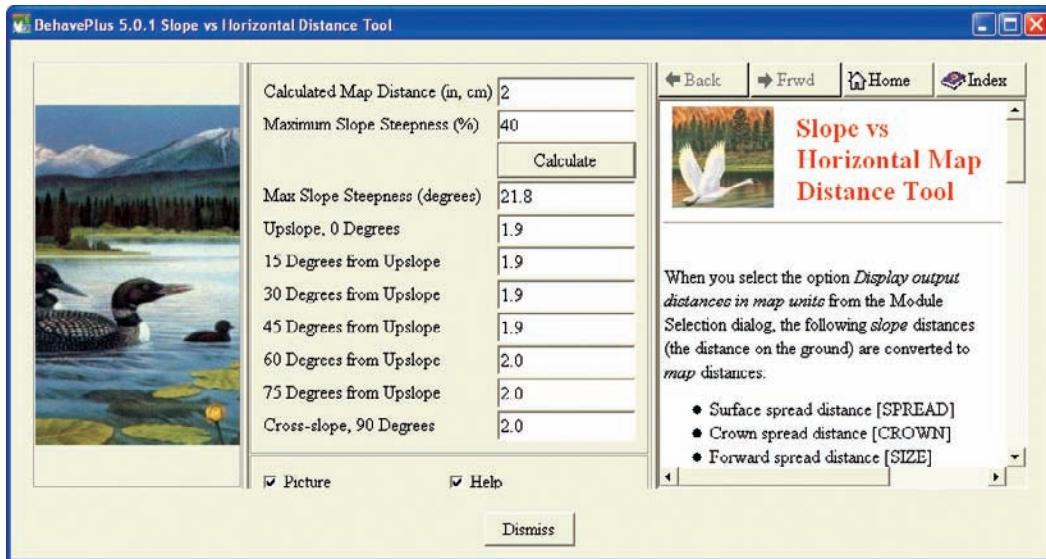
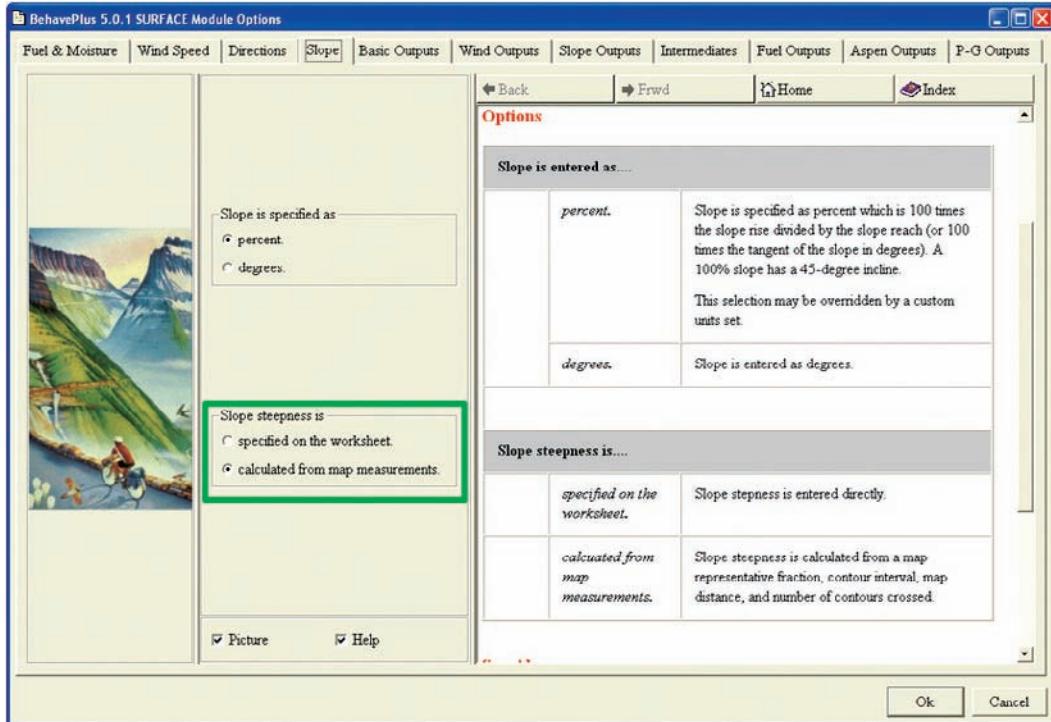


Figure 66—The **Slope vs horizontal map distance** tool converts a calculated map distance on the slope to a horizontal distance given the maximum slope steepness and various directions with respect to upslope.

14.3 Slope from Map Measurements

Slope steepness can be directly entered into a SURFACE worksheet, or it can be calculated from map measurements by changing the input option on the **Slope** tab (Figure 67). The **Slope Outputs** tab lets you select the calculated slope and intermediate values as outputs. Because BehavePlus builds a worksheet that requests only required input values, you can build a simple slope calculation worksheet by selecting only the above input option and slope output variables (Figure 67). Conversely, you can use the **Slope from map measurements** tool if slope steepness is the only desired output (Section 14.5).

(a)



(b)

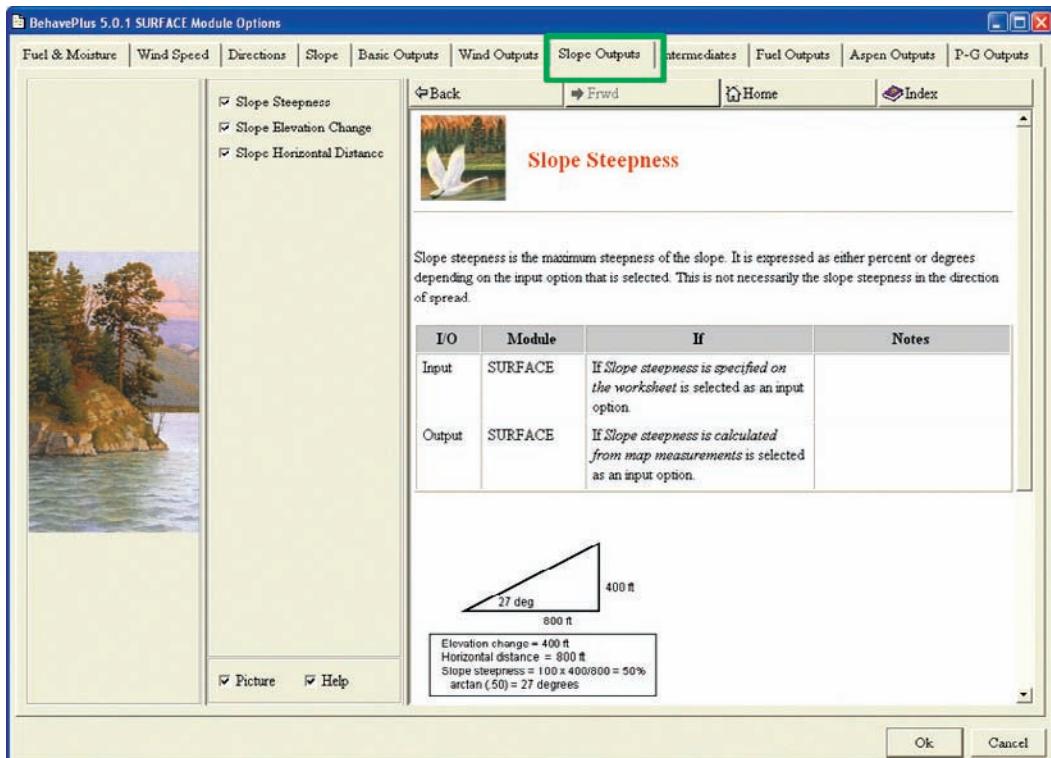


Figure 67—An input option allows calculation of slope steepness from map measurements (a). Slope output variables are on a separate tab. The Help window explains the relationship of the values (b). These selections generate a simple slope calculation worksheet using SURFACE (c).

(continued)

(c)

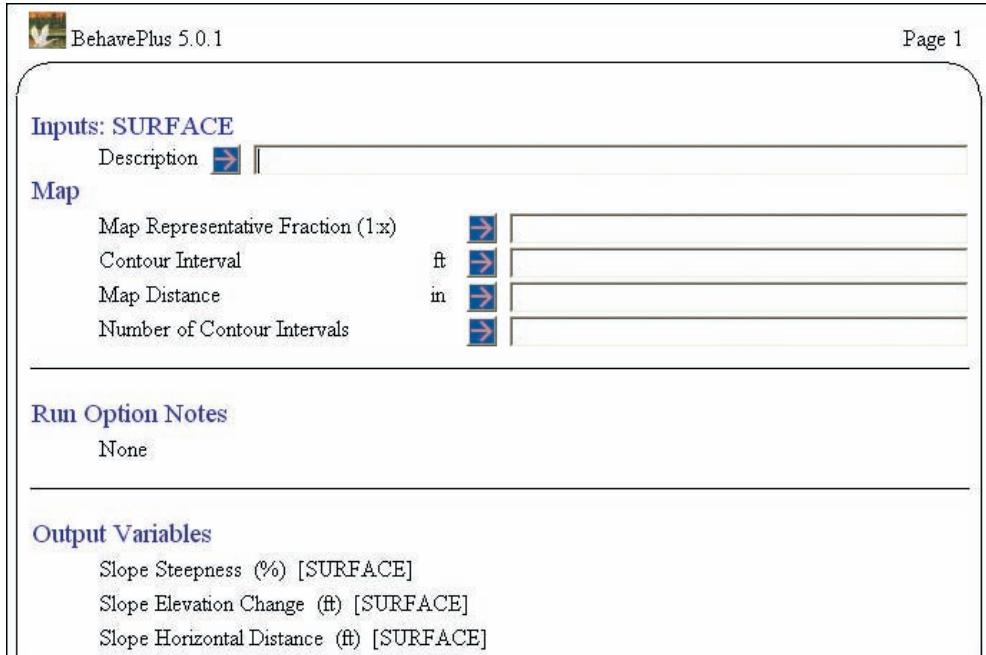
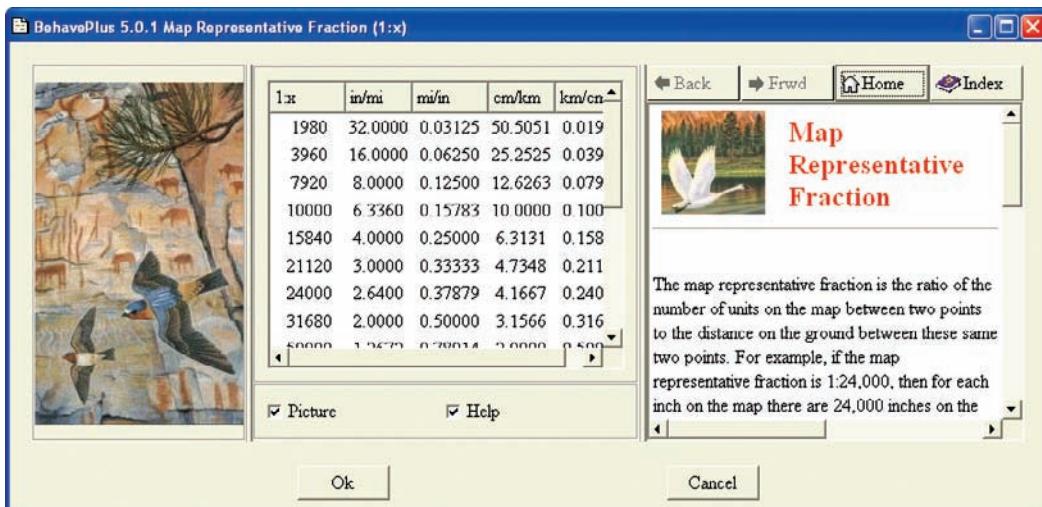


Figure 67—Continued from previous page.

14.4 Map Scale

When either **Display output distances in map units** or **Slope steepness is calculated from map measurements** is selected, the worksheet adds a section for **Map** input variables (Figure 67c). The **Guide** button for the map representative fraction offers a **Choices** button that provides several ways of specifying map scale (Figure 68).

Figure 68—The **Choices** button for map representative fraction gives map scale in several ways.

14.5 Slope Tool

A stand-alone tool is available for quick calculations of slope steepness in percent and degrees from map measurements (Figure 69). It requests the same map measurements and provides the same outputs as the SURFACE module when the input option **Slope steepness is calculated from map measurements** is selected.

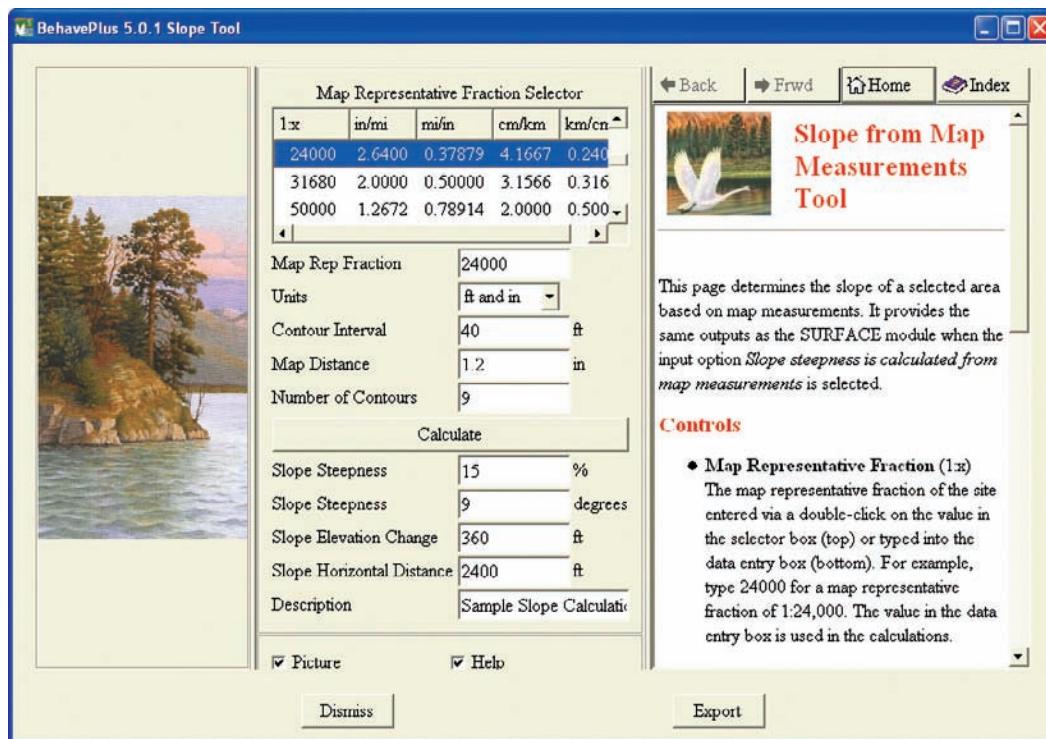


Figure 69—The **Slope from map measurements** tool can be used to calculate slope steepness without creating a worksheet. The results can be exported in HTML format.

15 Help

A variety of support material is available to users of the BehavePlus fire modeling system. One of the lessons listed in Appendix B was developed to describe the help that is available, both within and beyond the BehavePlus program. This section presents a more general overview of help information sources.

A click on the **Help** button in the top menu bar (Figure 70) provides a link to information about the program: **About BehavePlus**, **About Help**, the **User's Guide**, the Variables paper (**Variable Help**), an index of all components of the BehavePlus **Help** system in HTML format (**Master Index**), and **Installation Info** (Section 15.6).

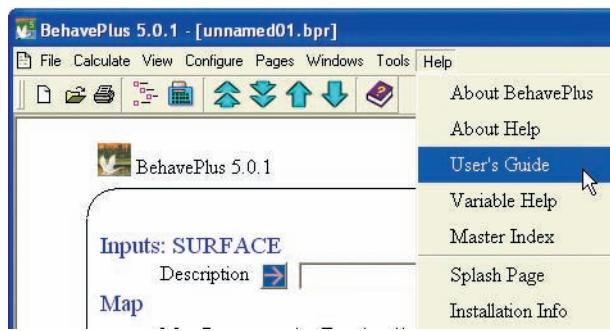


Figure 70—The **Help** item on the toolbar provides access to several types of help.

15.1 User's Guide

The User's Guide (Andrews and others 2008) is a reference guide on program operation. It does not provide information on the fire models. The User's Guide is a printable publication that is available as a PDF that comes with the program and can be opened with **Help > User's Guide**. Bookmarks and internal links allow quick navigation to the area of interest. Updates to BehavePlus, Version 5.0 did not involve basic program operation, so the User's Guide was not updated. The Version 4.0 User's Guide is still valid.

15.2 Variables Paper

The Variables paper (Andrews 2009) describes the more than 180 variables in BehavePlus along with information on input and output relationships. As with the User's Guide, it is available as a PDF that comes with the program (**Help > Variable Help**). The document includes information that was previously available only in separate **Help** windows. The variables are organized in several ways to facilitate finding the required information. Bookmarks and links within the paper allow a user to navigate among related variables.

15.3 Help Window

The right-hand pane of most BehavePlus windows contains information related to the subject of the window known as *context-sensitive Help*. The contents of any **Help** window can be printed with a right-click on the window.

The **Guide** button beside each variable on the worksheet opens a window for that variable. The **Help** window gives a description of the variable, explaining how and where it is used. Some of these descriptions include pictures and diagrams while others include flowcharts. Additional information is available for many variables. For example, the 20-ft wind speed variable **Help** window provides an illustration and table of the Beaufort Scale for estimating 20-ft wind speed (Figure 71). In the CONTAIN module, the line resource production rate **Help** window contains tables from the *Fireline Handbook, Appendix A* (National Wildfire Coordinating Group 2004).

In windows that list available output variables, hovering over a variable with the mouse will trigger a related **Help** window to appear (Figure 72). The **Help** window gives descriptions of input options, including links to additional information in some cases (Figure 73).

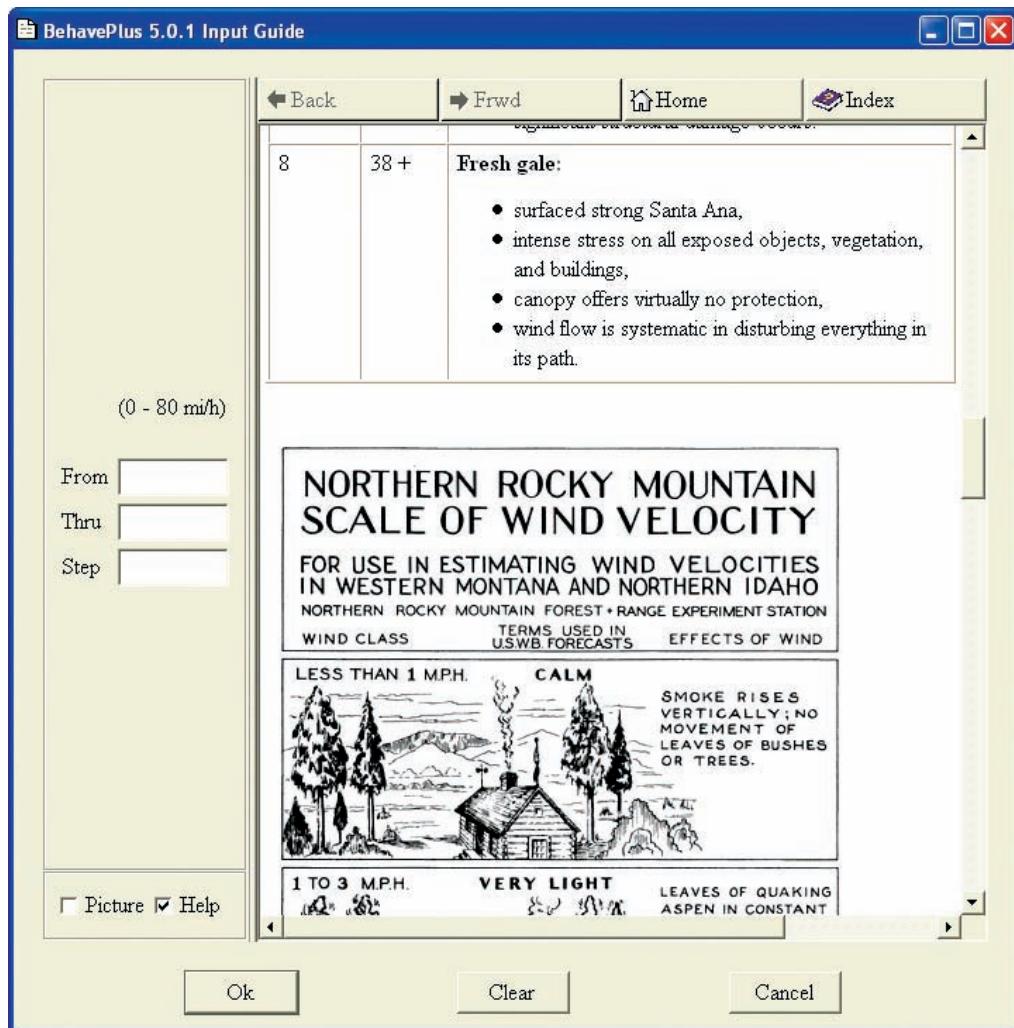


Figure 71—The 20-ft wind speed variable **Help** window contains a table and illustration for estimating wind speed using the Beaufort Scale.

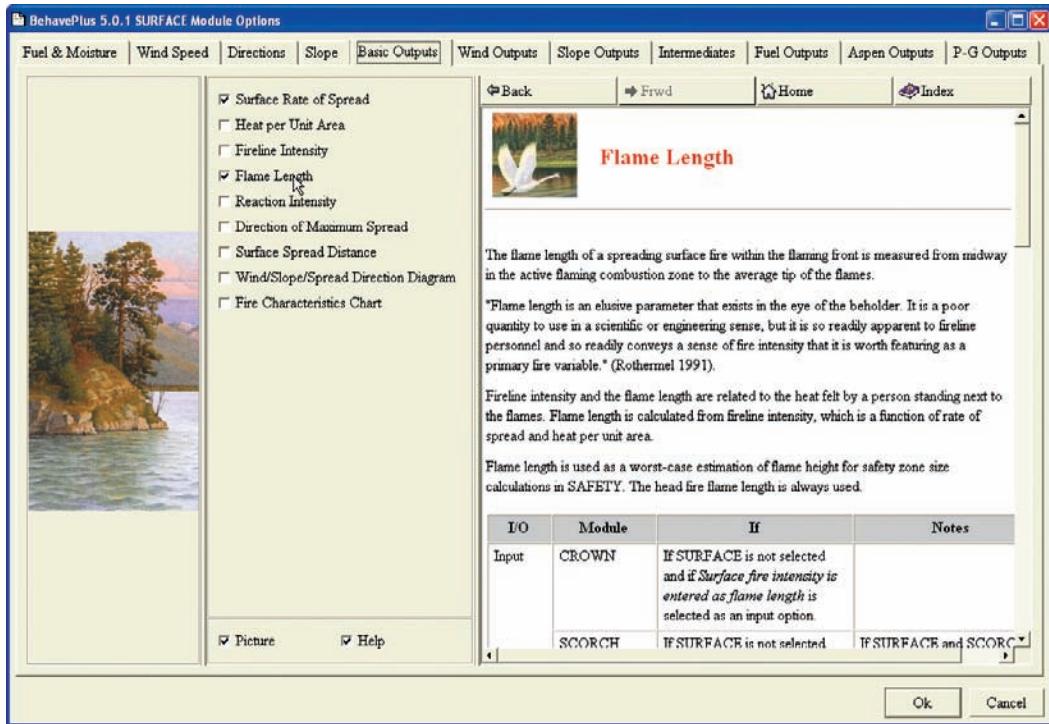


Figure 72—Hovering over a given output variable (for example, flame length) in a list of output variables will trigger the related **Help** window to appear.

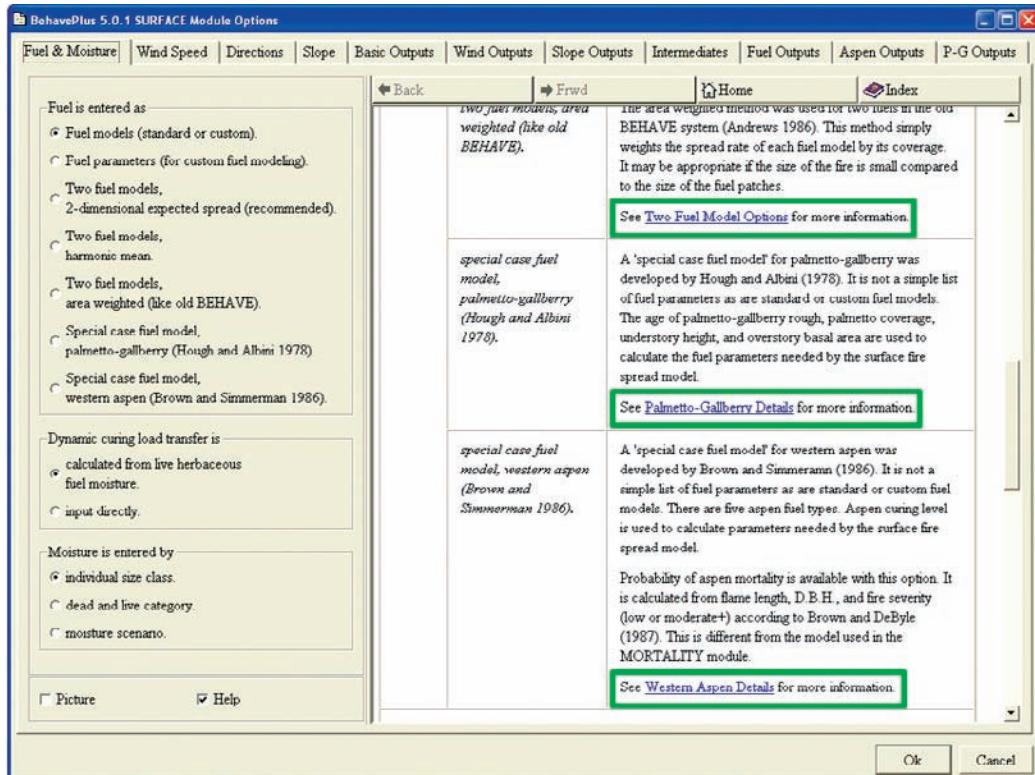


Figure 73—The **Help** window gives information on input options, including links to additional information.

15.4 Master Index

The **Master Index** (Figure 74) provides direct access to all of the information found in the *context-sensitive Help* system. It can be accessed via **Help** on the toolbar (Figure 70) or by clicking the **Index** button at the top of all of the right-hand **Help** windows previously described.

- **Variable Index** accesses all input and output variables from an alphabetical list.
- **Figure Index** gives a list of the figures contained in the **Help** system.
- **Table Index** is a similar list of the tables in the **Help** system.
- **Guide Index** lists all other information available from the **Help** system (for example, details on the two fuel model options, estimates of canopy bulk density, or a fuel model key for the original 13 standard models, as well as information regarding module input options, custom units, appearance preferences, and tools).
- **Table of References** lists models included in each BehavePlus module as well as relevant citations.

These five selections are also provided at the bottom of every page in the **Help** system.

You can navigate through the **Help** system using the **Back**, **Frwd** (Forward), **Home**, and **Index** buttons. The **Home** button will take you to the main **Help** window for the current section. For example, if an output page is showing, **Home** will take you to the **Help** file for **Select Output Variables**. If you are on an input options page, **Home** will take you to the **Help** file for that particular tab, regardless of how many times you have clicked through the **Help** system. If you are in the **Master Index**, the **Home** button will take you back to the **Master Index**. The **Index** button will return you to the **Master Index**, regardless of where you are in the program.

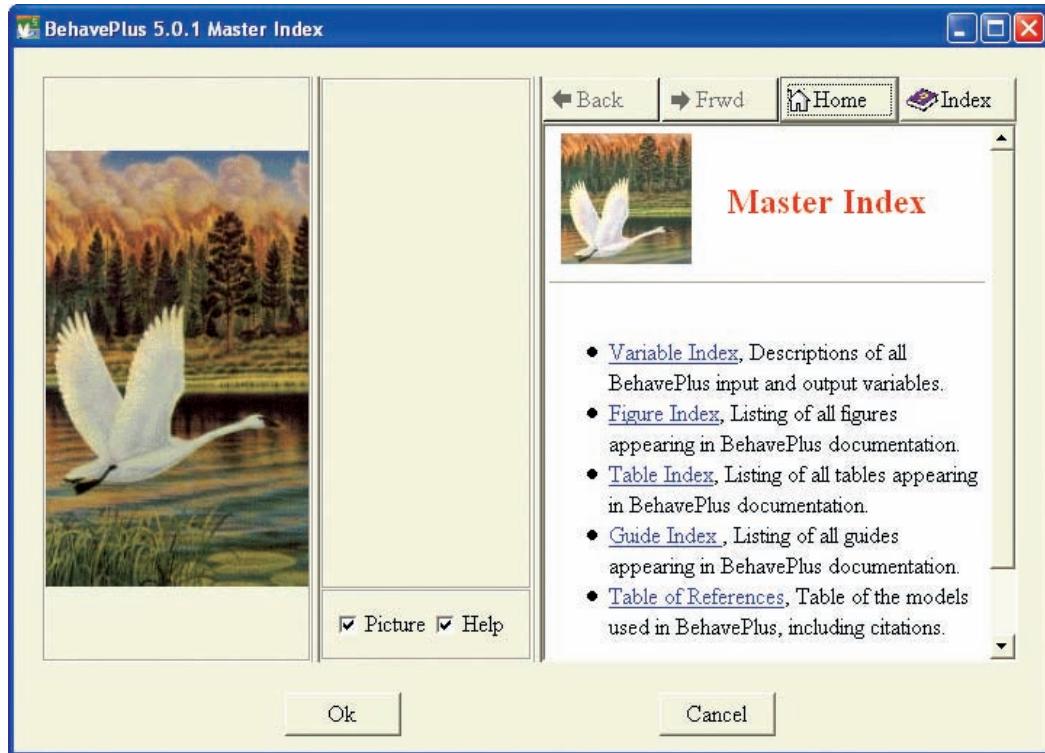


Figure 74—The **Master Index** provides links to information about the variables, figures, tables, guides, and references included in the program's HTML-based **Help** system.

15.5 Web Site

Much more help is available on the BehavePlus web site. There are copies of publications on the mathematical models comprising BehavePlus and on related fire behavior topics (Figure 75) and training material (Appendix B), as well as a tips page and a change log.

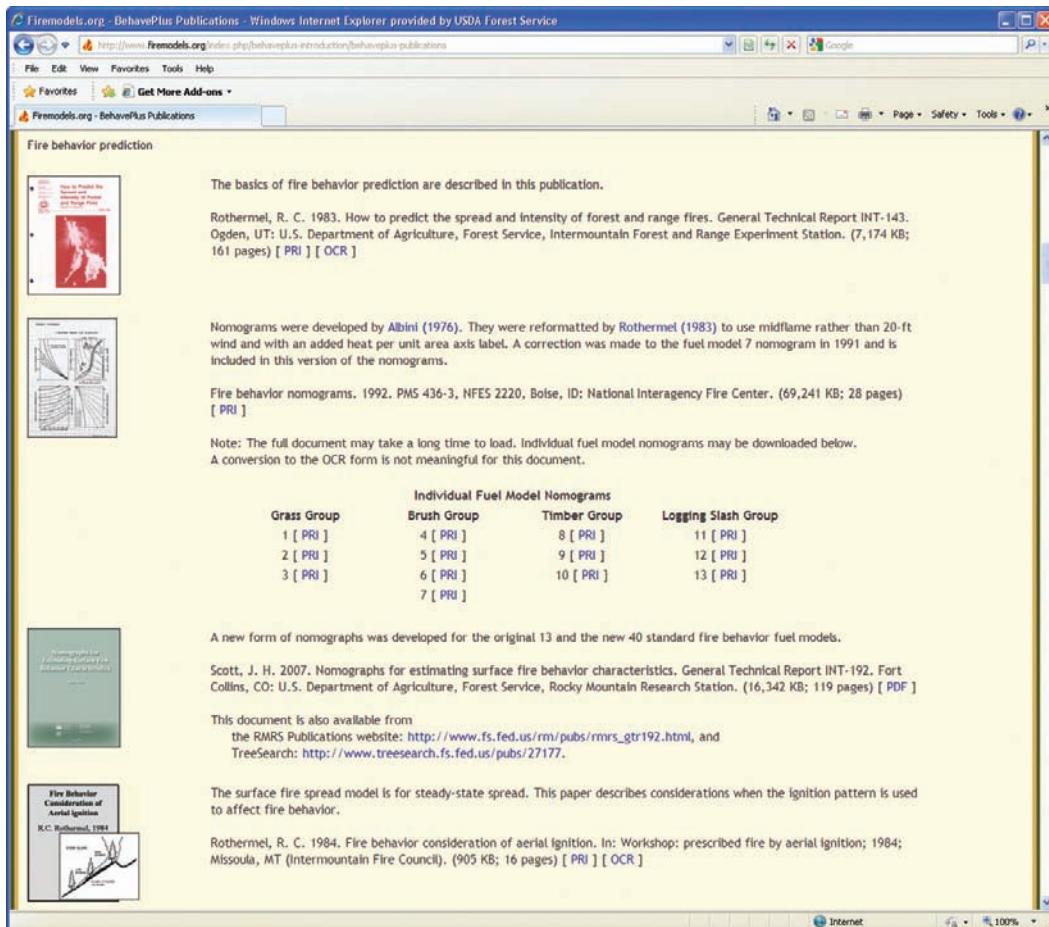


Figure 75—The BehavePlus website contains copies of publications related to many aspects of fire behavior modeling, including those specific to models used in BehavePlus.

15.6 Installation Information

Help on the main toolbar gives you access to **Installation Info** (Figure 70). The FYI window (Figure 76) that opens contains information about the BehavePlus setup that is organized according to categories.

- **Program Information** gives the location of the executable file, the build number, and the date and time it was compiled. This information can help you determine if you have the latest version and build of the program.
- **Directories** gives file locations—the most important being the location of the current workspace and the location and name of the startup worksheet.
- **Environment Variables** shows the current environment variable settings of the user's computer. The \$PATH environment variable, in particular, shows the order in which Microsoft Windows searches directories to find applications. This may be useful in determining exactly which BehavePlus executable file is being run or why one version is being run in preference to another.
- **Display Metrics** provides the resolution of your BehavePlus window on the desktop and the number of colors in use. This information can be changed by changing the desktop preferences of your Microsoft® Windows-based PC.
- **Image Files, Documentation Files, and Geographic Files** sections will let you know if any of the relevant files are missing from your program. If there are no missing files, the text will read **All [image, documentation, geographic location] files are present**. Reinstalling the program will fix any problems that you may have.
- Additional file information is available on files you have saved. You can find out about the fuel models, moisture scenarios, units sets, worksheet files, and run files in the current workspace. The window will tell you how many files you have created and where they are located.

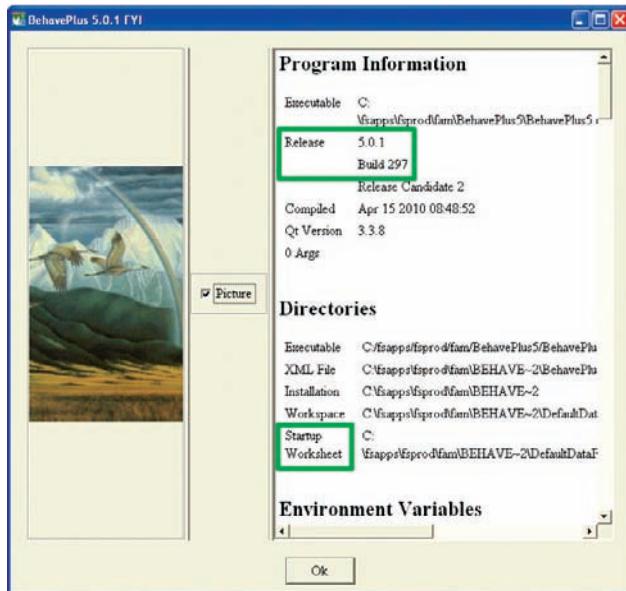


Figure 76—Help > Installation Info opens a window with information about file locations, etc. Of most importance are the build number and the location of your startup worksheet.

15.7 Technical Support

BehavePlus is a national system supported by U.S. Forest Service Fire and Aviation Management. The National Support Desk is available for software issues only and cannot deal with fire behavior questions. Contact information is available on the BehavePlus web site and in the Acknowledgments section of this report.

16 Program Updates

The BehavePlus program is occasionally updated as features and modeling capabilities are added to the program and as bugs are fixed. The BehavePlus web site provides the latest information. You can also subscribe to BehavePlus news on the web site to receive occasional e-mails regarding changes to BehavePlus.

17 Summary

This paper was written to assist in using the BehavePlus fire modeling system and to supplement the reference papers—the User’s Guide and the Variables paper. It is also a brief presentation of material found in the lessons on the BehavePlus web site.

This paper is not intended to teach professionals how to properly define inputs or interpret output. Those tasks are left to courses, such as the S-390 course, and field experience. We hope that users (novice and advanced) will use this document to learn how to more effectively use BehavePlus to support their fire modeling tasks.

Basic BehavePlus design decisions were made over 10 years ago with the update from the DOS BEHAVE system to BehavePlus (Andrews and Bevins 1998). Some of the internal design features cannot be changed without a total system rebuild. Although there are features that we would design differently now, we feel that the BehavePlus system has been successful in many ways. We hope this document might help people design future generations of fire modeling software.

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Appendix A. Tricks and Tips List

Following is a list of BehavePlus tips and tricks. These are discussed in more detail in the body of the paper (in each referenced section) or in the specified appendix.

Worksheet Setup

- Add additional **Description** lines to the worksheet header. (Section 3.1.3)
- Change the size of or remove the **Notes** section. (Section 3.1.3)
- Add tabs to the edge of BehavePlus pages to add space for additional documentation. (Section 3.1.2)
- All selections are stored as part of a worksheet or run, including those not visible on the current worksheet. Selections include module selection; input options; output variables; appearance of graphs, tables, and worksheets; and units and decimal settings. (Section 3 and Appendices D-H)
- Use the worksheets designed explicitly for fuel modeling because the additional decimal display for fuel load reduces round off problems. (Section 3.3.1 and 5.2)

Enter Input

- Enter values on a worksheet separated by commas, spaces, or any combination of commas and spaces. (Section 6.1)
- Pick from a list of selected values for some continuous variables using the **Choices** button. (Section 6.4)
- Check the range of valid values for a continuous variable using the **Guide** button. (Section 6.3)
- Use the **Guide** button input fields to enter one value or two values (e.g., minimum and maximum plot values) as well as the more common three values (**From**, **To**, **Step**). (Section 6.3)
- Look in the **Help** window for additional aid in determining input values. (Sections 6.5 and 15.3)

Format Output

- Enter a negative step size to format tables so that variables range from larger to smaller values (for example, fuel moisture). (Section 6.3)
- Table shading of every other line of output tables can be removed or the color can be changed. (Section 7.2)
- Using the option **Table shading for acceptable conditions** will create tables in which unacceptable values are crossed off or left blank. (Section 12)

- Graph appearance, including colors, size, and grid, can be changed. All of these selections are saved with the worksheet or run. (Section 7.3.1)
- Set the graph minimum values to either zero or the minimum calculated values. Let the Y-axis maximum be determined by the maximum calculated value or set the maximum value. (Section 7.3.3)
- Change the order of input values on the worksheet to change the position of curve labels. (Section 7.3.1)
- Decimal display of input variables on output tables is determined by the precision of values entered on the worksheet. (Section 5.1)
- Change units and output decimal display for the current run without saving a custom units set. (Section 5.4)

View

- Look at fuel model parameters or moisture scenario values by right-clicking on the selection in the **Guide** button window. (Section 10.2 and 11)
- Use the **View** command to zoom in for presentations or zoom out to show the whole page. (Section 4.1)
- Use the **Pages** command to jump directly to the page you want to view. (Section 4.3)
- If you prefer not to see Dolack's pictures in the left-hand window, you can turn them all off. That option will remain in effect for the next session. (Section 3.2.5)
- Temporarily close the Dolack **Picture** pane to give more space to the **Help** window. (Section 3.2.5)
- View multiple worksheets/runs at a time. (Section 4.2)
- Scroll down to see if there is additional helpful information in the **Help** window. (Section 6.5 and 15.3)
- Use the **Master Index** to look at tables, diagrams, variable description, etc., in the **Help** system. (Section 15.4)

Export and Print

- Table results can be exported to an HTML file and opened with a browser. Long and wide tables are not split to fit on 8½- by 11-inch paper. (Section 8.5)
- Open HTML files with spreadsheet software to do additional analysis and formatting. The file must be saved as a spreadsheet. (Section 8.6)

- Export moisture values calculated with the fine dead fuel moisture tool to an HTML file for documentation. (Section 13)
- Print any **Help** window by right-clicking the window. (Section 15.3)
- Capture a BehavePlus window with **Alt-PrintScr**n, insert it into a document, and crop it. (Section 8.4)

Personalization

- Set the worksheet that opens when BehavePlus starts. (Section 3.3.3)
- Example worksheets that come with the program have selections that we call defaults. A user can define alternate sets of defaults for various applications. (Section 3.3.2)
- Use workspaces for documentation files and to share BehavePlus worksheets, runs, etc. (Section 9.2)

Appendix B. BehavePlus Lessons List

BehavePlus self-study tutorials can be downloaded from the BehavePlus website.
Additional information about features described in this paper is available in the lessons.

Following are available or planned lessons at the time of this writing.

| Unit | Lesson |
|--------------|---|
| Overview | 1 - BehavePlus Overview |
| | 2 - BehavePlus Update |
| | 3 - Application of BehavePlus |
| | 4 - Before You Start with Fire Modeling |
| | 5 - Modeling Capabilities |
| | 6 - BehavePlus for Prescribed Fire |
| Introduction | 1 - Basic Start |
| | 2 - Worksheets |
| | 3 - Input Methods |
| | 4 - Calculations |
| Operation | 1 - Help, More Help, and Desperate for Help |
| | 2 - Features |
| | 3 - Worksheets (advanced) |
| | 4 - Independent vs. Linked Modules |
| | 5 - BehavePlus Results in Written Reports |
| | 6 - File Management |
| | 7 - Units and Decimals |
| | 8 - Table Shading |
| | 9 - Export to Spreadsheet |
| Modeling | 1 - Modeling Concepts |
| | 2 - Surface Fire Spread and Intensity |
| | 3 - Surface Fuel |
| | 4 - Standard Fuel Models |
| | 5 - Custom Fuel Models |
| | 6 - Custom Fuel Models (advanced) |
| | 7 - Dynamic Fuel Models |
| | 8 - Two Fuel Models |
| | 9 - Special Case Fuel Model, Palmetto-Gallberry |
| | 10 - Special Case Fuel Model, Western Aspen |
| | 11 - Dead Fuel Moisture |
| | 12 - Live Fuel Moisture |
| | 13 - Moisture Scenarios |
| | 14 - Slope |
| | 15 - Wind |
| | 16 - Wind Adjustment Factor |
| | 17 - Directions |
| | 18 - Overstory Vegetation |
| | 19 - Crown Fire Spread |
| | 20 - Crown Fire Intensity |
| | 21 - Safety Zone Size |
| | 22 - Scorch and Mortality |
| | 23 - Spotting and Ignition |
| | 24 - Size |
| | 25 - Contain |
| | 26 - Map Applications |

Appendix C. Comparison of BehavePlus to Spatial Fire Behavior Systems

Comparison of BehavePlus and the spatial fire behavior systems: FlamMap, FARSITE, and FSPro (from Andrews 2007).

| System | Condition variation in time | Condition variation in space | Duration specification | 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, and 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, weather, 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, weather, 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, and arrival time contours. Fuel treatment placement recommendation | 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, weather, 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 |

Appendix D. Input Options

Input options are specified in **Configure > Module selection > Options...** for each module. All selections are saved with a worksheet or run. This table presents available input options and those selected for the **0Default.bpw** and **BasicStart.bpw** worksheets.

| Module | Tab | Input option | 0Default.bpw and BasicStart.bpw selection | All input options |
|---------|-----------------|---|--|---|
| SURFACE | Fuel & Moisture | Fuel is entered as | Fuel models (standard or custom). | <ul style="list-style-type: none"> Fuel models (standard or custom). Fuel parameters (for custom fuel modeling). Two fuel models, 2-dimensional expected spread (recommended). Two fuel models, harmonic mean. Two fuel models, area weighted (like old BEHAVE). Special case fuel model, palmetto-gallberry (Hough and Albini 1978). Special case fuel model, western aspen (Brown and Simmerman 1986). |
| | | Dynamic curing load transfer is | calculated from live herbaceous fuel moisture. | <ul style="list-style-type: none"> calculated from live herbaceous fuel moisture. input directly. |
| | | Moisture is entered by | individual size class. | <ul style="list-style-type: none"> individual class size. dead and live category. moisture scenario. |
| | Wind Speed | Wind speed is entered as | midflame height. | <ul style="list-style-type: none"> midflame height. 20-ft wind and Input wind adjustment factor. 20-ft wind and Calculated wind adjustment factor. 10-m wind and Input wind adjustment factor. 10-m wind and Calculated wind adjustment factor. |
| | | Impose maximum reliable effective wind speed limit? | Yes | <ul style="list-style-type: none"> Yes No |
| | Directions | Surface fire spread direction is | only in the direction of maximum spread. | <ul style="list-style-type: none"> only in the direction of maximum spread. in directions specified on the worksheet. |
| | | Wind is | upslope. | <ul style="list-style-type: none"> specified on the worksheet. upslope. |
| | | Wind & spread directions are | degrees clockwise from upslope (direction the wind is pushing the fire). | <ul style="list-style-type: none"> degrees clockwise from upslope (direction the wind is pushing the fire). degrees clockwise from north (direction from which the wind is blowing). |
| | Slope | Slope is specified as | percent. | <ul style="list-style-type: none"> percent. degrees. |
| | | Slope steepness is | specified on the worksheet. | <ul style="list-style-type: none"> specified on the worksheet. calculated from map measurements. |
| CROWN | Input Options | Surface fire intensity is entered as | flame length. | <ul style="list-style-type: none"> flame length. fireline intensity. |
| CONTAIN | Input Options | Suppression input entered for | a single resource. | <ul style="list-style-type: none"> a single resource. multiple resources. |
| SCORCH | Input Options | Surface fire intensity is entered as | flame length. | <ul style="list-style-type: none"> flame length. fireline intensity. |

Appendix E. Output Variables

Output variables are selected in **Configure > Module selection > Options...** for each module. All selections are saved with a worksheet or run. This table presents available output variables and those selected for the **0Default.bpw** and **BasicStart.bpw** worksheets.

| Module | Tab | 0Default.bpw and BasicStart.bpw selections | All output options |
|---------|---------------|--|---|
| SURFACE | Basic Outputs | <ul style="list-style-type: none"> • Surface Rate of Spread • Flame Length | <ul style="list-style-type: none"> • Surface Rate of Spread • Heat per Unit Area • Fireline Intensity • Flame Length • Reaction Intensity • Direction of Maximum Spread • Surface Spread Distance • Wind/Slope/Spread Direction Diagram • Fire Characteristics Chart |
| | Wind Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • Midflame Wind Speed • Wind Adjustment Factor • Crown Ratio • Crown Fill Portion • WAF Calculation • Effective Wind Speed • Effective Wind Speed Limit • Max Eff Wind Exceeded? |
| | Slope Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • Slope Steepness • Slope Elevation Change • Slope Horizontal Distance |
| | Intermediates | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • Characteristic Dead Fuel Moisture • Characteristic Live Fuel Moisture • Live Fuel Moisture of Extinction • Characteristic SA/V • Bulk Density • Packing Ratio • Relative Packing Ratio • Dead Fuel Reaction Intensity • Live Fuel Reaction Intensity • Wind Factor • Slope Factor • Heat Source • Heat Sink • Flame Residence Time |
| | Fuel Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • Fuel Load Transfer Portion • Dead Herbaceous Fuel Load • Live Herb Fuel Load Remainder • Total Dead Fuel Load • Total Live Fuel Load • Dead Fuel Load Portion • Live Fuel Load Portion |
| | Aspen Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • 1-h Fuel Load • Live Herbaceous Fuel Load • Live Woody Fuel Load • 1-h SA/V • Live Woody SA/V • Probability of Aspen Mortality |
| | P-G Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • P-G Dead Fine Fuel Load • P-G Dead Medium Fuel Load • P-G Dead Foliage Fuel Load • P-G Live Fine Fuel Load • P-G Live Medium Fuel Load • P-G Live Foliage Fuel Load • P-G Litter Fuel Load • Fuel Bed Depth |

| Module | Tab | Default.bpw and BasicStart.bpw selections | All output options |
|---------------|-------------------|---|--|
| CROWN | Spread Outputs | <ul style="list-style-type: none"> • Critical Surface Intensity • Transition Ratio • Transition to Crown Fire? • Crown ROS • Critical Crown ROS • Active Ratio • Active Crown Fire? • Fire Type | <ul style="list-style-type: none"> • Critical Surface Intensity • Critical Surface Flame Length • Transition Ratio • Transition to Crown Fire? • Crown ROS • Critical Crown ROS • Active Ratio • Active Crown Fire? • Fire Type • Crown Spread Distance • Crown Fire Area • Crown Fire Perimeter • Crown Fire Length-to-Width Ratio |
| | Intensity Outputs | <ul style="list-style-type: none"> • None | <ul style="list-style-type: none"> • Crown Fireline Intensity • Crown Flame Length • Power of the Fire • Power of the Wind • Power Ratio • Wind-driven Fire? • Crown Load • Canopy Heat per Unit Area • Crown Fire Heat per Unit Area |
| SAFETY | Output Variables | <ul style="list-style-type: none"> • Safety Zone Separation Distance • Safety Zone Size | <ul style="list-style-type: none"> • Safety Zone Separation Distance • Safety Zone Size • Safety Zone Radius |
| SIZE | Output Variables | <ul style="list-style-type: none"> • Area • Perimeter | <ul style="list-style-type: none"> • Area • Perimeter • Length-to-Width Ratio • Forward Spread Distance • Backing Spread Distance • Fire Length • Maximum Fire Width • Fire Shape Diagram |
| CONTAIN | Output Variables | <ul style="list-style-type: none"> • Contain Status • Time from Report • Contained Area • Fireline Constructed | <ul style="list-style-type: none"> • Fire Area at Initial Attack • Perimeter at Initial Attack • Contain Status • Time from Report • Contained Area • Fireline Constructed • Number of Resources Used • Cost of Resources Used • Containment Diagram |

| Module | Tab | Default.bpw and BasicStart.bpw selections | All output options |
|---------------|-----------------------|--|---|
| SPOT | Basic Outputs | • Spotting Distance from Torching Trees | <ul style="list-style-type: none"> • Spotting Distance from Torching Trees • Spotting Distance from a Burning Pile • Spotting Distance from a Wind-Driven Surface Fire |
| | Torching Tree Outputs | • None | <ul style="list-style-type: none"> • Cover Ht Applied for Spotting Distance from Torching Trees • Steady State Flame Ht from Torching Trees • Tree Ht / Flame Ht Ratio for Torching Trees • Steady State Flame Duration from Torching Trees • Firebrand Ht from Torching Trees • Flat Terrain Spotting Distance from Torching Trees |
| | Burning Pile Outputs | • None | <ul style="list-style-type: none"> • Cover Ht Applied for Spotting Distance from a Burning Pile • Firebrand Ht from a Burning Pile • Flat Terrain Spotting Distance from a Burning Pile |
| | Surface Fire Outputs | • None | <ul style="list-style-type: none"> • Cover Ht Applied for Spotting Distance from a Wind-Driven Surface Fire • Firebrand Ht from a Wind-Driven Surface Fire • Firebrand Drift Distance from a Wind-Driven Surface Fire • Flat Terrain Spotting Distance from a Wind-Driven Surface Fire |
| SCORCH | Output Variables | • Scorch Height | <ul style="list-style-type: none"> • Scorch Height |
| MORTALITY | Output Variables | • Probability of Mortality | <ul style="list-style-type: none"> • Bark Thickness • Tree Crown Length Scorched • Tree Crown Volume Scorched • Probability of Mortality |
| IGNITE | Output Variables | • Probability of Ignition from a Firebrand | <ul style="list-style-type: none"> • Probability of Ignition from a Firebrand • Probability of Ignition from Lightning |

Appendix F. Menu Items and Options

This table presents options available by choosing the menu items **View** and **Configure**. All options and those selected for the **0Default.bpw** worksheet are given. **BasicStart.bpw** also includes selection of the SURFACE module. All selections except the following are saved with a worksheet or run: **View**, **Fuel model set selection**, and **Moisture scenario set selection**.

| Menu item | | 0Default.bpw and BasicStart.bpw selection | All menu item options |
|-----------|---------------------------------|---|---|
| View | | <ul style="list-style-type: none"> 100% | <ul style="list-style-type: none"> 50% 67% 75% 83% 100% 117% 133% 150% 167% 200% |
| Configure | Module selection | <ul style="list-style-type: none"> None (0Default.bpw) SURFACE (BasicStart.bpw) | <ul style="list-style-type: none"> SURFACE CROWN SAFETY SIZE CONTAIN SPOT SCORCH MORTALITY IGNITE |
| | Fuel model set selection | <ul style="list-style-type: none"> None | <ul style="list-style-type: none"> Fuel model set selection must be made for every session if using saved custom fuel models. The 53 (13 + 40) standard fuel models are always available (Anderson 1982; Scott and Burgan 2005). |
| | Moisture scenario set selection | <ul style="list-style-type: none"> None | <ul style="list-style-type: none"> Moisture scenario set selection must be made for every session if using saved custom moisture scenarios. The moisture scenarios used with the 40 standard fuel models (Scott and Burgan 2005) are always available. |
| | Units set selection | <ul style="list-style-type: none"> English | <ul style="list-style-type: none"> English Metric Custom |
| | Custom units preferences | <i>See Appendix G.</i> | |
| | Appearance preferences | <i>See Appendix H.</i> | |

Appendix G. Units and Decimals

Units of measure for all variables and the number of decimal places for *output* variables can be changed using **Configure > Custom units preferences**. (The number of decimal places displayed for *input* variables is determined by the variable of highest precision entered in the worksheet.) Changes can be saved as a custom units set and used again with **Configure > Units set selection > Custom**. Changes can also be applied to the open worksheet without saving a custom units set. Changes apply to all variables in a Units Category as given in this table. Settings for the default English and metric units and decimal set are given. *All* selections are saved with a worksheet or run.

| Units editor tab | Units category | Variable | English default | | Metric default | |
|----------------------------|---------------------------|---|----------------------------------|-----------------------|--------------------------------|-----------------------|
| | | | Units | Output decimal places | Units | Output decimal places |
| Fuel & Vegetation Units | Fuel Load | • 1-h Fuel Load • Crown Load • Dead Herbaceous Fuel Load • Live Herbaceous Fuel Load • Live Herbaceous Fuel Load Remainder • Live Woody Fuel Load • P-G Dead Fine Fuel Load • P-G Dead Foliage Fuel Load • P-G Dead Medium Fuel Load • P-G Litter Fuel Load • P-G Live Fine Fuel Load • P-G Live Foliage Fuel • P-G Live Medium Fuel Load • Total Dead Fuel Load • Total Live Fuel Load | ton/ac | 3 | tonne/ha | 2 |
| | | • 10-h Fuel Load • 100-h Fuel Load | | -- | | -- |
| Surface Area/Volume Ratio | Surface Area/Volume Ratio | • 1-h Surface Area/Volume Ratio • Characteristic Surface Area/Volume Ratio • Live Woody Surface Area/Volume Ratio | ft ² /ft ³ | 0 | m ² /m ³ | 0 |
| | | • Live Herbaceous Fuel Surface Area/Volume Ratio | | -- | | -- |
| Surface Fuel Depth | Surface Fuel Depth | • Fuel Bed Depth | ft | 2 | m | 2 |
| | | • P-G Height of Understory | | -- | | -- |
| Ground Fuel Depth | Ground Fuel Depth | • Lightning Duff and Litter Depth | in | -- | cm | -- |
| | | • Characteristic Dead Fuel Moisture • Characteristic Live Fuel Moisture • Live Fuel Moisture of Extinction | | percent | | percent |
| Fuel & Extinction Moisture | | • 1-h Moisture • 10-h Moisture • 100-h Moisture • Dead Fuel Moisture • Dead Fuel Moisture of Extinction • Foliar Moisture • Live Fuel Moisture • Live Herbaceous Moisture • Live Woody Moisture | | -- | | -- |
| | | • Dead Fuel Heat Content • Live Fuel Heat Content | | -- | | -- |
| | Fuel Bulk Density | • Bulk Density | lb/ft ³ | 4 | kg/m ³ | 4 |

| Units editor tab | Units category | Variable | English default | | Metric default | |
|--------------------------|-------------------------------------|--|---------------------|-----------------------|--------------------|-----------------------|
| | | | Units | Output decimal places | Units | Output decimal places |
| Fuel & Vegetation Units | Packing Ratio | <ul style="list-style-type: none"> Packing Ratio Relative Packing Ratio | ratio | 4 | ratio | 4 |
| | Tree & Canopy Height | <ul style="list-style-type: none"> Tree Crown Length Scorched | ft | 0 | m | 0 |
| | | <ul style="list-style-type: none"> Canopy Base Height Canopy Height Downwind Canopy Height Torching Tree Height | | -- | | -- |
| | Tree Dbh & Bark Thickness | <ul style="list-style-type: none"> Bark Thickness | in | 0 | cm | 0 |
| | | <ul style="list-style-type: none"> D.B.H. | | -- | | -- |
| | Canopy Bulk Density | <ul style="list-style-type: none"> Canopy Bulk Density | lb/ft ³ | -- | kg/m ³ | -- |
| | Coverage | <ul style="list-style-type: none"> Canopy Cover First Fuel Model Coverage P-G Palmetto Coverage | percent | -- | percent | -- |
| | Basal Area | <ul style="list-style-type: none"> P-G Overstory Basal Area | ft ² /ac | -- | m ² /ha | -- |
| | Load & Crown Fill Portion | <ul style="list-style-type: none"> Crown Fill Portion Dead Fuel Load Portion Fuel Load Transfer Portion Live Fuel Load Portion | percent | 0 | percent | 0 |
| | | <ul style="list-style-type: none"> Aspen Curing Level | | -- | | -- |
| Weather Units | Crown Ratio | <ul style="list-style-type: none"> Crown Ratio | fraction | 2 | fraction | 2 |
| | Wind Speed | <ul style="list-style-type: none"> Effective Wind Speed Effective Wind Speed Limit Midflame Wind Speed | mi/h | 1 | km/h | 1 |
| | | <ul style="list-style-type: none"> 10-m Wind Speed 20-ft Wind Speed | | -- | | -- |
| | Temperature | <ul style="list-style-type: none"> Air Temperature | °F | -- | °C | -- |
| | Shading from Sun | <ul style="list-style-type: none"> Fuel Shading from the Sun | percent | -- | percent | -- |
| Terrain & Spotting Units | Wind Adjustment Factor | <ul style="list-style-type: none"> Wind Adjustment Factor | fraction | 2 | fraction | 2 |
| | Slope Steepness | <ul style="list-style-type: none"> Slope Steepness | percent | 0 | percent | 0 |
| | Slope & Elevation | <ul style="list-style-type: none"> Slope Elevation Change Slope Horizontal Distance | ft | 0 | m | 0 |
| | | <ul style="list-style-type: none"> Ridge-to-Valley Elevation Difference | | -- | | -- |
| | Ridge-to-Valley Horizontal Distance | <ul style="list-style-type: none"> Ridge-to-Valley Horizontal Distance | mi | -- | km | -- |
| | Spotting Distance | <ul style="list-style-type: none"> Firebrand Drift from a Wind-Driven Surface Fire Flat Terrain Spotting Distance from a Burning Pile Flat Terrain Spotting Distance from a Wind-Driven Surface Fire Flat Terrain Spotting Distance from Torchings Trees Spotting Distance from a Burning Pile Spotting Distance from a Wind-Driven Surface Fire Spotting Distance from Torchings Trees | mi | 1 | km | 1 |

| Units editor tab | Units category | Variable | English default | | Metric default | |
|--------------------------|--|--|--------------------------|-----------------------|-------------------|-----------------------|
| | | | Units | Output decimal places | Units | Output decimal places |
| Terrain & Spotting Units | Firebrand & Cover Height | <ul style="list-style-type: none"> Cover Height Applied for Spotting Distance from a Burning Pile Cover Height Applied for Spotting Distance from a Wind-Driven Surface Fire Cover Height Applied for Spotting Distance from Torching Trees Firebrand Height from a Burning Pile Firebrand Height from a Wind-Driven Surface Fire Firebrand Height from Torching Trees | ft | 1 | m | 1 |
| | Flame and Duration Ratios (can change decimal places only) | <ul style="list-style-type: none"> Steady State Flame Duration from Torching Trees Tree Height / Flame Height Ratio for Torching Trees | no units | 1 | no units | 1 |
| Fire & Effects Units | Surface Rate of Spread | <ul style="list-style-type: none"> Surface Rate of Spread | ch/h | 1 | m/min | 1 |
| | Crown Rate of Spread | <ul style="list-style-type: none"> Critical Crown Rate of Spread Crown Rate of Spread | ch/h | 1 | m/min | 1 |
| | Fire Heat Per Unit Area | <ul style="list-style-type: none"> Canopy Heat per Unit Area Crown Fire Heat per Unit Area Heat per Unit Area | Btu/ft ² | 0 | kJ/m ² | 0 |
| | Fireline Intensity | <ul style="list-style-type: none"> Critical Surface Intensity Crown Fireline Intensity Fireline Intensity | Btu/ft/s | 0 | kW/m | 0 |
| | Flame Length & Scorch Height | <ul style="list-style-type: none"> Critical Surface Flame Length Crown Flame Length Flame Length Scorch Height Steady State Flame Height from Torching Trees | ft | 1 | m | 1 |
| | | <ul style="list-style-type: none"> Flame Height from a Burning Pile | | -- | -- | -- |
| | Heat Source & Reaction Intensity | <ul style="list-style-type: none"> Dead Fuel Reaction Intensity Heat Source Live Fuel Reaction Intensity Reaction Intensity | Btu/ft ² /min | 0 | kW/m ² | 0 |
| | Heat Sink | <ul style="list-style-type: none"> Heat Sink | Btu/ft ³ | 1 | kJ/m ³ | 1 |
| | Spread Distance | <ul style="list-style-type: none"> Backing Spread Distance Crown Spread Distance Fire Length Forward Spread Distance Maximum Fire Width Surface Spread Distance | ch | 1 | m | 1 |
| | Fire Area | <ul style="list-style-type: none"> Area Contained Area Crown Fire Area Fire Area at Initial Attack Fire Size at Report | ac | 1 | ha | 1 |
| | Fire Perimeter | <ul style="list-style-type: none"> Crown Fire Perimeter Perimeter Perimeter at Initial Attack | ch | 1 | m | 0 |

| Units editor tab | Units category | Variable | English default | | Metric default | |
|------------------------|--|--|-----------------------------|-----------------------|---------------------------|-----------------------|
| | | | Units | Output decimal places | Units | Output decimal places |
| Fire & Effects Units | Probability of Mortality & Crown Volume Scorched | <ul style="list-style-type: none"> • Probability of Aspen Mortality • Probability of Mortality • Tree Crown Volume Scorched | percent | 0 | percent | 0 |
| | Probability of Ignition | <ul style="list-style-type: none"> • Probability of Ignition from a Firebrand • Probability of Ignition from Lightning | percent | 0 | percent | 0 |
| | Fire Ratios | <ul style="list-style-type: none"> • Active Ratio • Crown Fire Length-to-Width Ratio • Length-to-Width Ratio • Power Ratio • Transition Ratio | ratio | 1 | ratio | 1 |
| | Wind, Slope Factor, & Cost | <ul style="list-style-type: none"> • Cost of Resources Used • Slope Factor • Wind Factor | ratio | 1 | ratio | 1 |
| | | <ul style="list-style-type: none"> • Resource Base Cost • Resource Hourly Cost | no units | -- | no units | -- |
| | Power | <ul style="list-style-type: none"> • Power of the Fire • Power of the Wind | ft-lb/s/ ft ² | 0 | m-kg/s/ m ² | 0 |
| Time & Map Units | Time | <ul style="list-style-type: none"> • Time from Report | h | 1 | h | 1 |
| | | <ul style="list-style-type: none"> • Elapsed Time • Resource Arrival Time • Resource Duration | | -- | | -- |
| | Flame Residence Time | <ul style="list-style-type: none"> • Flame Residence Time | min | 2 | min | 2 |
| | P-G Age of Rough | <ul style="list-style-type: none"> • P-G Age of Rough | years | -- | years | -- |
| | Contour Interval | <ul style="list-style-type: none"> • Contour Interval | ft | -- | m | -- |
| | Map Distance | <ul style="list-style-type: none"> • Backing Spread Map Distance • Crown Fire Spread Map Distance • Fire Length Map Distance • Forward Spread Map Distance • Maximum Fire Width Map Distance • Ridge-to-Valley Horizontal Map Distance • Spotting Map Distance from a Burning Pile • Spotting Map Distance from a Wind-Driven Surface Fire • Spotting Map Distance from Torching Trees • Spread Map Distance | in | 2 | cm | 2 |
| | | <ul style="list-style-type: none"> • Map Distance (for slope calculation) | | -- | | -- |
| | | | | | | |
| | | | | | | |
| Contain & Safety Units | Line Production Rate | <ul style="list-style-type: none"> • Resource Line Production Rate | ch/h | -- | m/h | -- |
| | Containment Distances | <ul style="list-style-type: none"> • Fireline Constructed | ch | 0 | m | 0 |
| | | <ul style="list-style-type: none"> • Line Construction Offset | | -- | | -- |
| | Safety Zone Distances | <ul style="list-style-type: none"> • Safety Zone Radius • Safety Zone Separation Distance | ft | 0 | m | 0 |
| | Safety Zone Size | <ul style="list-style-type: none"> • Safety Zone Size | ac | 2 | ha | 0 |
| | Personnel & Equipment Areas | <ul style="list-style-type: none"> • Area per Heavy Equipment • Area per Person | ft ² | -- | m ² | -- |

Appendix H. Appearance Preferences

Appearance of the BehavePlus window, worksheets, tables, and graphs can be changed with **Configure > Appearance preferences**. This table presents all available options and those selected for the **0Default.bpw** and **BasicStart.bpw** worksheets. Selections on the **Application** tab remain in effect for the next BehavePlus session. *All* other selections are saved with a worksheet or run.

| Appearance preferences tab | Option | 0Default.bpw and BasicStart.bpw selection | All appearance preference tab options |
|----------------------------|-------------------|---|--|
| Application | Show help pane | • Selected | • Cleared • Selected |
| | Show picture pane | • Selected | • Cleared • Selected |
| | Border Color | • Black | • White • Black • Grey • Red • Green • Blue • Magenta • Cyan • Yellow • Dark Red • Dark Green • Dark Blue • Dark Magenta • Dark Cyan • Dark Yellow |
| | Border Width | • 1 | • 0 = No border • 1-9 = Increasingly thicker border |
| Graph Size | Graph Size (%) | • 50% | • 25 – 100% by 5% increment |
| | Graph Title | • Short | • Short • Long |
| | X Axis Origin | • Zero | • Zero • Min Value |
| | Y Axis Origin | • Zero | • Zero • Min Value |
| Graph Elements | Background | • White | • See Application > Border Color |
| | Rainbow Colors | • 3 | • 3-18 |
| | Bar Color | • Red | • See Application > Border Color • Rainbow Colors |
| | Curve Points | • 100 | • 4-100 |
| | Curve Color | • Rainbow Colors | • See Application > Border Color • Rainbow Colors |
| | Curve Width | • 3 | • 0 = No curve line • 1-9 = Increasingly thicker curve line |
| | Axis Color | • Black | • See Application > Border Color |
| | Axis Width | • 1 | • 1-9 = Increasingly thicker axis |
| | Gridline Color | • Yellow | • See Application > Border Color |
| | Gridline Width | • 1 | • 0 = No gridline • 1-9 = Increasingly thicker gridline |

| Appearance preferences tab | Option | 0Default.bpw and BasicStart.bpw selection | All appearance preference tab options |
|-----------------------------------|--|--|--|
| Page Tabs | Display the page tab | • Cleared | • Cleared • Selected |
| | Tabs per Page | • 4 | • 0 = No tabs • 1-10 = number of tabs per page |
| | Tab Position | • 0 | • 0 = No tabs • 1-4; position 1 is always the upper edge of the right margin |
| | Tab Text | • Blank | • Blank • User defined |
| | Tab Text Color | • Black | • See Application > Border Color |
| | Tab Font Size | • 12 | • 8-24 |
| Tables | Shade alternate table rows | • Selected | • Cleared • Selected |
| | Shade | • Light Grey | • Light Grey • Light Pink • Light Green • Light Blue • Light Cyan • Light Yellow • Light Goldenrod • Light Coral • Light Salmon • Light Slate Grey • Light Slate Blue • Light Sky Blue • Light Steel Blue • Light Sea Green |
| | Show only acceptable conditions when table shading | • Cleared | • Cleared • Selected |
| | Prescribed fire plan worksheet header | • Cleared | • Cleared • Selected |
| Worksheet | Fire behavior projection worksheet header | • Cleared | • Cleared • Selected |
| | Training worksheet header | • Cleared | • Cleared • Selected |
| | Show descriptions for all discrete variable codes | • Cleared | • Cleared • Selected |
| | Show descriptions only for entered discrete variable codes | • Selected | • Cleared • Selected |
| | Show output variables to be calculated | • Selected | • Cleared • Selected |
| | Show notes section | • Selected | • Cleared • Selected |
| | Notes Lines | • 4 | • 1-10 |

Appendix I. Glossary

Definition of terms in the context in which they are used in this report.

1-h, 10-h, 100-h—Dead fuel size classes based on a relationship of the timelag from a change in weather and a resulting change in fuel moisture. 1-h timelag fuels are less than $\frac{1}{4}$ inch diameter and respond quickly to changes in temperature and humidity.

BehavePlus—The BehavePlus fire modeling system produces tables, graphs, and simple diagrams of fire behavior, fire effects, and the fire environment. It is a point-based system; each individual calculation assumes constant conditions. (Appendix C)

BEHAVE—The BEHAVE fire behavior prediction and fuel modeling system consisted of five computer programs and has been replaced by the BehavePlus fire modeling system. (Preface)

Build number—Build number changes with each program update. The version number stays the same for beta versions while the build number changes (Build 297). It is located via **Help > Installation Info**. (Section 15.6)

Calculate—Menu item or icon that produces output pages for a BehavePlus run. (Section 3)

Choices—A button at the bottom of the guide window for some continuous variables that gives a list of selected input values. It is not an exhaustive list of all possible inputs. (Section 6.4)

Context-sensitive Help—Located in the right-hand pane of many BehavePlus windows; contains information related to the current variable, selection, or topic. (Section 15.3)

Continuous variable—Any value in a valid range can be assigned to a continuous variable (for example, fuel moisture and wind speed). (Section 6)

Defaults—Selections that were made for the example worksheets that come with the program (including **0Default.bpw**). A user can develop an alternate set of defaults. (Section 3.3.2)

Discrete variable—Only specific values or codes can be assigned to discrete variables (for example, fuel model and spotting source location). (Section 6)

FARSITE—A fire growth simulation system in which conditions change in both time and space. (Appendix C)

Features paper—This publication is the Features paper. It describes many of the features of BehavePlus. The focus is on operation, not fire modeling.

File extension—BehavePlus uses different file extensions for various file types: fuel models as **.bpf**, worksheets as **.bpw**, runs as **.bpr**, etc. (Section 9.1)

File structure—BehavePlus has a prescribed file structure that is installed with the program (for example, **FuelModelFolder** and **RunFolder**). (Section 9.1)

FlamMap—A spatial fire behavior system, in which basic operation conditions are constant in time and vary in space. (Appendix C)

Fuel model—A code such as 2 or GR2 is entered to assign a set of values that describe the fuels (for example, fuel load and fuel bed depth) for the surface fire spread model in the SURFACE module. (Section 10)

Guide button—A blue **Guide** button that contains an arrow is associated with each input variable on the worksheet. It opens a window with guidance on input values in the center pane and help information in the right-hand pane. (Section 3.1.3)

Help window—The right-hand pane of most BehavePlus windows that contains information related to the subject of the window. (Section 15.3)

Icon—Icons on a toolbar at the top of the BehavePlus window are for commonly used commands (for example, **Module Selection**, **Calculate**, and page navigation). (Section 3.1.1)

Input options—Options that define input methods (such as the option to input or to calculate wind adjustment factor). Selection is made on the window that opens from the **Options...** button associated with a module. (Section 3.2.3; Appendix D)

Map distance—A check mark in the **Module Selection** window adds map distance outputs for selected distance output variables (for example, surface spread distance and spotting distance). Map distance is the calculated distance times the map scale. (Section 14.1)

Menu—The menu items located in the toolbar at the top of the BehavePlus window provide access to all BehavePlus commands. (Section 3.1.1)

Model—Mathematical relationships that describe an aspect of wildland fire (for example, flame length and scorch height). (Section 2)

Module—A logical grouping of models in BehavePlus (for example, SURFACE, SIZE, and CROWN). (Section 2)

Moisture scenario—A code such as D2L3 is entered to assign a set of fuel moisture values (1-h, 10-h, 100-h, live herbaceous, and live woody) for the surface fire spread model in the SURFACE module. (Section 11)

Native units—The units of the publication that describes a mathematical model. BehavePlus calculations are done in the native units, regardless of the units selected for input and output variables. Internal conversions can lead to differences due to round off. (Section 5)

Run—A BehavePlus worksheet in which values have been assigned to the required input categories. A run file includes not only what is visible, but an entire suite of selections, including selections made on table and graph output. (Section 3; Appendices D-H).

Session—A period of time a person is running BehavePlus, from the time the program is started until it is closed. Selections on the **Configure > Appearance preferences > Application** tab are carried over from one session to another (**Help** and **Picture** pane display and border color and width). (Section 3.2)

Slope distance—Map distance is the distance along the slope, on the ground. A BehavePlus tool makes the conversion to a horizontal map distance. (Section 14.2)

System—A computer program or some other packaging of models, interface, and data into a form that fire managers can use (for example, nomograms, BehavePlus, FARSITE, and FlamMap). (Section 2)

Tool—BehavePlus tools are stand-alone calculations and are available from the main menu (for example, fine dead fuel moisture and relative humidity). (Section 13)

User's Guide—A reference guide that describes the operation of BehavePlus. It is available in the program from **Help > User's Guide**. Basic operation was not changed with the update to Version 5.0; the Version 4.0 User's Guide is still valid. (Section 15.1; Andrews and others 2008)

Variables paper—A reference guide that describes the more than 180 variables in BehavePlus. It is available in the program from **Help > Variable Help**. (Section 15.2; Andrews 2009)

Version number—Program version number (5.0.1) appears at the top of every BehavePlus page. (Section 15.6)

Worksheet—A form that guides user input to BehavePlus. It is created based on user selection of modules, input options, and output variables. Only required input values are included on the worksheet. A worksheet file includes not only what is visible, but an entire suite of selections. (Section 3; Appendices D-H)

Workspace—Parent directory of the BehavePlus file structure and all its subdirectories and files (**DefaultDataFolder** or a user-defined folder). Workspaces are useful for documentation and for sharing BehavePlus files. (Section 9.2)



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