

Introduction

The Surface Fire Spread (SURFACE) module offers various ways of specifying directions for wind, slope, and fire spread. In this lesson, you will make changes to options and observe changes to the Worksheet and to calculated values.

Rothermel's surface fire spread model (1972) was developed for head fire spreading upslope with the wind. Adaptations have been made to allow calculations for head fire when the wind is not blowing upslope and for spread in directions other than the direction of maximum spread.

Objectives

1. Change input options for the direction of spread and wind.
2. Compare the results of different direction option selections.
3. Develop and save worksheets and runs for the two wind direction options.

Where This Lesson Fits In

This is a lesson in the Modeling Unit. We assume that you have basic skills with program operation, as covered in the four Introduction lessons. There are no other prerequisites for this lesson.

Although fire behavior predictions are often done for head fire spread, it is especially important for a person to understand direction options for the wind in BehavePlus.

Lesson Changes: V4.0 to V5.0

Changes to the BehavePlus program did not require changes to this lesson. We updated the headers and footers, but did not redo the screen captures labeled BehavePlus 4.0.0.

Introduction

The direction of the wind vector is the direction in which the wind is pushing the fire, and is useful in examining the relative effects of wind and slope on fire spread. Wind direction in weather forecasts and observations is the direction from which the wind is blowing, 180-degrees from the direction of the wind vector.

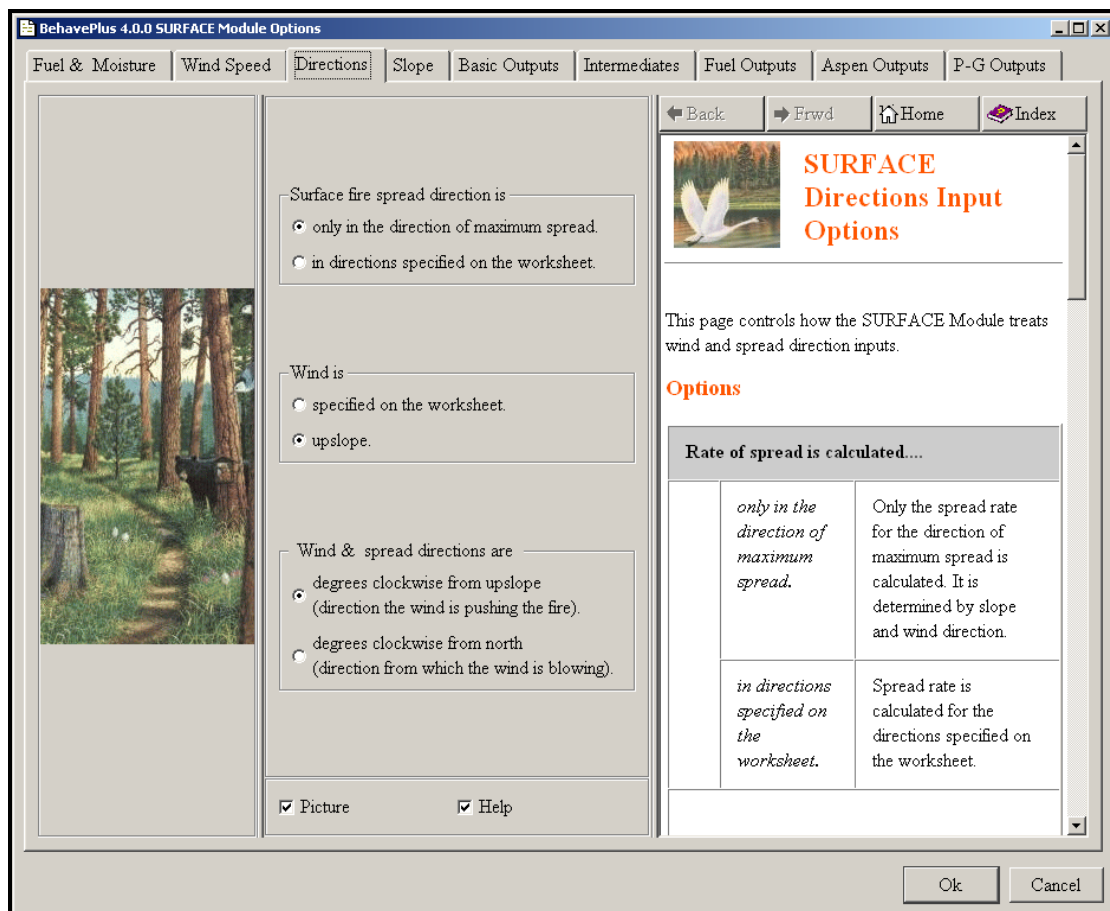
Surface Rate of Spread can be calculated for the Direction of Maximum Spread (the head fire) or for other directions from the ignition point of an elliptically shaped fire.

Direction Options

Direction options are selected on the **Module Selection > SURFACE Options... > Module Options > Directions** tab.

The default selections for **0Startup.bpw** and **BasicStart.bwp** are as shown below.

- **Surface fire spread direction is** only in the direction of maximum spread.
- **Wind is** upslope.
- **Wind & spread directions are** degrees clockwise from upslope (direction the wind is pushing the fire).



The **Surface fire spread direction** is calculated either in the direction of maximum spread (head fire) or in directions specified on the Worksheet, as shown below:

Surface fire spread direction is —

☒ only in the direction of maximum spread.

☐ in directions specified on the worksheet.

When the selection is **Surface fire spread direction is only in the direction of maximum spread**, spread direction input is not requested as an input. The calculated direction of maximum spread can be selected as an output variable. The listing of the output variable Surface Rate of Spread includes the notation “maximum” as a reminder of this.

When the selection is **Surface fire spread direction is in directions specified on the worksheet**, calculations can be done for other than the head fire.

Wind direction can be either specified on the Worksheet or set to always be blowing upslope.

Wind is —

☐ specified on the worksheet.

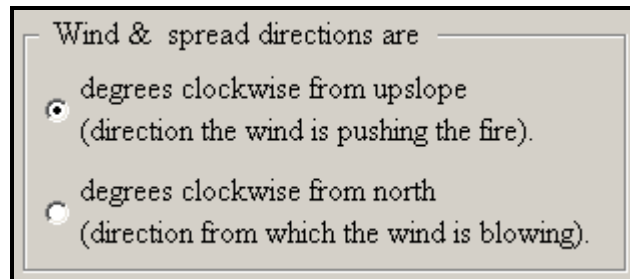
☒ upslope.

When the selection is **Wind direction is specified on the worksheet**, the method of specifying wind direction depends on the selection that was made for wind and spread direction.

When the selection is **Wind direction is upslope**, Wind Direction input is not requested. This option is just a simplification for a commonly used condition. The input request for wind speed includes the notation “upslope” as a reminder.

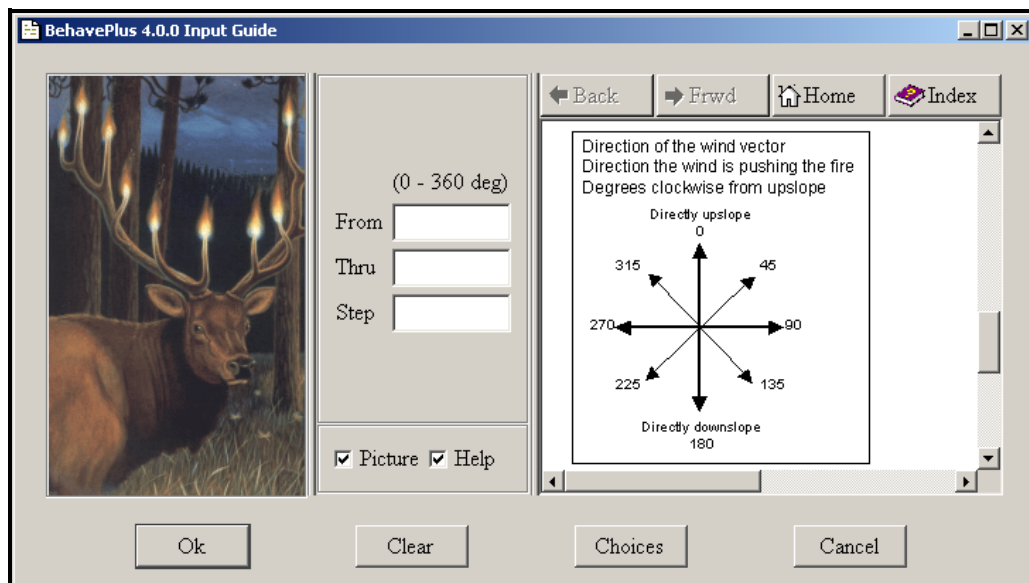
Wind & spread directions can be specified in one of two ways:

- **Degrees clockwise from upslope**, in which case Wind Direction is the direction the wind is pushing the fire.
- **Degrees clockwise from north**, in which case Wind Direction is the direction from which the wind is blowing.



When the selection is **Wind & spread directions are degrees clockwise from upslope**, Wind Direction is the direction of the wind vector, the direction the wind is pushing the fire. This is the method used to calculate the direction of maximum spread by vectoring described in Rothermel's (1984) "How to Predict the Spread and Intensity of Wildland Fire" and is the method used in the old BEHAVE program (Andrews 1986). This method is best suited to examination of the effects of wind and slope and their relative directions on fire spread.

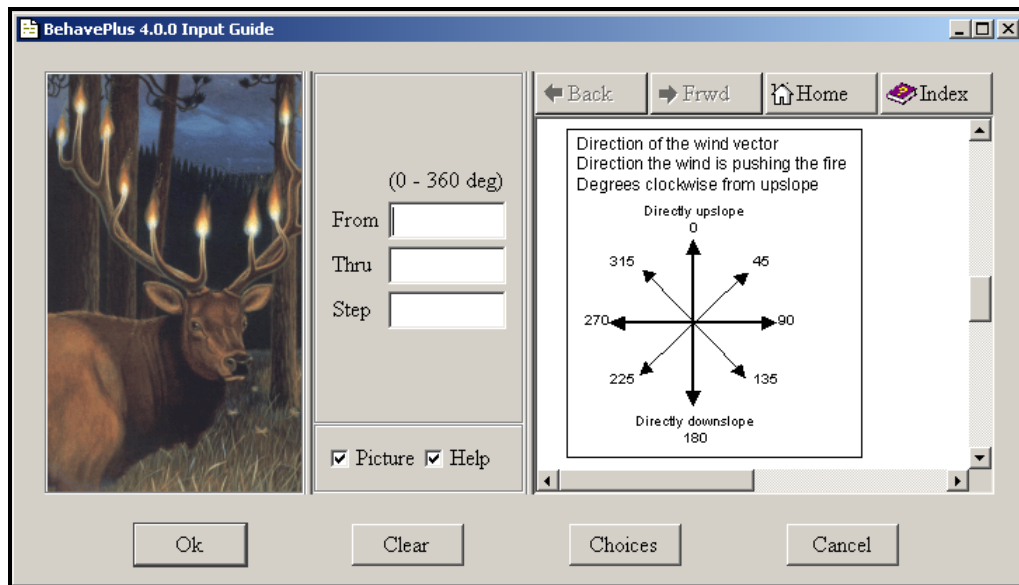
The Help window includes diagrams to remind you how the directions are specified. In the following diagram, arrows indicate the direction of the wind vector (direction the wind is pushing the fire).



When the selection is **Wind & spread directions are degrees clockwise from north**, Wind Direction is the direction from which the wind is blowing. This is the way that Wind Direction is specified in weather forecasts. Aspect direction must also be specified

as the way to determine the direction of upslope. This method is best suited to projection of the spread of a specific fire given weather forecasts and terrain information.

In the following diagram, the arrow indicates the direction the wind is blowing or the direction of upslope. A north wind is blowing from the north and pushed the fire to the south. A Southeast wind is specified as 135-degrees from north; the wind is blowing from the SE and is pushing the fire to the NW. An east aspect is specified as 90 degrees from north; upslope on an east aspect is to the west.

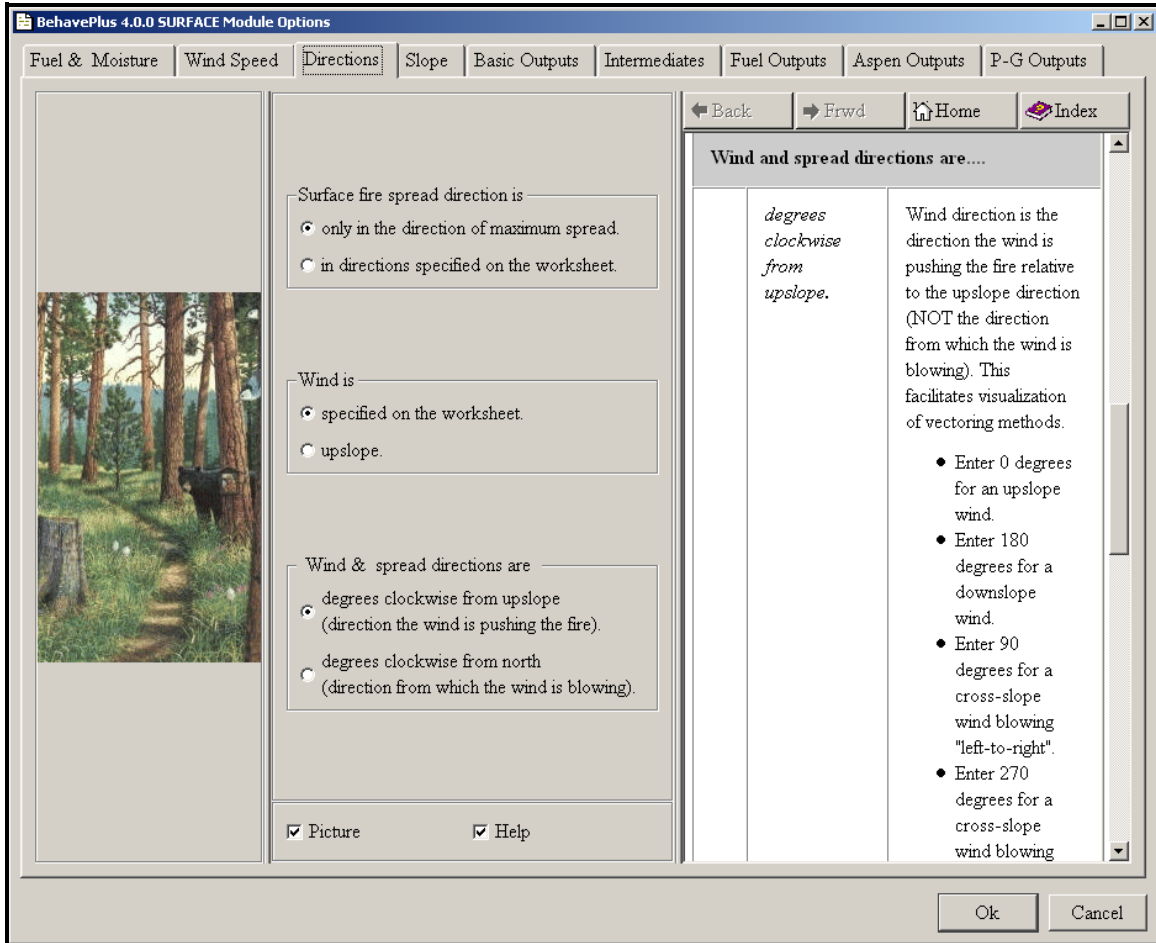


Changing Direction Options

We will change the direction option selections and observe changes in the Worksheet.

- Open the **BasicStart.bpw** Worksheet.
- Click the **SURFACE Options...** button.
- Select the **Direction** tab.
- Note the defaults for the direction options.

- Scroll down to see the description of the options in the help window.



The Worksheet should look like this. The **Run Option Notes** section of the Worksheet records the selections.

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Inputs: SURFACE

Description []

Fuel/Vegetation, Surface/Understory

Fuel Model []

Fuel Moisture

1-h Moisture	%	[]
10-h Moisture	%	[]
100-h Moisture	%	[]
Live Herbaceous Moisture	%	[]
Live Woody Moisture	%	[]

Weather

Midflame Wind Speed (upslope) mi/h []

Terrain

Slope Steepness % []

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]

- Go to the **SURFACE Options... > Directions** tab.
- Change the selections so that the surface fire spread and wind directions are both specified on the Worksheet.

Surface fire spread direction is —

☐ only in the direction of maximum spread.

☒ in directions specified on the worksheet.

Wind is —

☒ specified on the worksheet.

☐ upslope.

Your Worksheet should now look like the following.

- Notice the additional **Inputs** lines.
- The change is noted in the **Run Option Notes** section.

- The modifier 'maximum' is no longer associated with the output variable Surface Rate of Spread.

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Inputs SURFACE

Description

FuelVegetationSurfaceUnderstory

Fuel Model

FuelMoisture

1-h Moisture %

10-h Moisture %

100-h Moisture %

Live Herbaceous Moisture %

Live Woody Moisture %

Weather

Midflame Wind Speed mi/h

Direction of Wind Vector (from upslope) deg

Terrain

Slope Steepness %

Fire

Spread Direction (from upslope) deg

RunOptionNotes

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

Calculations are for the specified spread directions [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].

OutputVariables

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

Flame Length (ft) [SURFACE]

- Go to the **SURFACE Options... > Directions** tab.
- Change the selection for **Wind & spread directions** so that Wind direction is the direction from which the wind is blowing.

Wind & spread directions are

☐ degrees clockwise from upslope
(direction the wind is pushing the fire).

☒ degrees clockwise from north
(direction from which the wind is blowing).

The Worksheet should now look like the following. The modifier 'from north' is now associated with both spread and wind directions. Aspect is now a required input so that the direction of upslope can be determined.

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Inputs SURFACE

Description

FuelVegetationSurfaceUnderstory

Fuel Model

FuelMoisture

1-h Moisture %

10-h Moisture %

100-h Moisture %

Live Herbaceous Moisture %

Live Woody Moisture %

Weather

Midflame Wind Speed mi/h

Wind Direction (from north) deg

Terrain

Slope Steepness %

Aspect deg

Fire

Spread Direction (from north) deg

RunOptionNotes

Maximum reliable effective wind speed limit IS imposed [SURFACE].
 Calculations are for the specified spread directions [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 north [SURFACE].
 Wind direction is the direction from which the wind is blowing [SURFACE].

OutputVariables

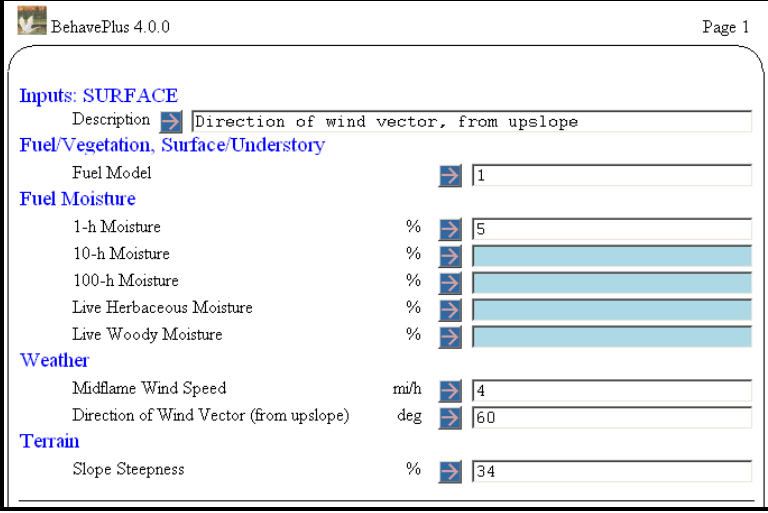
Surface Rate of Spread (ch/h) [SURFACE]
 Flame Length (ft) [SURFACE]

Comparison of the Effect of Direction Option Selection

In this section we compare calculations for two Runs with different direction options and the same input conditions. The calculated fire behavior is the same. The difference is in the selected method of specifying directions.

- Select input options so you are calculating head fire spread with the direction of the wind specified as the direction of the wind vector from upslope.
- Select an additional output variable: Direction of Maximum Spread.

- Enter values as shown.



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Inputs: SURFACE

Description ➤ Direction of wind vector, from upslope

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 1

Fuel Moisture

1-h Moisture % ➤ 5

10-h Moisture % ➤

100-h Moisture % ➤

Live Herbaceous Moisture % ➤

Live Woody Moisture % ➤

Weather

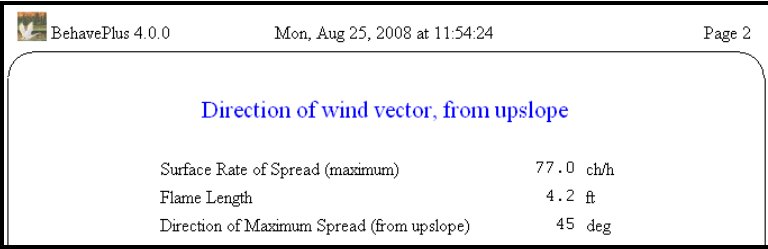
Midflame Wind Speed mi/h ➤ 4

Direction of Wind Vector (from upslope) deg ➤ 60

Terrain

Slope Steepness % ➤ 34

- Calculate the Run to get the following results.



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Direction of wind vector, from upslope

Surface Rate of Spread (maximum)	77.0 ch/h
Flame Length	4.2 ft
Direction of Maximum Spread (from upslope)	45 deg

- Save the Run as **WindVector.bpr** for future reference. Put it in a Run folder called **DirectionLesson**.
- Now change the input option to **Wind & spread directions are degrees clockwise from north (direction from which the wind is blowing)**.

- Enter values on the Worksheet as follows.

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Inputs: SURFACE

Description ➤ Direction FROM which the wind is blowing

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 1

Fuel Moisture

1-h Moisture % ➤ 5

10-h Moisture % ➤

100-h Moisture % ➤

Live Herbaceous Moisture % ➤

Live Woody Moisture % ➤

Weather

Midflame Wind Speed mi/h ➤ 4

Wind Direction (from north) deg ➤ 285

Terrain

Slope Steepness % ➤ 34

Aspect deg ➤ 225

- Calculate the Run to get the following results.

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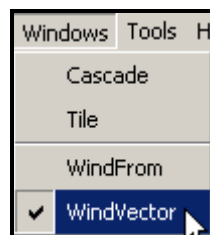
Direction FROM which the wind is blowing

Surface Rate of Spread (maximum) 77.0 ch/h

Flame Length 4.2 ft

Direction of Maximum Spread (from north) 90 deg

- Save the Run as **WindFrom.bpr** for future reference.
- Open the Run **WindVector.bpr** so that both Runs are now open.
- On the Windows menu, **WindFrom** and **WindVector** are listed. The check next to **WindVector**, the second Run that was opened, indicates that it is the top Run currently displayed in the BehavePlus main window.



- Calculate the Run for **WindVector**.
- Use **Windows > Cascade** or **Tile** to view both Runs at the same time.

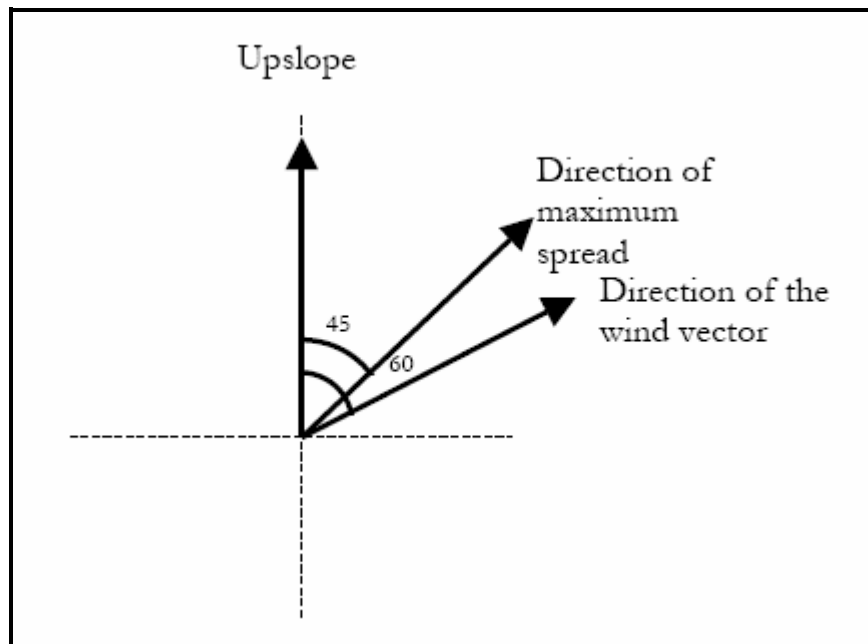
- Review the two Worksheets and their corresponding output tables.

The following diagrams are associated with the two Runs.

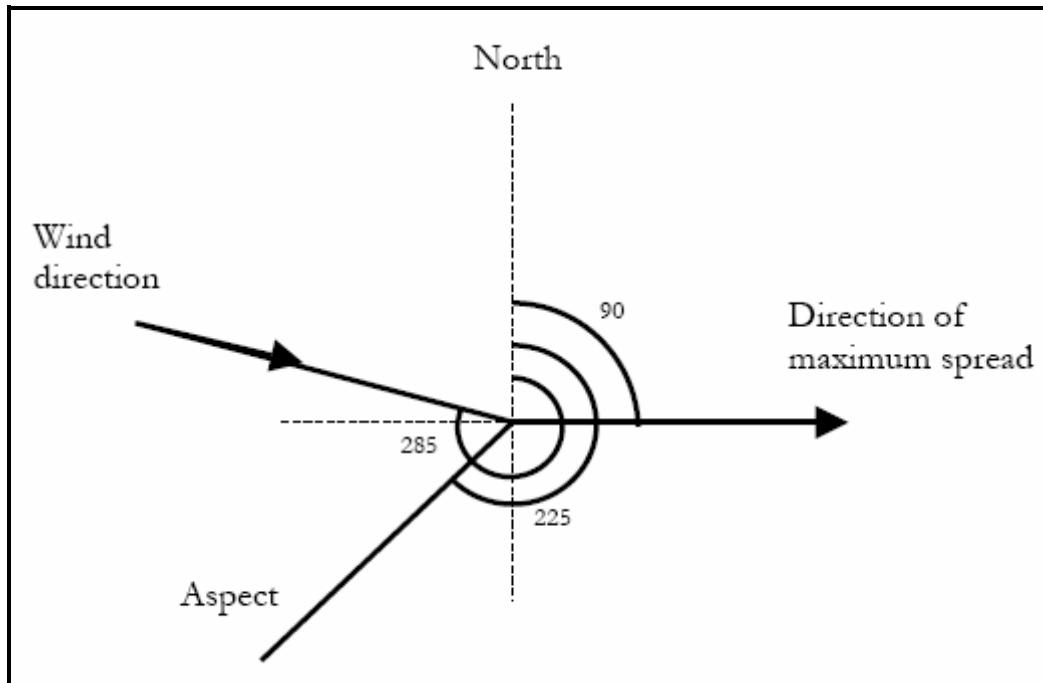
In both cases Wind Speed is 4 mi/hr and Slope Steepness is 34%.

Calculated Surface Rate of Spread in the direction of maximum spread is 77 ch/hr.

- Examine the diagram below associated with the **WindVector** Run. Wind and spread directions are degrees clockwise from upslope. Direction of the wind vector is the direction the wind pushing the fire. Direction of wind vector (from upslope) is 60 degrees. Calculated direction of maximum spread is 45 degrees.



- Examine the diagram below associated with the **WindFrom** Run. Wind and spread directions are degrees clockwise from north. Wind direction is the direction from which the wind is blowing. Wind direction (from north) is 285-degrees. Aspect (from north) is 225-degrees. Calculated direction of maximum spread (from north) is 90-degrees.



Given an Aspect of 225°, Upslope is located at $225^\circ - 180^\circ = 45^\circ$ from North.

The calculated Direction of maximum spread is 90° from North, making the Direction of maximum spread $90^\circ - 45^\circ = 45^\circ$ from Upslope.

The direction options illustrated in the **WindVector** Run are suited to understanding the *combined effects* of wind and slope on fire spread. Manual vectoring methods are similar, and are used when a computer program (like BehavePlus) is not available.

The direction options illustrated in the **WindFrom** Run are suited to calculating the spread of a *specific* fire and plotting distances on a map. Wind direction is specified in forecasts and observations as the direction from which the wind is blowing.

You may find it useful to save the Worksheets associated with these Runs in your **MyWorksheets** folder for future use. (Alternatively, put them in a **DirectionLesson** Worksheet folder.)

- Go to the **WindVector** Run.
- Save as Worksheet **SurfaceBasicVector**.
- Go to the **WindFrom** Run.


- Save as Worksheet **SurfaceBasicFrom**.
- Select **File > Close** twice to close the Runs.

Calculate Non-Head Fire Spread

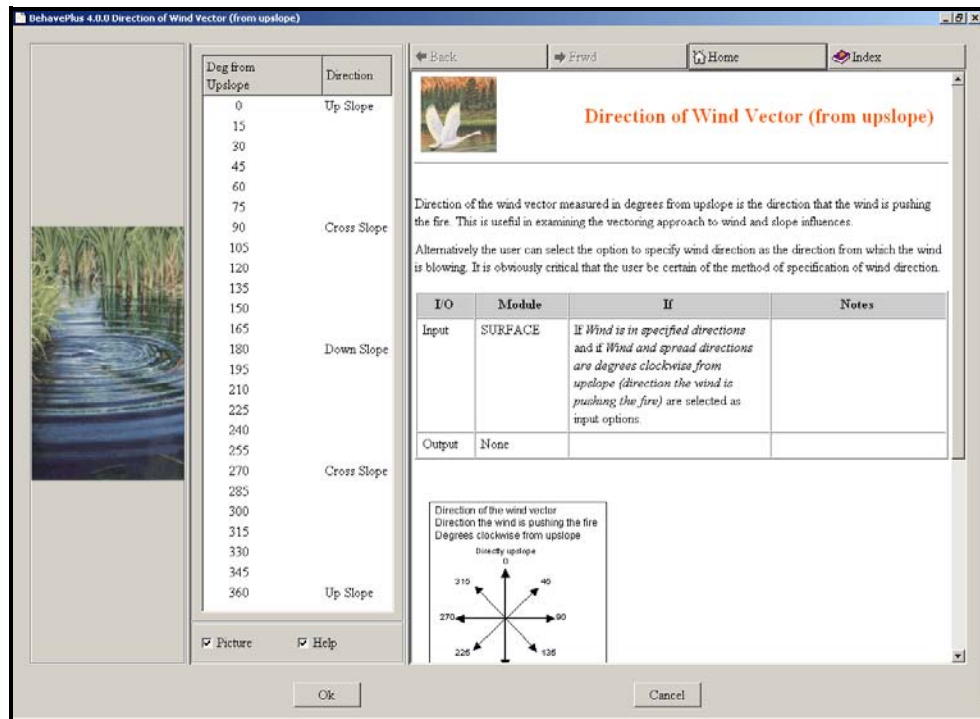
- Open the Worksheet that you just saved: **SurfaceBasicVector.bpw**.
- Change the direction option to **Surface fire spread direction is in directions specified on the worksheet**.

The Worksheet should look like this.

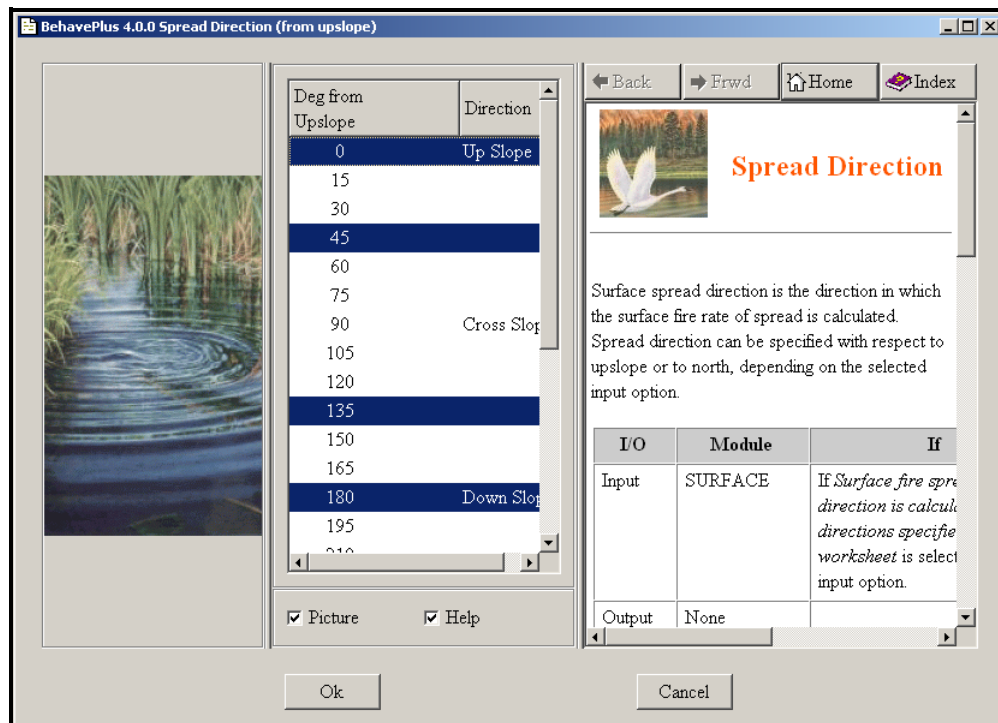
The screenshot shows the BehavePlus 4.0.0 worksheet interface. The title bar indicates 'BehavePlus 4.0.0' and 'Page 1'. The main content area is divided into sections with blue headers: 'Inputs: SURFACE', 'Fuel/Vegetation, Surface/Understory', 'Fuel Moisture', 'Weather', 'Terrain', and 'Fire'. Each section contains input fields with corresponding units and a blue arrow button to the right of each field. The 'Description' field is currently empty. The 'Fuel Model' field is empty. The 'Fuel Moisture' section has five fields: '1-h Moisture' (6%), '10-h Moisture' (6%), '100-h Moisture' (6%), 'Live Herbaceous Moisture' (6%), and 'Live Woody Moisture' (6%). The 'Weather' section has two fields: 'Midflame Wind Speed' (mi/h) and 'Direction of Wind Vector (from upslope)' (deg). The 'Terrain' section has one field: 'Slope Steepness' (%). The 'Fire' section has one field: 'Spread Direction (from upslope)' (deg).

- Type 'Calculations in a specified direction' in the **Description** field.
- Enter the following inputs:
 - Fuel Model = 1,
 - 1-h fuel Moisture = 6%,
 - Midflame Wind Speed = 5 mi/h, and
 - Slope Steepness = 20%
- Click on the **Direction of Wind Vector (from upslope)**  Guide Button.
- Click the **Choices** button.

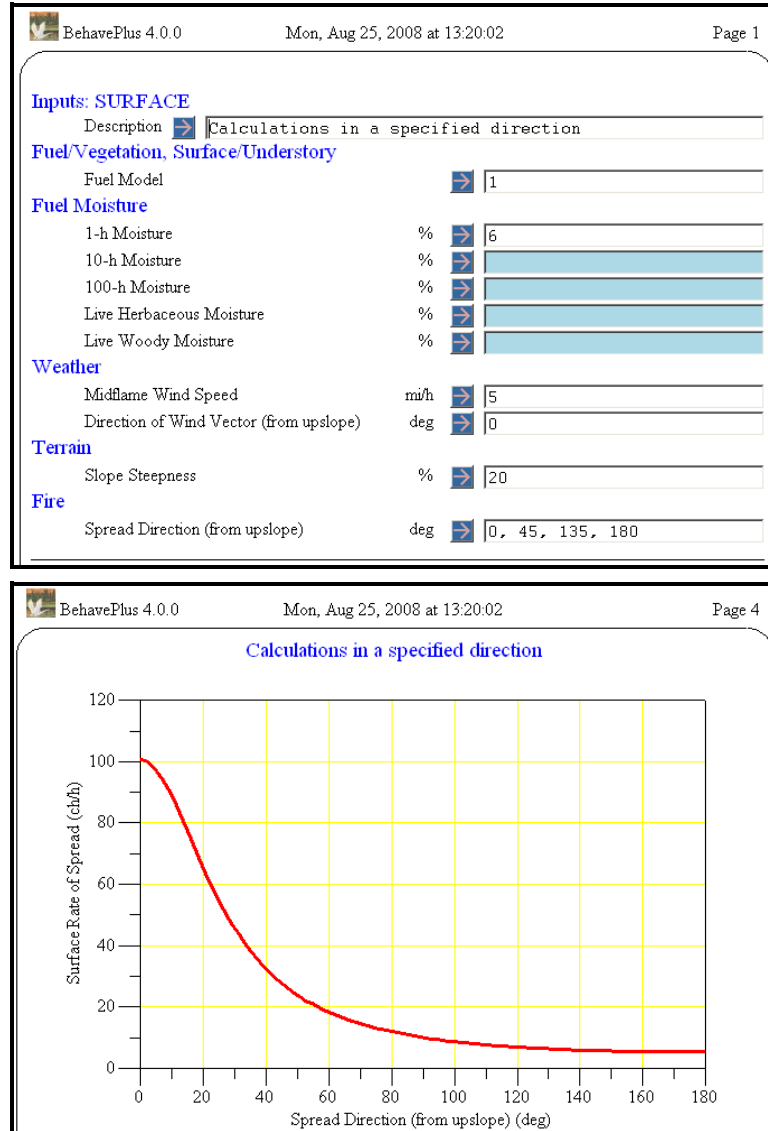
- Select **0** for **Up Slope** (Note the diagrams in the Help pane).



- Click the **Spread Direction (from upslope)** Guide button.
- Click the **Choices** button.
- Select **0, 45, 135, and 180**.



The Worksheet and resulting Surface Rate of Spread plot look like the following.



The calculated Surface Rate of Spread varies with the specified spread direction. Also note that the **Direction of Maximum Rate of Spread** is upslope (0 degrees) in every case because the wind is blowing upslope.

Next, vary the direction of the wind.

- Type “0, 45, 90, 135, 180” in the **Direction of Wind Vector (from upslope)** field. (Remember you can also use the Guide button and Choices window to do this.)

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Inputs: SURFACE

Description ➤ Calculations in a specified direction

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 1

Fuel Moisture

1-h Moisture % ➤ 6

10-h Moisture % ➤

100-h Moisture % ➤

Live Herbaceous Moisture % ➤

Live Woody Moisture % ➤

Weather

Midflame Wind Speed mi/h ➤ 5

Direction of Wind Vector (from upslope) deg ➤ 0, 45, 90, 135, 180

Terrain

Slope Steepness % ➤ 20

Fire

Spread Direction (from upslope) deg ➤ 0, 45, 135, 180

The resulting Surface Rate of Spread table appears as follows.

Note that the Surface Rate of Spread varies with both the direction specified for the spread calculation and the direction of the wind vector.

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Calculations in a specified direction
Surface Rate of Spread (ch/h)

Wind Dir (upslope) deg	Spread Direction (from upslope) deg			
	0	45	135	180
0	100.8	27.7	6.2	5.3
45	30.0	97.7	9.5	6.0
90	10.5	30.6	23.5	9.2
135	6.0	10.1	88.0	23.6
180	5.0	5.8	25.6	87.0

- Click the  **Next Page** button to view the other output tables.

Note that the **Direction of Maximum Spread** does not vary with the direction of the spread calculation, but it does change with a change in the direction of the wind vector.

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Calculations in a specified direction
Direction of Maximum Spread (from upslope) (deg)

Wind Dir (upslope) deg	Spread Direction (from upslope) deg			
	0	45	135	180
0	0	0	0	0
45	42	42	42	42
90	86	86	86	86
135	132	132	132	132
180	180	180	180	180

- Change the direction option to **Surface fire spread direction is only in the direction of maximum spread.**
- Change Slope Steepness from 20 to 45%.
- Delete the text in the **Description** field.

Note that the Spread Direction input is no longer an input.

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Inputs: SURFACE

Description ➤

Fuel/Vegetation, Surface/Understory

Fuel Model ➤ 1

Fuel Moisture

1-h Moisture % ➤ 6

10-h Moisture % ➤

100-h Moisture % ➤

Live Herbaceous Moisture % ➤

Live Woody Moisture % ➤

Weather

Midflame Wind Speed mi/h ➤ 5

Direction of Wind Vector (from upslope) deg ➤ 0, 45, 90, 135, 180

Terrain

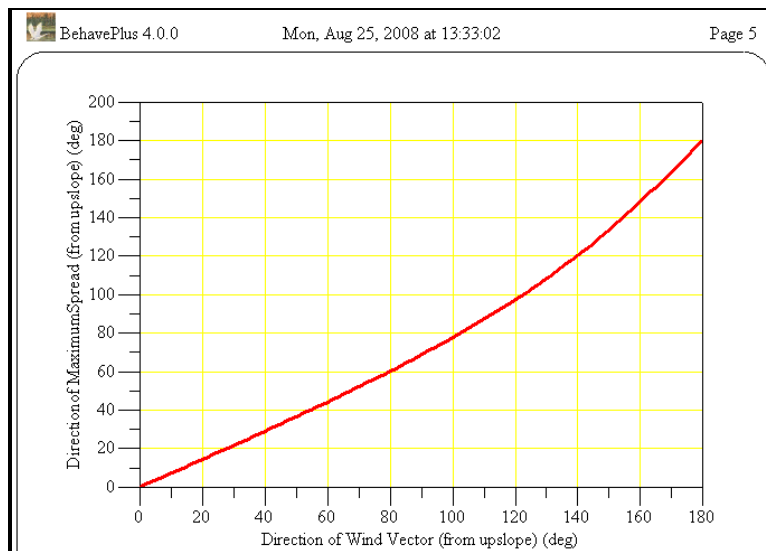
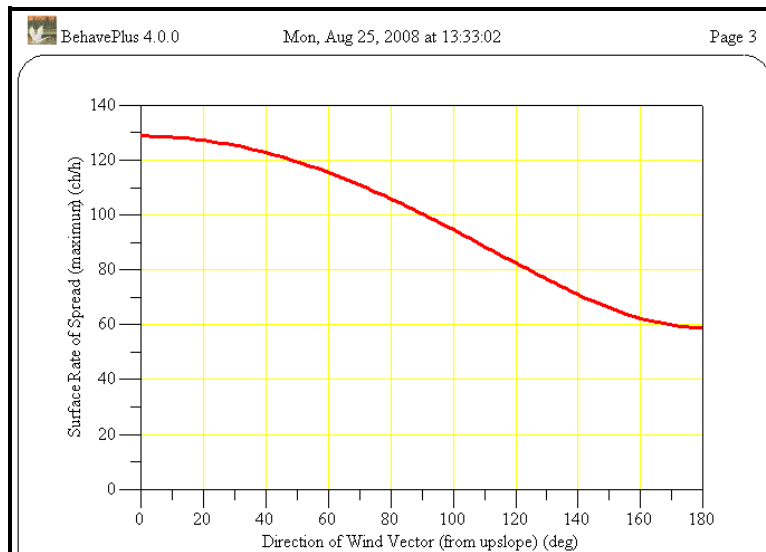
Slope Steepness % ➤ 45

- Calculate the Run to see the following.

Note how the Wind Direction affects head fire Surface Rate of Spread and its Direction.

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Wind Dir (upslope) deg	ROS (max) ch/h	Flame Length ft	Direction Max ROS deg
0	128.8	5.3	0
45	121.2	5.2	33
90	100.4	4.7	69
135	73.7	4.1	114
180	59.0	3.7	180



Summary

Very often surface fire spread, intensity, and flame length calculations will be for a head fire burning upslope with the wind. The default directions options are set that way for the **BasicStart.bpw** Worksheet. There are options on the Directions tab of the SURFACE options that allow you to enter other wind and spread direction options.