Introduction

The CROWN module in BehavePlus is based on models developed by Van Wagner (1977, 1993), Rothermel (1991), Thomas (1963), and Byram (1959). Outputs are listed on tabs labeled **Spread Outputs** and **Intensity Outputs**. This lesson addresses Spread Outputs.

BehavePlus calculates the rate of spread of a surface fire and of an active crown fire. It does not calculate a rate of spread that transitions from one fire type to the other based on crown fraction burned (as in, for example, Scott and Reinhardt 2001). The Surface Rate of Spread is used for a torching fire.

A user also should be aware of the many important factors that affect crown fire but are not included in the models. Great care should be used in using models and systems to predict extreme fire behavior.

Objectives

1. Understand how crown fire spread and transition from surface to crown fire is modeled in BehavePlus.
2. Create a worksheet that produces a CROWN run to evaluate crown fire spread rate, area, and perimeter.
3. Understand transition ratio, active ratio, and their relationship to fire type (surface, torching, crowning, or conditional crown).
4. Correctly interpret BehavePlus CROWN module runs.

Where This Lesson Fits In

This is an optional lesson in the Modeling Unit. Lessons in the Modeling Unit cover capabilities, limitations and assumptions, and sensitivity of the various models in BehavePlus. It is assumed that the trainee has skill with program operation.

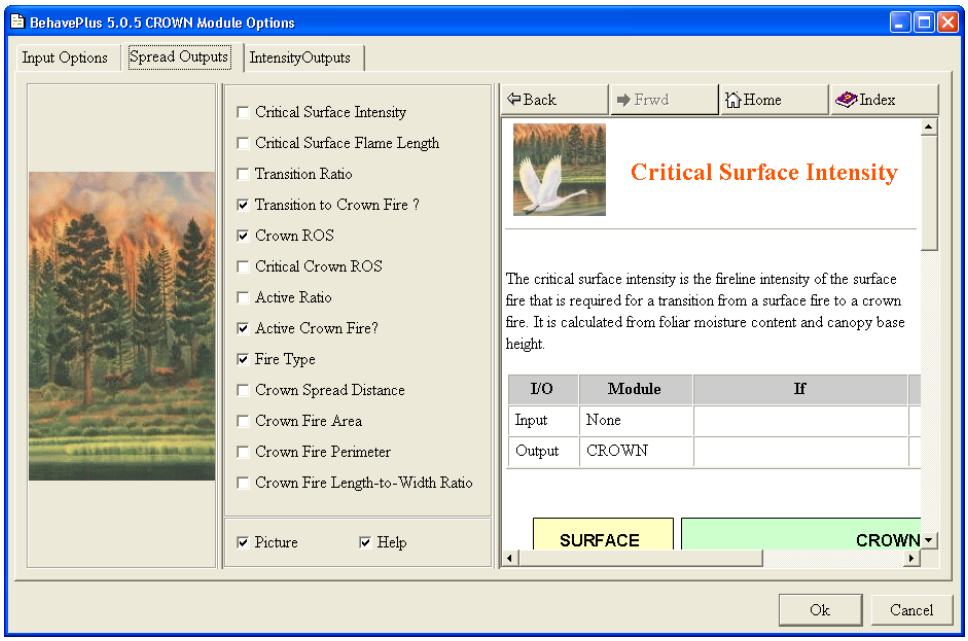
The **Surface Fire Spread and Intensity** lesson should be done before this lesson.

There are two lessons associated with crown fire modeling in BehavePlus. The associated **Crown Fire Intensity** lesson covers crown fireline intensity and flame length, heat per unit area (canopy and crown), Power of the Fire, Power of the Wind, and whether a fire is likely to be wind-driven or plume-dominated.

A Crown Fire Run

To begin the lesson, let's create a simple Run using the CROWN module to calculate Fire Type.

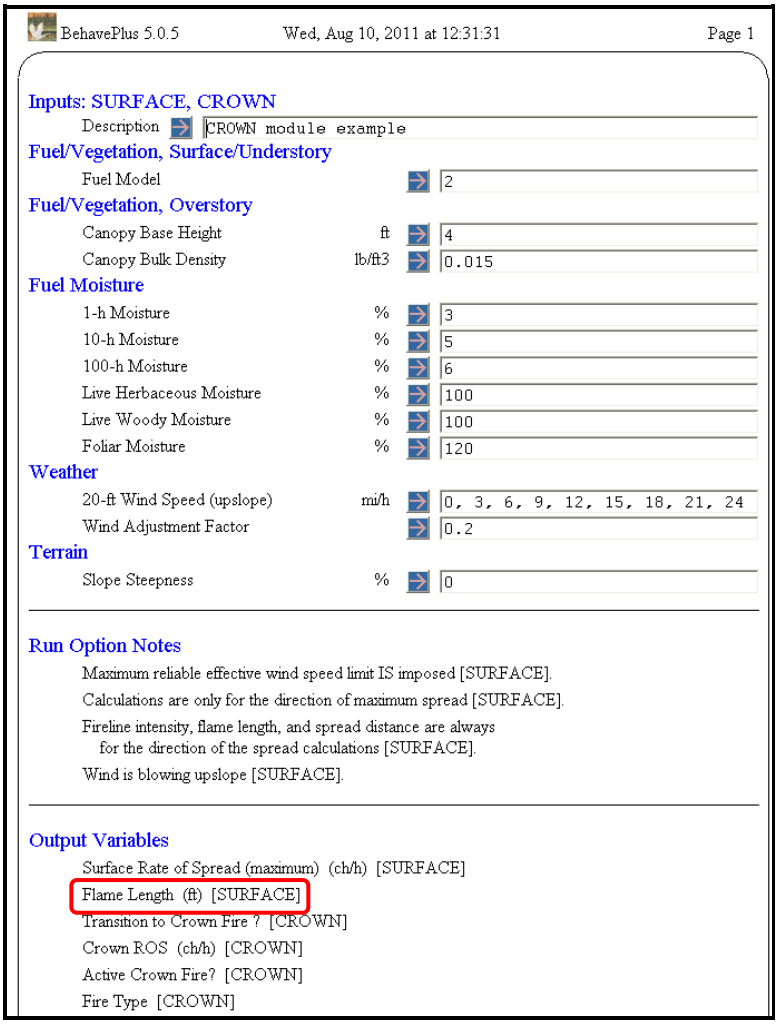
- Open the **SurfaceCrown.bpw** Worksheet in the **ExampleWorksheets** folder.
- Go to **Module Selection**.
  - **Note:** Both the SURFACE and CROWN modules are selected.
- Open the **CROWN > Options… > Spread Outputs** tab and select only the variables shown below.
  - Transition to Crown Fire?
  - Crown ROS
  - Active Crown Fire?
  - Fire Type



- Click **Ok** once.

- Open the **SURFACE > Options… > Wind Speed** tab and note that **Wind speed is entered as 20-ft wind and Input wind adj. factor**.
- Make sure Surface Rate of Spread and Flame Length are selected on the **Basic Outputs** tab.
- Click **Ok** twice.

- Enter the following values on the Worksheet.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Inputs: SURFACE, CROWN

Description		CROWN module example
Fuel/Vegetation, Surface/Understory		
Fuel Model		2
Fuel/Vegetation, Overstory		
Canopy Base Height	ft	4
Canopy Bulk Density	lb/ft3	0.015
Fuel Moisture		
1-h Moisture	%	3
10-h Moisture	%	5
100-h Moisture	%	6
Live Herbaceous Moisture	%	100
Live Woody Moisture	%	100
Foliar Moisture	%	120
Weather		
20-ft Wind Speed (upslope)	mi/h	0, 3, 6, 9, 12, 15, 18, 21, 24
Wind Adjustment Factor		0.2
Terrain		
Slope Steepness	%	0

Run Option Notes

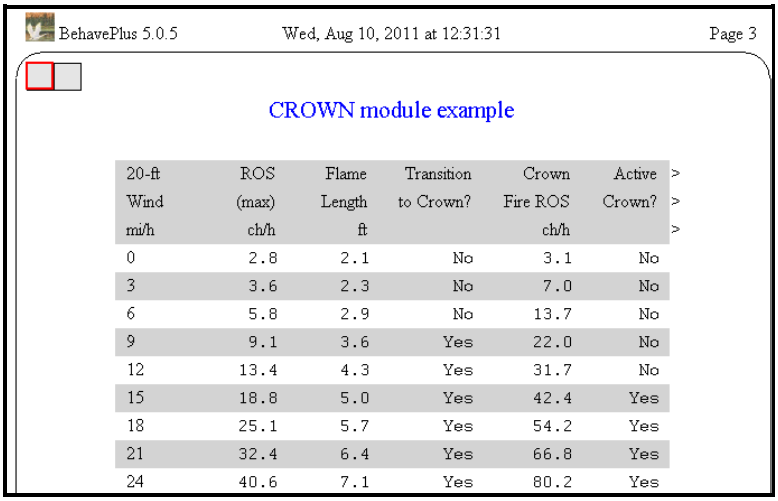
Maximum reliable effective wind speed limit IS imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind is blowing upslope [SURFACE].

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]
Flame Length (ft) [SURFACE]
Transition to Crown Fire ? [CROWN]
Crown ROS (ch/h) [CROWN]
Active Crown Fire? [CROWN]
Fire Type [CROWN]

Note: Flame Length is for the surface fire, calculated in the SURFACE module.

- **Calculate** the Run to produce the following output table.



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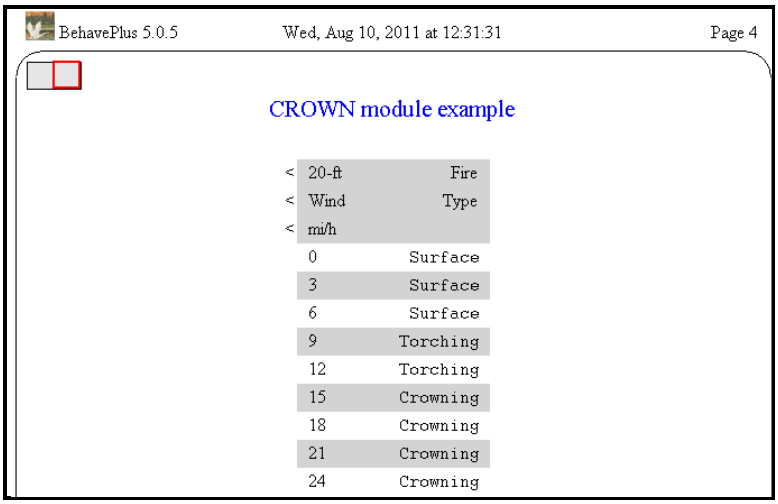
CROWN module example

20-ft Wind mi/h	ROS (max) ch/h	Flame Length ft	Transition to Crown?	Crown Fire ROS ch/h	Active Crown?
0	2.8	2.1	No	3.1	No
3	3.6	2.3	No	7.0	No
6	5.8	2.9	No	13.7	No
9	9.1	3.6	Yes	22.0	No
12	13.4	4.3	Yes	31.7	No
15	18.8	5.0	Yes	42.4	Yes
18	25.1	5.7	Yes	54.2	Yes
21	32.4	6.4	Yes	66.8	Yes
24	40.6	7.1	Yes	80.2	Yes



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CROWN module example

20-ft Wind mi/h	Fire Type
0	Surface
3	Surface
6	Surface
9	Torching
12	Torching
15	Crowning
18	Crowning
21	Crowning
24	Crowning

Here are some things to keep in mind when viewing crown fire outputs:

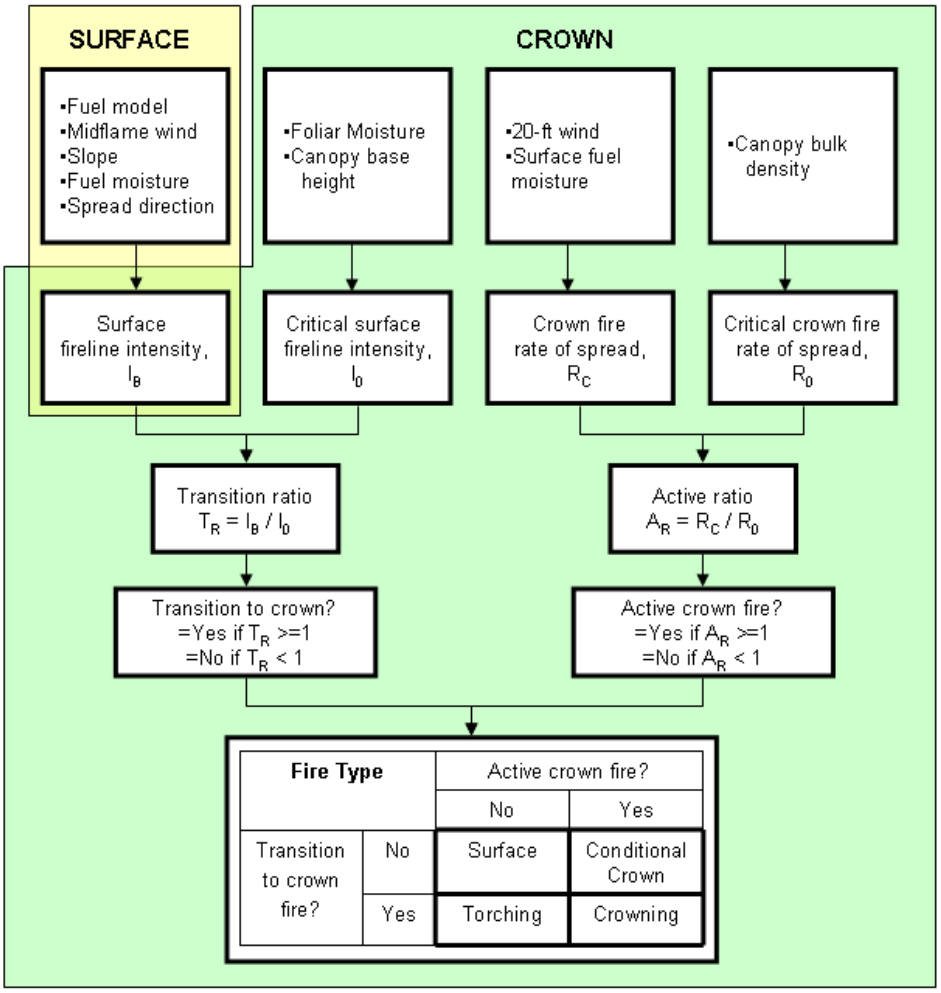
- **Crown Fire ROS** values are only applicable for *active* crown fire, when the **Active Crown?** column value is **Yes**.
- The **Crown Fire ROS** includes the influence of spotting (Rothermel 1991).
- For a Fire Type of **Torching**, the surface fire rate of spread should be used.
- Flame Length values are for the surface fire.
  - For a crown fire, it is called Crown Flame Length in BehavePlus.

This is a quick, simplistic overview of crown fire modeling. Let's explore how the crown fire model works to better understand how to avoid misinterpreting your results.

BehavePlus Crown Fire Logic

To better understand the workings of the BehavePlus crown fire logic on this flow chart, we will look at the individual components using intermediate output variables.

The chart shown below illustrates the relationships in BehavePlus for modeling variables associated with crown fire spread. Two variables are required to determine the Fire Type (surface, conditional crown, torching, crowning). They are the Transition to Crown? and Active Crown Fire? variables.



Transition to Crown Fire? (Transition Ratio)

The Transition Ratio tells the user if the Surface Fireline Intensity is sufficient for a transition from surface to crown fire.

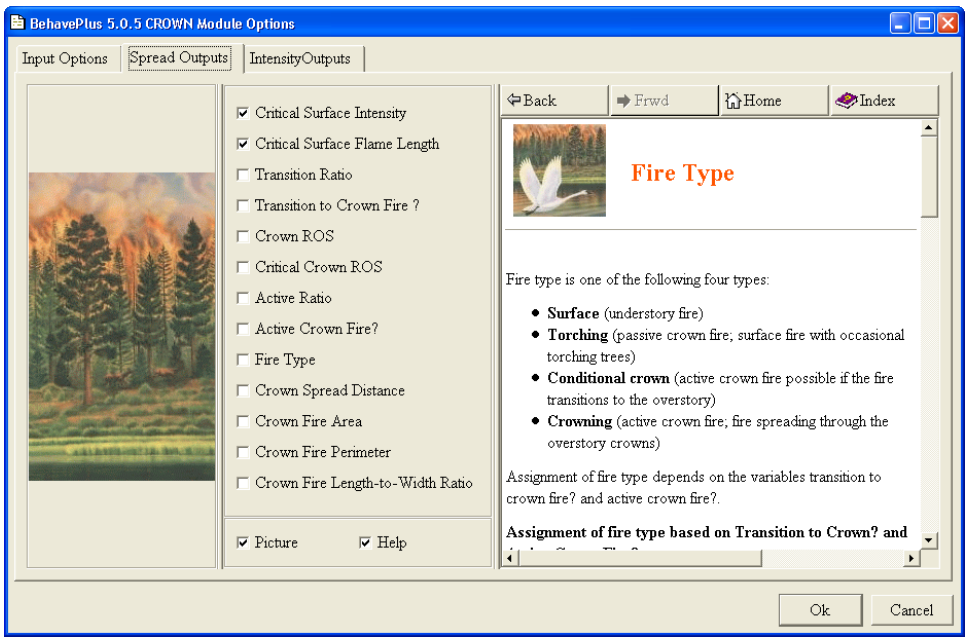
Surface Fireline Intensity

The first component used to calculate Transition Ratio is Surface Fireline Intensity (I_B). Remember from your previous fire behavior training that fireline intensities are directly related to Flame Length. Surface Fireline Intensity and Flame Length are calculated in BehavePlus using the SURFACE module. You also have the option of inputting values for Surface Fireline Intensity or Flame Length.

Critical Surface Fireline Intensity

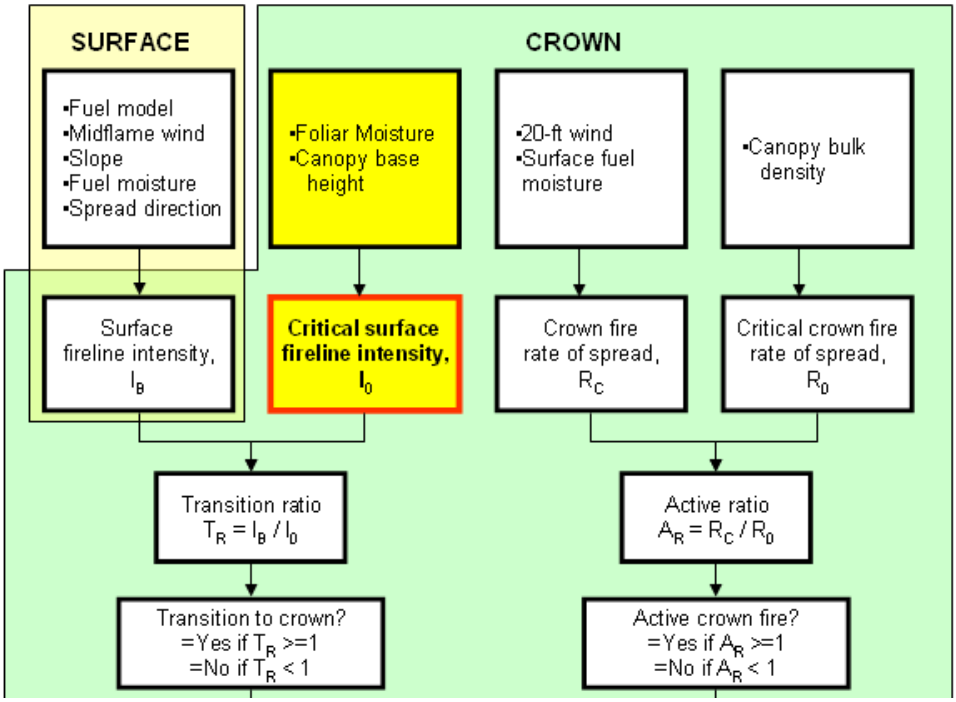
Critical Surface Fireline Intensity is the intensity required for a fire to make the transition from surface to crown fire (either passive or active). It is calculated in the CROWN module.

- Open a new **SurfaceCrown.bpw** Worksheet.
- Open **Module Selection**.
- Uncheck the **SURFACE module** checkbox. The **CROWN module** should be the only module selected.
- Open the **CROWN Options… > Spread Outputs** tab and select only Critical Surface Intensity and Critical Surface Flame Length.

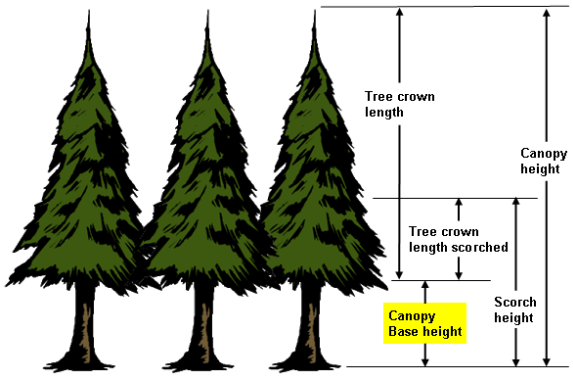


- Click **Ok** twice to close the dialog boxes and return to the Worksheet.

Look at the following flow chart to see the process for Critical Surface Fireline Intensity calculation and the required input values.



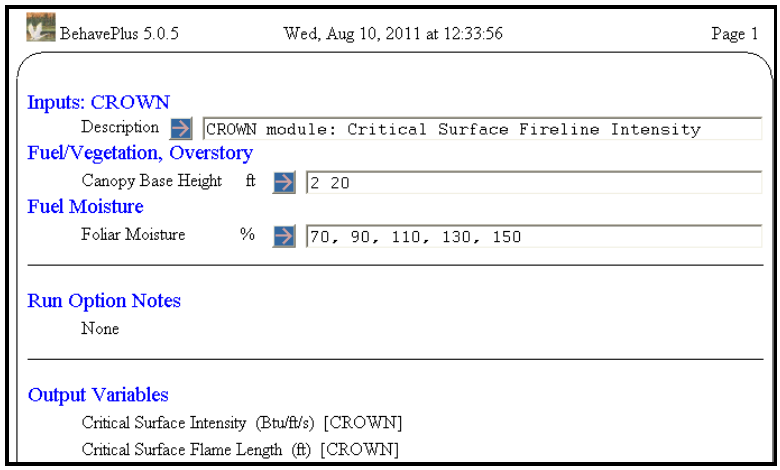
Two variables are required: Canopy Base Height (CBH) and Foliar Moisture. CBH is a measure of how close the easily ignitable portions of a conifer (mainly needles) are to the surface fire. For a single tree it is the height to the bottom of the live crown. It can be tricky when attempting to expand this to a stand or area basis. CBH should reflect the effects of ladder fuels (if present) in increasing vertical continuity.



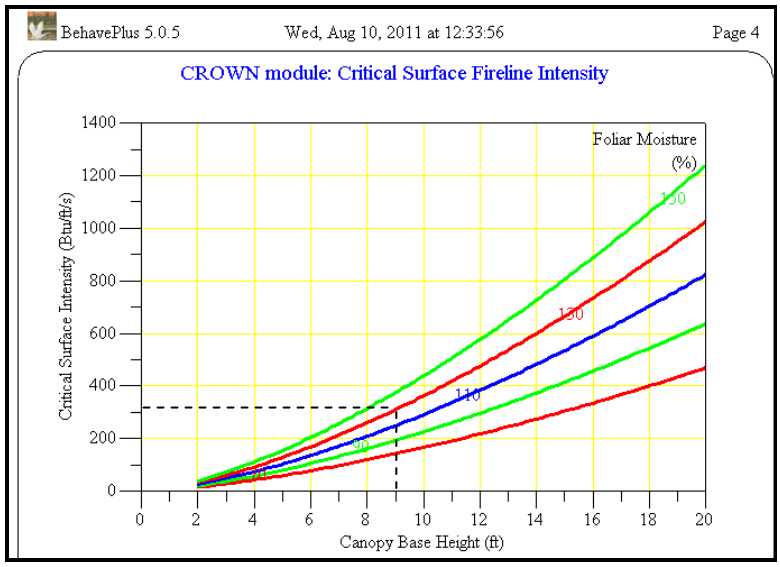
Foliar Moisture is the moisture content of live coniferous needles. Foliar Moisture has a narrower range of realistic values than Surface Fuel Live Woody Moisture since conifer needles do not cure on a seasonal basis. Normal ranges for Foliar Moisture are 120–150%; severe drought conditions exhibit a range of 80–100%, except for black spruce, which is normally less than 100%. Given the empirical nature of Van Wagner's (1977) crown fire initiation model, applying Foliar Moisture values less than 70% is not recommended. If better data do not exist, a value of 100% is a reasonable estimate (Scott and Reinhardt 2001).

- Enter values for Canopy Base Height of 2 and 20 ft.
- Enter Foliar Moisture values of 70 to 150% with an increment of 20%.

Your Worksheet should look like the following.

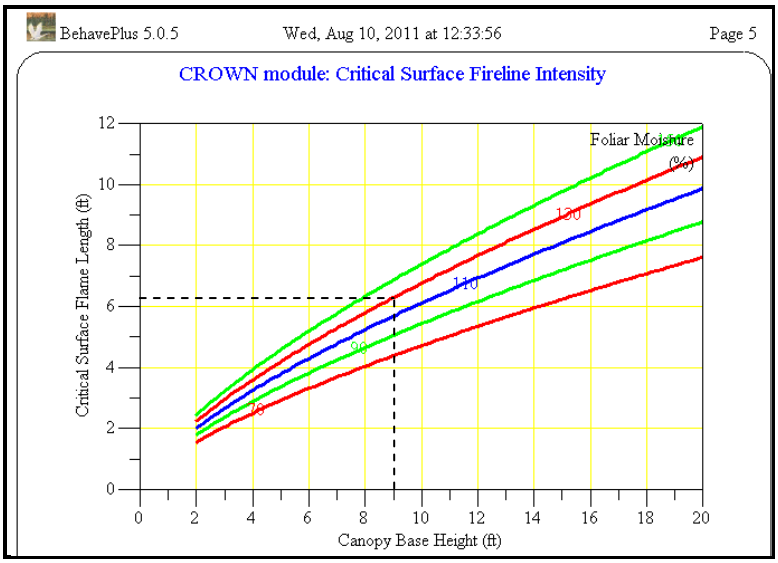


- **Calculate** the results. View the two graphs (the dashed lines have been added to the graphs for this lesson and won't show up in your graph).



A Canopy Base Height of 9 feet and a Foliar Moisture content of 130% results in a Critical Surface Fireline Intensity of 309 Btu/ft/s. The other curves show the Critical Surface Flame Length for Foliar Moisture contents of 70, 90, 110, and 150%.

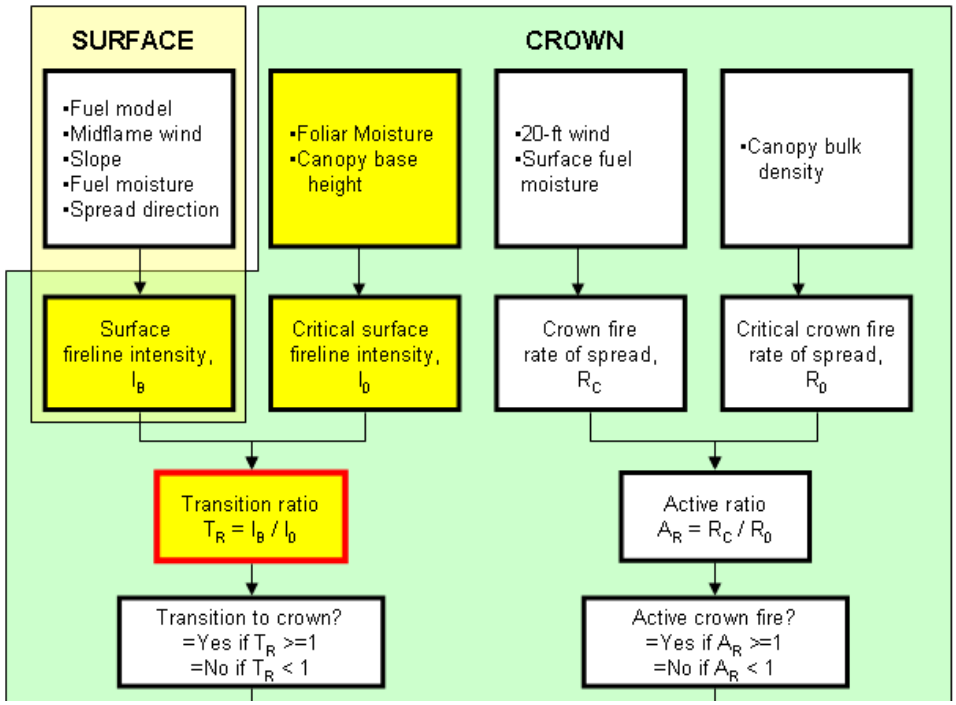
In the following graph, a CBH of 9 ft and a Foliar Moisture content of 130% lead to a Critical Surface Flame Length of 6.3 ft. This means you need a surface Flame Length of *at least* 6.3 feet to transition to some type of crown fire.



Other curves show Critical Surface Flame Lengths required for transition to crown fire if Foliar Moisture content is 70, 90, 110, and 150%.

Transition Ratio

Now we will use the Surface Fireline Intensity (I_B) and the Critical Surface Fireline Intensity (I_0) to calculate the Transition Ratio (T_R), which is used in BehavePlus to determine transition to crown fire. It's also very handy for looking at the sensitivity of the transition to crown fire.

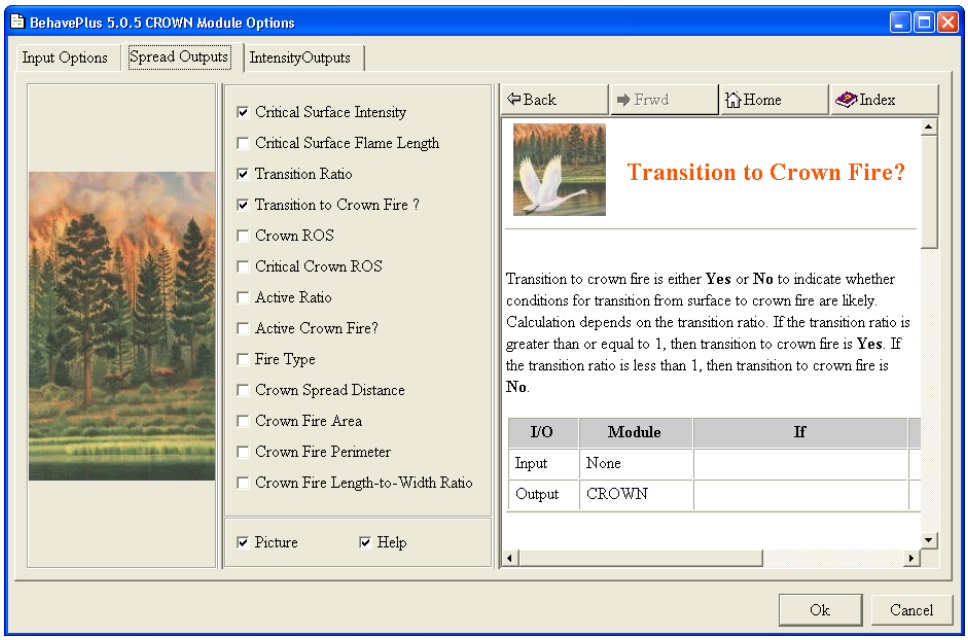


The Transition Ratio (T_R) is simply the ratio of the calculated Surface Fireline Intensity (I_B) to the required Critical Surface Fireline Intensity (I_0), such that

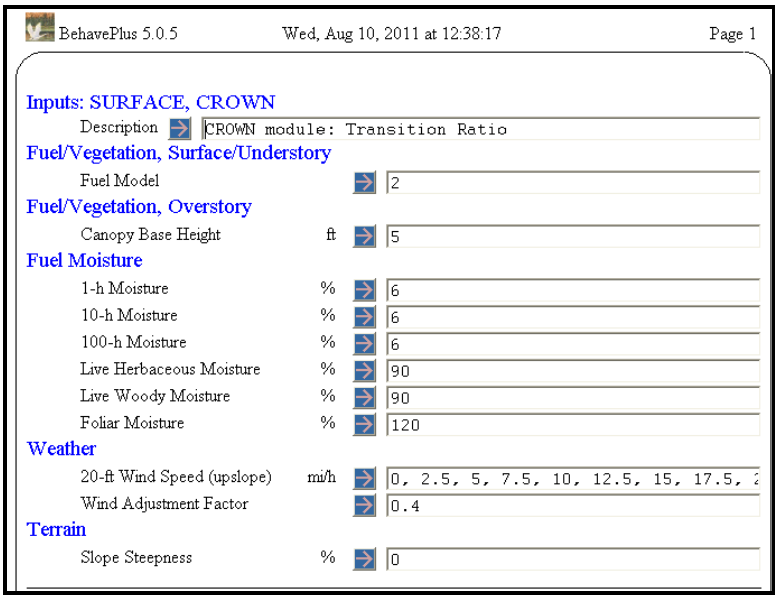
$T_R = I_B / I_0$. Equation 1

The Transition Ratio (T_R) is greater than 1.0 when the calculated Surface Fireline Intensity (I_B) is greater than the Critical Fireline Intensity (I_0), indicating there is a transition to crown fire.

- Go to the **Configure > Module Selection > CROWN > Options… > Spread Outputs** tab and select the following three output variables.
  - Critical Surface Intensity
  - Transition Ratio
  - Transition to Crown Fire?



- Click the **Ok** button to close the **CROWN Module Options** dialog box.
- Select the **SURFACE Module** in addition to the **CROWN Module** to calculate the Fireline Intensity for the surface fire.
- Now click the **SURFACE > Options…** button and select only Fireline Intensity and Flame Length.
- In the **Wind Speed** tab, select **Wind speed is entered as 20-ft wind and Input wind adj factor**.
- Click **Ok** twice to close both dialog boxes.
- Enter the following input values on the Worksheet.
  - 20-ft Wind Speed values should range from 0 to 25 mi/h with a step of 2.5.



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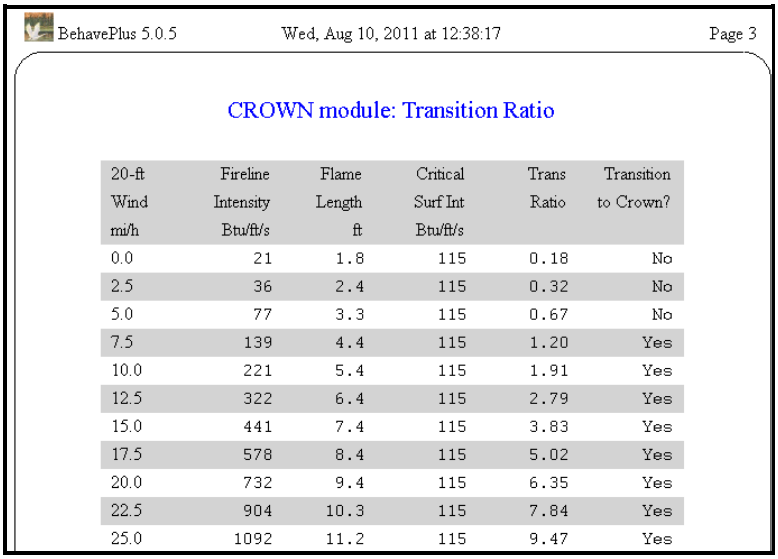
Inputs: SURFACE, CROWN

Description		CROWN module: Transition Ratio
Fuel/Vegetation, Surface/Understory		
Fuel Model		2
Fuel/Vegetation, Overstory		
Canopy Base Height	ft	5
Fuel Moisture		
1-h Moisture	%	6
10-h Moisture	%	6
100-h Moisture	%	6
Live Herbaceous Moisture	%	90
Live Woody Moisture	%	90
Foliar Moisture	%	120
Weather		
20-ft Wind Speed (upslope)	mi/h	0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 2
Wind Adjustment Factor		0.4
Terrain		
Slope Steepness	%	0

- **Calculate** the Run to produce the following table.



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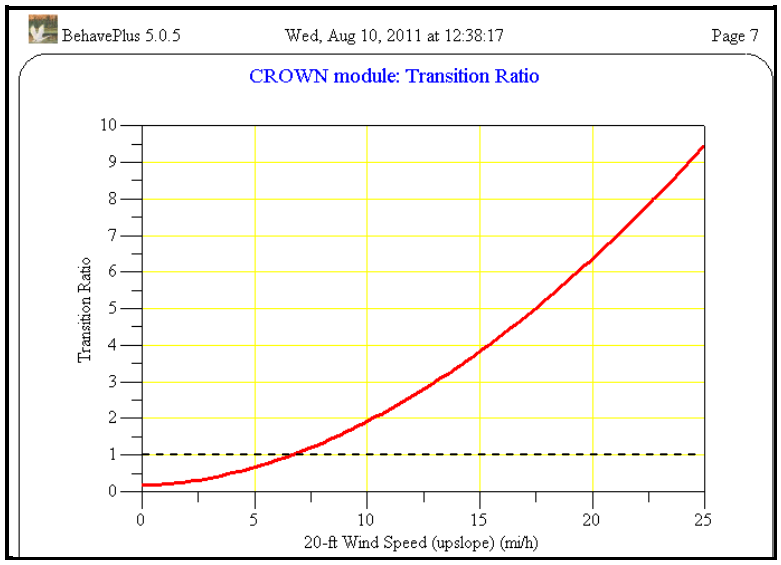
CROWN module: Transition Ratio

20-ft Wind mi/h	Fireline Intensity Btu/ft/s	Flame Length ft	Critical Surf Int Btu/ft/s	Trans Ratio	Transition to Crown?
0.0	21	1.8	115	0.18	No
2.5	36	2.4	115	0.32	No
5.0	77	3.3	115	0.67	No
7.5	139	4.4	115	1.20	Yes
10.0	221	5.4	115	1.91	Yes
12.5	322	6.4	115	2.79	Yes
15.0	441	7.4	115	3.83	Yes
17.5	578	8.4	115	5.02	Yes
20.0	732	9.4	115	6.35	Yes
22.5	904	10.3	115	7.84	Yes
25.0	1092	11.2	115	9.47	Yes

Notice that Critical Surface Fireline Intensity (I_0) does not change with wind speed, since it depends only on CBH and Foliar Moisture. However, the surface fire Fireline Intensity (I_B) does increase with wind speed.

When the surface fire Fireline Intensity exceeds the critical value, the Transition Ratio is greater than 1.0 and the variable **Transition to crown?** is **Yes**.



The Transition Ratio lets you look at more than just a **Yes** or **No** answer to the transition question. It allows you see how sensitive the transition to crown fire is to the input variable – in this case, Midflame Wind Speed. For example, if you were expecting Midflame Wind Speeds of 2-4 mi/h, torching would be intermittent as the wind fluctuated above and below a Transition Ratio of 1.0. You would carefully review your other inputs (Fuel Model, Fuel Moistures, and Canopy Base Height) and realize there is a high degree of uncertainty in your prediction. If, on the other hand, Midflame Wind Speeds were predicted to be in the 5-8 mi/h range, you would be much more confident in your prediction to expect torching.

Active Crown Fire? (Active Ratio)

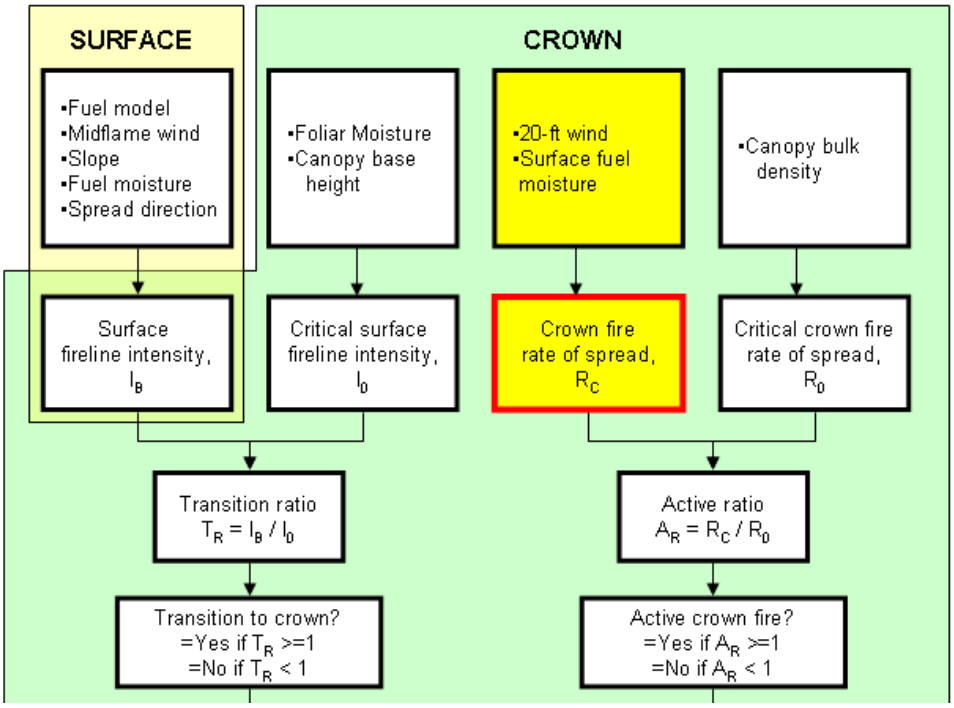
The Active Ratio tells the user if the Crown Fire Rate of Spread is sufficient to maintain an active crown fire.

Crown Fire Rate of Spread

Next let's look at crown fire rate of spread (Crown ROS). This is the spread rate of an active, wind-driven crown fire. For passive crown fire (torching) the Surface Rate of Spread is used to estimate the forward spread of the fire. However it should be used in conjunction with a calculated spotting distance to understand the effect of torching and spotting on the forward spread of the fire.

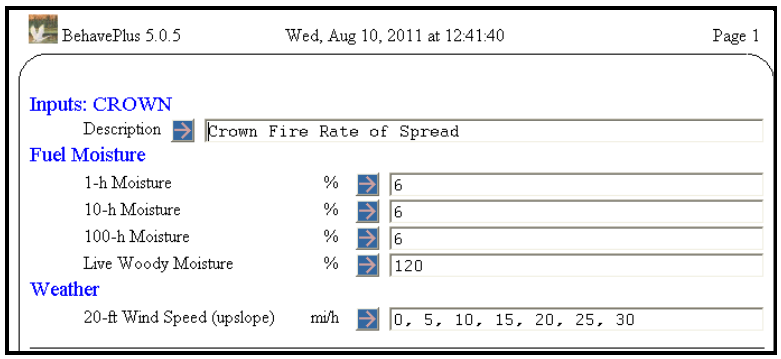
Crown ROS is calculated using a simple correlation developed by Rothermel (1991) using the surface fire spread model (Rothermel 1972) to integrate moisture and wind conditions. The surface fuel model and surface fire behavior are not a consideration. Notice that a description of the crown fuel is not an input.

Rothermel's (1991) Crown ROS was designed to predict the spread of a crown fire over a long (several hour) time period and over long distances with variable fuel and slope conditions. Think about how fuel and terrain change over this temporal and spatial range.

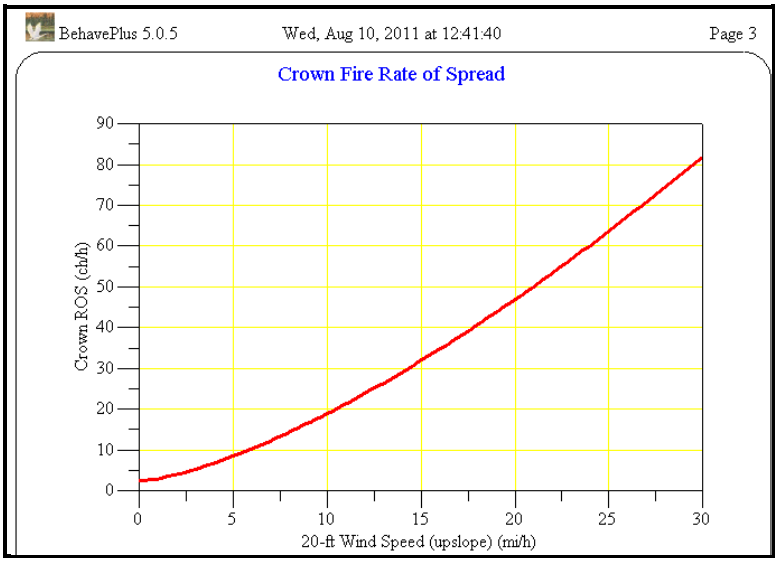


Rothermel's (1991) Crown ROS includes the effects of spotting. FARSITE and FlamMap users take note – although these tools also use Rothermel's (1991) crown fire ROS model, the spread rate is reduced in an attempt to remove the specific modeling of spotting, since spotting is calculated separately in FARSITE and FlamMap. BehavePlus outputs should not be used to calibrate FARSITE/FlamMap crown fire rates of spread.

- Open a new **SurfaceCrown.bpw** Worksheet.
- Go to **Module Selection** and clear the **SURFACE Module** check box.
- Open the **CROWN > Options… > Spread Outputs** tab and select only the **Crown ROS** check box. Clear all other check boxes.
- Return to the Worksheet and enter the following values.

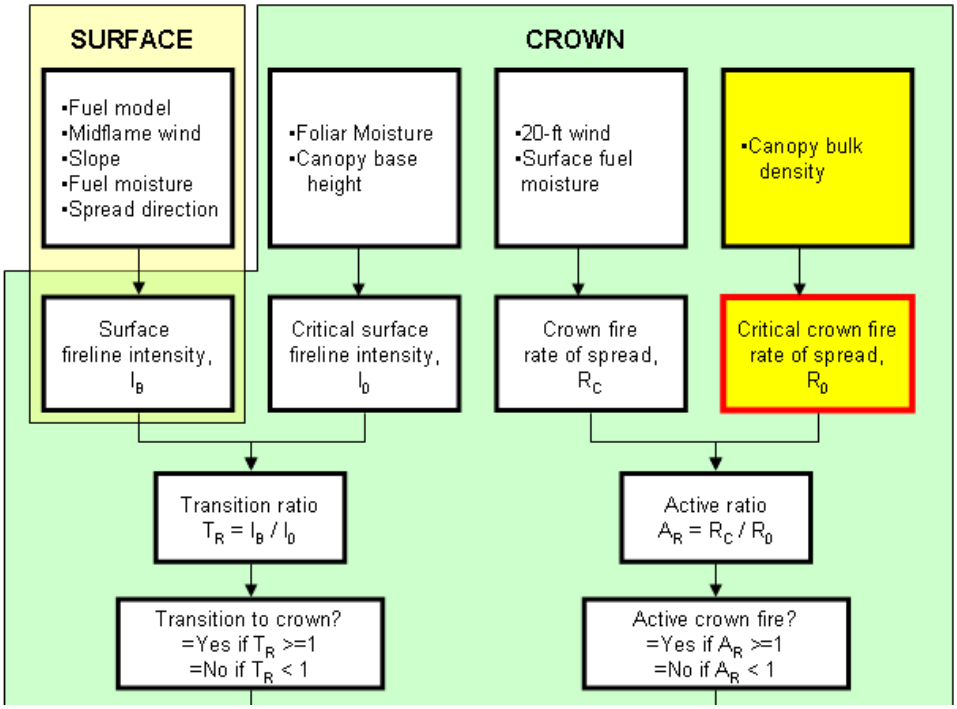


- **Calculate** the Run to get a graph of Crown Fire ROS:



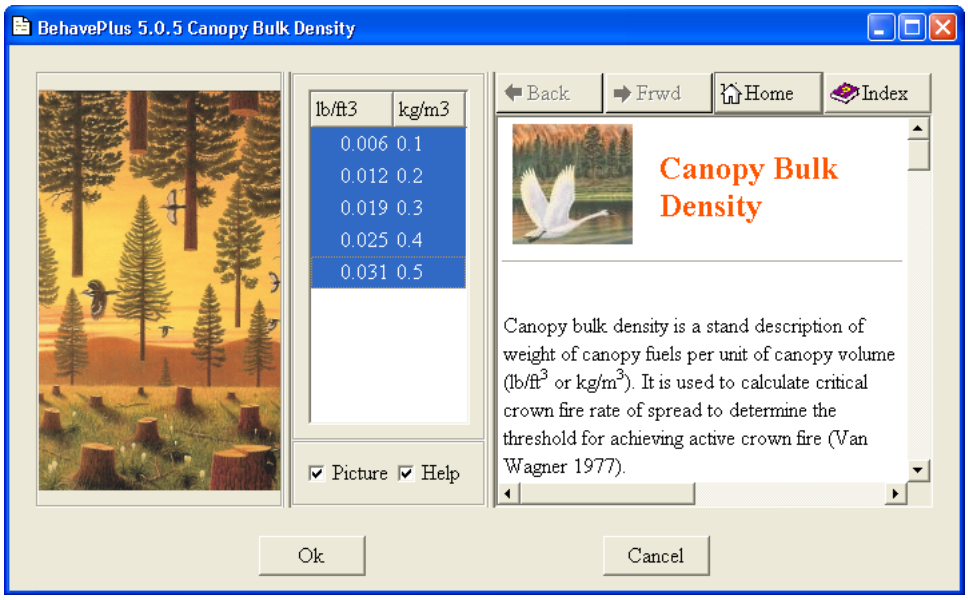
Critical Crown Fire Rate of Spread

The Critical Crown Fire Rate of Spread (ROS) is the rate at which a crown fire must spread to maintain itself as an active crown fire (Van Wagner 1977). It is calculated using only Canopy Bulk Density.



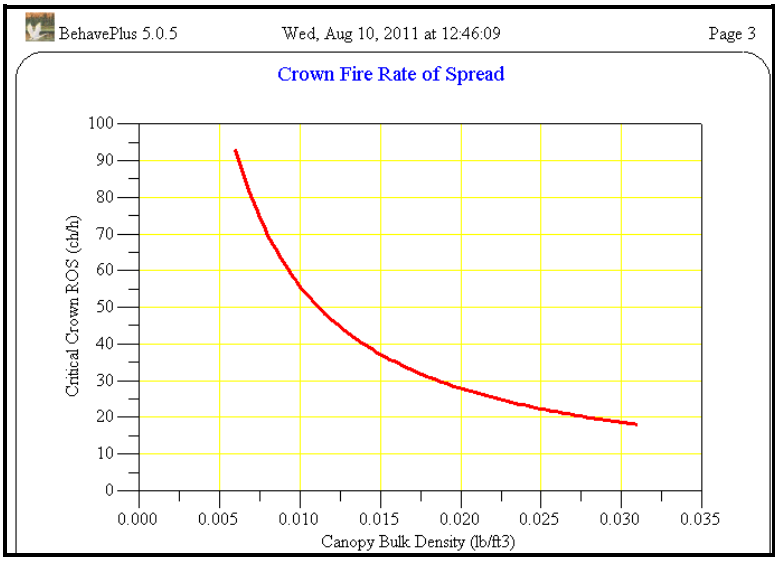
For the next exercise, you can either modify your previous Crown Fire ROS Worksheet or load a new **SurfaceCrown.bpw** example Worksheet.

- Select the **Configure > Module Selection** command and make sure the **SURFACE Module** check box is cleared in the **Module Selection** dialog box.
- Open the **CROWN > Options… > Spread Outputs** tab and select the **Critical Crown ROS** check box and clear all other check boxes.
- Return to the Worksheet, press the **Guide** Button for Canopy Bulk Density, click on the **Choices** button and select all values.
    - Note: Remember, you only need to click on a value to select it. Click again to deselect it.



The Worksheet should look like the following.

- **Calculate** the Run and look at the graph.

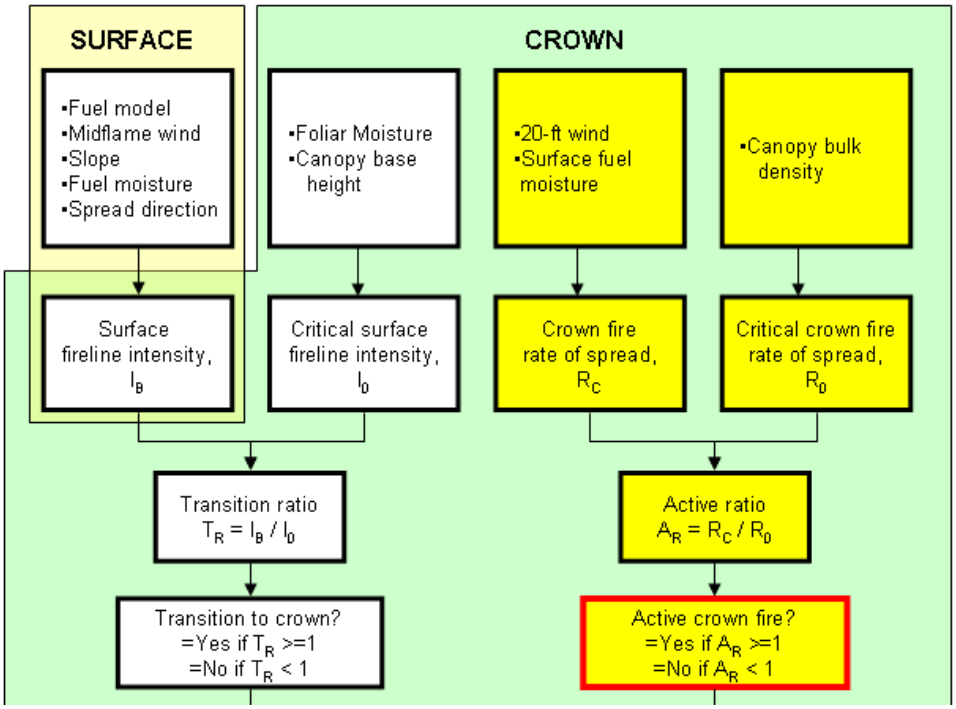


As the Canopy Bulk Density (CBD) increases, the Crown Fire ROS necessary to maintain an active crown fire decreases. To put it another way, as more crown fuels are available, less severe fire conditions (wind and fuel moisture) are needed to sustain an active crown fire. This concept will be more obvious as you gain understanding of the Active Ratio discussed in the next section.

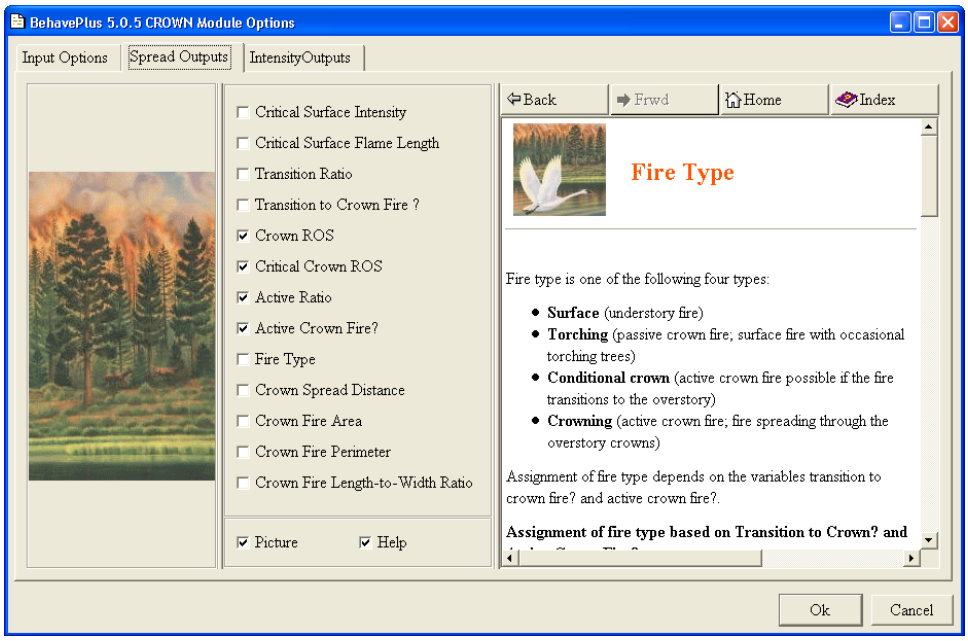
Active Ratio

The concept of the Active Ratio is similar to the Transition Ratio discussed previously. The Active Ratio determines if an active crown fire can be sustained. If not, the crown fire is considered passive (torching). The Active Ratio (A_0) is calculated from the Crown ROS (R_C) and the Critical Crown Fire ROS (R_0).

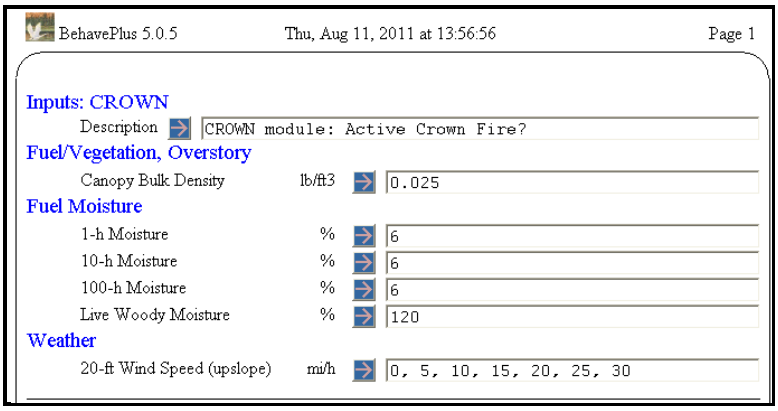
$A_0 = R_C / R_0$ Equation 2



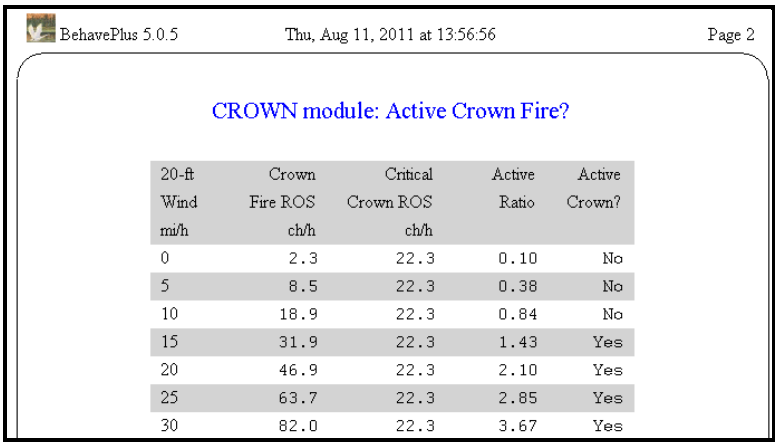
- Open the **Module Selection** window.
- Ensure the **SURFACE** module is not selected.
- On the **CROWN > Options… > Spread Outputs** tab and select the following outputs.
  - Crown ROS
  - Critical Crown ROS
  - Active Ratio
  - Active Crown Fire?



- Fill in the Worksheet using the values below.



- **Calculate** the Run and look at the output table.



20-ft Wind mi/h	Crown Fire ROS ch/h	Critical Crown ROS ch/h	Active Ratio	Active Crown?
0	2.3	22.3	0.10	No
5	8.5	22.3	0.38	No
10	18.9	22.3	0.84	No
15	31.9	22.3	1.43	Yes
20	46.9	22.3	2.10	Yes
25	63.7	22.3	2.85	Yes
30	82.0	22.3	3.67	Yes

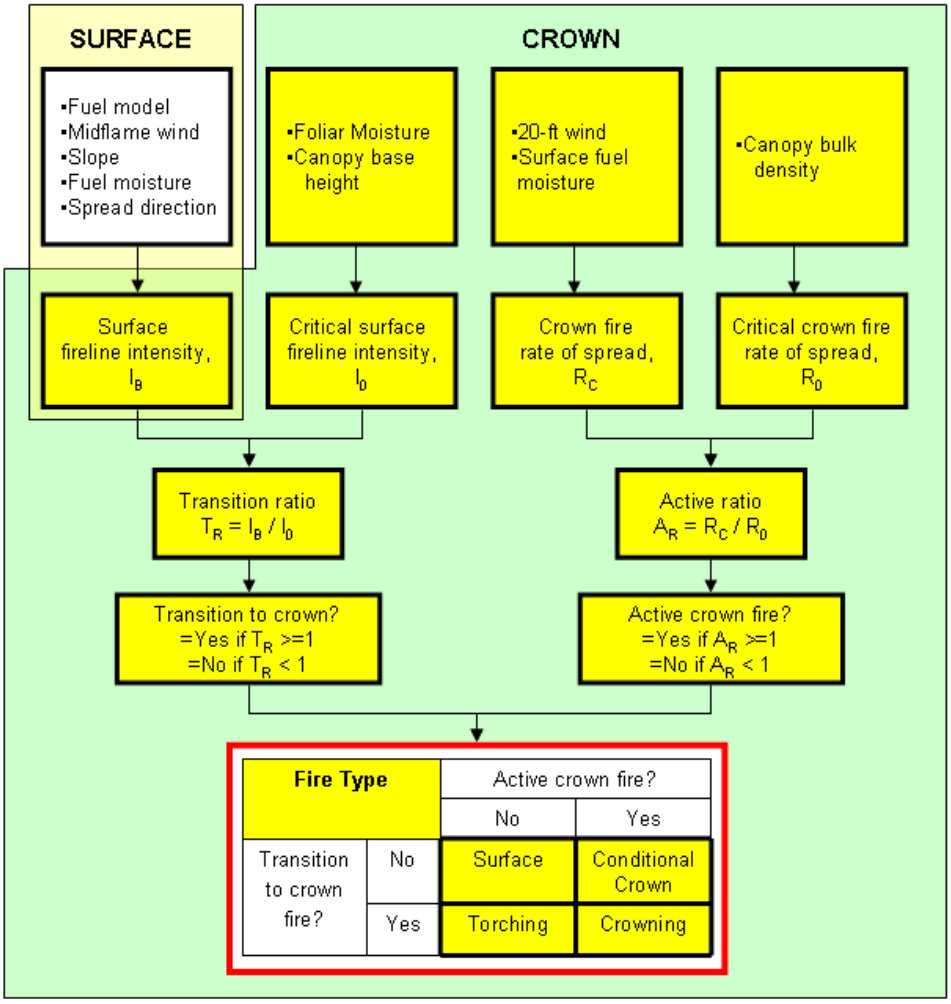
When the actual Crown ROS is greater than the Critical Crown ROS, conditions are such that an active crown fire can sustain itself. These conditions result in an Active Ratio (A_R) greater than 1.0, and the Active Crown Fire? variable is **Yes**.

Putting It All Together – Fire Type

To summarize this lesson so far, you have used the Critical Surface Fireline Intensity and the Surface Fireline Intensity to calculate the Transition Ratio (Equation 1). Transition Ratios greater than 1.0 indicate a surface fire will transition to a crown fire, either passive or active.

The Active Ratio determines which type of crown fire occurs. It is calculated from the Crown Fire ROS and the Critical Crown Fire ROS (Equation 2). Active Ratios greater than 1.0 indicate conditions are available for an active crown fire. If the Active Ratio is less than 1.0, the crown fire type is passive.

The Transition to Crown? and Active Crown Fire? variables determine the fire type. For example, if Transition to Crown? is **Yes** and the Active Crown Fire? is **No**, the Fire Type is Torching as shown in the flow chart below.

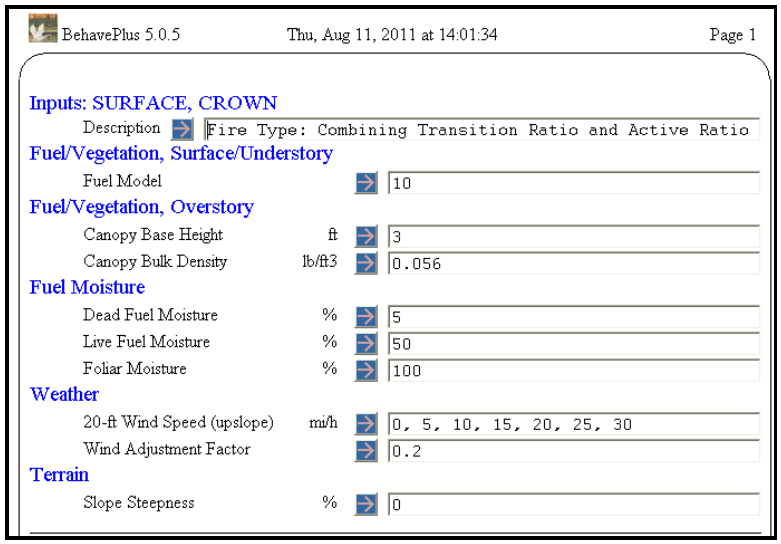


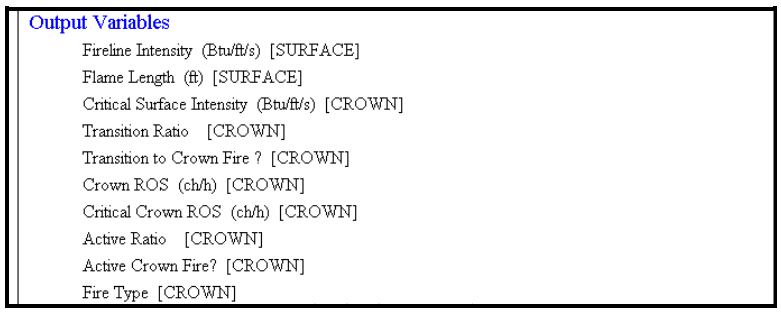
The following table shows the four possible combinations of the Active and Transition Ratios, leading to the Fire Type.

Fire Type		**Active Crown Fire? $A_R \geq 1.0$?**	
		No	**Yes**
Transition to Crown Fire? $T_R \geq 1.0$?	**No**	Surface	Conditional Crown
	Yes	Torching	Crowning

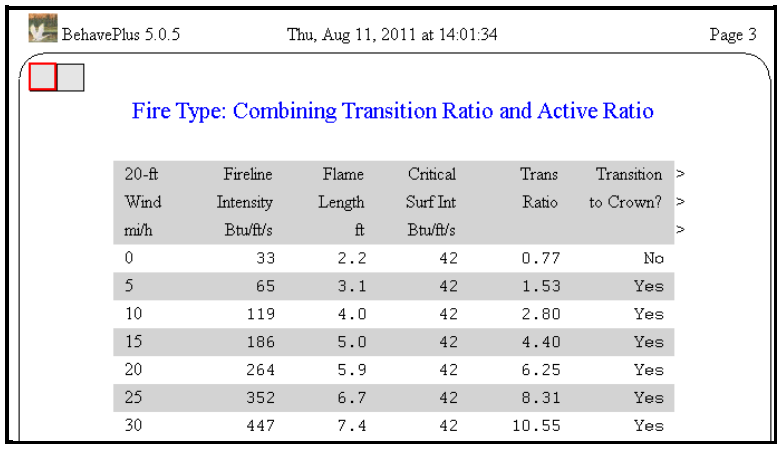
Let's do an example to put it all together.

- Set up a **SurfaceCrown.bpw** Worksheet as shown below. Both the **SURFACE** and **CROWN** modules are selected. Select the output variables shown below.
- Modify the Worksheet to use Dead and Live Fuel Moisture with the **Module Selection > SURFACE > Options… > Moisture** tab.





- **Calculate** this Run and review the following output table. Notice that it is a two page table.



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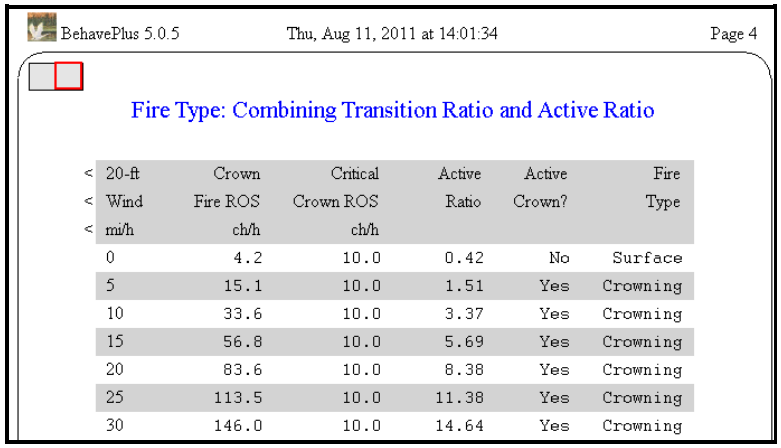
Fire Type: Combining Transition Ratio and Active Ratio

20-ft Wind mi/h	Fireline Intensity Btu/ft/s	Flame Length ft	Critical Surf Int Btu/ft/s	Trans Ratio	Transition to Crown?
0	33	2.2	42	0.77	No
5	65	3.1	42	1.53	Yes
10	119	4.0	42	2.80	Yes
15	186	5.0	42	4.40	Yes
20	264	5.9	42	6.25	Yes
25	352	6.7	42	8.31	Yes
30	447	7.4	42	10.55	Yes



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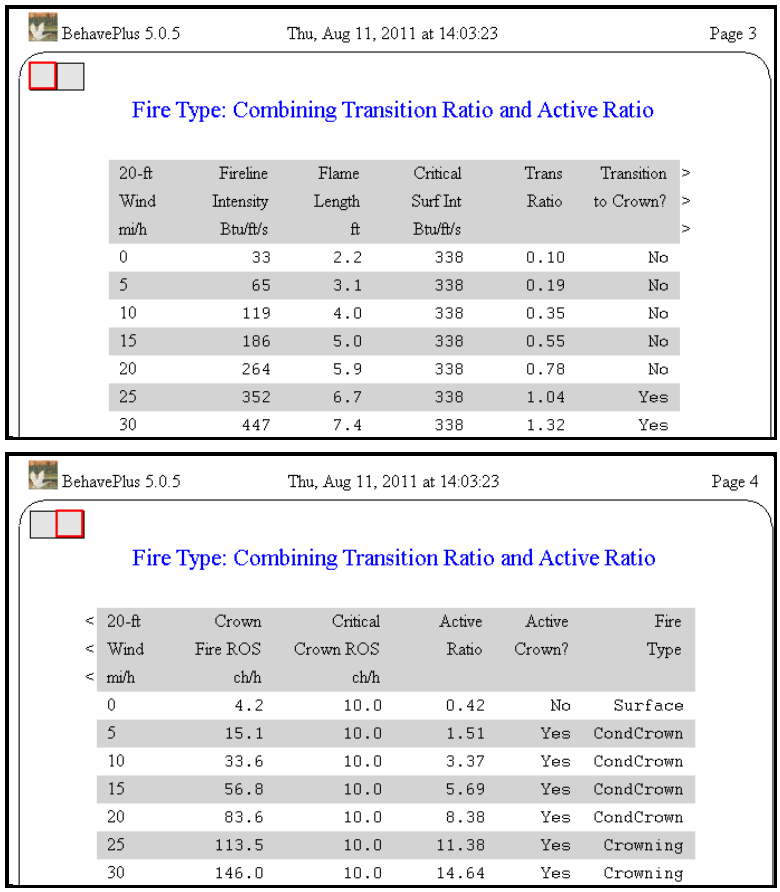
Fire Type: Combining Transition Ratio and Active Ratio

20-ft Wind mi/h	Crown Fire ROS ch/h	Critical Crown ROS ch/h	Active Ratio	Active Crown?	Fire Type
0	4.2	10.0	0.42	No	Surface
5	15.1	10.0	1.51	Yes	Crowning
10	33.6	10.0	3.37	Yes	Crowning
15	56.8	10.0	5.69	Yes	Crowning
20	83.6	10.0	8.38	Yes	Crowning
25	113.5	10.0	11.38	Yes	Crowning
30	146.0	10.0	14.64	Yes	Crowning

For 20-ft wind speed of 0 mi/h, the surface fire Fireline Intensity is too small for the fire to transition to crown. In addition, conditions do not indicate active crown fire, so the fire type is **Surface**.

For wind 5 mi/h and above, Transition to Crown? is **Yes** and Active Crown? is **Yes**. So the fire type is **Crowning**.

- Now change the **Canopy Base Height** from 3 ft to 12 ft on the Worksheet.
- **Calculate** the Run and review the resulting table.



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Fire Type: Combining Transition Ratio and Active Ratio

20-ft Wind mi/h	Fireline Intensity Btu/ft/s	Flame Length ft	Critical Surf Int Btu/ft/s	Trans Ratio	Transition to Crown?
0	33	2.2	338	0.10	No
5	65	3.1	338	0.19	No
10	119	4.0	338	0.35	No
15	186	5.0	338	0.55	No
20	264	5.9	338	0.78	No
25	352	6.7	338	1.04	Yes
30	447	7.4	338	1.32	Yes

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Fire Type: Combining Transition Ratio and Active Ratio

20-ft Wind mi/h	Crown Fire ROS ch/h	Critical Crown ROS ch/h	Active Ratio	Active Crown?	Fire Type
0	4.2	10.0	0.42	No	Surface
5	15.1	10.0	1.51	Yes	CondCrown
10	33.6	10.0	3.37	Yes	CondCrown
15	56.8	10.0	5.69	Yes	CondCrown
20	83.6	10.0	8.38	Yes	CondCrown
25	113.5	10.0	11.38	Yes	Crowning
30	146.0	10.0	14.64	Yes	Crowning

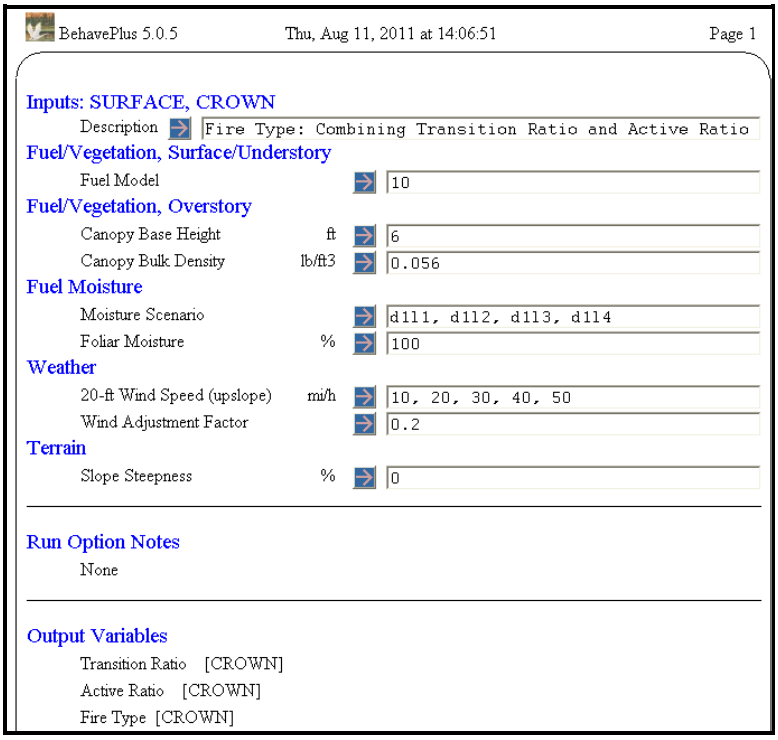
Looking at the output table shows that raising the CBH makes it more difficult for the fire to transition to a crown fire. Transition to Crown? is not **Yes** until wind speed is 25 mi/h.

For 20-ft wind speed of 5 to 20 mi/h, Transition to crown? is **No**, but Active Crown? is **Yes**. The Fire Type is **Conditional Crown** to indicate that if the fire does find a way to transition to the crowns, that an active crown fire is possible.

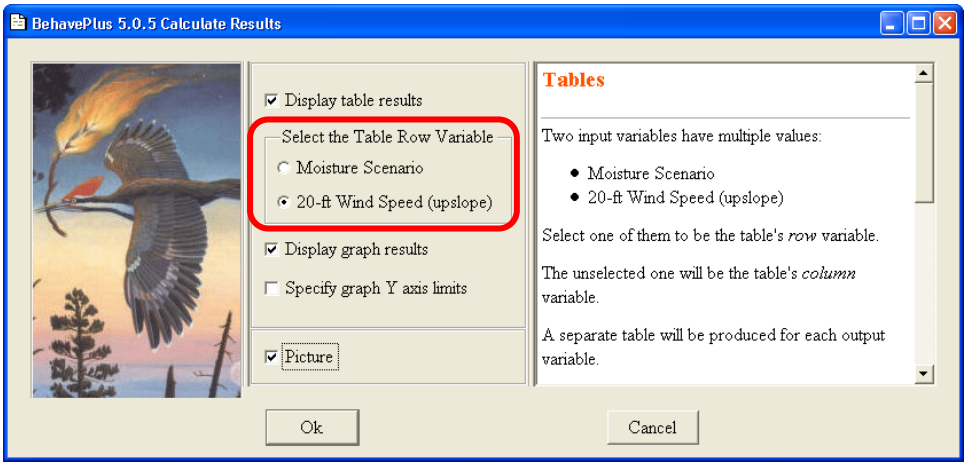
At this point, let's create some runs with the surface and overstory fuels held constant, and look at the change in fire type as a function of wind and fuel moisture.

- Modify the Worksheet to use moisture scenarios with the **Module Selection > SURFACE > Options… > Moisture** tab.
- Select only these three output variables:
  - Transition Ratio,
  - Active Ratio, and
  - Fire Type.

- Enter values on the Worksheet as shown below.



- **Calculate** the Run.
- Change the **Table Row Variable** to **20-ft Wind Speed (upslope)** in the **Calculate Results** dialog box.



- Click **Ok** and review the **Fire Type** table.

Two of the four fire types are possible for these fuels depending on the wind speed and fuel moistures.

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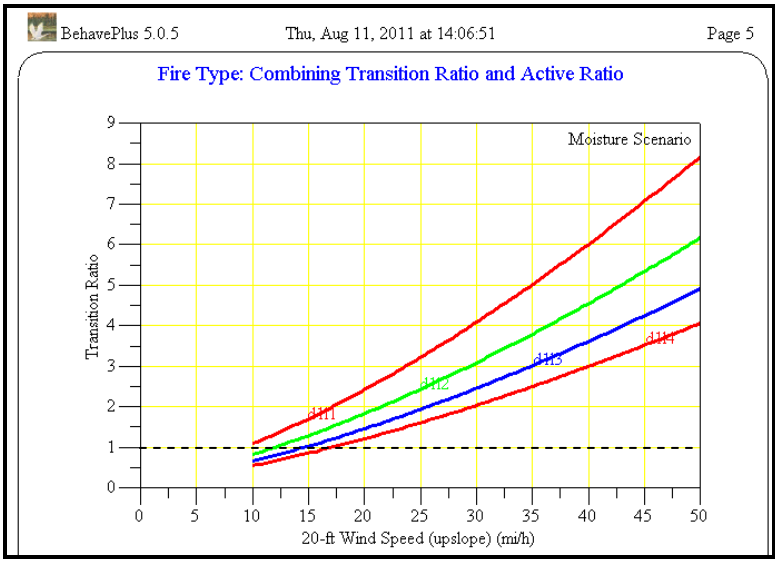
Fire Type: Combining Transition Ratio and Active Ratio

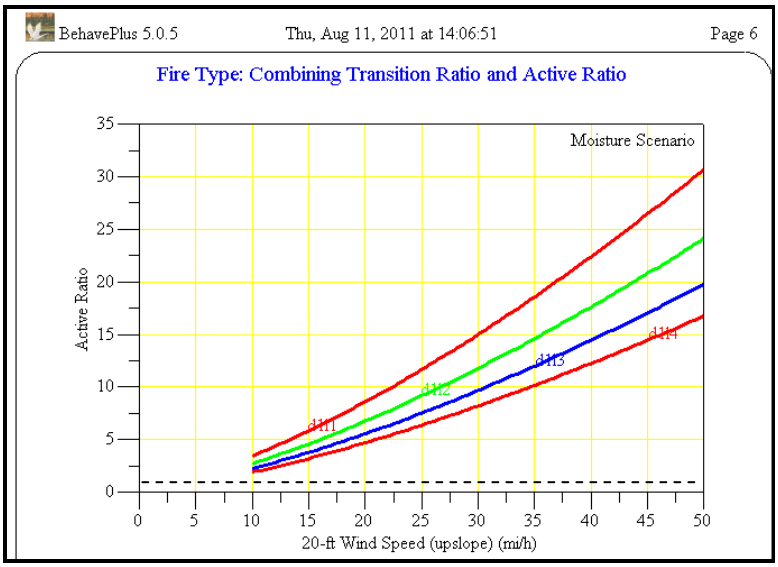
Fire Type

20-ft Wind	Moisture Scenario			
mi/h	d111	d112	d113	d114
10	Crowning	CondCrown	CondCrown	CondCrown
20	Crowning	Crowning	Crowning	Crowning
30	Crowning	Crowning	Crowning	Crowning
40	Crowning	Crowning	Crowning	Crowning
50	Crowning	Crowning	Crowning	Crowning

As you can see, the Fire Type also changes as the Moisture Scenario changes. Review the differences in the Moisture Scenarios. How will that affects the Fire Type?

Look also at the graphs of the Transition Ratio and Active Ratio. Again notice the wide range of the two ratios, remember a ratio of 1.0 is where the fire type changes.





In this lesson, we used a sample Worksheet that you may wish to use with SURFACE and CROWN (**SurfaceCrown.bpw**). If you prefer to use something else, design your own Worksheet and save it for later use.

Summary

Hopefully this lesson has given you the ability to utilize the BehavePlus CROWN module for rate of spread and fire type and to critically review the results you obtain from it.

It is important to note that results from BehavePlus crown fire modeling should be used with extreme caution in any type of operational setting. The many assumptions and limitations of the underlying models can be found in Rothermel (1991). In addition, there are no standard methods for measuring the major crown fuel properties of Canopy Bulk Density and Canopy Base Height. Average values likely do not describe the conditions that determine crown fire behavior. Estimates of CBD from field data computed in FFE-FVS, FuelCalc, and Fire Management Analyst (FMAplus) will give an estimate of CBD that is too low to produce reasonable crown fire behavior; these estimates may need to be adjusted.

References

Byram, G. 1959. Combustion of forest fuels. *In* Forest fire control and use. Kenneth P. Davis, ed. McGraw-Hill Book Co., New York. p 90.

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Rothermel, R. C. 1991. Predicting behavior and size of crown fires in the northern Rocky Mountains. Res. Pap. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 46 p.

Scott, J. H.; Reinhardt, E. D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

Thomas, P. H. 1963. The size of flames from natural fires. *In* Proceedings, 9th International Symposium on Combustion; 1962; Ithaca, NY: Academic Press: 844-859.

Van Wagner, C. E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7:23-34.

Van Wagner, C. E. 1993. Prediction of crown fire behavior in two stands of jack pine. Canadian Journal of Forest Research. 23: 442-449.

Exercises

1. Compare the fire types using fuel models TU1, TU3, TU5, 8 and 10 for a range of 1-h dead fuel moistures. Use a canopy bulk density of 0.015 lb/ft3 and a canopy base height of 6 ft. Use your experience to estimate the other inputs.

2. Modify the Run in Exercise 1 to compare the fire types using fuel models TU1, TU3, TU5, 8 and 10 for a range of wind speeds while holding the fuel moistures constant.

3. Modify the Run in Exercise 2 to determine at which wind speed the Fire Type changes for Fuel Model 10 under these conditions. Remove all fuel models except Fuel Model 10 and use a range of wind speeds based on your results from Exercise 2. This will provide more information on the influence of wind speed on Fire Type for this Fuel Model.