

Introduction

Wind is one of the most important influences on fire behavior. Determining an appropriate wind speed to use in modeling surface fire spread and intensity is not easy. There is significant temporal variation in wind speed and direction, on the order of hours, minutes and even seconds. Wind also varies spatially as it is affected by the terrain. There are also differences in wind speed in the vertical direction. The wind that affects surface fire, called midflame wind, may be only 10% of the wind speed forecast by the National Weather Service at a standard 20 feet above the vegetation (20-ft wind). In BehavePlus midflame wind is obtained by multiplying 20-ft wind by a Wind Adjustment Factor (WAF). (Another factor converts 10-m wind speed to 20-ft wind speed.)

Midflame Wind Speed is used in the calculation of surface fire Flame Length, which is used to estimate whether a surface fire will transition to a crown fire. The 20-ft Wind Speed is also used to estimate Crown Fire Rate of Spread and Spotting Distance.

Objectives

1. Distinguish the different methods of applying a Wind Adjustment Factor in a BehavePlus run.
2. Examine how Wind Adjustment Factors are calculated.
3. Identify the inputs required to calculate a Wind Adjustment Factor.

Where This Lesson Fits In

This is a lesson in the Modeling Unit. It is assumed that the trainee has completed the four lessons in the Introduction Unit and has basic BehavePlus operation skills.

Lesson Changes: V4.0 to V5.0

Changes to the BehavePlus program required some minor changes to this lesson. SURFACE output variable tabs changed; there is now a Wind Outputs tab. We updated the headers and footers, but did not redo many of the screen captures labeled BehavePlus 4.0.0.

Background

Rothermel's 1972 surface fire spread model requires input of an average wind speed at "midflame height". Midflame Wind Speed is equal to the 20-ft wind speed multiplied by a Wind Adjustment Factor. We use the term "Wind Adjustment Factor" rather than "wind reduction factor" to avoid confusion in interpretation. A WAF = 0.40 reduces the 20-ft wind by 60%.

"Midflame" wind is poorly defined, and in practice is often taken to be "eye-level" wind speed as measured by a hand-held anemometer. The National Weather Service sometimes provides eye-level wind speed in spot weather forecasts. For many applications Midflame Wind Speed is supplied directly to the surface fire spread model.

The actual variation in fuel bed depth, stand characteristics, flame length and height, and wind speed and direction can be more important than the Wind Adjustment Factor. Nevertheless, it is necessary to define a repeatable method of calculating WAF based on a description of the fuel and vegetation and not on the variable height of the flame.

Albini and Baughman (1979) presented mathematical models for wind characteristics above a vegetative cover that is a single-stratum fuel (grass, brush, etc.) and for wind under a forest canopy. Baughman and Albini (1980) produced a more practical tabular form based on fuel bed depth for the original 13 standard fire behavior Fuel Models and on the degree of sheltering from the wind provided by the overstory. They gave guidance based in the effect of topography, e.g. "Fuels on high ridges where trees offer little shelter from wind." Rothermel (1983) presented a further simplification of that table.

The WAF for fuels unsheltered from the wind is a function of the fuel bed depth. We use the term "unsheltered from the wind" rather than "exposed to the wind" to avoid confusion with characterization of understory exposure to the sun in discussing fuel moisture.

Wind speed beneath the canopy does not depend on the surface Fuel Model, but rather on the fraction of the overstory filled with tree crowns. This is estimated from percent Canopy Cover, Canopy Height, and Crown Ratio. If less than 5% of the tree volume is filled, we use the model for Unsheltered WAF.

Wind Speed Options

Several options are available for entering wind speed in BehavePlus.

- Open the **BasicStart.bpw** Worksheet.
- Look at the available options for the input of Wind Speed by clicking on the **Configure > Module selection > SURFACE Options... > Wind Speed** tab.

Wind speed is entered as midflame height is selected for this Worksheet.

Alternatively, wind speed can be entered for either 20 foot or 10 meter standard heights. If the 10-meter option is selected, wind speed is divided by 1.15 to get the 20-ft wind and the WAF values are applied to the 20-ft wind.

The WAF used to convert 20-ft (or 10-m) Wind Speed to Midflame Wind Speed can be directly entered on the Worksheet by selecting one of the radio buttons that specify **Input wind adj factor**.

The option of calculating a WAF is selected with either of two radio buttons that specify **Calculate wind adj factor**. Calculating a WAF will require that overstory tree information be entered on the Worksheet. Calculation of WAF is based on two models or methods, one for fuels not sheltered from the wind and one for fuels sheltered by an overstory of trees.

Inputting a Wind Adjustment Factor

- Select **Wind speed is entered as 20-ft wind and Input wind adj factor** on the **Wind Speed** tab.

BehavePlus 4.0.0 SURFACE Module Options

Fuel & Moisture | **Wind Speed** | Directions | Slope | Basic Outputs | Intermediates | Fuel Outputs | P-G Outputs | Aspen Outputs

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SURFACE Wind Speed Input Options

This page controls the SURFACE Module's wind speed options.

Options

Wind speed is entered as....	
<i>midflame height.</i>	Wind speed at midflame height is entered on the worksheet.
<i>20-ft wind and Input wind adjustment factor.</i>	Wind speed at 20 feet above the vegetation and wind adjustment factor (WAF) are entered on the worksheet. WAF depends on sheltering of

Wind speed is entered as

☐ midflame height.
☒ 20-ft wind and Input wind adj factor.
☐ 20-ft wind and Calculated wind adj factor.
☐ 10-m wind and Input wind adj factor.
☐ 10-m wind and Calculated wind adj factor.

Impose maximum reliable effective wind speed limit?

☒ Yes
☐ No

☒ Picture ☒ Help

Ok Cancel

- Close the **SURFACE Module Options** dialog box by clicking the **Ok** button.
- Click **Ok** again to return to the Worksheet.

Selecting the **20-ft wind and Input wind adj factor** radio button adds to the Worksheet lines for 20-ft Wind Speed (upslope) and Wind Adjustment Factor.

WAF	Description
0.10	FULLY SHELTERED from wind under a DENSE stand, all fuel models
0.20	FULLY SHELTERED from wind under an OPEN stand, all fuel models
0.30	PARTIALLY SHELTERED from wind, all fuel models
0.30	UNSHELTERED from wind, surface fuel bed depth below 0.9 ft (0.3 m)
0.40	UNSHELTERED from wind, surface fuel bed depth 0.9-2.7 ft (0.3-0.8 m)
0.50	UNSHELTERED from wind, surface fuel bed depth over 2.7 ft (0.9 m)

This gives common choices for the WAF based on sheltering and, for unsheltered conditions, Fuel Bed Depth. We reference Fuel Bed Depth here because of the large number of standard Fuel Models and the option of using custom Fuel Models. (Remember you can look up the Fuel Bed Depth by clicking the Fuel Model Guide button, selecting a Fuel Model, then right clicking to look at the Fuel Model Parameters.)

A table with Unsheltered WAF values for all 53 standard Fuel Models is found in the help pane of the “Wind Adjustment Factor” dialog box.

Fuel Bed Depth	Unsheltered WAF	Fuel Model
<0.9 ft (<0.3 m)	0.3	<ul style="list-style-type: none"> • 8, 9 • GR1 • TU1, TU4 • TL1, TL2, TL3, TL4, TL5, TL6, TL7, TL8, TL9
0.9 - 2.7 ft (0.3 - 0.8 m)	0.4	<ul style="list-style-type: none"> • 1, 2, 3, 5, 6, 7, 10, 11, 12 • GR2, GR3, GR4, GR5, GR6 • GS1, GS2, GS3, GS4 • SH1, SH2, SH3, SH4, SH6 • TU2, TU3, TU5 • SB1, SB2, SB3, SB4
>2.7 ft (>0.8 m)	0.5	<ul style="list-style-type: none"> • 4, 13 • GR7, GR8, GR9 • SH5, SH7, SH8, SH9

The Help Pane also has diagrams and tables for guidance on determining Unsheltered, partially Sheltered, or Unsheltered conditions. As noted by Rothermel (1983) “Experience must play a large part in learning to choose the best Wind Adjustment Factor.” That continues to be the case.

Effect of WAF on Fire Behavior

We will look at a table and graphs to examine the effect of WAF on Surface fire Rate of Spread and Flame Length for a head fire in Fuel Model 2—timber grass and understory.

Fill in the **BasicStart.bpw** Worksheet with the following values:

- Fuel Model 2
 - 1-h Moisture = 5%
 - 10-h Moisture = 6%
 - 100-h Moisture = 7%
 - Live Fuel Moisture = 100%
 - 20-ft Wind Speed = 20 mi/hr
 - Slope = 30%
- Enter a range of values for WAF from 0.1 to 0.3 to demonstrate differences in the effect of sheltering by an overstory.

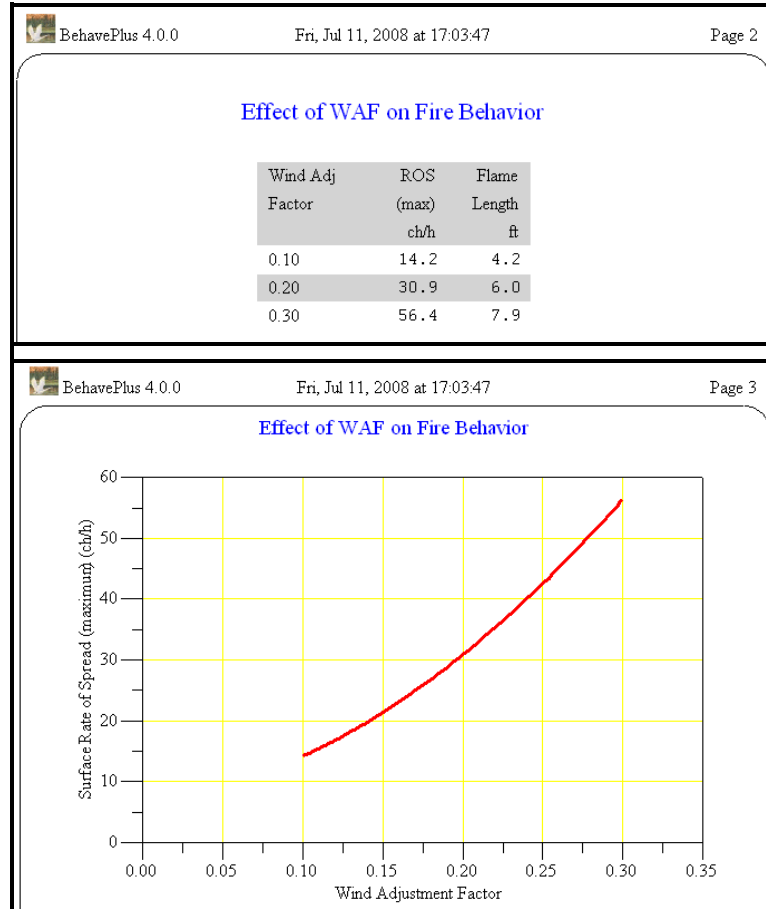
The Worksheet should look like this:

The screenshot shows the BehavePlus 4.0.0 interface. The title bar says 'BehavePlus 4.0.0' and 'Page 1'. The main window has a tab labeled 'Inputs: SURFACE'. Below this, the 'Description' field contains 'Effect of WAF on Fire Behavior'. The 'Fuel/Vegetation, Surface/Understory' section includes 'Fuel Model' set to 2. The 'Fuel Moisture' section includes '1-h Moisture' (5%), '10-h Moisture' (6%), '100-h Moisture' (7%), 'Live Herbaceous Moisture' (100%), and 'Live Woody Moisture' (empty). The 'Weather' section includes '20-ft Wind Speed (upslope)' (20 mi/h) and 'Wind Adjustment Factor' (0.10, 0.20, 0.30). The 'Terrain' section includes 'Slope Steepness' (30%).

Category	Parameter	Unit	Value
Fuel/Vegetation, Surface/Understory	Fuel Model		2
	Fuel Moisture		
	1-h Moisture	%	5
	10-h Moisture	%	6
	100-h Moisture	%	7
Weather	Live Herbaceous Moisture	%	100
	Live Woody Moisture	%	
Weather	20-ft Wind Speed (upslope)	mi/h	20
	Wind Adjustment Factor		0.10, 0.20, 0.30
Terrain	Slope Steepness	%	30

- Click on the  Calculate toolbar button.

The table and graph for Surface Rate of Spread and Flame Length then look like this:



For the same 20-ft Wind Speed, Surface Rate of Spread varies from 13.3 to 52.8 ch/hr, and Flame Length from 3.9 to 7.4 feet. Obviously determining the appropriate WAF value is an important consideration in fire behavior prediction.

Calculating an Unsheltered WAF

When the option of a Calculated WAF is selected (in the **Wind Speed** tab), additional lines are added to the Worksheet to describe the overstory.

- Continue with the Worksheet from the previous section.
- Change the input option to **Wind speed is entered as 20-ft wind and Calculated wind adj factor** (on the **Configure > Module selection > SURFACE Options... > Wind Speed** tab).

Your Worksheet should now look like the following.

BehavePlus 4.0.0 Fri, Jul 11, 2008 at 17:03:47 Page 1

Inputs: SURFACE

Description ➤ Effect of WAF on Fire Behavior

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 2

Fuel/Vegetation, Overstory

Canopy Cover % ➤

Canopy Height ft ➤

Crown Ratio fraction ➤

Fuel Moisture

1-h Moisture % ➤ 5

10-h Moisture % ➤ 6

100-h Moisture % ➤ 7

Live Herbaceous Moisture % ➤ 100

Live Woody Moisture % ➤

Weather

20-ft Wind Speed (upslope) mi/h ➤ 20

Terrain

Slope Steepness % ➤ 30

Note that a value must be entered for Canopy Cover. If zero is entered for Canopy Cover, entries are not required for Canopy Height or Crown Ratio.

Now we will produce a plot that shows the Unsheltered WAF calculated as a function of Fuel Bed Depth.

- On the **Configure > Module selection > SURFACE Options... > Wind Outputs** tab, select only the **Wind Adjustment Factor** check box. Uncheck all other boxes, including those on the Basic Outputs tab.

BehavePlus 5.0.0 SURFACE Module Options

Fuel & Moisture Wind Speed Directions Slope Basic Outputs **Wind Outputs** Slope Outputs Intermediates Fuel Outputs

Back Forward Home Index

☐ Midflame Wind Speed

☒ Wind Adjustment Factor

☐ Crown Ratio

☐ Crown Fill Portion

☐ WAF Calculation

☐ Effective Wind Speed

☐ Effective Wind Speed Limit

☐ Max Eff Wind Exceeded?

☒ Picture ☒ Help

Wind Adjustment Factor

Wind adjustment factor (WAF) is a value between 0 and 1 used to adjust the wind speed at 20-ft above the vegetation to midflame wind speed.

- midflame wind speed = 20-ft wind speed * WAF.

Wind adjustment factor depends on sheltering of fuels from the wind. If fuels are not sheltered from the wind, WAF is a function of fuel bed depth. If fuels are sheltered from the wind, WAF is not affected by the surface fuel model. Sheltering is determined by canopy cover and by position on the slope. If WAF is calculated, then the user should be cautious of terrain and canopy features that are not input. It might be preferable to use judgment to enter WAF directly.

I/O	Module	If
Input	SURFACE	If Wind speed is entered as 20-ft (or 10-m) wind and Input wind adjustment factor is selected as an input option.
Output	SURFACE	If Wind speed is entered as 20-ft (or 10-m) wind and

Ok Cancel

- On the **Fuel & Moisture** tab, select **Fuel is entered as Fuel parameters (for custom modeling)**.
- Click **Ok** twice to return to the Worksheet.

Your Worksheet should look similar to this.

BehavePlus 4.0.0 Fri, Jul 11, 2008 at 17:03:47 Page 1

Inputs: SURFACE

Description ➤ Calculating an Unsheltered WAF

Fuel/Vegetation, Surface/Under: Initialize from a Fuel Model

Fuel Bed Depth ft ➤ 1.00

Fuel/Vegetation, Overstory

Canopy Cover % ➤

Canopy Height ft ➤

Crown Ratio fraction ➤

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

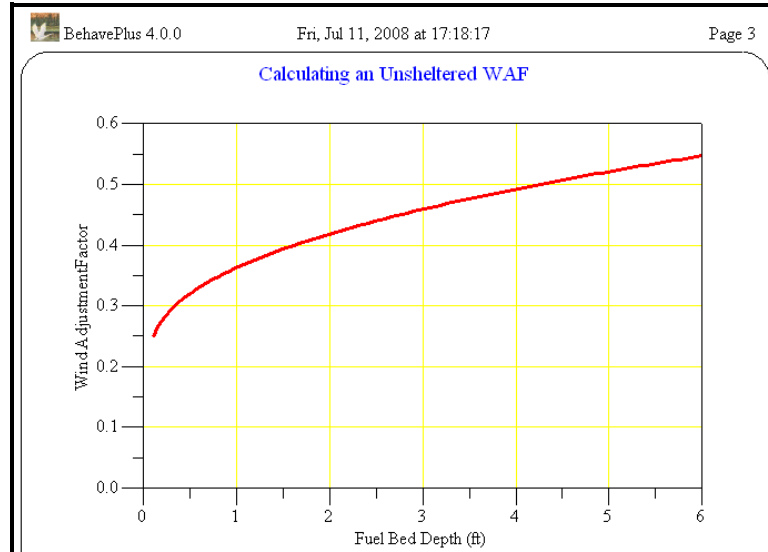
Wind Adjustment Factor [SURFACE]

Notice the simplicity of this Worksheet, even though the fuels are described as fuel parameters, only one text box (**Fuel Bed Depth**) is shown. This is because Fuel Bed Depth is the only parameter necessary to calculate the one output selected, Wind Adjustment Factor. This is an important feature of BehavePlus. Once you select your output variables, BehavePlus will only ask for the necessary inputs on the Worksheet.

To see the effect of Fuel Bed Depth on WAF:

- Enter a range of “0.1 6.0” for Fuel Bed Depth.
- Enter “0” for Canopy Cover.

- Calculate the Run to produce this graph.

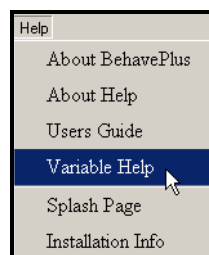


The WAF for exposed fuels (those without tree overstory) depends solely on the Fuel Bed Depth (one of the Fuel Model parameters). The WAF for fuels with an overstory is based on the stand characteristics of Canopy Cover, height, and Crown Ratio. Remember, since shrubs are described as surface fuel, they are not considered part of the overstory.


Calculating a Sheltered WAF


The Wind Adjustment Factor can be calculated from a description of the overstory—Canopy Cover, Canopy Height, and Crown Ratio. The effect of terrain on WAF is not part of the calculations and is left to the user's knowledge of the situation being modeled. Depending on the application, it might be more appropriate to input an estimated WAF rather than calculating it.

If you are unfamiliar with the terms Canopy Cover, Canopy Height, and Crown Ratio, a brief description can be found in the Help pane of the Input Guide or in the *Variables* paper. To access the Variables Paper, click on **Help > Variable Help**. The Variables Paper will open in a new window and can be either printed or accessed interactively using a PDF viewer.




We will look at the effect of a change in the overstory description on calculated Surface Rate of Spread and Flame Length. This is a result of different Wind Adjustment Factors, which leads to different Midflame Wind Speed values.


- Open a new Worksheet using the Example Worksheet **SurfaceSimple.bpw**.
- Modify the Worksheet to look like the one below, using the  toolbar button. Note the selected output variables.

 BehavePlus 4.0.0
 Page 1


Inputs: SURFACE


Description  Calculating a Sheltered WAF


Fuel/Vegetation, Surface/Understory

Fuel Model  2


Fuel/Vegetation, Overstory


Canopy Cover %  60

Canopy Height ft  30, 60, 90, 120


Crown Ratio fraction  0.3 1.0

Fuel Moisture


Dead Fuel Moisture %  5

Live Fuel Moisture %  100

Weather

20-ft Wind Speed (upslope) mi/h  20

Terrain

Slope Steepness %  0

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]

Heat per Unit Area (Btu/ft²) [SURFACE]

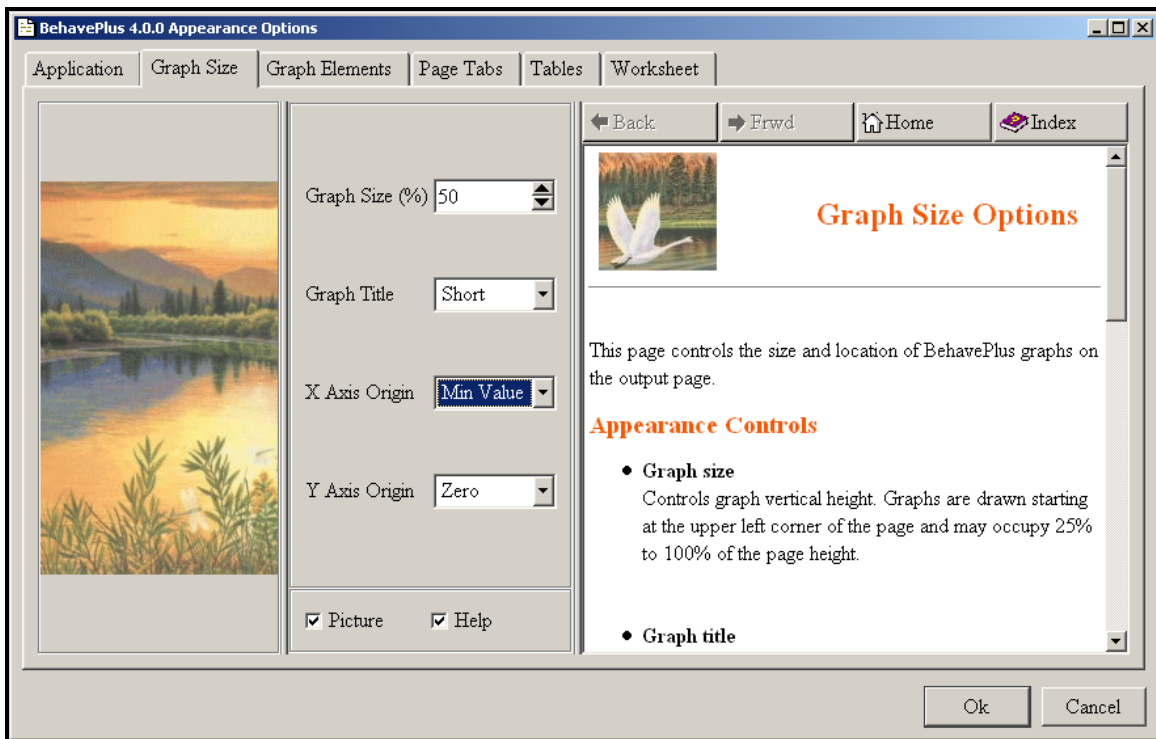
Fireline Intensity (Btu/ft/s) [SURFACE]

Flame Length (ft) [SURFACE]

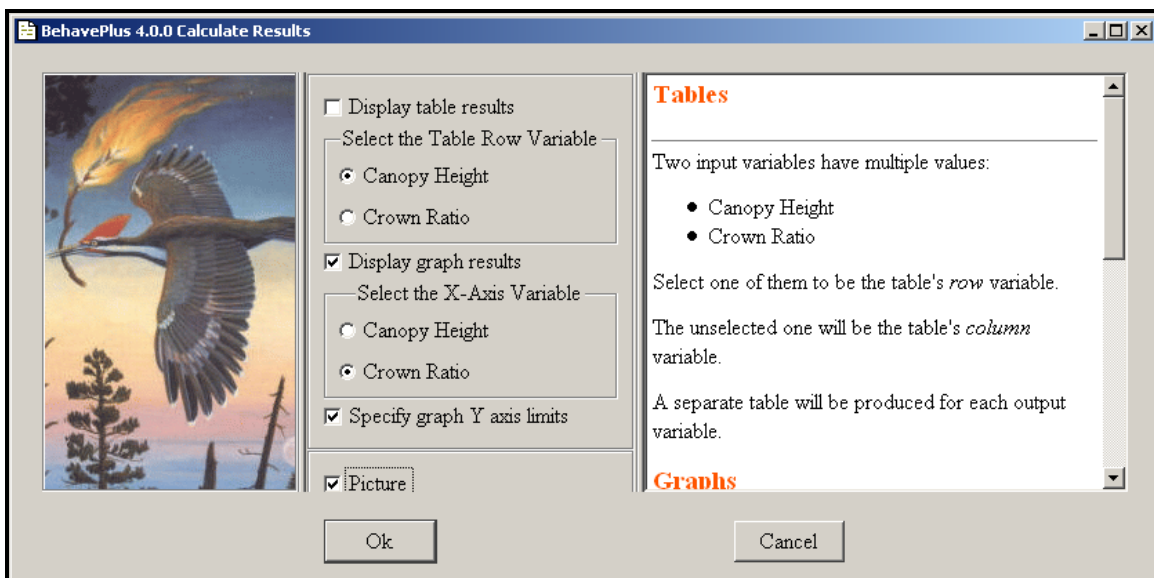
Max Eff Wind Exceeded? [SURFACE]

To produce the graphs we want to look at, it is necessary to change some appearances.

- On the **Configure > Appearance preferences > Graph Size** tab, select **Min Value** for the **X Axis Origin**.



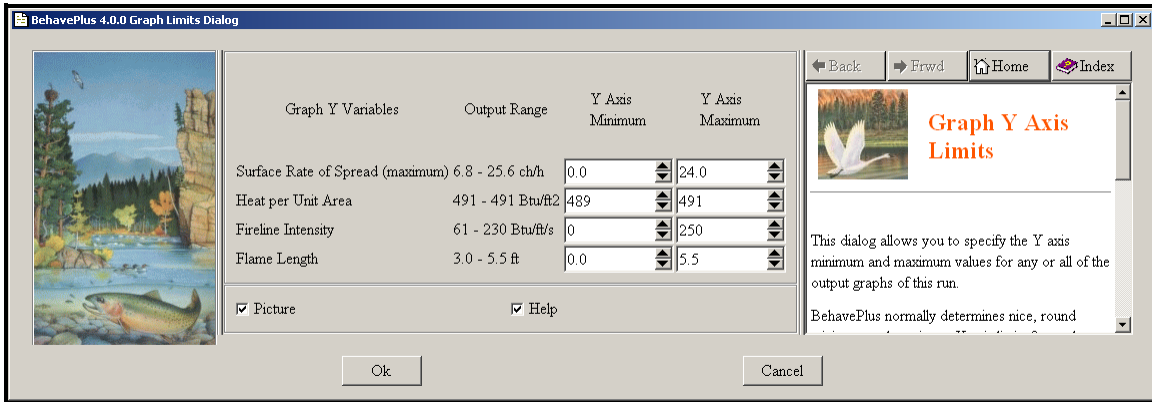
- Click **Ok**.
- When calculating the Run, clear the **Display table results** check box.
- Check the **Crown Ratio** radio button under **Select the X-Axis Variable**.
- Select the **Specify graph Y axis limits** check box on the **Calculate Results** dialog box, as seen below.



- Click **Ok**.

The **Graph Limits Dialog** box will appear.

- Make the following changes.



The dialog box titled "BehavePlus 4.0.0 Graph Limits Dialog" contains a table for setting Y-axis limits for various graph variables. The table has columns for "Graph Y Variables", "Output Range", "Y Axis Minimum", and "Y Axis Maximum". The variables listed are Surface Rate of Spread (maximum), Heat per Unit Area, Fireline Intensity, and Flame Length. The minimum and maximum values are set to 0.0 and 24.0 for Surface Rate of Spread, 489 and 491 for Heat per Unit Area, 0 and 250 for Fireline Intensity, and 0.0 and 5.5 for Flame Length. There are also checkboxes for "Picture" and "Help", and "Ok" and "Cancel" buttons at the bottom.

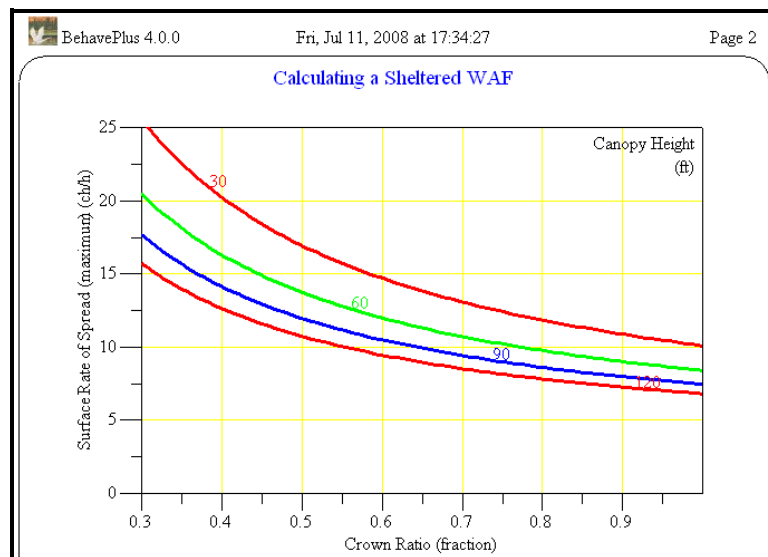
Graph Y Variables	Output Range	Y Axis Minimum	Y Axis Maximum
Surface Rate of Spread (maximum) 6.8 - 25.6 ch/h		0.0	24.0
Heat per Unit Area 491 - 491 Btu/ft ²		489	491
Fireline Intensity 61 - 230 Btu/ft/s		0	250
Flame Length 3.0 - 5.5 ft		0.0	5.5

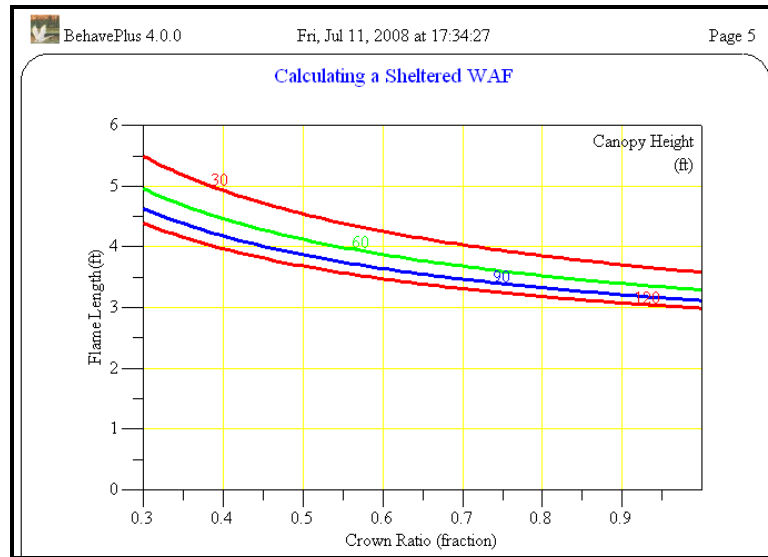
☒ Picture ☒ Help

Ok Cancel

- Click **Ok**.

Graphs for Surface Rate of Spread and Flame Length are generated.





Crown Ratio and Canopy Height have a significant effect on Midflame Wind Speed and the subsequent predicted fire behavior.

Let's further explore this idea by seeing the effect of a range of Canopy Cover has on the WAF.

- Change the following inputs on the Worksheet:
 - Description title "Effect of Canopy Cover".
 - Canopy Cover range of 30 to 90% in increments of 10%.
 - Canopy Height of 90 ft.
 - Crown Ratio of 0.7.
 - Slope Steepness to 30%.
- Select Surface Rate of Spread, Flame Length, Midflame Wind Speed and Wind Adjustment Factor as output variables.

The Worksheet looks like the following.

BehavePlus 4.0.0 Fri, Jul 11, 2008 at 17:45:01 Page 1

Inputs: SURFACE

Description ➤ Effect of Canopy Cover

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 2

Fuel/Vegetation, Overstory

Canopy Cover % ➤ 30, 40, 50, 60, 70, 80, 90

Canopy Height ft ➤ 90

Crown Ratio fraction ➤ 0.7

Fuel Moisture

Dead Fuel Moisture % ➤ 5

Live Fuel Moisture % ➤ 100

Weather

20-ft Wind Speed (upslope) mi/h ➤ 20

Terrain

Slope Steepness % ➤ 30

- Calculate the Run.
- Check the box by **Display table results**.
- Clear the box by **Specify graph Y axis limits**.
- Click **Ok**.

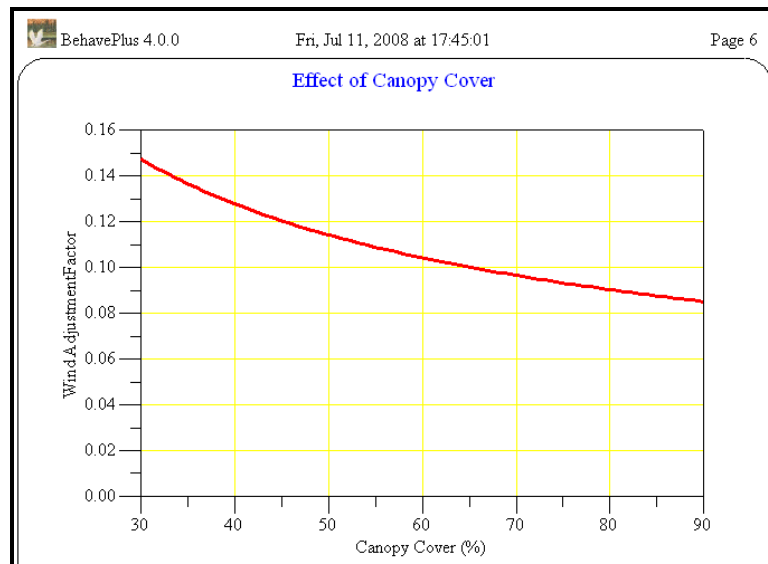
The output table should look like the following.

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Effect of Canopy Cover

Canopy Cover %	ROS (max) ch/h	Flame Length ft	Midflame Wind Speed mi/h	Wind Adj Factor
30	21.0	5.0	2.9	0.15
40	17.9	4.7	2.6	0.13
50	16.0	4.4	2.3	0.11
60	14.7	4.3	2.1	0.10
70	13.8	4.1	1.9	0.10
80	13.1	4.0	1.8	0.09
90	12.6	4.0	1.7	0.09

If the WAF were displayed to only one decimal place, the WAF values would all be 0.1. Recall that you can change the number of decimal places displayed. The graph always shows the unrounded values.

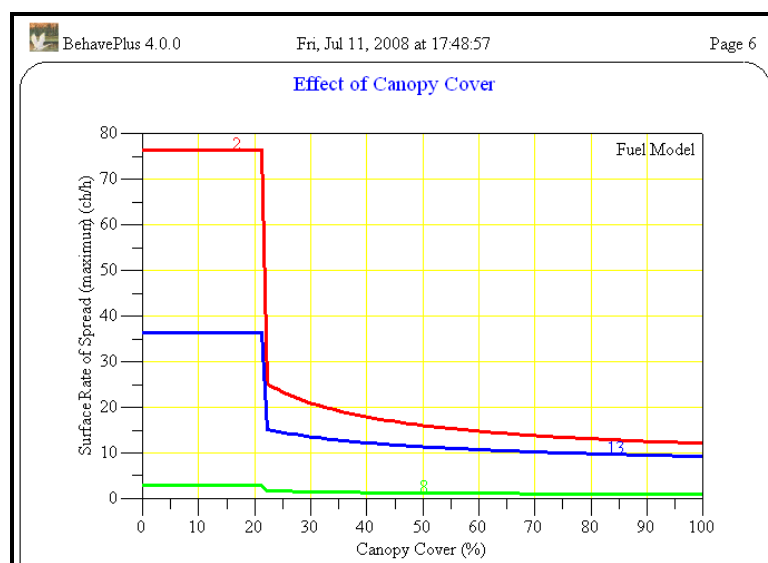


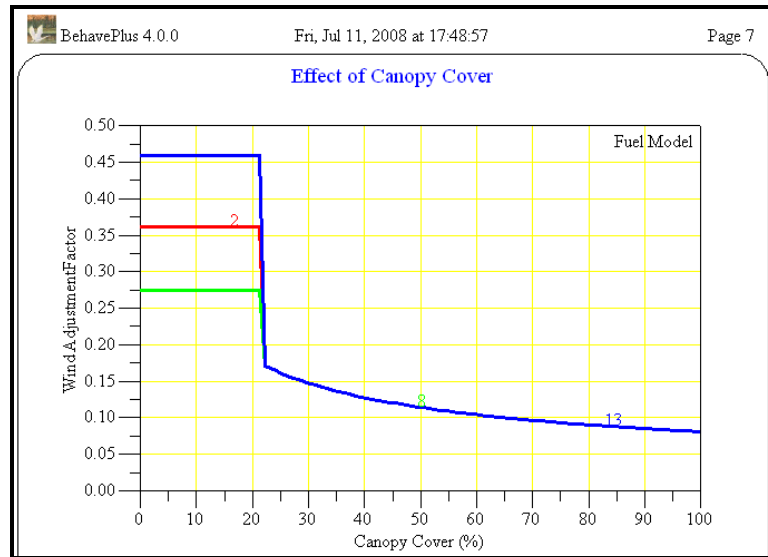
Unsheltered to Sheltered WAF Transition

Make the following changes to view the range of Canopy Cover for three Fuel Models.

- Add Fuel Models **8** and **13**
- Change the Canopy Cover range to 0 -100% in increments of 10%.
- Select Rate of Spread and Wind Adjustment Factor as output variables.

Calculate the Run and look at the graphs.





As you can see, there is a large drop in ROS for all three Fuel Models. This corresponds to the lower Midflame Wind Speed and higher Wind Adjustment Factor. This illustrates the transition from the calculation of an Unsheltered WAF (a function of Fuel Bed Depth) to a sheltered WAF (based on overstory crown characteristics).

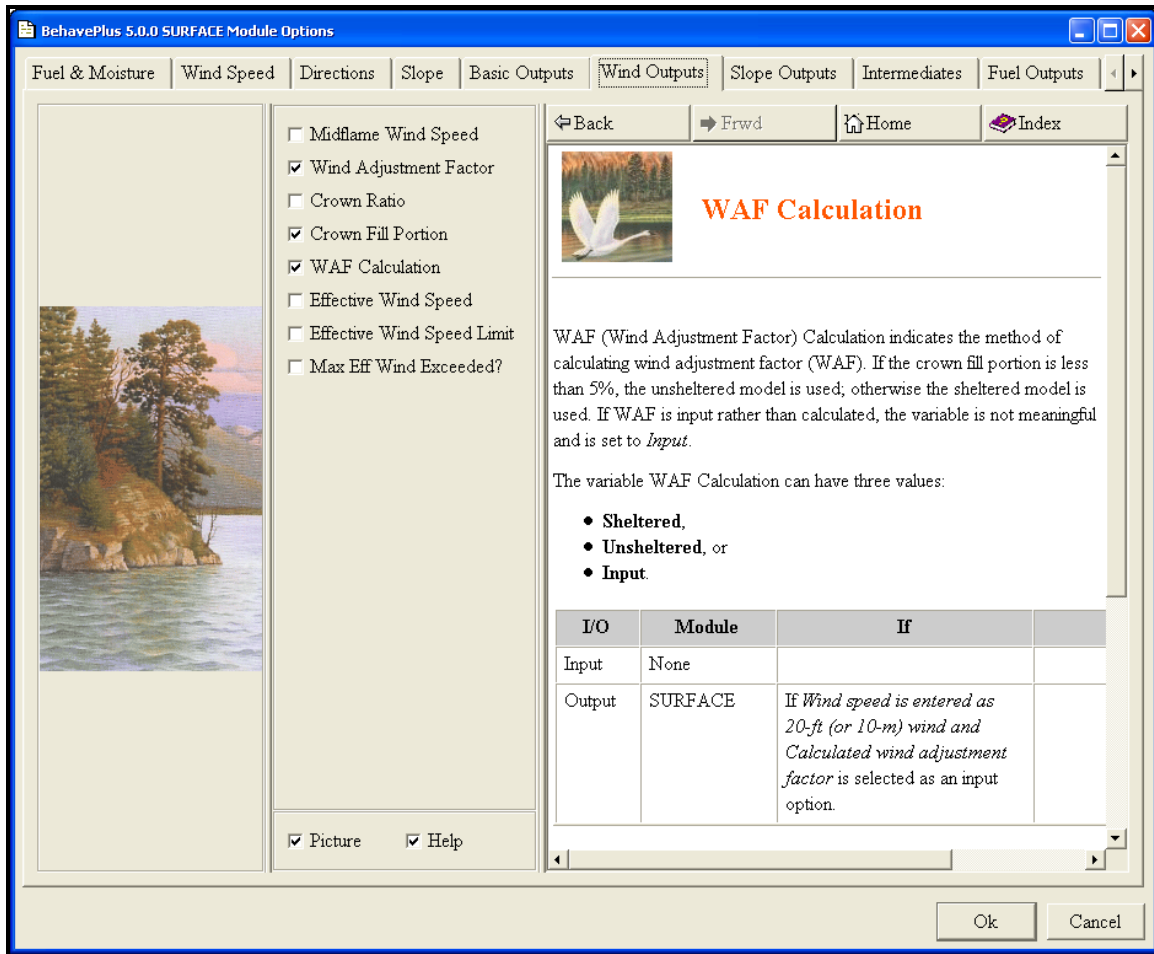
Recall that 20-ft Wind Speed is measured 20 feet above the top of the vegetation. For the sheltered condition, this is 20 feet above the tree tops. For the Unsheltered condition, it is 20 feet above the surface vegetation.

Consider a forested area where trees are removed to the point where they are all gone. The fully forested case is certainly sheltered, and the case with no trees is certainly unsheltered. The transition between Sheltered and Unsheltered occurs before the number of trees reaches zero. When there are only a very few trees in a large area, they would not affect the wind and would be an unsheltered condition. The 5% Crown Fill Portion is used as the indicator of whether the Sheltered or Unsheltered calculation model will be used.

We will now do some additional calculations to examine the transition point.

- Look at only Fuel Model 2.

- Select additional intermediate output variables on the Wind Outputs tab to understand what is happening.



The Worksheet should look like the following.

BehavePlus 4.0.0 Fri, Jul 11, 2008 at 17:56:31 Page 1

Inputs: SURFACE

Description ➤ Sheltered and Unsheltered WAF Calculations

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 2

Fuel/Vegetation, Overstory

Canopy Cover % ➤ 0, 10, 20, 30, 40, 50, 60, 70,

Canopy Height ft ➤ 90

Crown Ratio fraction ➤ 0.7

Fuel Moisture

Dead Fuel Moisture % ➤ 5

Live Fuel Moisture % ➤ 100

Weather

20-ft Wind Speed (upslope) mi/h ➤ 20

Terrain

Slope Steepness % ➤ 30

Look at the table output.

BehavePlus 4.0.0 Fri, Jul 11, 2008 at 17:57:01 Page 2

Sheltered and Unsheltered WAF Calculations

Canopy Cover %	ROS (max) ch/h	Wind Adj Factor	Crown Fill %	WAF Calculation
0	76.5	0.36	0.0	Unsheltered
10	76.5	0.36	2.3	Unsheltered
20	76.5	0.36	4.7	Unsheltered
30	21.0	0.15	7.0	Sheltered
40	17.9	0.13	9.3	Sheltered
50	16.0	0.11	11.7	Sheltered
60	14.7	0.10	14.0	Sheltered
70	13.8	0.10	16.3	Sheltered
80	13.1	0.09	18.7	Sheltered
90	12.6	0.09	21.0	Sheltered
100	12.1	0.08	23.3	Sheltered

The equations used to calculate WAF changes when the Crown Fill Portion is 5%. The Unsheltered equation is used for Crown Fill Portion less than 5% and the Sheltered equation is used for Crown Fill Portion greater than 5%. The change corresponds to the jump in the graph.

To further investigate this issue, make this change to your Worksheet:

- Change the Crown Ratio to a range of 0.1 to 0.9 in increments of 0.2.
- Calculate the Run, changing **Select the X-axis Variable to Canopy Cover**.

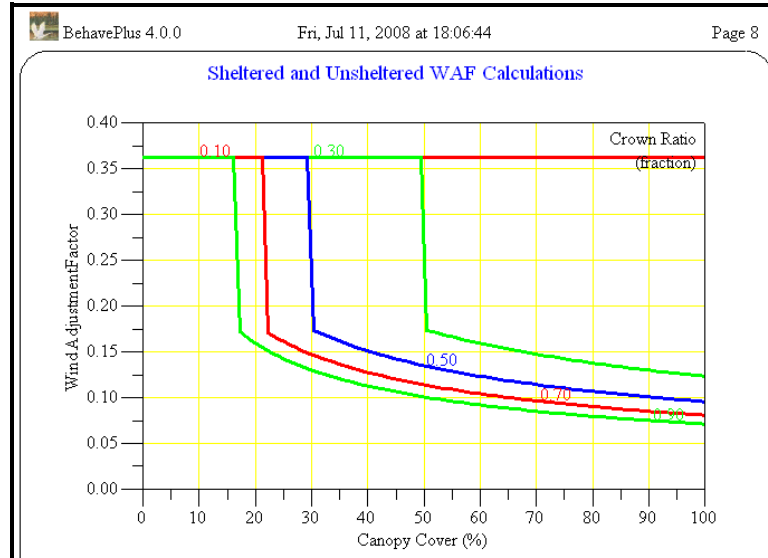
Look at the WAF Calculation table to see the WAF calculation method (equation) used.

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Sheltered and Unsheltered WAF Calculations
WAF Calculation

Canopy Cover %	Crown Ratio fraction			
	0.10	0.30	0.50	0.70
0	Unsheltered	Unsheltered	Unsheltered	Unsheltered
10	Unsheltered	Unsheltered	Unsheltered	Unsheltered
20	Unsheltered	Unsheltered	Unsheltered	Unsheltered
30	Unsheltered	Unsheltered	Unsheltered	Sheltered
40	Unsheltered	Unsheltered	Sheltered	Sheltered
50	Unsheltered	Unsheltered	Sheltered	Sheltered
60	Unsheltered	Sheltered	Sheltered	Sheltered
70	Unsheltered	Sheltered	Sheltered	Sheltered
80	Unsheltered	Sheltered	Sheltered	Sheltered
90	Unsheltered	Sheltered	Sheltered	Sheltered
100	Unsheltered	Sheltered	Sheltered	Sheltered

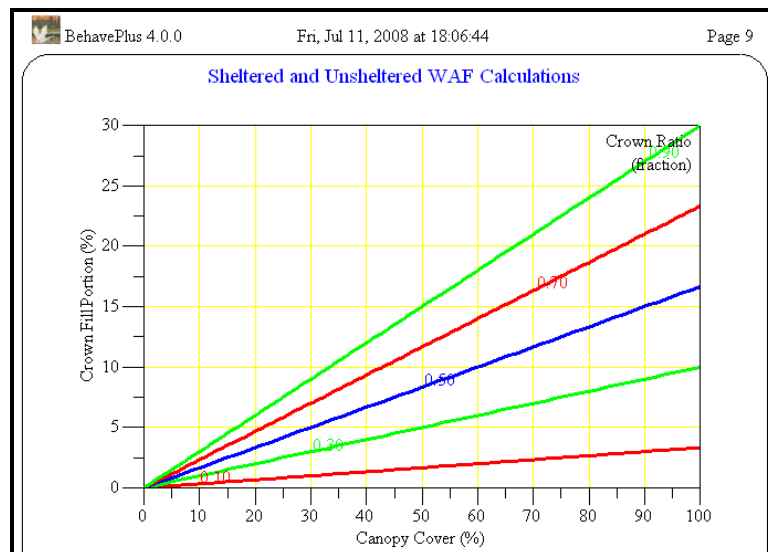
Look at the WAF plot to see the corresponding change.



Note that the step occurs at different combinations of Canopy Cover and Crown Ratio. In this case a Crown Ratio of 0.10 will always use an Unsheltered calculated WAF regardless of the Canopy Cover. A stand with a Crown Ratio of 0.70 transitions to a Sheltered WAF calculation at a Canopy Cover of about 22%.

Visualize what these stands may look like. For example, a stand with a Crown Ratio of 0.90 and 15% Canopy Cover could be a stand of scattered Douglas-fir with branches covering most of the bole.

Crown Fill Portion is calculated from Canopy Cover, Canopy Height, and Crown Ratio.



Realistically, surface fire behavior isn't going to take a drastic jump when an additional tree or two is removed. This step phenomenon in the model is the result of using two different methods for calculating WAF and is a limitation in the model. We again remind you that as a BehavePlus user, you are required to understand the relation between fire and fire models and think about what you are doing, and how to interpret the results of the model for real world situations.

Summary

Wind is one of the most important influences on fire behavior. Midflame Wind Speed is used in the calculation of surface fire Flame Length, which is used to estimate whether a surface fire will transition to a crown fire. Wind Adjustment Factor (WAF) is a value between 0 and 1 used to adjust the wind speed at 20-ft above the vegetation to Midflame Wind Speed. WAF depends on sheltering of surface fuels from the wind, location on the terrain, and Fuel Model for exposed fuel.

At the end of this lesson, you should be able to employ the different methods for applying a Wind Adjustment Factor, and identify the methods and inputs required to calculate a Wind Adjustment Factor.

Exercises

1. Compare Surface Rate of Spread for the dry climate Grass and Grass-Shrub Fuel Models with no overstory using a range of 1-h Moisture and a 20-ft Wind Speed with a calculated Wind Adjustment Factor.
2. Compare Surface Rate of Spread for Fuel Model TU3 the fire behavior for a range of 1-h Moisture and a range of Canopy Cover.