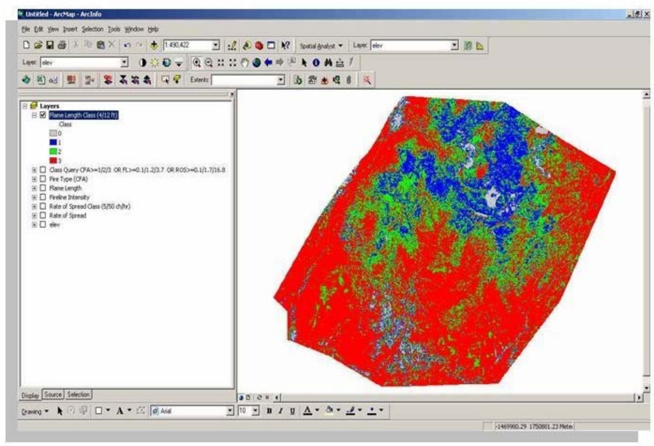


Fire Behavior Assessment Tool User's Guide

Version 1.3.0

for ArcMap 9.2

June 2, 2008

National Interagency
Fuels Coordination Group

Preface

The Fire Behavior Assessment Tool (FBAT) provides an interface between ArcMap and FlamMap3 (Finney and others 2006), a fire behavior mapping and analysis program that computes potential fire behavior characteristics (flame length, rate of spread, fire type or crown fire activity (CFA), and fireline intensity) at a pixel level (see Appendix B). In summary, FBAT runs FlamMap in the background from an ArcMap platform while producing many of the same fire behavior characteristics that are output by FlamMap (such as flame length, fire line intensity, rate of spread, and fire type). FBAT also includes several additional functions that are not currently available in FlamMap (explained later in this document).

A primary objective behind the creation of FBAT was to develop a tool that would assist managers in prioritizing fuel treatments on the basis of fire behavior and in assessing the effectiveness of fuel treatment proposals. FBAT can also be used to support the analysis of prescribed and wildland fires and to calibrate fuel input layers for more complex FlamMap or FARSITE (Finney 1998) applications.

We chose to link ArcMap with FlamMap because FlamMap predicts fire behavior characteristics across an entire assessment area, whereas FARSITE estimates fire behavior characteristics for only those areas within the simulated fire perimeter. FBAT uses an ArcGRID format and consequently there is no longer any need to convert files back and forth between ASCII and ArcGRID formats as required by FlamMap.

We assumed that most fire behavior issues could be adequately addressed by working with predictions of potential flame length, rate of spread, fire type, and fireline intensity. Thus, by default, FBAT outputs these four fire behavior characteristics as individual layers. In addition, FBAT has two options that allow the user to query specific fire behavior conditions that may occur within an analysis area based on user-defined thresholds of potential flame length, rate of spread, and fire type. That is, FBAT can be used to integrate flame length, rate of spread, and fire type into a single metric that is based on user-defined queries.

Certain photos courtesy of Fire Management Today

FBAT is a planning tool that can be used to help:

- Identify the location of hazardous fuels
- Prioritize, design, and evaluate fuel treatment projects
- Develop burn plans for prescribed fire
- Infer fire effects
- Assess appropriate management response to wildland fire
- Develop suppression strategies and tactics for wildland fire
- Calibrate fuel data layers based upon observed fire behavior

FBAT outputs can be used to help identify the location of hazardous fuels within an analysis area and to prioritize, design, and evaluate the effectiveness of proposed fuel treatments in altering fire behavior. For example, the tool can help answer the question "Where on a landscape is potential fire behavior likely to be most problematic in regards to specific land management objectives?" And after a fuel treatment prescription is developed, FBAT can be used to address the question "Will the fuel treatment prescriptions actually achieve the desired fire behavior characteristics?"

FBAT outputs – such as maps showing potential fire behavior characteristics under different weather conditions and fuel moisture scenarios – can also be used to develop burn plans for prescribed fires. For example, the tool can help answer the question "What wind and fuel moisture conditions will result in controllable fire behavior characteristics?" Moreover, fire behavior characteristics, such as flame length, fireline intensity, rate of spread, and fire type, can be used to infer potential first-order fire effects. For example, flame length can be used to estimate scorch height.

FBAT can also be used to assess the appropriate management response to wildland fire. Response to wildland fire depends on land management objectives and on whether a fire can be managed within a defined boundary with no adverse outcomes to life or property. FBAT output maps showing potential fire behavior characteristics and inferences to potential fire effects can be used to support these decisions. FBAT output maps showing potential fire behavior characteristics can also be used to help develop suppression strategies. For example, fire managers can use FBAT outputs to prioritize suppression resources based on potential spread rates, natural barriers to fire spread, and the location of potential burnout areas.

Lastly, one of the most powerful applications of FBAT is that the fire behavior outputs can be used to calibrate fuel input layers used in FARSITE, FlamMap, and FBAT. Fuel layers are commonly developed using vegetation characteristics as correlates; however, vegetation attributes alone can be poor predictors of the fuel complex. FBAT outputs may suggest that a certain fire behavior characteristic is difficult to simulate on a given landscape even though that characteristic has frequently been observed during actual fire events, indicating problems with one or more of the fuel input layers. For example, the lack of simulated passive crown fire may indicate a problem with the fire behavior fuel model, canopy base height, and/or canopy cover layers. Fuel layers can then be refined or calibrated until the appropriate fire behavior is simulated by FBAT. This version of FBAT (version 1.3.0) was released in March 2008. Future versions may incorporate additional features, so be sure to check the NIFTT website (www.niftt.gov) for possible tool updates and enhancements as well as associated updates to this user's guide.

What's new in version 1.3.0?

A beta version of the Fire Behavior Assessment Tool (FBAT) was released for review and testing in 2005. All known bugs were fixed and many of the ideas suggested by users were incorporated into FBAT version 1.2.0 which is compatible with ArcGIS 9.0 and 9.1. Notable changes incorporated into the November, 2007 release of version 1.2.0 include:

- Incorporated FlamMap3 executable
- Deleted Absolute fire behavior metric from outputs
- Deleted Relative fire behavior metric from outputs
- Added Scott and Reinhardt (2001) method for calculating the transition between passive and active crown fire
- Added canopy foliar moisture content as an input parameter
- Added Scott's wildland fire intensity metric (see Appendix C)
- Added a text file that documents run parameters
- Omitted need for ASCII grids for the creation of the landscape (LCP) file

A beta version of FBAT version 1.3.0 was released for testing in March, 2008. This version has been updated to operate with ArcGIS 9.2. Important additional changes to version 1.3.0 include:

- Updated for compatibility with ArcGIS 9.2
- Improvements to User Interface
- Spotting distance is now generated automatically as an output

Prerequisites

FBAT serves as an interface between ArcMap and FlamMap, so users should be familiar with both of these software tools. More importantly, users should have at least a basic understanding of fire behavior, including knowledge pertaining to fuels (such as fire behavior fuel models), weather (such as wind and fuel moisture), topography, and wildfire situations. Moreover, users should also understand the relationships between disturbance, vegetation attributes, and fuel characteristics. This understanding should be accompanied by an ability to use a non-spatial fire behavior prediction system such as BehavePlus or NEXUS. FBAT users should be capable of using fire behavior programs to directly analyze the effects of various input changes on outputs. Only those with the proper fire behavior training and experience should use FBAT whenever the outputs are to be used in fire and land management decisions.

FBAT version 1.3.0 requires ArcGIS 9.2 and certain computer hardware for operation. Specific computer requirements are described in detail in Chapter 1 of this guide. FBAT has not yet been tested with the Microsoft Vista operating system.

Obtaining copies

To obtain additional copies of this FBAT User's Guide or to obtain the FBAT Tutorial, follow these steps:

1. Go to www.niftt.gov
2. Under *NIFTT Quick Links* at the left side of the page, click on **NIFTT Tools and User Documents**.
3. At the center of the page under *NIFTT Tools and User Documents*, click on **NIFTT User Documents**.
4. Click on the material you wish to download (User's Guide or Tutorial).

Obtain the FBAT Help Utility, Installation Notes, or the latest version of FBAT, as follows:

1. Go to www.niftt.gov
2. Under *NIFTT Quick Links* at the left side of the page, click on **NIFTT Tools and User Documents**.
3. At the center of the page under *NIFTT Tools and User Documents*, click on **NIFTT Tools**.
4. Click on the material you would like to download (Help Utility, Installation Notes, or the latest version of FBAT).

Credits

FBAT was developed for the National Interagency Fuels Technology Team (NIFTT) by Dale Hamilton (NIFTT member) of Systems for Environmental Management (SEM), Missoula, Montana. Technical guidance was provided by Mark Finney, Jeff Jones, and Wendel Hann of the USDA Forest Service.

Support for the development of FBAT was provided by the National Interagency Fuels Coordination Group through NIFTT. Funding was provided by the U.S. Department of Agriculture Forest Service and the U.S. Department of Interior.

This Fire Behavior Assessment Tool User's Guide was written by NIFTT members Jeff Jones of the USDA Forest Service and Deb Tirmenstein of Systems for Environmental Management.

Lastly, we thank NIFTT member Christine Frame of Systems for Environmental Management for her editorial proficiency.

Your input

We value your input. Please forward any questions, comments, reports of bugs, or ideas to the National Interagency Fuels Technology Team (NIFTT) at helpdesk@niftt.gov.

Table of Contents

Chapter 1: About the FBAT User's Guide

1.1 Before you begin

This user's guide describes the basic operation of FBAT, which serves as an interface between ArcMap and FlamMap. Because we assume that FBAT users have experience operating and understanding the ArcMap and FlamMap applications (as well as ArcGIS and Microsoft Windows in general), this user's guide will not repeat specific instructions for using these tools. Instead, we encourage users to refer to the help functions available within ArcGIS and FlamMap should questions arise.

1.2 How to use this guide

You need not read the entire guide to carry out a specific task. Once you are familiar with the basic concepts associated with FBAT, you can quickly locate commonly performed tasks by reviewing the headings in the Table of Contents. Whenever possible, screen captures are used to illustrate the steps required to complete a task.

The FBAT User's Guide is not intended to provide step-by-step guidance on the tool's operation; rather, it is intended to serve as a reference guide. The FBAT Tutorial provides basic step-by-step instructions with specific examples.

1.3 Computer requirements

Ensure the following programs are installed and functioning properly on your computer:

- ArcGIS 9.2
- Spatial Analyst extension of ArcGIS 9.2
- Microsoft Excel (2000 or higher)
- Microsoft Access (2000 or higher)

Although system requirements to run ArcGIS 9.2 will suffice to run NIFTT tools, at least 10 GB of free hard drive space and 2 GB of RAM are recommended. Generally, faster processors, more memory, and increased free hard drive space will improve performance. In addition, NIFTT tools were developed for Windows Operating Systems.

> ***Note****: Make sure that you have sufficient space and adequate permissions for storing FBAT outputs on your computer.*

> ***Note****: Make sure that the FBAT version you are using correctly matches the version of ArcGIS on your computer. Use FBAT version 1.3.0 only with ArcGIS 9.2. FBAT version 1.2.0 is compatible with ArcGIS 9.0 or 9.1.*

Chapter 2: FBAT Function

2.1 What does FBAT do?

FBAT provides an interface that allows FlamMap to be run from the ArcMap platform. Accordingly, many (but not all) of the input and output options available with FlamMap are also available with FBAT. Key limitations pertaining to input options are as follows: 1) the current version of FBAT cannot utilize wind grids or fuel moisture conditioning; 2) in respect to fire behavior outputs, FBAT does not derive heat per unit area, horizontal movement rate, mid-flame wind speed, or spread vectors; and 3) FBAT does not incorporate the Minimum Travel Time (MTT) or the Treatment Optimization Model (TOM) fire growth models that are currently available in FlamMap (see Appendix B for additional information on FlamMap).

FBAT incorporates three main processing steps. First, FBAT builds the landscape (LCP) file required to run FlamMap (or FARSITE). Next, FBAT runs FlamMap and produces layers depicting potential flame length, fireline intensity, rate of spread, fire type, and maximum spotting distance. FBAT also has an option to derive wildland fire intensity, which is the common logarithm of fireline intensity (see Appendix C). FBAT then classifies the floating point grids denoting flame length and rate of spread into three classes using a classification scheme adapted from Scott and Burgan (2005).

> ***Note**: A floating point grid is a layer with values expressed in a type of numeric field for storing real numbers with a decimal point. The decimal point can be in any position in the field and, thus, may "float" from one location to another for different values stored in the field.*

Lastly (and the primary advantage of using FBAT rather than FlamMap to assess fire behavior), FBAT contains two querying options for synthesizing flame length, rate of spread, and fire type into a single fire behavior metric. All FBAT outputs are in ArcGRID format.

2.2 Synthesizing fire behavior characteristics into a single metric

Fire and fuel managers are commonly interested in assessing the cumulative hazard associated with several characteristics of fire behavior. For instance, managers may be concerned with potential flame length, as well as with the likelihood that torching might occur (in other words, passive or active crown fire). Or, they may be concerned with flame length, rate of spread, and the likelihood of torching. FBAT contains two different options for assessing the cumulative hazard associated with flame length, rate of spread, and fire type. FBAT offers an easy means to query fire characteristics predicted by FlamMap, allowing managers to customize their analyses to address fire behavior issues specific to their assessment areas.

> ***Note**: Fireline intensity was not included as a characteristic to be integrated with other fire behavior characteristics because it is directly related to flame length. As flame length increases, fireline intensity increases exponentially. Consequently, it would be redundant to include both flame length and fireline intensity. Fireline intensity is a metric for heat output in the flaming front and is useful in its own right as a measure of fire behavior and as a correlate with frontal fire effects.*

FBAT's Simple Query is a binary query in which the user defines the characteristics of interest, the thresholds of interest for each characteristic, and whether the query involves an AND or an OR conditional statement. The query is binary because only two values are contained in the output layer: those conditions meeting the conditions of the query (Value = 1) and those conditions not meeting the conditions of the query (Value = 0). For example, perhaps a manager is interested in knowing where potential flame length would exceed 8 ft (2.4 m) **or** where torching is likely to occur. Alternatively, the manager might want to know where potential flame length would exceed 8 ft (2.4 m) **and** torching is likely to occur. Both questions could be answered using the Simple Query.

On the other hand, the Classification Query classifies the entire assessment area into four categories indicating different levels of hazard (very low, low, moderate, and high). The user again identifies the characteristics of interest as well as the thresholds of each characteristic that distinguish between classes. The Classification Query also includes options for either an AND or an OR conditional statement. A manager may want to identify high hazard areas where potential flame length would exceed 12 ft (3.7 m) and the rate of spread exceeds 55 ft/min (16.8 m/min). Moderate hazard areas could be identified where flame length exceeds 4 ft (1.2 m) but is less than 12 ft (3.7 m) and the rate of spread exceeds

5.6 ft/min (1.7 m/min) but is less than 55 ft/min (16.8 m); low hazard areas could be identified where flame length exceeds .3 ft (0.1 m) and rate of spread exceeds .3 ft/min (0.1 m/min), but is less than 5.6 ft/min (1.7 m/min). All remaining areas not meeting these conditions would be classified as very low hazard.

Chapter 3: Input Data

3.1 Description of input data

The prediction of potential fire behavior requires site-specific information pertaining to fuels and topography as well as information relating to fuel moisture and the fire weather scenario of interest. In FBAT, fuel and topographic information is provided by spatial input layers. Environmental factors describing a particular fuel moisture and fire weather scenario are provided by an initial fuel moisture file and a user interface that requires specifying the 20 ft (6.1 m) wind speed, wind direction, and percent foliar moisture.

3.2 Spatial layers

Before potential fire behavior can be predicted, FBAT must first build a landscape (LCP) file that characterizes topography and fuels from eight rasters (see table 3-1) which must be in ArcGRID format.

In order to successfully build a landscape file, FBAT uses the same input theme requirements as FlamMap and FARSITE. That is, the input grids must have identical coordinate systems, spatial extents, cell resolutions, and cell alignments. However, unlike FlamMap and FARSITE, FBAT does not have flexibility in the units used to characterize each input layer. The units used in FBAT must correspond to those shown in table 3-1. These units also correspond to the units used for LANDFIRE data:

Table 3-1. Input grids.

Description	Units
Elevation	Meters
Slope[1]	Degrees
Aspect[1]	Degrees
Fire Behavior Fuel Model	Class
Canopy Cover	Percent
Canopy Height	Meters*10
Canopy Base Height	Meters* 10
Canopy Bulk Density	Kilograms/Cubic Meter * 100

[1]Slope and aspect layers are optional as they can be derived from the elevation layer.

> ***Note**: Slope and aspect layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive the slope and aspect layers from the elevation layer. However, be careful when using elevation data that contain any values other than elevation. For example, slope may be calculated inaccurately if your data contains pixels with a value of "-9999," which denotes that those pixels lack data.*

FBAT can also be executed using a landscape file that was previously created by FlamMap, FARSITE, or FBAT. However, remember that the landscape file must have been derived from input grids having the same units specified in table 3-1.

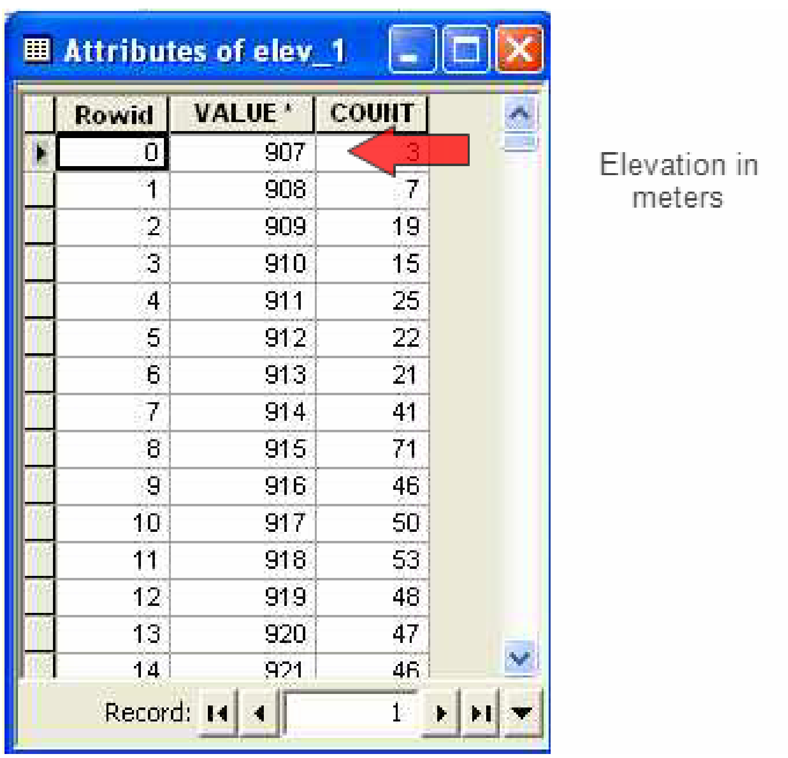
> ***Note:** FlamMap does not currently have a means for changing the units within a landscape file. Thus, users must first convert the input layers to the desired units prior to building the landscape file. Arc's "Raster Calculator" can easily be used to convert data – simply multiply the grid values by the conversion factor. In FARSITE, the user can change the units of the landscape file from English to metric by using the "Landscape Calculator" and "Editor" dialog box.*

With the exception of the layers denoting fire behavior fuel models, the ArcGRIDs used for running FBAT must be formatted so that the cell value represents the thematic value as a continuous or discrete variable. For example, the grid value of the elevation grid must denote the actual elevation in meters (see fig. 3-1). The grid value can also denote an ordered class of data in which the grid value denotes the midpoint of the class (see fig. 3-6).

The grid value of the fuel model layer must denote the actual fuel model class unless the grid value denotes a non-fuel class (such as water, rock, or agriculture). For canopy fuel, remember that the grid value corresponds to a specific unit. Therefore, a grid value of 10 in the canopy base height grid actually represents a canopy base height of 3.3 ft (1 m), whereas a grid value of 10 in the canopy bulk density grid represents a canopy bulk density of 0.01 lbs/ft^3 (0.1 kg/m^3).

3.2.1 Elevation

The elevation layer must represent meters above sea level, and zero values are used for those areas that are at or below sea level. Figure 3-1 shows the Value Attribute Table of an elevation layer. FlamMap and FARSITE use the elevation theme for the fuel conditioning utility to adjust fuel moistures using adiabatic lapse rates. The elevation layer is also used for conversion of fire spread between horizontal and slope distances. In addition, FBAT can derive slope and aspect layers from the elevation layer, if desired.

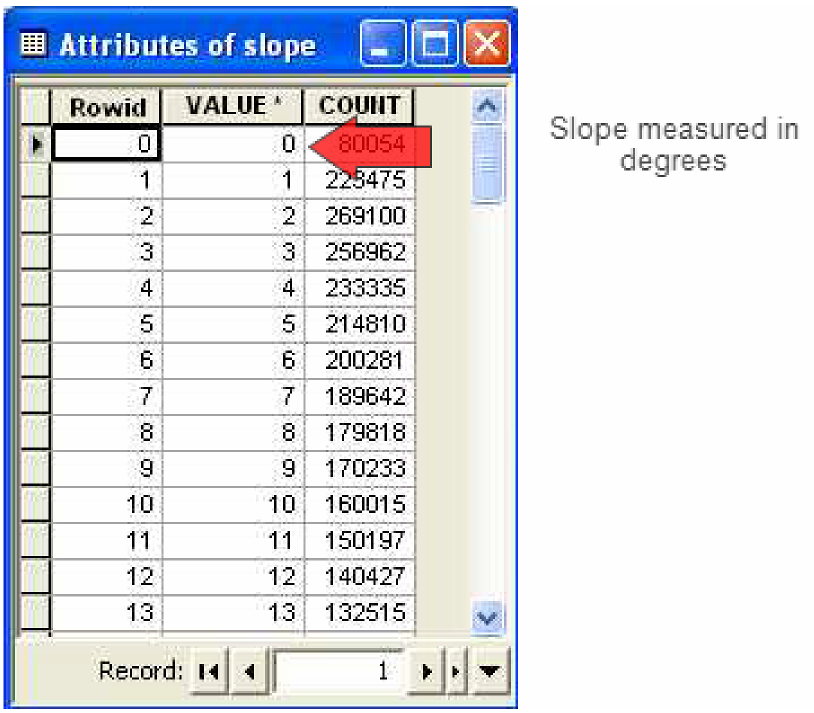


Rowid	VALUE *	COUNT
0	907	3
1	908	7
2	909	19
3	910	15
4	911	25
5	912	22
6	913	21
7	914	41
8	915	71
9	916	46
10	917	50
11	918	53
12	919	48
13	920	47
14	921	46

Figure 3-1. Example Value Attribute Table of an FBAT Elevation layer. The value field must depict elevation in meters above sea level.

3.2.2 Slope

FlamMap uses the slope layer for computing slope effects on flame length, fire spread, and solar radiance. The slope layer can have cell values represented by either floating point numbers (decimals) or integers. Figure 3-2 displays the Value Attribute Table of a slope layer. FBAT requires that slope units be given in degrees rather than in percent. FBAT will derive the slope layer from the elevation layer if it is not provided by the user.

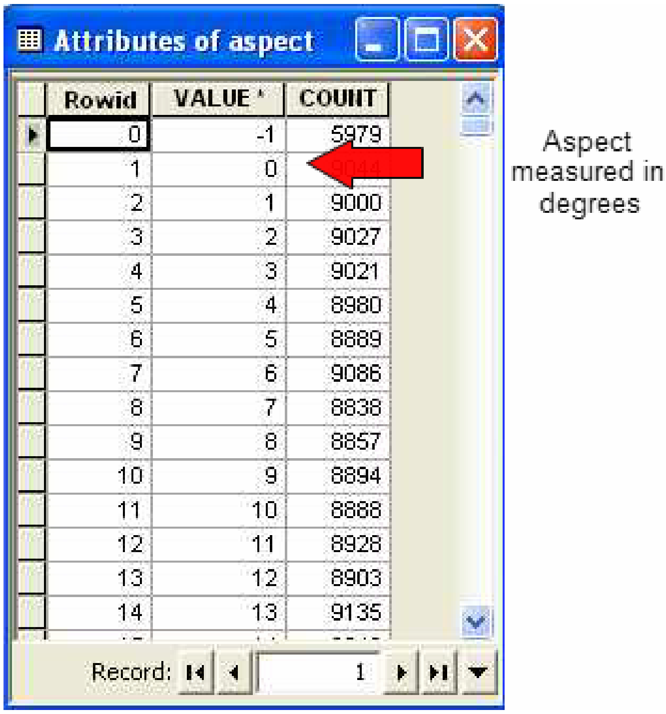

Attributes of slope

Rowid	VALUE *	COUNT
0	0	80054
1	1	223475
2	2	269100
3	3	256962
4	4	233335
5	5	214810
6	6	200281
7	7	189642
8	8	179818
9	9	170233
10	10	160015
11	11	150197
12	12	140427
13	13	132515

Figure 3-2. Example Value Attribute Table of an FBAT Slope layer. The value field must show slope in degrees.

3.2.3 Aspect

The aspect layer is used for the fuel conditioning function in FlamMap and FARSITE. (Fuel conditioning varies fuel moisture with respect to solar radiance). The FBAT aspect layer denotes slope azimuth in degrees clockwise from the north (fig. 3-3). Cell values can be represented by either floating point numbers (decimals) or integers. Flat areas which lack an aspect are given a value of -1. FBAT will derive the aspect layer from the elevation layer if it is not provided by the user.



Rowid	VALUE *	COUNT
0	-1	5979
1	0	[illegible]
2	1	9000
3	2	9027
4	3	9021
5	4	8980
6	5	8889
7	6	9086
8	7	8838
9	8	8857
10	9	8894
11	10	8888
12	11	8928
13	12	8903
14	13	9135

Figure 3-3. Example Value Attribute Table of an Aspect layer. The value field must depict aspect in degrees. (A value of -1 denotes a flat area which has no aspect).

3.2.4 Fire Behavior Fuel Model

FBAT can use either the fire behavior fuel models characterized by Anderson (1982) or those characterized by Scott and Burgan (2005). However, FBAT cannot use a fuel layer containing custom fuel models. Cells must contain integers denoting the numeric codes of Anderson's (1982) models (values: 1 to 13) or the Scott and Burgan (2005) models (values: 91 to 204) (fig. 3-4). Non-burnable fuels must be denoted by values 91, 92, 93, 98, and 99, which characterize urban/developed, snow/ice, agriculture, water, and bare ground, respectively. Additional attributes (such as a text descriptor of the model) are commonly included in the FBFM layer.

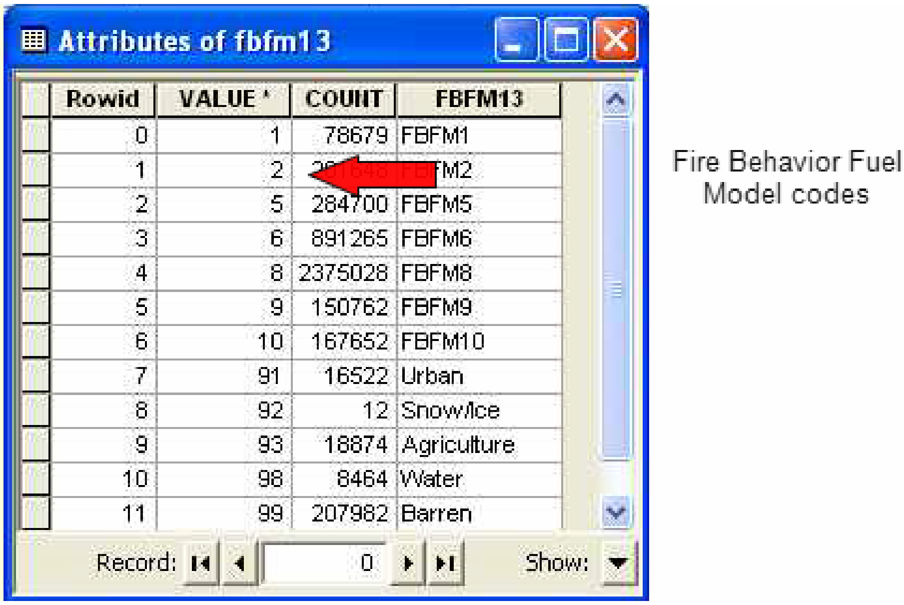
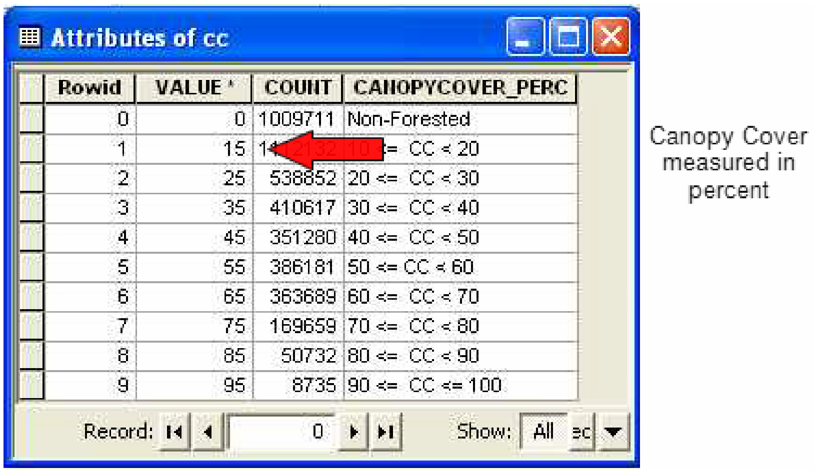


Figure 3-4. Example Value Attribute Table for a Fire Behavior Fuel Model layer (Scott and Burgan 2005). The value field must correspond to the numeric fire behavior fuel model codes of Anderson (1982) or Scott and Burgan (2005).

3.2.5 Canopy Cover

Canopy cover is a stand attribute that corresponds to the proportion of the ground that is covered directly overhead by the overstory canopy (that is, the vertical projection of the canopy to the ground). The canopy cover layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the mid-flame height. The canopy cover layer is also used to modify solar radiance with the fuel conditioning function of FlamMap and FARSITE. FBAT requires that the canopy cover layer be expressed in percent (fig. 3-5). A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers.

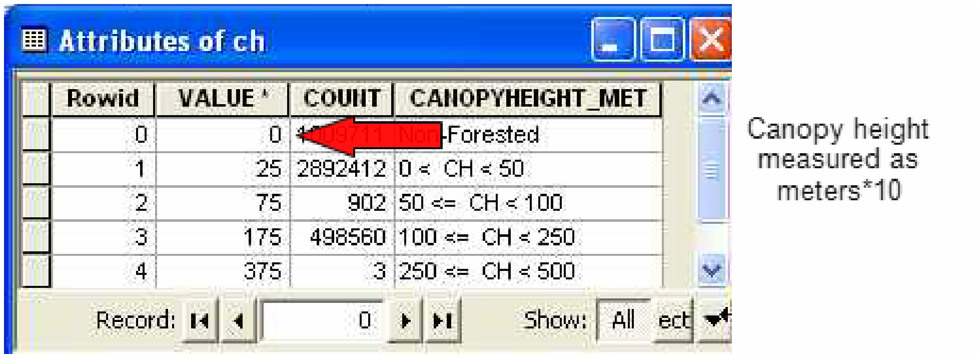


Rowid	VALUE *	COUNT	CANOPYCOVER_PERC
0	0	1009711	Non-Forested
1	15	[illegible]	[illegible]= CC < 20
2	25	538852	20 <= CC < 30
3	35	410617	30 <= CC < 40
4	45	351280	40 <= CC < 50
5	55	386181	50 <= CC < 60
6	65	363689	60 <= CC < 70
7	75	169659	70 <= CC < 80
8	85	50732	80 <= CC < 90
9	95	8735	90 <= CC <= 100

Figure 3-5. Example Value Attribute Table for an FBAT Canopy Cover layer. The value field denotes canopy cover in percent. A value of 0 indicates a non-forested setting. In this example, canopy cover has been grouped into 10 classes in which the cell value corresponds to the class mid-point. Thus, a cell value of 15 represents a canopy cover class with values ranging from 10 to 20 percent.

3.2.6 Canopy Height

Canopy height is a stand attribute that reflects the average height of the overstory dominant and co-dominant in a stand. The canopy height layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the mid-flame height. In FARSITE, the canopy height layer is also used for estimating spotting distances from torching trees. FBAT requires the canopy height layer units to be in meters*10 (fig. 3-6). A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers.

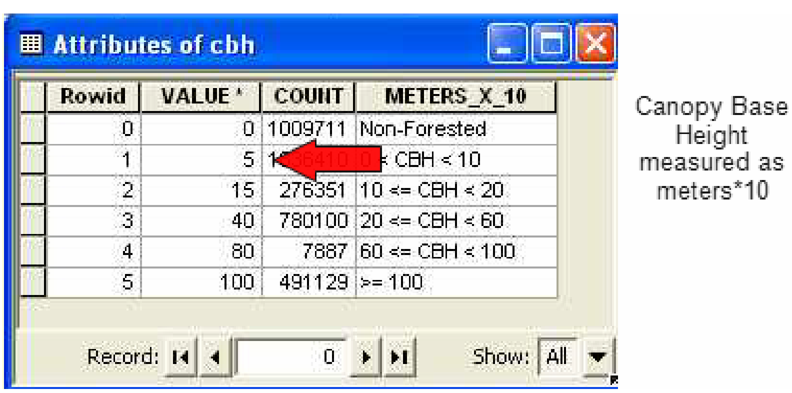


Rowid	VALUE	COUNT	CANOPYHEIGHT_MET
0	0	[illegible]	Non-Forested
1	25	2892412	0 < CH < 50
2	75	902	50 <= CH < 100
3	175	498560	100 <= CH < 250
4	375	3	250 <= CH < 500

Figure 3-6. Example Value Attribute Table for a Canopy Height layer. The value field must depict canopy heights in meters*10. In this example, the canopy heights have been grouped into five classes in which the cell value corresponds to the mid-point of the class. For example, a value of 25 relates to a canopy height class that ranges between 0 and five meters.

3.2.7 Canopy Base Height

Canopy base height is a stand attribute that denotes the lowest height above the ground above which there is sufficient canopy fuel to propagate fire vertically. The canopy base height layer is necessary for determining the transition from a surface fire to a crown fire. Typically, lower canopy base heights increase the likelihood of torching (in other words, lower heights increase the likelihood of passive crown fires). FBAT requires canopy base height layer units to be expressed in meters*10 (fig. 3-7). Non-forested settings are given a cell value of 0. Cell values can be denoted by either floating point numbers (decimals) or integers.

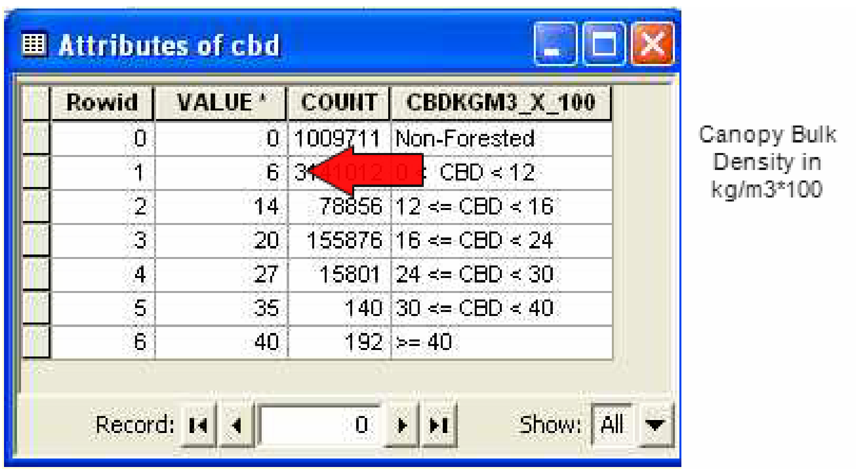


Rowid	VALUE	COUNT	METERS_X_10
0	0	1009711	Non-Forested
1	5	[illegible]	[illegible] CBH < 10
2	15	276351	10 <= CBH < 20
3	40	780100	20 <= CBH < 60
4	80	7887	60 <= CBH < 100
5	100	491129	>= 100

Figure 3-7. Example Value Attribute Table for an FBAT Canopy Base Height layer. The value field must depict heights expressed in meters*10. Thus, a cell value of 20 corresponds to a 2 meter canopy base height.

3.2.8 Canopy Bulk Density

Canopy bulk density is a stand attribute that refers to the weight (mass) of "available" canopy fuel, both dead and live, per unit volume of canopy. Available canopy fuel is of a size and type that would be consumed in the flaming front. FARSITE and FlamMap use canopy bulk density to determine the transition between passive and active crown fire. (See Scott and Reinhardt [2001] for discussion on the derivation of crown fire activity). FBAT requires the units of the canopy bulk density layer to be expressed in kg/m3 *100 (fig. 3-8). Cell values can be represented by floating point numbers (decimals) or integers.



Attributes of cbd

Rowid	VALUE *	COUNT	CBDKGM3_X_100
0	0	1009711	Non-Forested
1	6	341012	0 <= CBD < 12
2	14	78856	12 <= CBD < 16
3	20	155876	16 <= CBD < 24
4	27	15801	24 <= CBD < 30
5	35	140	30 <= CBD < 40
6	40	192	>= 40

Figure 3-8. Example Value Attribute Table for an FBAT Canopy Bulk Density layer. The value field must depict canopy bulk density in kg/m3 *100. A value of 0 identifies non-forested areas.

3.3 Fuel Moisture File

Like FlamMap, FBAT requires a text file (.fms) that specifies the initial fuel moisture values (1-hr, 10-hr, 100-hr, live herbaceous (LH), and live woody (LW) fuels) for each of the fire behavior fuel models (fig. 3-9). The most important step in selecting appropriate fuel moisture values is to describe the type of fire weather and fuel moisture scenario to be simulated. For example, simulations designed for fire use or prescribed fire applications would likely have higher fuel moistures than those used for simulating rare event large wildfires in the extremes of the wildfire season. We recommend using data provided by the Weather Information Management System (WIMS) at http://fam.nwcg.gov/fam-web/ along with FireFamily Plus software (available at http://www.fire.org) to identify appropriate fuel moisture values for specific scenarios.

Unlike FlamMap, FBAT cannot vary fuel moisture by elevation, slope, aspect, and shading. Consequently, FBAT uses the same fuel moisture values for a fuel model, regardless of where that fuel model is located in the landscape.

The fuel moisture file used by FBAT is a space-delimited text file that has an .fms extension instead of a .txt extension. A column header is not included in the file; it is therefore very important that users understand the format. There are six columns in the .fms file that denote the following: fire behavior fuel model, 1-hour (1-hr) fuel moisture, 10-hour (10-hr) fuel moisture, 100-hour (100-hr) fuel moisture, live-herbaceous fuel moisture (LH), and live-woody fuel moisture (LW), respectively (fig. 3-9). The values representing fire behavior fuel models (FBFM) correspond to the numeric codes used by Anderson (1982) or Scott and Burgan (2005). Fuel moisture values represent percent moisture and must be integers (in other words, no decimals).

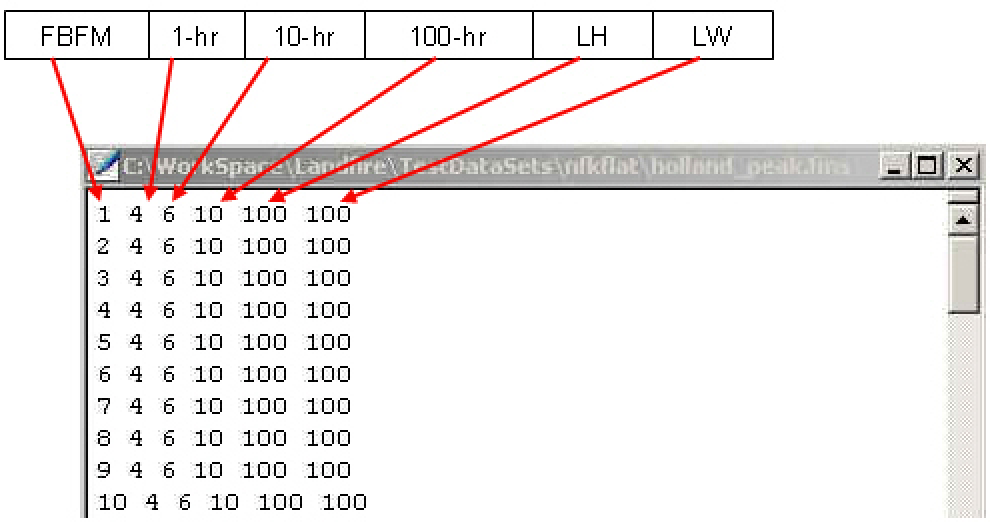


Figure 3-9. Example FBAT fuel moisture file that includes the first 10 fuel models characterized by Anderson (1982). (FBFM = fire behavior fuel model; 1-hr = 1-hr fuel moisture; 10-hr = 10-hr fuel moisture; 100-hr = 100-hr fuel moisture; LH = live herbaceous fuel moisture; LW = live woody fuel moisture).

3.4 Wind Speed

The FBAT user must input the 20 ft (6.1 m) wind speed to be used for predicting potential fire behavior. The wind speed refers to observations at 20 ft (6.1 m) above the canopy of the dominant vegetation. Thus, in grasslands, the wind speed denotes winds at 20 ft (6.1 m) above the herbaceous canopy, whereas in forests, the value represents winds 20 ft (6.1 m) above the forest canopy. Values must be given in integers expressing wind speed in miles per hour.

3.5 Wind Direction

Two options are available for entering wind direction. FBAT users may specify that the wind is blowing uphill, or they may enter an azimuth in degrees indicating the direction that the wind is blowing from. Selecting the Wind Direction Uphill option will maximize potential fire behavior for any given pixel.

3.6 Foliar Moisture

Foliar moisture represents the percent moisture contained by live leaves or needles of the overstory. Foliar moisture influences the transition between surface and crown fires. Typical foliar moisture values range from 80 to 130 percent. A value of 100 percent is frequently used for typical conditions and is used as the default value in FBAT. A value of 80 percent typically reflects the effects of cumulative drought in systems where average annual precipitation is less than 30 in (76 cm), while 100 percent would reflect those same areas having recovered from drought. A value of 130 percent would reflect moist forest systems in a normal year, whereas 100 percent may reflect moist forest systems experiencing cumulative drought.

> ***Note**: In general, short needle species appear to have lower foliar moisture than long needle species and dry faster during dry seasons.*

Chapter 4: Obtaining Input Data

4.1 Options for acquiring input data

The NIFTT tool suite utilizes LANDFIRE data layers as input. A complete description of LANDFIRE data products can be found at http://www.landfire.gov/.

LANDFIRE National layers represent vegetation composition and structure, historical fire regimes, and surface and canopy fuel characteristics. The LANDFIRE Project is scheduled to complete consistent, comprehensive maps of the entire nation, including Alaska and Hawaii by the end of 2009.

1. Navigate to http://www.landfire.gov/ and click on **Data Products**.

2. Under L*ANDFIRE National*, locate the *Data Product Access* menu listing four methods for accessing LANDFIRE data. The first two methods, the *USGS National Map* and *LANDFIRE Data Access Tool*, are the focus of these instructions. After reading about the various options, you may find the remaining options more suitable to your needs.

3. The first method describes the process for downloading data directly from the National Map LANDFIRE. The second method briefly describes use of the LANDFIRE Data Access Tool (LFDAT), which facilitates the downloading of LANDFIRE data from the National Map within the ArcGIS application ArcMap.

4.2 Downloading data directly from the National Map

1. On http://www.landfire.gov/ click on the **Link to National Map LANDFIRE** found near the bottom left side of that page.

   The National Map LANDFIRE website can also be accessed directly at http://landfire.cr.usgs.gov/viewer/.

2. When the *National Map LANDFIRE* opens, notice the legend for data availability and the links for additional support. Two links – *Data Versioning Alerts* and *Data Notifications* – provide up-to-date information on LANDFIRE data. These can also be subscribed to through RSS feeds with Internet Explorer 7.0 or higher.

3. After viewing the legend, click on the map in your geographic area of interest, according to your data needs.

4. The next web page will display a shaded relief map of the approximate geographic location that you selected in the previous step. Options for navigating the National Map are on the left side of the map and options to Display and Download data are on the right.

   Using the navigation tools on the left, zoom in and out and pan until the specific area of interest is within view. If needed, use the *Display* tab to access layers under the Places and Boundaries menus to better help locate your area of interest (fig. 4-1).

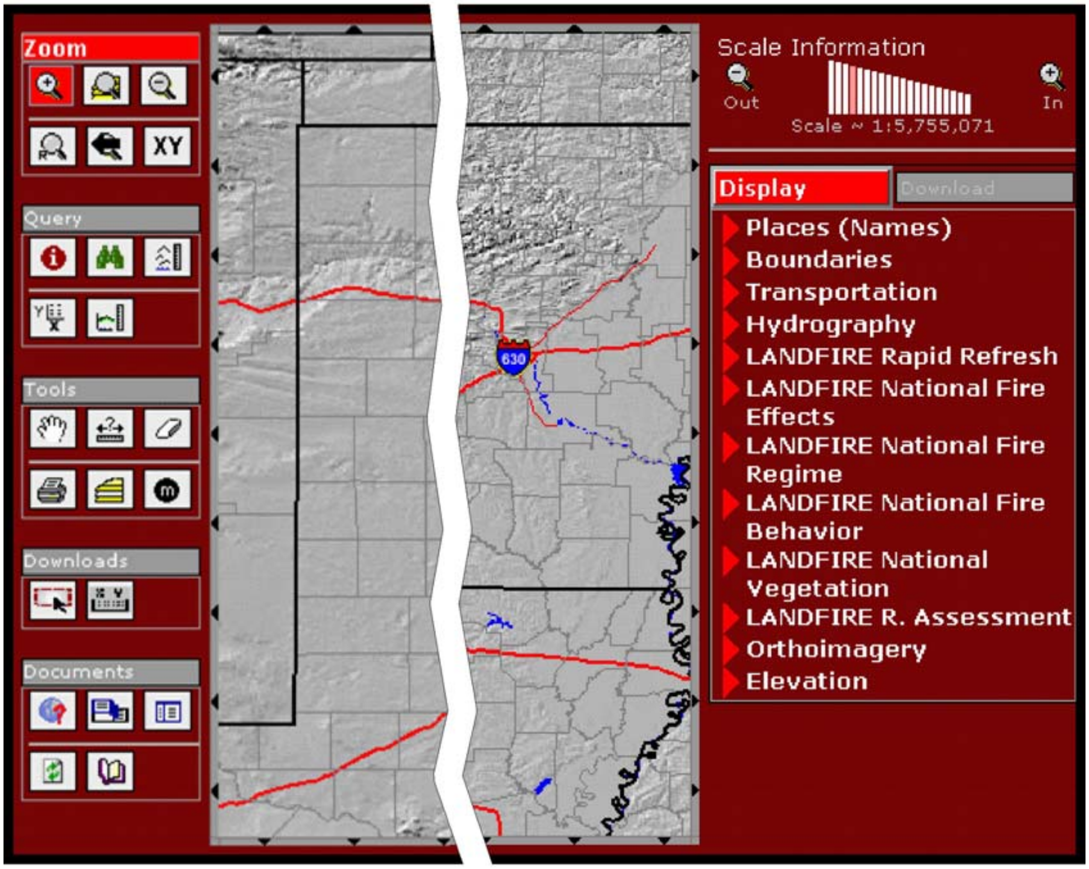


Figure 4-1. National Map LANDFIRE

5. Click on the **Download** tab to identify the LANDFIRE layers that you wish to download. Check all layers to be downloaded. Be sure to check the data input requirements for the specific NIFTT tool to ensure that you will download all necessary data layers.

6. Under the *Downloads* tools on the left-hand side of the map (fig. 4-1 to the left), click on either of the two download options: **Define Rectangular Download Area** or **Define Download Area by Coordinates**.

   If you chose the *Define Rectangular Download Area*, click and drag the mouse until you get the rectangular extent that encompasses your area of interest. Otherwise, if you chose the *Define Download Area by Coordinates* option, enter the extent coordinates in the fields provided.

7. When you have finished drawing an extent rectangle or selecting coordinates, the *Data Server Summary Request* page (fig. 4-2) will appear with a list of all layers selected for download. Notice the Modify Request, Tutorial, and Help buttons located near the top.

   The *Modify Request* allows you to select:

- additional layers for download
- the data format
- an output projection and datum
- a Landscape (LCP) file

   To return to the *Request Summary Page,* click one of the two options at the bottom of the *Modify Request* page.

   On the *Request Summary Page*, the *Tutorial* gives a thorough overview on how to use the National Map. *Help* provides additional information on modifying a data request.

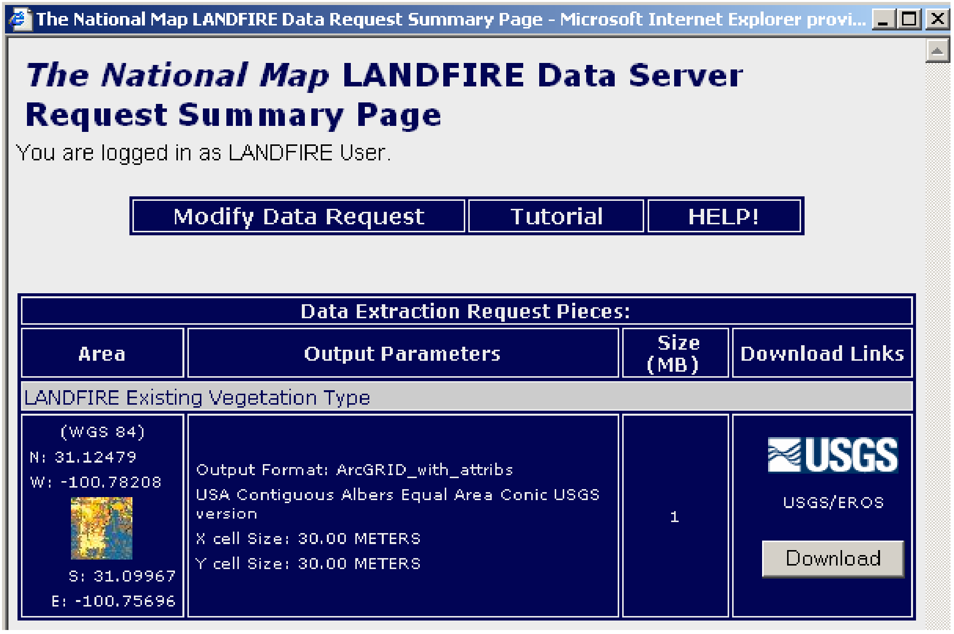


Figure 4-2. Request Summary Page.

8. Click on the **Download** button next to the first layer in your summary report and the file will download as a .zip file with a random numeric name. The .zip file will contain a grid identified by the same random number as the .zip file.

   After unzipping the file, it is recommended that you change the name of the grid in ArcCatalog to reflect the thematic nature of the layer. One way to determine the name of the grid is to open ArcCatalog and select the grid. Click on the **Metadata** tab and the name of the grid will appear in the metadata title.

9. At this point, the data should be ready for further processing as input for one of the NIFTT tools.

4.3 Downloading data using LFDAT

1. Once you are familiar with the National Map, acquiring LANDFIRE data using the LANDFIRE Data Access Tool (LFDAT) is the most efficient method and recommended if a broadband Internet connection is available. LFDAT allows a user to download and process LANDFIRE data directly within ArcMap.

2. The LFDAT can be obtained directly from www.niftt.gov under *Other Tools.* Because the following information only briefly describes the use of

the LFDAT, it is strongly recommended that the LFDAT Tutorial be taken prior to this tutorial. (The tutorial is found at the same location as the tool).

3. Open ArcMap to a new map document. From the LFDAT toolbar, click on the  button to add the LANDFIRE data availability layer to your project. Notice that the green polygons represent zones where data are available for download.

4. To begin, click the **Get LANDFIRE National Map Data** tool icon: . With the tool, click to the upper left of the area of interest and drag a box to the lower right (fig.4-3).

   Drag a box as many times as needed until you have the extent that you want. To do so, you will need to close out the *Download Data* window that appears after every extent box has been drawn.

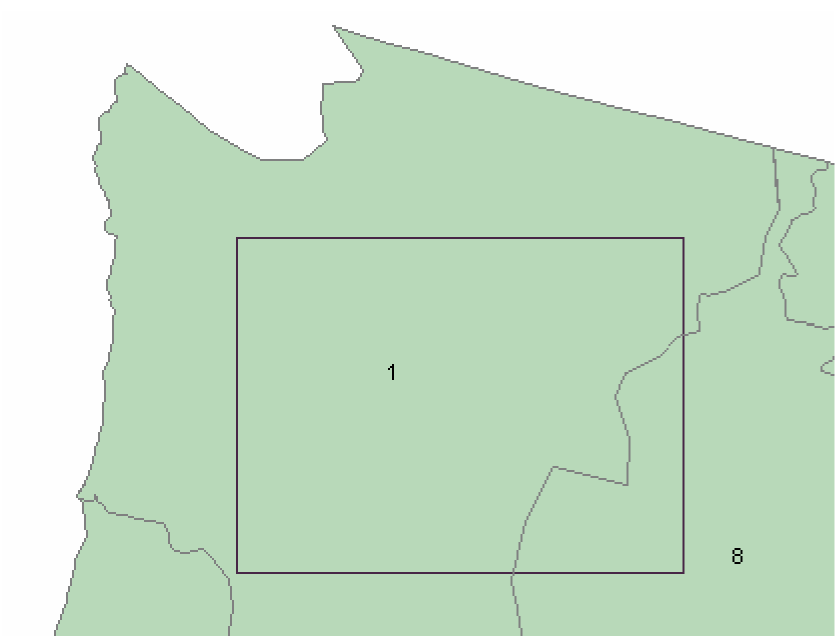


Figure 4-3. Draw extent box.

5. Once you have the extent you want, save the extent in the *Download Data* window by typing a meaningful name in the box labeled *Save this extent as*: and click the **Save** icon: . You will only need to do this once for each extent. This allows you to go back and download additional data with the same extent.

6. Click the down arrow to the left of *Request Download* and select the desired layer. For demonstration purposes, we will choose the first layer, 13 Anderson Fire Behavior Fuel Models (fig. 4-4).

If you experience difficulties downloading data from the National Map via LFDAT, click the **About LANDFIRE Data Access Tool** button on the LFDAT toolbar and check for updates. If you continue to have problems, open your Internet browser to http://landfire.cr.usgs.gov/viewer/ and click on **Having Trouble Downloading**?

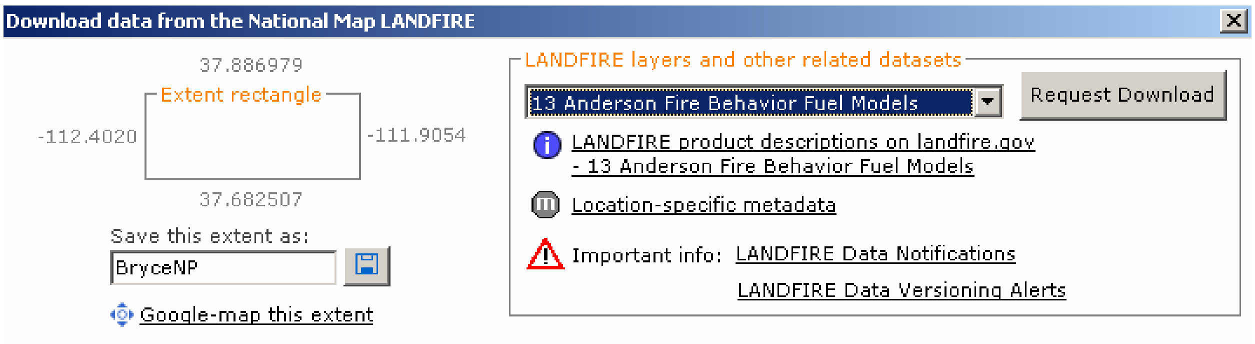


Figure 4-4. Request Download from National Map.

7. With the 13 Fire Behavior Fuel Models selected from the list, click on the **Request Download** button. This button initiates a process that extracts the data from the National Map.

8. Click on the **Download** button from the *SDDS Request Summary Page* to save the data to your computer. After the Raster Extract completes, a *File Download* dialog box appears. Click **Save**.

9. In the *Save As* dialog box, navigate to a location of your choice, right-click in the white space in the dialog box and select **New > Folder** (fig. 4-5).

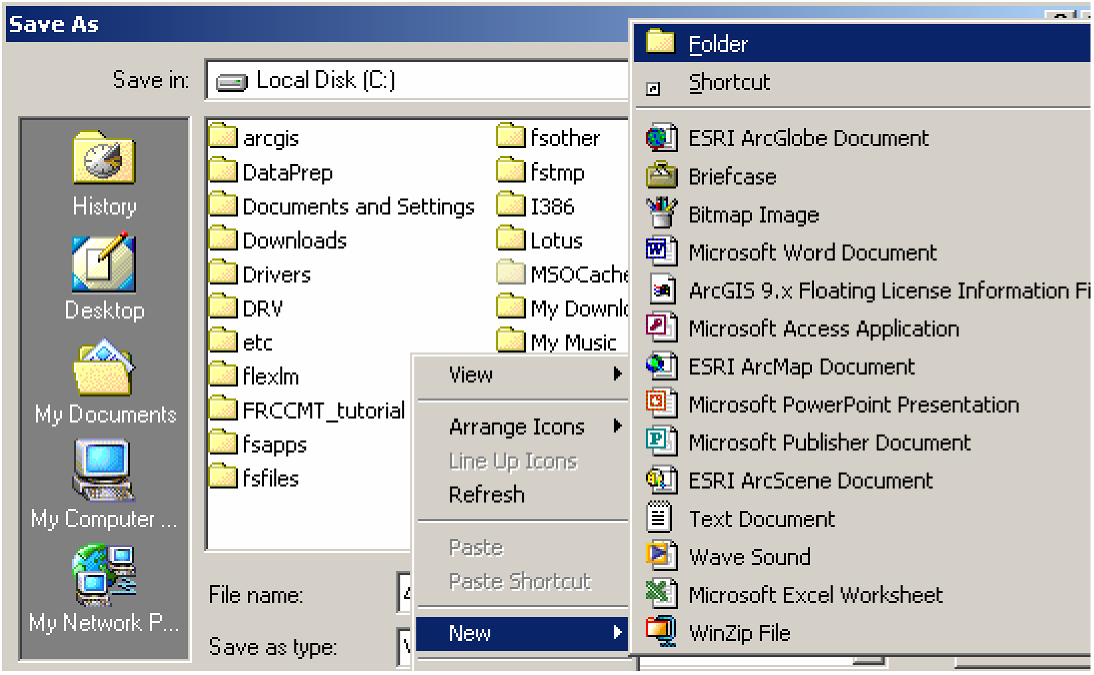


Figure 4-5. Create new folder.

10. Name the new folder *LF_Inputs* and double-click on it to save and open this folder. Click the **Save** button and the file will download into the LF_Inputs folder.

11. A progress window opens during the save process. After the download is complete, close the R*aster Extract Has Completed* window. To download additional files, you need to repeat this process for each data layer. For instance, the Fire Behavior Assessment Tool (FBAT) requires eight layers.

12. Close the *Download Data* window from the National Map LANDFIRE. Next, click on the **Process and Assemble LANDFIRE National Map Data** tool , also referred to as the Smart Assembler.

13. In the top entry of the dialog box, navigate to the *LF_Inputs* folder. Click the folder icon for an output location. Click **New Folder** and name the new folder *LF_Outputs*. Keep the default output file type ESRI GRID. Use separate input and output folders for each download and processing session for best results. The ESRI GRID format will allow the Smart Assembler to attach attributes. Other options are available, but LFDAT does not automatically add the attributes with the Smart Assembler (fig. 4-6).

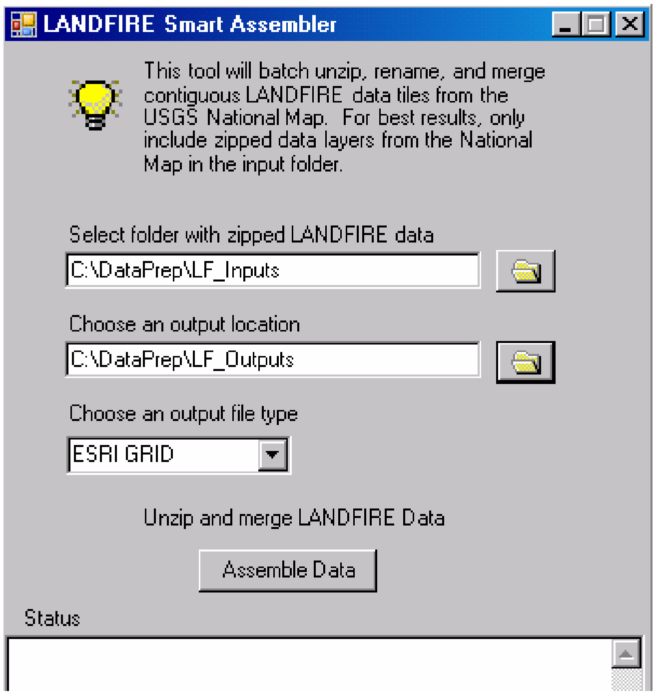


Figure 4-6. The LANDFIRE Smart Assembler dialog box.

14. Click on the **Assemble Data** button. A progress bar displays at the bottom of the dialog box. Close the *Smart Assembler* when the process completes.

15. Add the layer from *LF_Outputs* folder to the map. Notice that the LFDAT Smart Assembler appropriately renames the downloaded data layers.

16. At this point, the data should be ready for further processing as input for one of the NIFTT tools.

Chapter 5: Output Data

5.1 Utility of outputs

FBAT outputs can be used to spatially identify problematic areas from a fire behavior perspective based on fireline intensity, flame length, rate of spread, and fire type (crown fire activity). Outputs may be useful for assessing the appropriate management response to wildland fires (including wildland fire use), locating fuel treatment opportunities, evaluating fuel treatment effectiveness, and for calibrating fuel input layers to mimic observed fire behavior. For example, potential rate of spread, flame length, and fire type may provide useful information when deciding on the appropriate management response to wildland fire or when prioritizing suppression resources. Outputs are also helpful in assessing fire risk relative to ecological and social values and in subsequent prioritization of fuel treatment opportunities.

Once a project has been identified, FBAT outputs can be used to help formulate fuel treatment prescriptions. For example, a potential fuel treatment might involve changing the surface fuel model to reduce potential flame length and/or rate of spread, changing the canopy base height to reduce the likelihood of surface to crown fire transition, or decreasing canopy bulk density to lessen the possibility of active crown fire. After a project has been designed, pre-treatment fire behavior characteristics can be compared to post-treatment characteristics to evaluate whether the proposed fuel treatment will produce the desired outcome. In some instances, a fuel treatment prescription may produce unintended consequences. For example, an objective to decrease flame length by altering the fire behavior fuel model may result in reduced canopy cover, which subsequently decreases fuel moisture and increases mid-flame wind speed. As a consequence of changing the fire behavior fuel model, flame length may actually increase rather than decrease.

FBAT outputs can also be useful for calibrating fuel and fire weather inputs. For example, if the outputs do not resemble the observed behavior of a historical or current fire, the fuel and fire weather inputs must be modified so that the simulated and observed fire behaviors are similar. These refined outputs will then improve the predictive capabilities of fire behavior systems such as FlamMap and FARSITE.

5.2 Description of outputs

Ten spatial layers are generated by FBAT: seven layers are produced automatically and three layers are optional (table 5-1). Five layers are direct outputs from FlamMap: flame length, fireline intensity, rate of spread, maximum spotting distance, and fire type or crown fire activity. These outputs will not be discussed further here as they are fully described in the user guides and help systems of FlamMap, FARSITE, and BehavePlus. All other outputs are FBAT derivatives and will be discussed individually.

Table 5-1. Spatial outputs generated by FBAT characterizing potential fire behavior.

Grid Name	Description	Grid Format	Units	Delivery
Cfa	Crown fire activity (fire type)	Integer	Class 0 = non-burnable 1 = surface fire 2 = passive crown fire 3 = active crown fire	Automatic
Flameln	Flame length	Floating point	Meters	Automatic
Flcls	Flame length class - Flame length is divided into four classes	Integer	Class 0 = non-burnable 1 = low (0.1 to 1.22 m) 2 = moderate (1.2 to 3.66 m) 3 = high (exceeds 3.66 m)	Automatic
Lineintn	Fireline intensity	Floating point	Kilowatts/meter	Automatic
ros	Rate of spread	Floating point	Meters/minute	Automatic
roscls	Rate of spread class Rate of spread is divided into four classes	Integer	Class 0 = non-burnable 1 = low (0.1 to 1.68 m/min) 2 = moderate (1.68 to 16.76 m/min) 3 = high (exceeds 16.76 m/min)	Automatic
MSD	Maximum spread distance	Integer	Meters	Automatic
firintn	Wildland fire intensity (common log of fireline intensity)	Floating point	Log10(kW/meter)	Optional
fbquery	Fire behavior – simple binary query	Integer	Class 0 = does not meet query specs 1 = meets query specs	Optional
fbclass	Fire behavior – classification query	Integer	Class 0 = very low 1 = low 2 = moderate 3 = high	Optional

5.2.1 Flame Length Class (flcls)

Flame Length Class is derived by classifying flame length observations into four flame length classes: non-burnable, low, moderate, and high. Class thresholds (table 5-2) were modified from the Scott and Burgan (2005) six-class system. Converting the flame length layer from a continuous variable (floating point grid) to a categorical variable (integer grid with four classes) simplifies its use for those who are not interested in precise estimates of potential flame length.

Table 5-2. The classification of potential flame length (FL) used by FBAT.

Flame Length Class	Flame Length ft (meters)	Class Description
0	0	Non-burnable
1	0 < FL < 4 ft (1.219 m)	Low
2	4 ft (1.219 m) < FL < 12 ft (3.658 m/min)	Moderate
3	12 ft (3.658 m/min) < FL	High

The Flame Length Class layer (fig. 5-1) uses a default color scheme of gray, blue, green, and red, which corresponds to non-burnable, low, moderate, and high flame lengths, respectively.

***Note**: The default symbology for all output grids can be saved if the ArcMap project containing the outputs is saved. The default symbology is lost when the output grids are added to a new ArcMap project.*

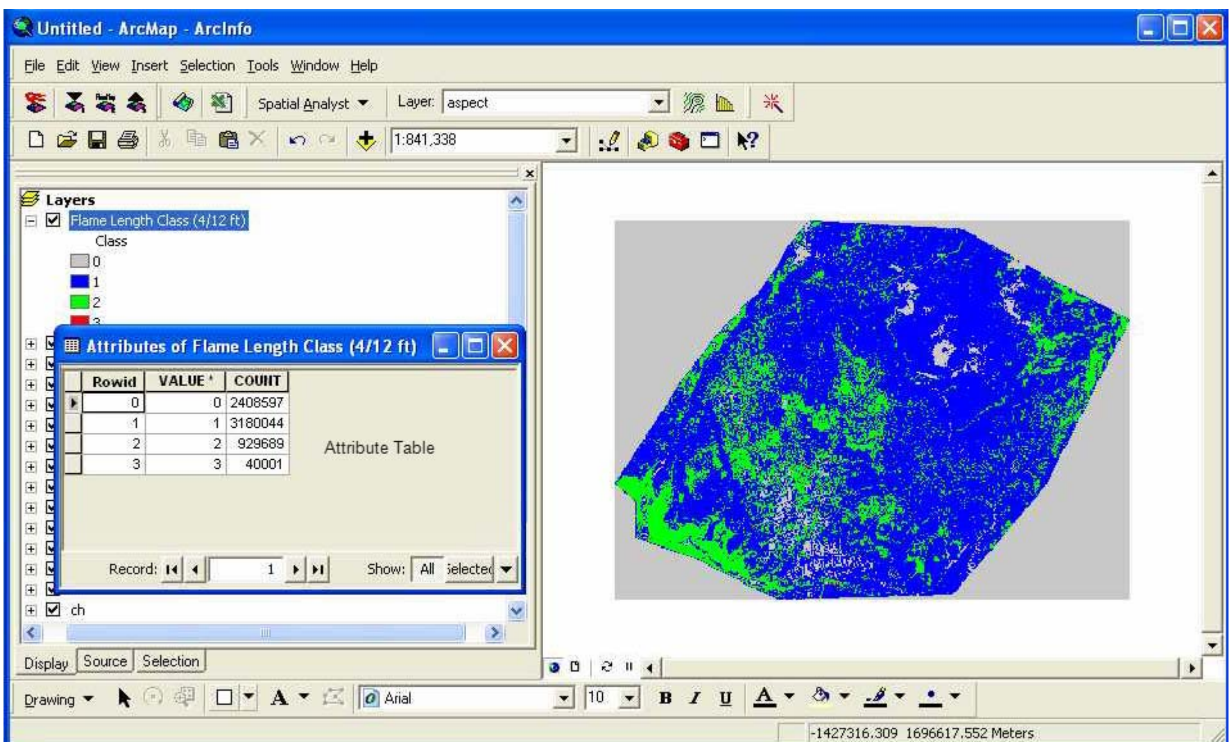


Figure 5-1. Example of Flame Length Class output. (0 = non-burnable, 1 = low flame lengths, 2 = moderate flame lengths, and 3 = high flame lengths).

5.2.2 Rate of Spread Class (roscls)

Rate of spread observations are grouped into four classes representing non-burnable, low, moderate, and high spread rates. The class thresholds defined by Scott and Burgan (2005) were modified to fit our four-class system (table 5-3). Converting the rate of spread layer from a continuous variable (floating point grid) to a categorical variable (integer grid having four classes) simplifies its use by those who are not interested in precise estimates of potential rate of spread.

Table 5-3. Classification of potential rate of spread (ROS) used by FBAT.

ROS Class	ROS ft/min (m/min)	Class Description
0	0	Non-burnable
1	0.3 ft/min (0.1 m/min) < ROS < 5.5 ft/min (1.676 m/min)	Low
2	5.5 ft/min (1.676 m/min) < ROS < 55 ft/min (16.764 m/min)	Moderate
3	55 ft/min (16.764 m/min) < ROS	High

Note: *The ROS Class layer (fig. 5-2) uses the same default color scheme as the Flame Length Class layer: gray, blue, green, and red, which correspond to non-burnable, low, moderate, and high spread rates, respectively.*

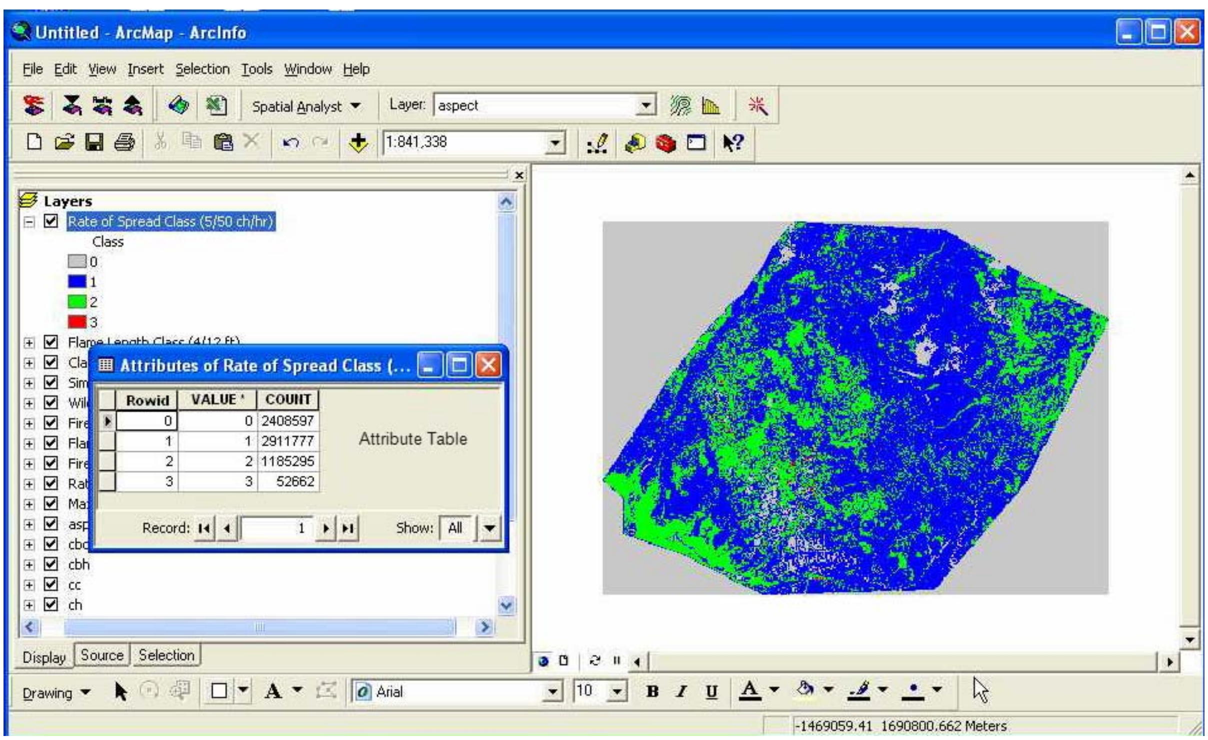


Figure 5-2. Example ROS Class output. (0 = non-burnable, 1 = low spread rates, 2 = moderate spread rates, and 3 = high spread rates).

5.2.3 Wildland Fire Intensity (firintn)

The Wildland Fire Intensity metric was proposed by Scott (see Appendix C) to facilitate communication about and interpretation of fireline intensity. In essence, it is analogous to the logarithmic Richter scale used to measure the magnitude of earthquakes. The Wildland Fire Intensity metric is derived from the common logarithm of fireline intensity. Values typically range between zero and six, where each whole number represents an incremental increase of one order of magnitude. That is, a value of 2.0 is 10 times more intense than a value of 1.0; a value of 3.0 is 100 times more intense than a value of 1.0 and 10 times more intense than a value of 2.0.

The Wildland Fire Intensity layer is a floating point grid (fig. 5-3). Consequently, there is no way to view the Value Attribute Table in ArcMap.

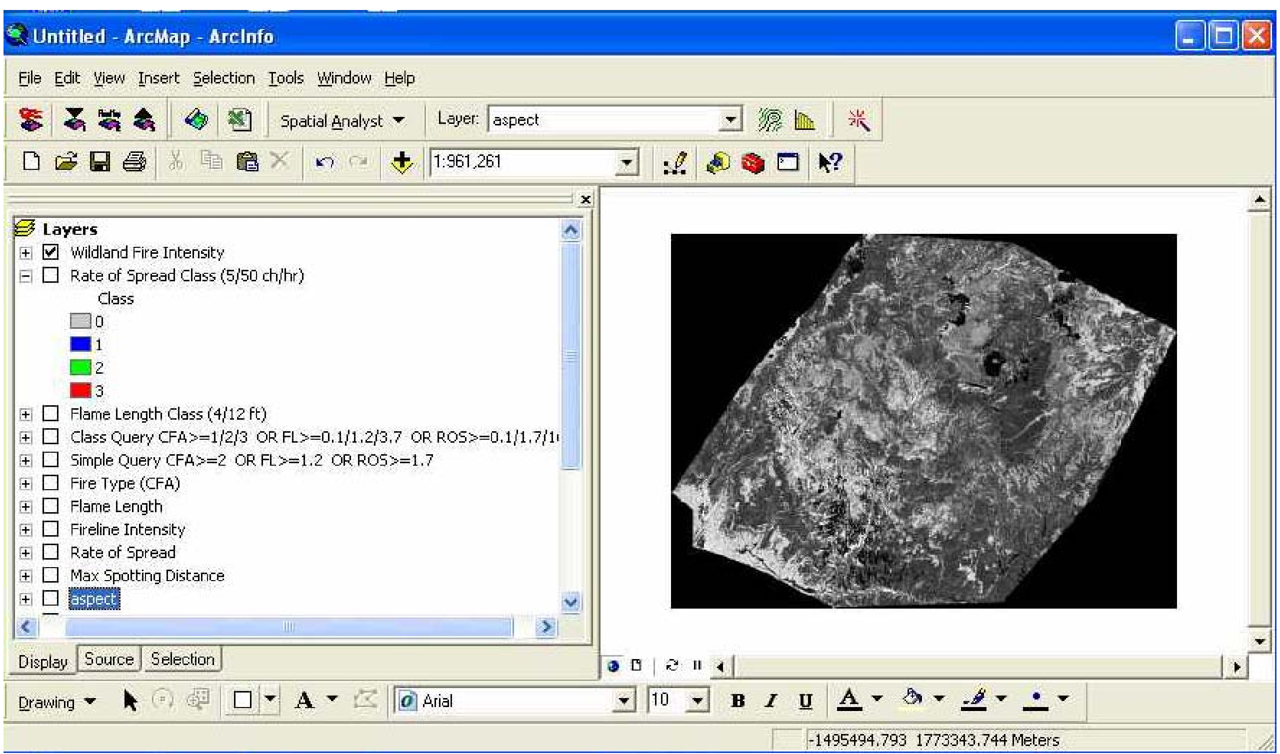


Figure 5-3. Example Wildland Fire Intensity output layer. Darker colors denote higher values. In this example, values range from 0.0 to approximately 5.73.

5.2.4 Fire Behavior Simple Query (fbquery)

The Fire Behavior Simple Query is a user-defined query that produces output with multiple fire behavior characteristics but which allows users to focus on a single set of thresholds. The FBAT user must first identify all combinations of flame length, rate of spread, and fire type that are applicable to his or her assessment. The FBAT user must then specify the threshold of each fire behavior characteristic that is meaningful to the application. And lastly, the user must specify whether the query should include an AND or an OR conditional statement.

For example, a manager may want to prioritize fuel treatment unit locations in areas where potential fire behavior is especially problematic from a suppression perspective. These conditions could be identified by querying for those areas where potential flame length would exceed 13.1 ft (4 m) or where passive or active crowning could potentially occur.

The Fire Behavior Simple Query is a binary query. Those conditions meeting the query parameters are mapped with a cell value of 1; all other values (not meeting the query parameters) are assigned a cell value of 0 (fig. 5-4). Consequently, the output is "simple" – a cell is identified by whether it meets the conditions of the query. The Fire Behavior Simple Query can be used to characterize potential fire behavior within an analysis area based on the interaction of multiple fire behavior characteristics. The Simple Query also enhances user understanding of the interaction between fuels and multiple fire behavior characteristics. For example, a user concerned about fire type (crown fire activity), flame length, and rate of spread might observe that a certain fuel treatment prescription alters the crown fire activity as intended (such as if passive crown fire is changed to surface fire), but with the unintended consequences of increasing potential flame length and rate of spread. Thus, a user may find that a proposed prescription actually increases fire behavior concerns.

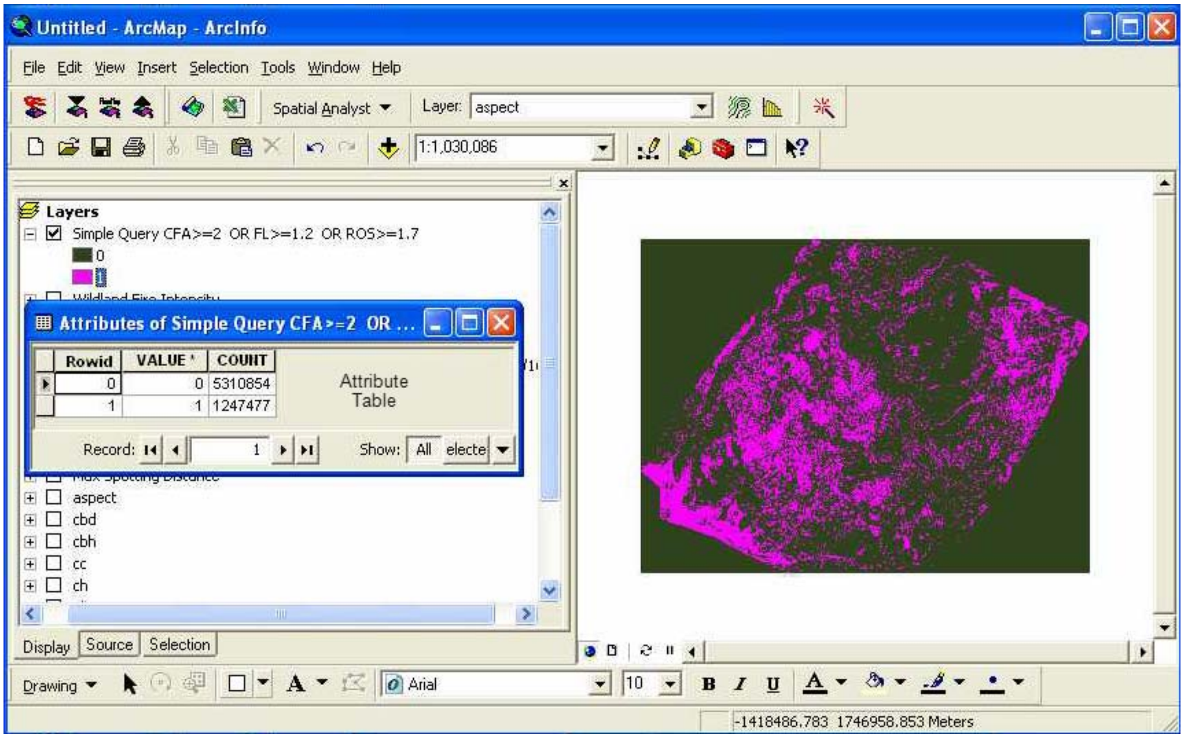


Figure 5-4. Example Fire Behavior Simple Query output. The spatial output contains two values: 0 (yellow) identifies those areas that do not satisfy the parameters of the query; 1 (black) identifies those areas that do satisfy the parameters of the query. In this example, the query identifies those areas that have the potential for crown fire (passive or active) OR areas where potential flame length will exceed 3.9 ft (1.2 m), OR areas where potential spread rate will exceed 5.6 ft/min (1.7 m/min).

By default, the Simple Query uses an OR conditional statement and the threshold values shown in table 5-4. However, users can easily change any of the threshold values and can select an AND conditional statement, if desired.

Table 5-4. Default parameters of the Simple Query.

Fire Behavior Characteristic	Threshold[1]
Flame length	1.2-meter < FL
Rate of spread	1.7-meter/minute < ROS
Fire type	2 < CFA (i.e., passive or active crown fire)

[1]FL = flame length; ROS = rate of spread; CFA = fire type (crown fire activity).

***Note**: Simple Query results can be used to compare and prioritize different assessment areas only if the query parameters are consistent across the areas to be compared.*

5.2.5 Fire Behavior Classification Query (fbclass)

The Fire Behavior Classification Query is also defined by the FBAT user. The user must identify applicable fire behavior characteristics (in other words, flame length, rate of spread, and fire type) and their respective thresholds that are of interest to analysis objectives. Unlike the Fire Behavior Simple Query which classifies the landscape into two classes (meets the conditions of the query or does not), the Fire Behavior Classification Query classifies the landscape into four user-defined classes that indicate very low, low, moderate, and high fire behavior activity.

A manager may want the four classes to represent the following: "high" denotes where flame lengths would likely exceed 23.0 ft (7 m) or where active crowning is likely to occur; "moderate" denotes areas where flame lengths would likely exceed 13.1 ft (4 m) or where torching would be expected to occur; "low" denotes areas where flame lengths would likely exceed 3.3 ft (1 m) or where surface fire would be expected, and "very low" denotes remaining areas that did not meet the specifications of the low class. This example uses the conditional OR statement to define class thresholds; however, a query could also use the conditional AND statement.

***Note**: The Classification Query is set up with default thresholds suggesting very low, low, moderate, and high fire behavior classes (table 5-5) and uses an OR conditional statement. However, users can easily change any of the thresholds and can select an AND conditional statement, if preferred.*

Table 5-5. Default thresholds used in the Classification Query to derive very low, low, moderate, and high fire behavior classes.

Flame Length ft (meters)	Rate of Spread ft/min (m/min)	Fire Type (CFA)	Fire Behavior Class
< .3 ft (0.1 m)	< .3 ft/min (0.1 m/min)	None	0 (very low)
.3 ft (0.1m) to 4ft (1.2 m)	.3 ft/min (0.1 m/min) to 5.6 ft/min (1.7 m/min)	Surface	1 (low)
4 ft (1.2 m) to 12 ft (3.7 m)	5.6 ft/min (1.7 m/min) to 55 ft/min (16.8 m/min)	Passive crown fire	2 (moderate)
> 12 ft (3.7 m)	> 55 ft/min (16.8 m/min)	Active crown fire	3 (high)

The output layer is a simple integer grid containing four values (0, 1, 2, and 3) that represent the four fire behavior classes as defined by the user (fig. 5-5). This layer can be used to help prioritize fuel treatment projects and to evaluate the effectiveness of a proposed treatment by comparing pre-and post-treatment fire behavior. Classification Query output may also be useful for assessing wildland fire use scenarios for fire management planning or for designing suppression tactics during a wildland fire incident.

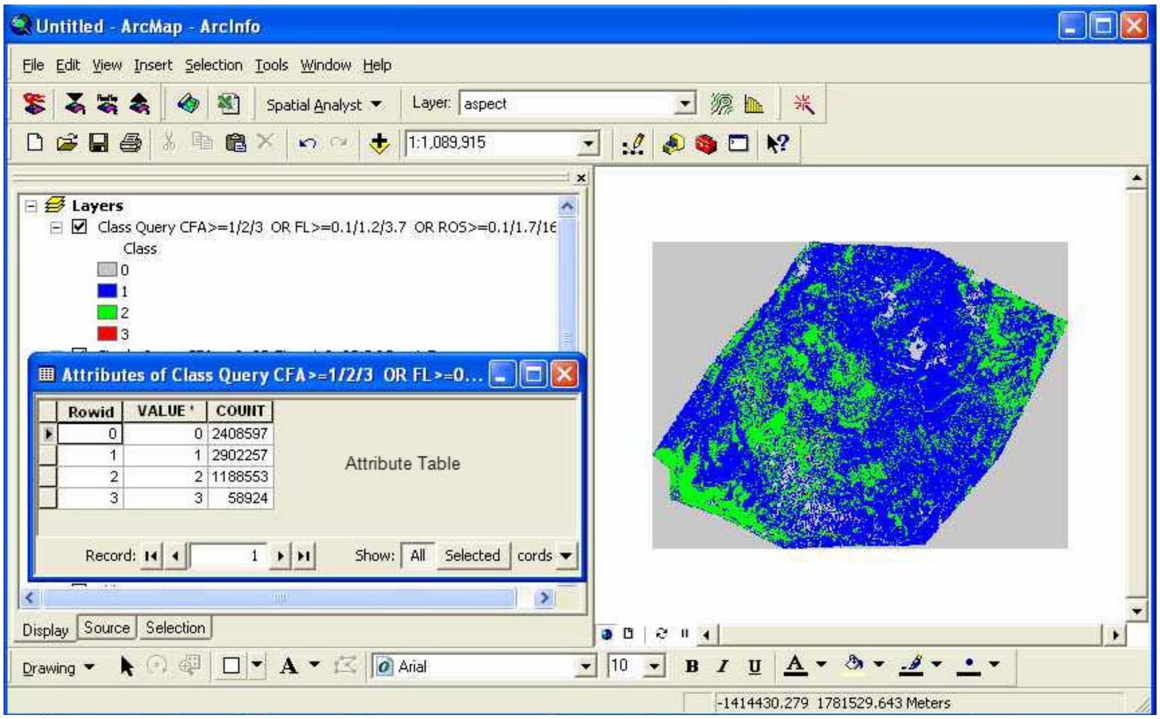


Figure 5-5. An example Classification Query output layer. The attribute table contains values 0 through 3 which represent very low, low, moderate, and high fire behavior, respectively.

***Note**: The Classification Query can be used to compare different analysis areas only if the query parameters are consistent across the multiple areas.*

Chapter 6: Installing FBAT

6.1 General installation instructions

All NIFTT tools, including the Fire Behavior Assessment Tool (FBAT), are now downloaded and installed as single tools. A complete or package install is no longer available for versions of NIFTT tools compatible with ArcMap 9.2.

> ***Note**: For FBAT version 1.3.0 to operate properly, you will need to verify that you are using ArcGIS 9.2.*

If you have an earlier version of FBAT installed on your computer, you will first need to uninstall it before proceeding with installation of the current version.

To determine which version is currently installed on your computer, go to **Start > Control Panel > Add or Remove Programs** as shown:

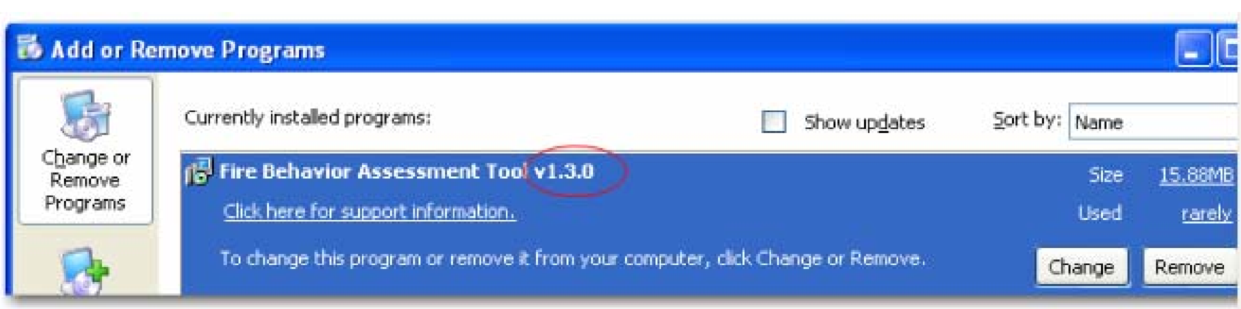


Figure 6- 1. FBAT version 1.3.0.

***Note**: NIFTT naming conventions are as follows: FBAT_ 130_071113 indicates that this "install" is version 1.3.0 and was completed on 11/13/2007.*

You may need administrative privileges to install FBAT. Contact your system administrator if you experience problems with the installation.

6.2 FBAT installation

6.2.1 Downloading FBAT

If you would like to install or reinstall the Fire Behavior Assessment Tool (FBAT) follow these steps:

***Note**: If you have an earlier version of FBAT installed on your computer, you will first need to uninstall it before proceeding with installation of the current version. Refer to section 6.1 for more information on this subject.*

Download FBAT from the website at www.niftt.gov/. Go to **NIFTT > Downloads** located at the left side of the page.

Figure 6- 2. Select Downloads.

Click on the **FBAT Install File** from the table as shown to begin the download process.

Individual Tool Install for: **Fire Behavior Assessment Tool (FBAT)** *Note: This tool is for use with ArcMap versions 9.0 or 9.1. **Installation Notes (FBAT)** **FBAT Help Utility**	January 2007 Version 1.2.0	Download **FBAT Install File** Download **FBAT Installation Notes** Download **FBAT Help Utility**

Figure 6- 3. Click on FBAT Install File.

***Note**: To continue with the download, you will need to have WinZip or a similar program installed on your computer.*

Click **OK** or **Save File** to download the self-extracting WinZip FBAT installation file and then save it to a convenient location on your computer.

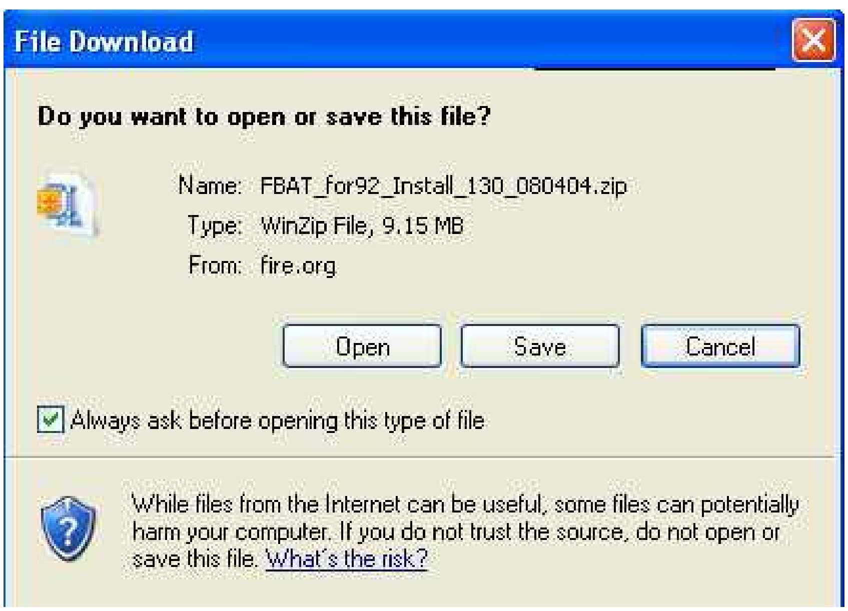


Figure 6- 4. Download and save installation file.

6.2.2 Beginning the installation process

Go to the file in which you stored the FBAT zip file and double click on the file as shown in figure 6-5.

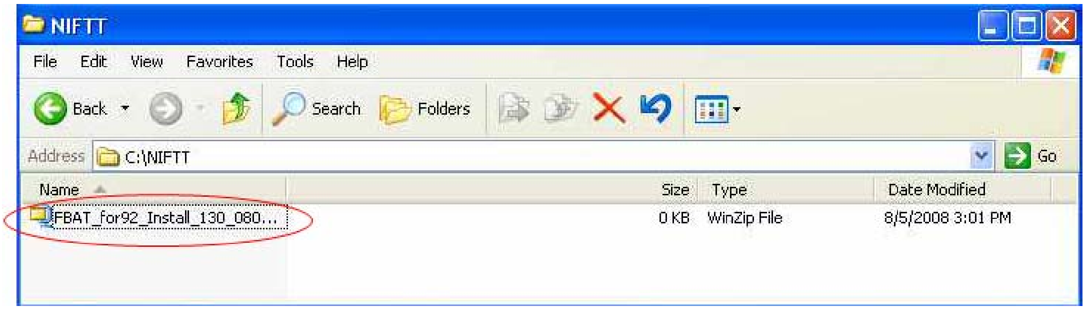


Figure 6- 5. Self-extracting FBAT installation file has been downloaded and saved.

The box shown in figure 6-6 will open. Unzip the files to either the default location (C:\\NIFTT as shown in figure 6-5) or to another location of your choice by using the browse button. Next, navigate to the directory in which you have saved your extracted FBAT files.

Note: *Do not install FBAT or any other NIFTT tool to a pathway that may contain a space in the folder name such as "My Documents" or "Program Files."*

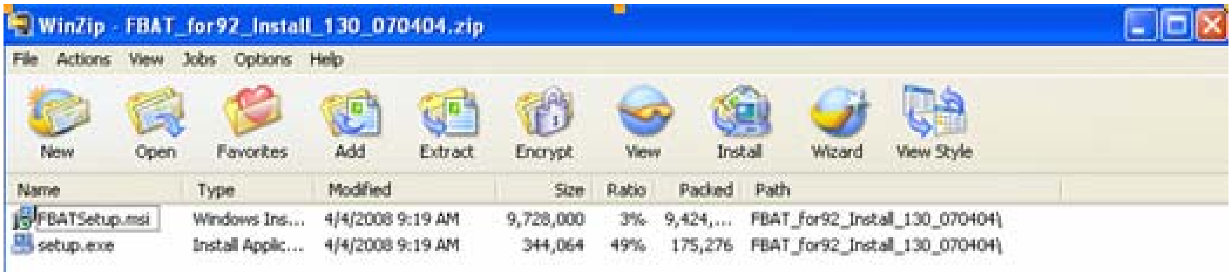


Figure 6- 6. FBAT installation files.

Click on **setup.exe**.

Note*: If the setup determines that an earlier version of FBAT is already installed on your computer, go to* ***Start > Control Panel*** *and select* ***Add/Remove Programs.*** *Uninstall the previous version of FBAT and then rerun setup.exe.*

If the setup.exe determines that you already have the proper .NET Framework (2.0) installed on your computer, the FBAT zip file contains everything that you will need to install FBAT. A series of dialog boxes will now open. Skip to section 6.2.4 to continue installation.

6.2.3 Obtaining the latest .NET Framework

If the installer determines that the setup requires a .NET Framework that has not been previously installed on your computer, you will see a dialog box similar to figure 6-7 instead of the first FBAT Setup Wizard screen as shown in figure 6-14.

Figure 6-7. Dialog box indicating the need to first install .NET Framework for installation to proceed.

Click on **Yes** and follow all prompts as directed. If the .NET Framework 2.0 has not been previously installed on your computer, the setup will at this point direct you to a website where you will be able to download the appropriate file (fig. 6-8).

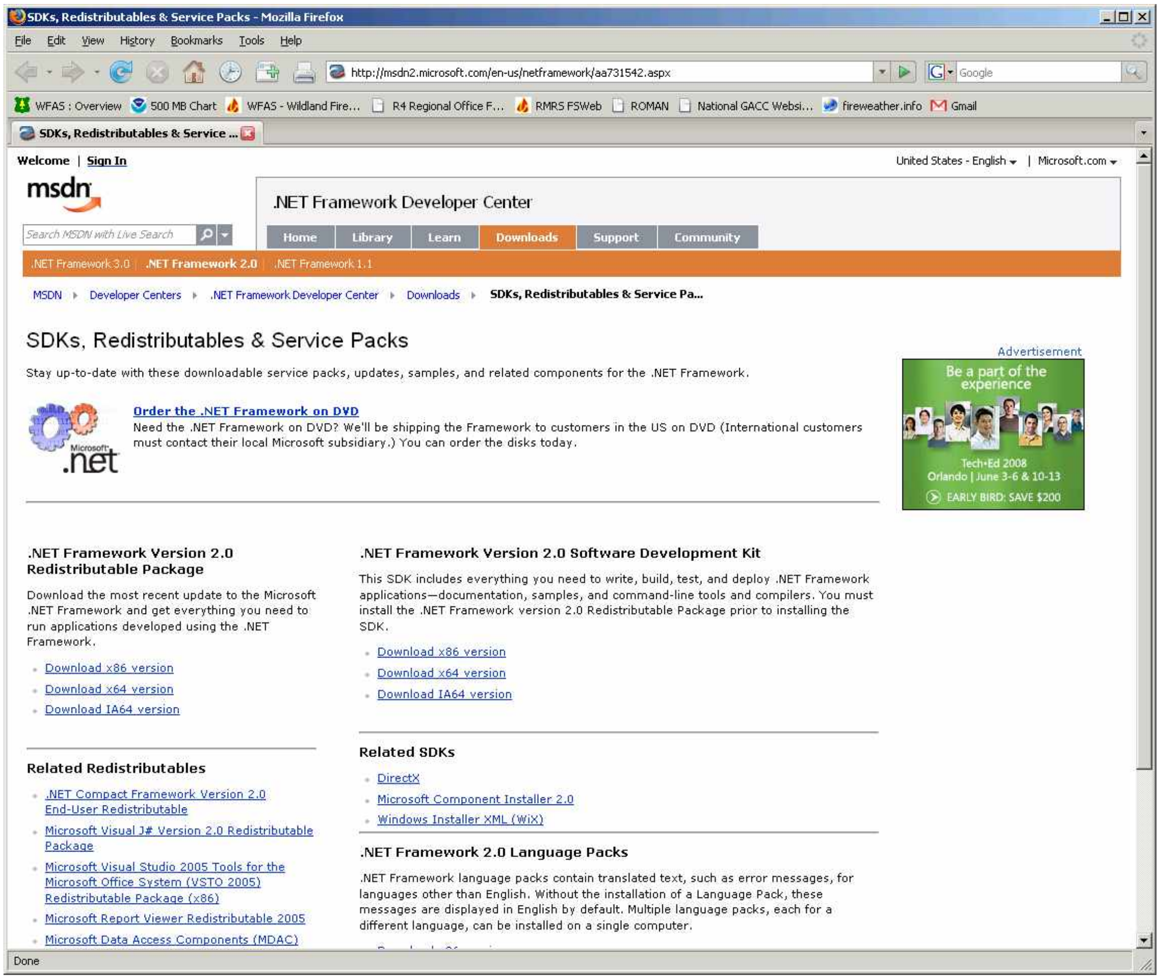


Figure 6-8. Website for downloading .NET Framework 2.0.

As shown in figure 6-9, you will now need to specify which version of .NET Framework you would like to install on your computer. Select the x86 version if you have a Pentium (or other 32-bit) computer. Click on **Download x86 version**.

Tip: *Most users will need to specify the x86 version of NET Framework 2.0. If you are unsure, contact your system administrator.*

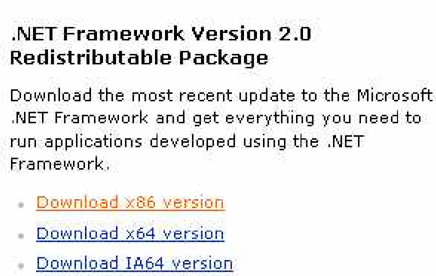


Figure 6-9. Select an appropriate version of .NET Framework.

A screen similar to the following (fig. 6-10) will appear after your selection has been made. Click on the **Download** button to continue.

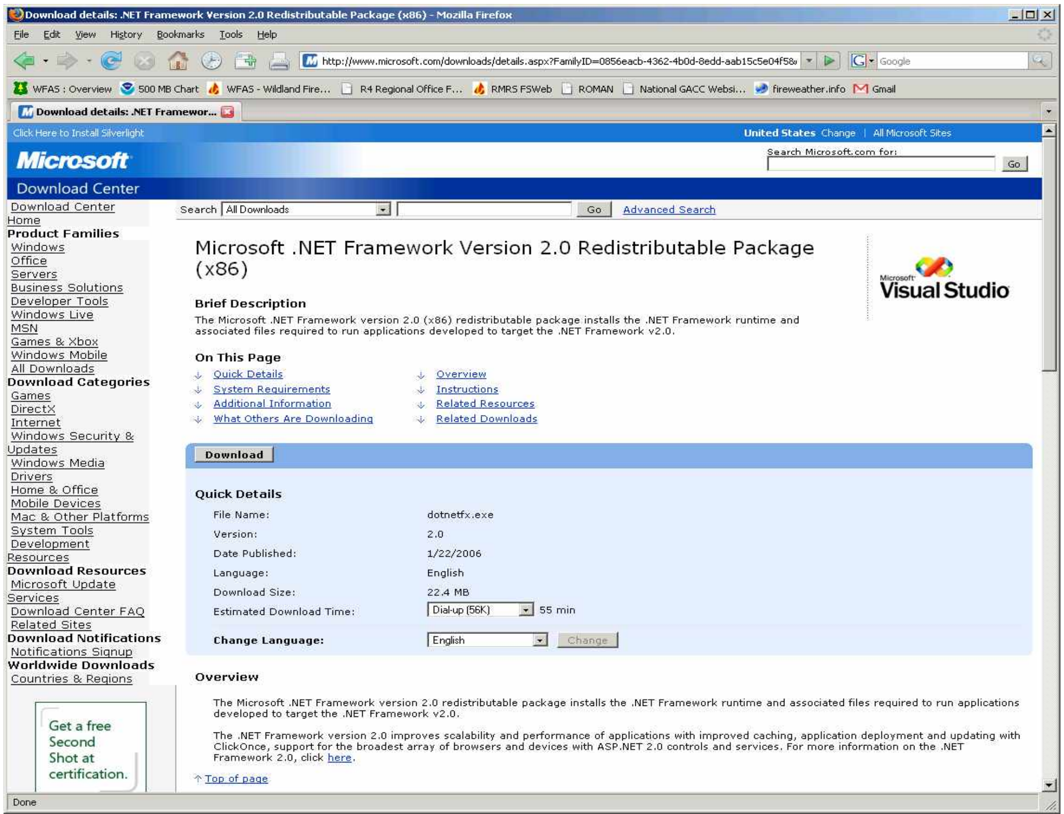


Figure 6-10. Microsoft .NET Framework Version 2.0 (x86) download page.

Browse to a location of your choice. Download and save the *dotnetx.exe* file as shown below (fig. 6-11).

Figure 6-11. Save the file to a location of your choice.

Figure 6-12. Progress bar for download of dotnetfx.exe.

The Microsoft .NET framework 2.0 will download, extract and install automatically as shown in figures 6-12 and 6-13.

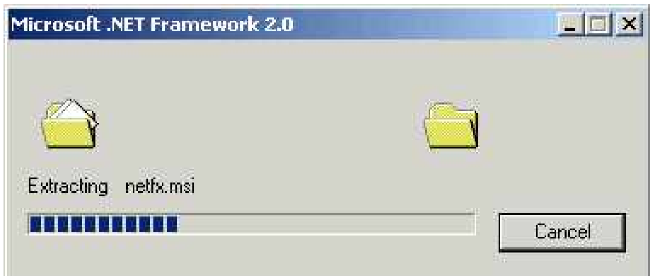


Figure 6-13. .NET Framework installation.

Click on the setup.exe file as shown in figure 6-6 to initiate the setup wizard and to continue installation of FBAT.

At this point, you may need administrative privileges to continue. Contact your system administrator if you experience problems

6.2.4 Finishing the installation

After clicking on the setup.exe file, the first in a series of FBAT Setup Wizard dialog boxes will open. Follow all instructions as directed by the dialog boxes in the FBAT Setup Wizard. During the installation process you may see a radio button asking you to specify whether the tool is to be installed for "Everyone" or "Just Me." Select the "Everyone" option.

***Note**: With FBAT version 1.3.0, it is no longer necessary to reboot your computer during the installation process.*

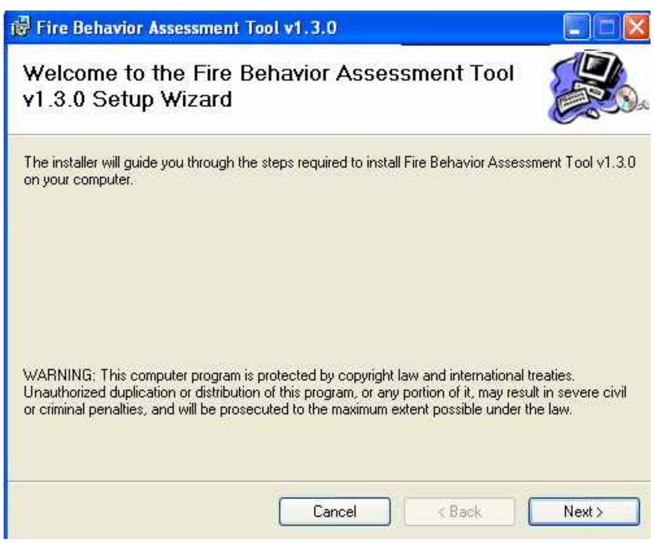


Figure 6- 14. FBAT setup wizard.

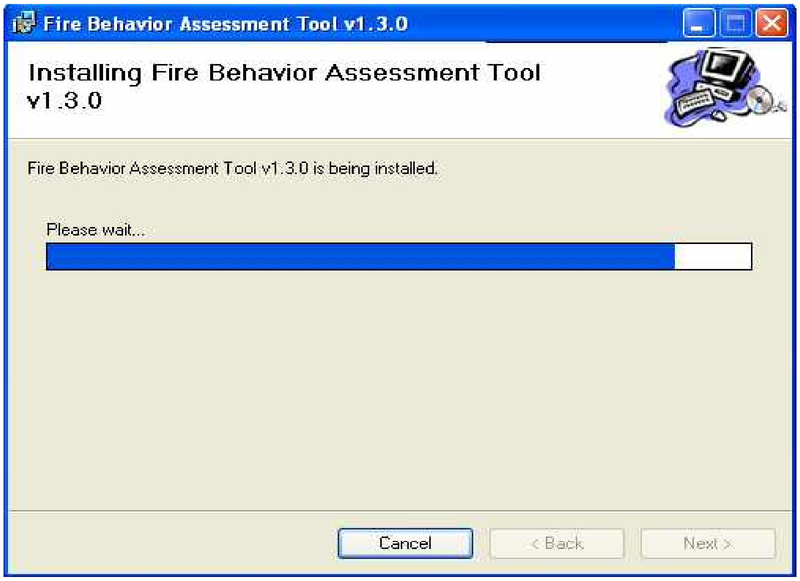


Figure 6-15. Setup Wizard continues installation process.

Click on **Finish** when the FBAT installation is complete.

Open ArcMap and make sure that the FBAT toolbar  is visible.

Note: *The FBAT toolbar may be "floating." If so, you will need to anchor it in a convenient location.*

Tip*: For best results, make sure that you have installed the most recent ArcGIS service packs and patches. Go to* ***www.esri.com*** *to verify that you have the most recent versions for 9.2 already installed on your computer. If you do not, download the newer service packs and patches as directed on the website.*

6.3 Troubleshooting FBAT installation

If the FBAT toolbar as shown at right  does not install automatically, select **View > Toolbars** and check the box to the left of FBAT as shown in figure 6-16:

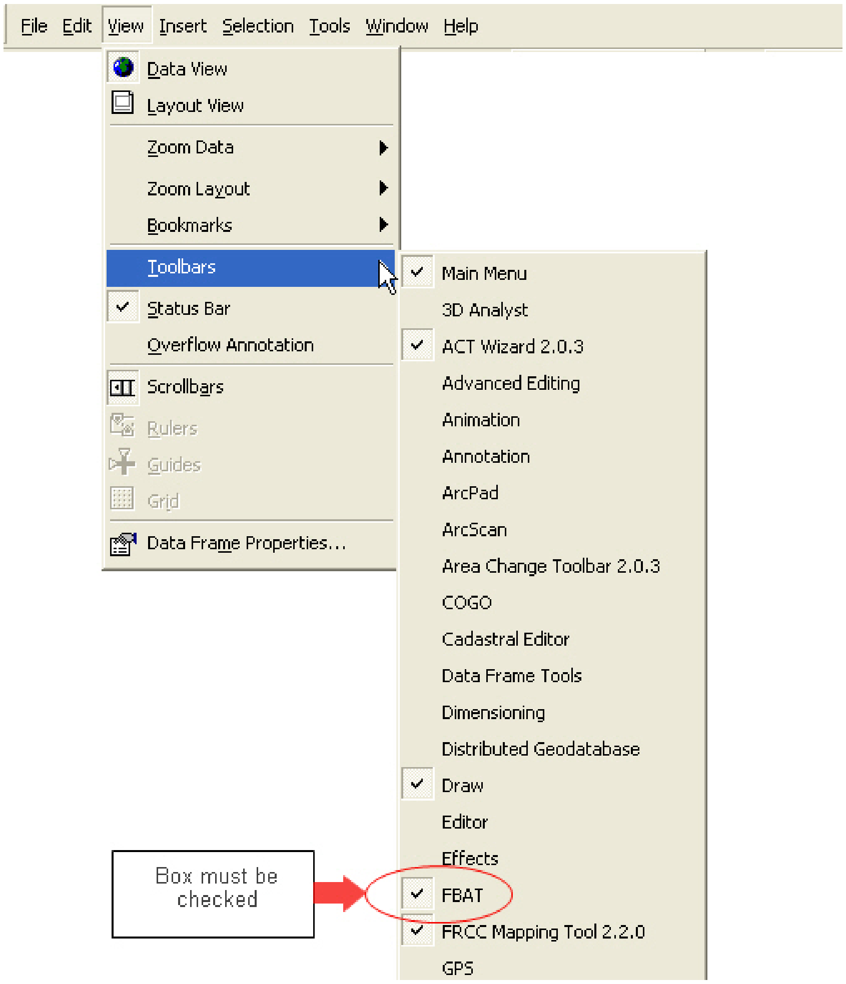


Figure 6- 16. Verify that the FBAT toolbar is enabled.

In ArcMap, select the **Tools** menu and click on **Customize**. Again, make sure that the box to the left of FBAT is checked.

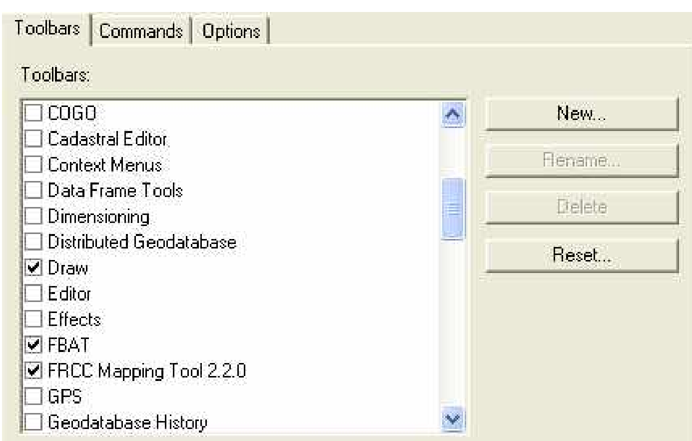


Figure 6- 17. Check the box to the left of FBAT.

If the FBAT box is still unavailable in the Toolbars list, click on **Add from file** (fig. 6-18).

> ***Note**: To continue this process, you must first log on as an "Administrator." Contact your systems administrator if you experience problems.*

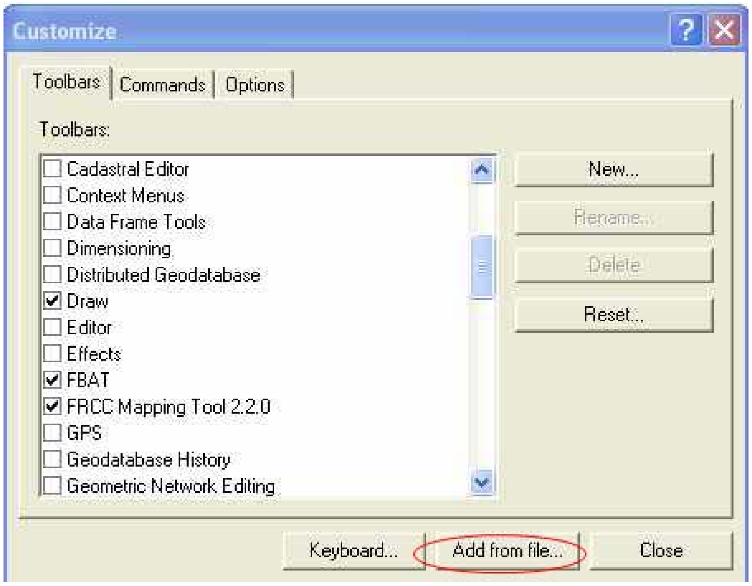


Figure 6- 18. Select Add from file...

Navigate to the directory in which you have saved your extracted FBAT files (the default location is (C:\\NIFTT)) and select **FBAT.dll** from the bin folder as shown in Figure 6-19.

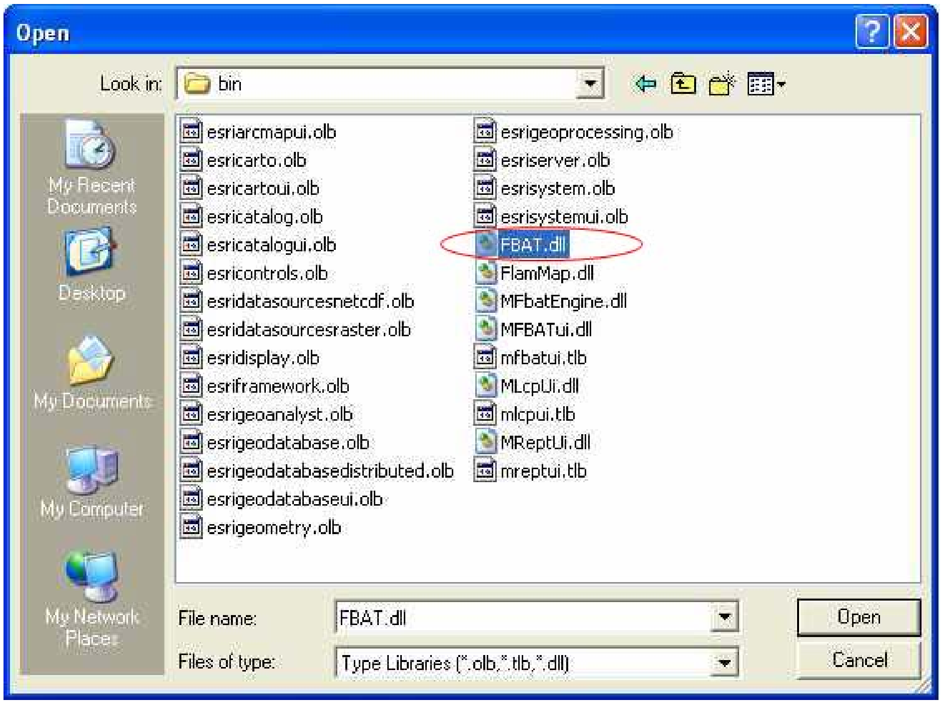


Figure 6- 19. Select FBAT.dll from bin.

The FBAT toolbar should now be enabled and ready for use. Check it now if it is not already selected.

> ***Note**: For all NIFTT tools including – FBAT- to function properly, the Spatial Analyst extension must be installed and activated. To make sure, open ArcMap, go to the Tools menu and select Extensions. Make sure that the box to the left of Spatial Analyst is checked and click Close.*

Figure 6- 20. Check the box to the left of Spatial Analyst.

Direct any questions on FBAT installation to helpdesk@niftt.gov.

Chapter 7: Running FBAT

7.1 The FBAT toolbar

The FBAT toolbar contains four icons (commands). Placing your cursor on each icon will display associated tool tips as shown in figure 7-1. We will briefly discuss the function of each icon.

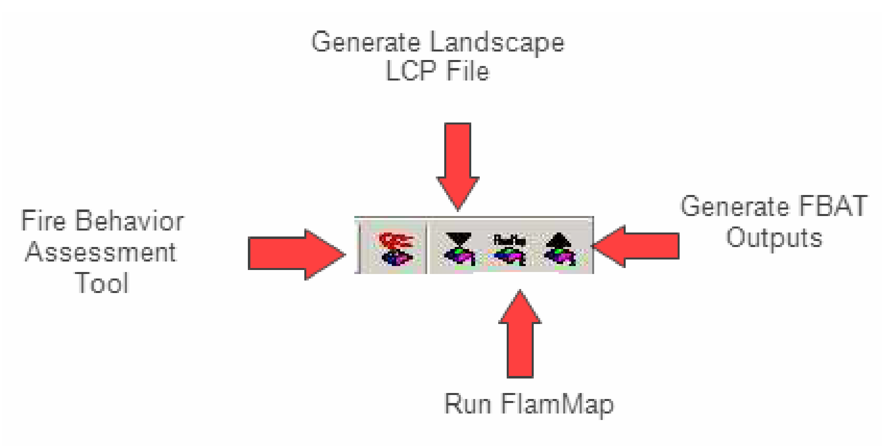


Figure 7-1. FBAT toolbar.

Fire Behavior Assessment Tool –  This command initiates FBAT. Clicking on this button will open a dialog box, which allows the FBAT user to select desired inputs and outputs.

Generate Landscape (LCP) File –  This command is used when an FBAT simulation is not required. It allows creation of a landscape file for later use with FlamMap, FARSITE, or FBAT. Clicking on this icon will open a dialog box in which the user can specify the required inputs for creating a landscape file.

Run FlamMap –  This command will initiate FlamMap and is provided for users who want to build a landscape file using FBAT but then wish to use FlamMap utilities that are not available in FBAT (such as MTT, TOM, fuel conditioning, and wind vectors).

> ***Note**: Users will need to first install FlamMap separately for this function to operate.*

Generate FBAT Outputs –  This command is used to run new queries from an existing FBAT run. Clicking on this button will open a dialog box that is used to identify input layers and to design new queries – it does not build a new landscape file, nor does it rerun FlamMap. This command is typically used when the user merely wants to adjust the query parameters but not the FlamMap inputs.

7.2 How to run FBAT

To run FBAT, follow these steps:

1. Start ArcMap and select **A new empty map** as shown in figure 7-2:

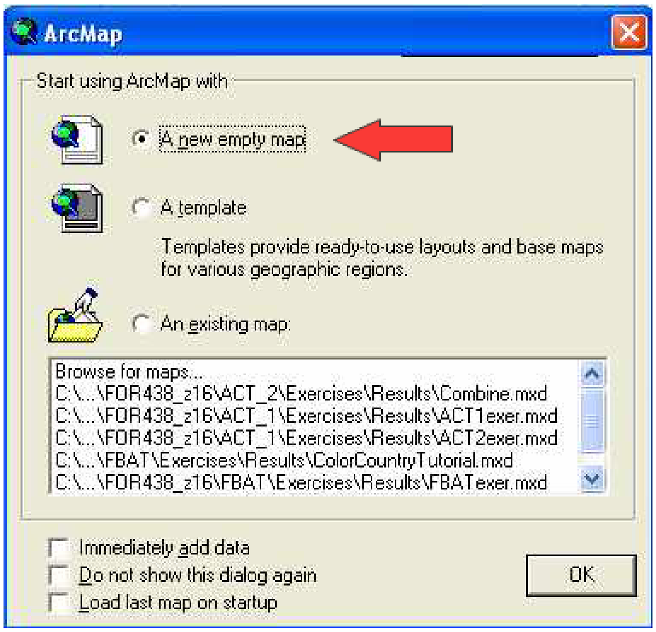


Figure 7-2. Creating a new project in ArcMap.

> ***Note***: *The analysis area that you select is currently limited to approximately 4 million pixels or about 1 million acres in size.*

2. Next, load input layers into your ArcMap project by clicking the **Add Data** icon (fig. 7-3):

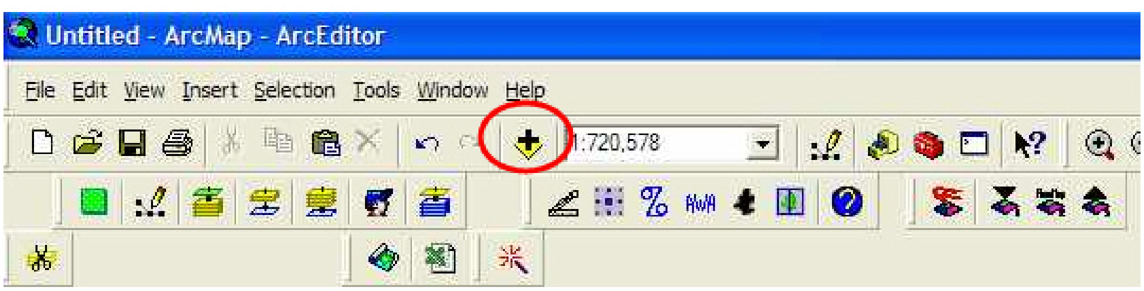


Figure 7-3. Loading input layers.

3. Navigate to the directory where your data layers are stored and add the following input layers: elevation, aspect and slope (if available), fire behavior fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density. These eight layers provide the direct input for FBAT.

> ***Tip***: *At this point, you may see several "Create pyramids" dialog boxes similar to the box shown in figure 7-4. Click No to speed up processing. If*

you do not want to see this box again, put a check in the lower left-hand corner to disable it.

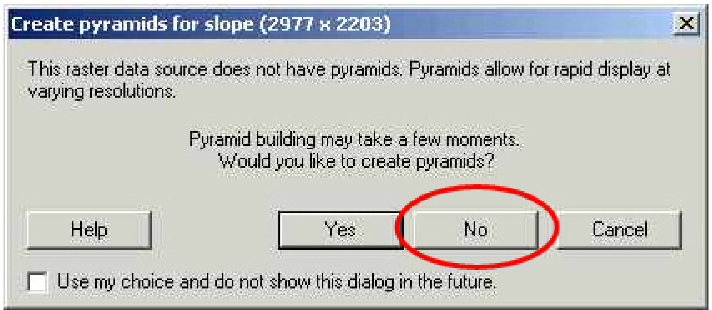


Figure 7-4. Create pyramids dialog box.

4. Ancillary layers can be added at this time. Layers such as cities, roads, streams, wildland-urban interface, ownership, and other files can often be useful for interpretation and description, as well as for consideration of management implications.

5. Save your project and rename the data frame by clicking the **Save** icon on the toolbar

6. If desired, rename the data frame as shown in figure 7-5 with a slow double-click on the default Data Frame name **Layers**.

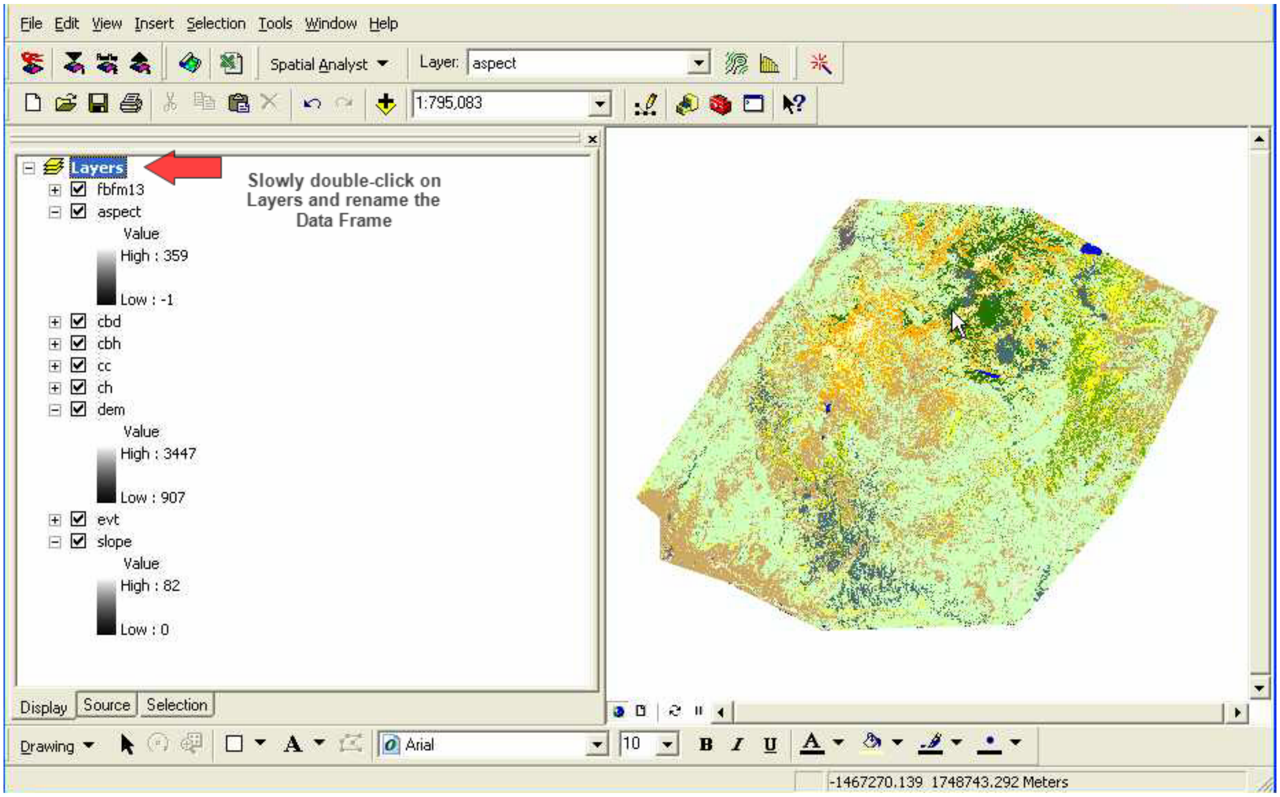


Figure 7-5. Renaming the data frame.

7. Save your project with the file name of your choice.

   ***Note**: You do not need to include the extension .mxd when naming your project.*

7.2.1 Selecting FBAT input parameters

Click on the Fire Behavior Assessment Tool icon on the FBAT toolbar in ArcMap as shown in figure 7-6:

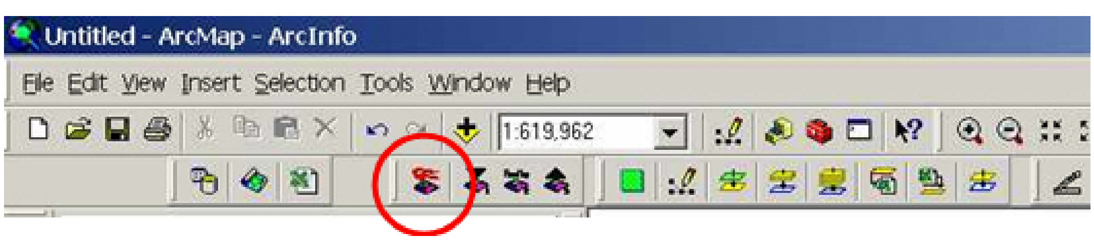


Figure 7-6. Fire Behavior Assessment Tool icon.

The following Fire Behavior Assessment Tool dialog box will open:

***Note**: First click on the "Inputs" tabs if this screen is not already active.*

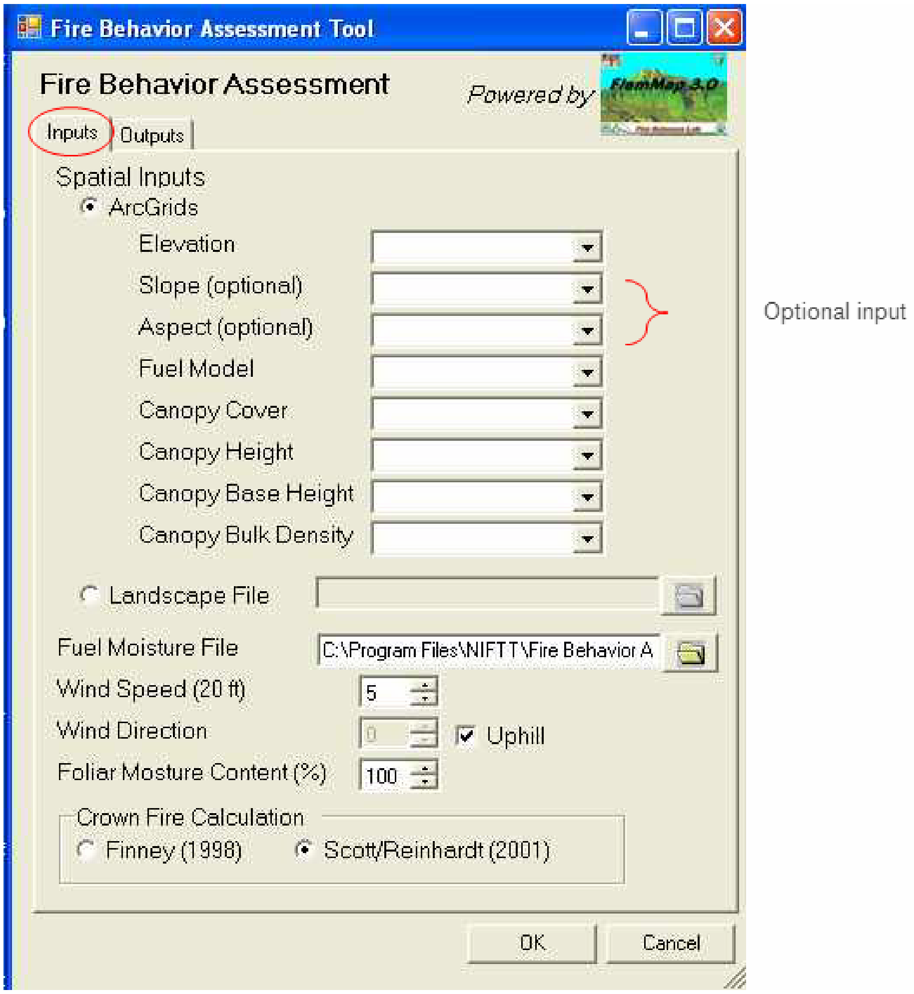


Figure 7-7. The FBAT dialog box with the Inputs tab selected. Notice the spatial inputs required for FBAT.

The *Inputs* tab of the dialog box is used to select the topographic and fuels spatial layers, environmental parameters, and the crown fire algorithm used for calculating fire type. Although eight spatial layers are required, the slope and aspect layers are considered optional. FBAT will derive slope and aspect layers from the elevation layer if these two layers are not provided.

7.2.2 Selecting spatial parameters

First identify the spatial layers from your ArcMap project that will be used to build the landscape file and subsequently for calculating fire behavior characteristics. Select the appropriate layer from the drop-down menu located to the right of each layer. Clicking on the drop-down menu will display all raster layers that are currently loaded in your ArcMap project.

Tip: *The elevation layer will not always be named "elev." In some data sources it will be named "dem" ("Digital Elevation Model").*

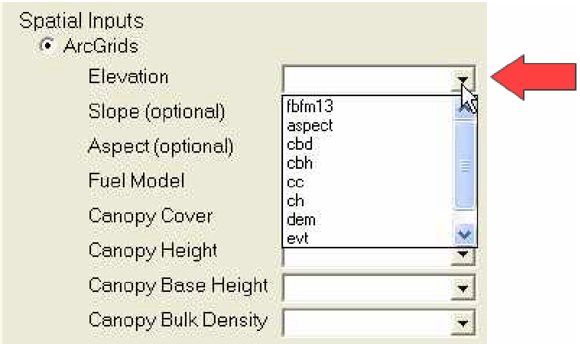


Figure 7-8. Selecting spatial inputs from drop-down menu.

Note: *Slope and aspect layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive the slope and aspect layers from the elevation layer. However, slope may be calculated incorrectly if your data contains pixels with a value of "-9999," which denotes pixels that do not have data.*

A substantial portion of FBAT's processing time is spent creating the landscape file. Thus, run times can be significantly shortened by using previously created landscape files whenever appropriate. If such a landscape file is available, click on the radio button to the left of Landscape File and browse to the desired file instead of selecting the ArcGrids.

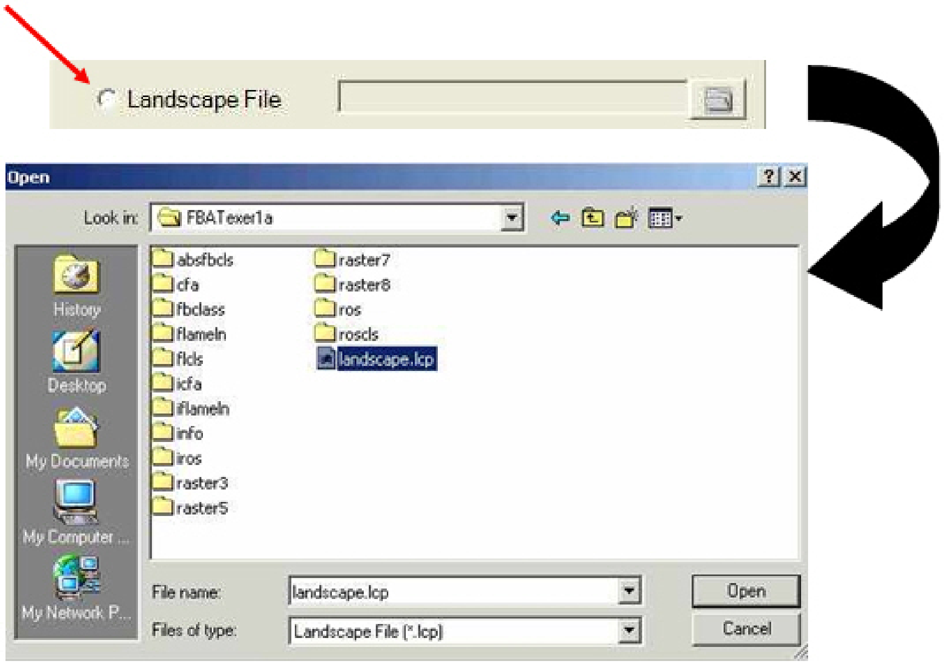


Figure 7-9. Click on the browse button to navigate to the landscape file.

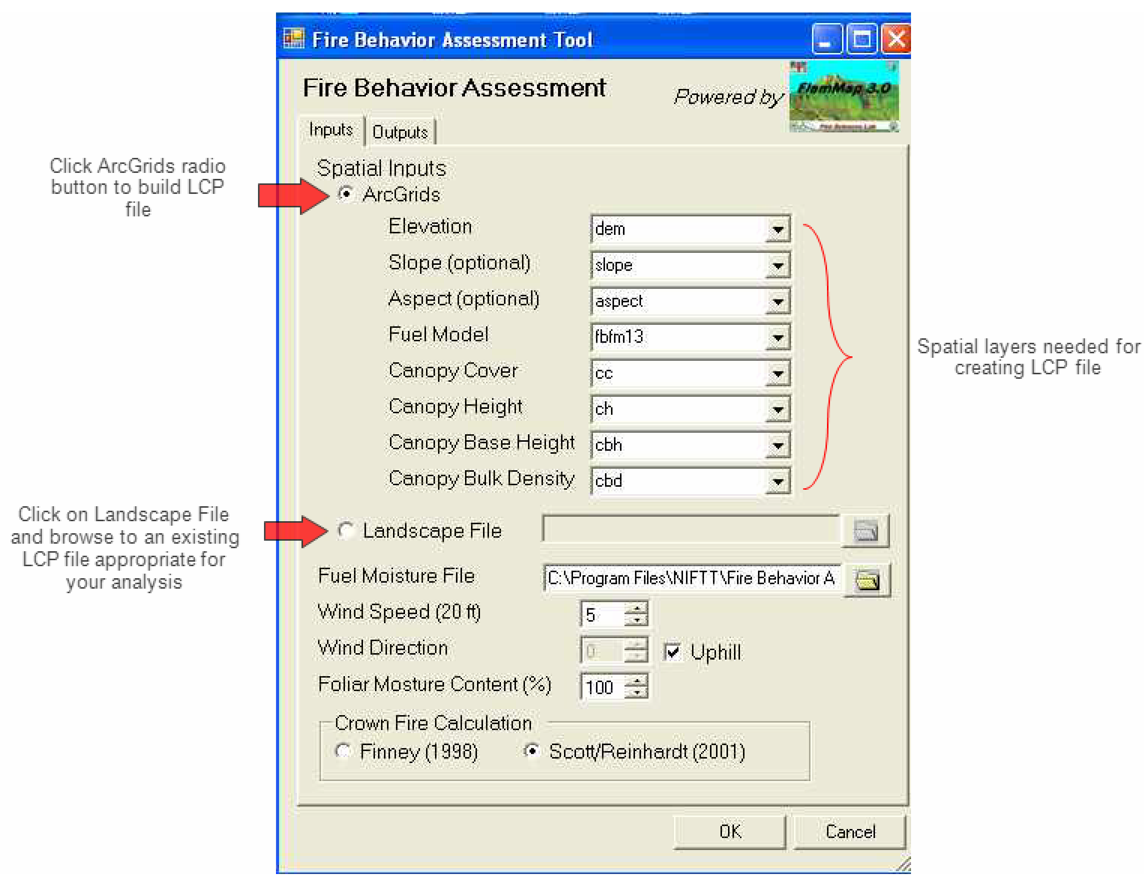


Figure 7-10. Fire Behavior Assessment dialog box.

You have now completed the fuel and terrain inputs necessary for running FBAT. The next step will involve selecting environmental parameters for your run.

7.2.3 Selecting environmental parameters

The environmental parameters necessary for running FBAT include values for fuel moisture, wind speed, wind direction, and foliar moisture content. Start by selecting an appropriate Fuel Moisture File by clicking on the browse button to the right of the Fuel Moisture File box (fig. 7-11).

Recall that the Fuel Moisture File is a text file that identifies both dead and live fuel moisture for each fire behavior fuel model (see Chapter 3 for a description of the Fuel Moisture File).

Note*: The Fuel Moisture File must contain the fire behavior fuel models that correspond to the fuel model layer used in the analysis. For example, if the landscape file was created using Scott and Burgan (2005) fuel models, then the Fuel Moisture file must also contain Scott and Burgan (2005) fuel models. In addition, it is imperative that the Fuel Moisture File characterizes the environmental conditions that are appropriate for your analysis scenario. For example, you might want to use 60th to 90th percentile conditions for predicting potential fire behavior for a prescribed burn or wildland fire use scenario, but you may want to use 97th percentile conditions for modeling a wildfire scenario. See Chapter 3 for more information.*

Now enter a 20-foot wind speed in the box to the right of Wind Speed (20 ft). You can type in the value directly, or you can use the spinner box to raise or lower the value. Remember that this parameter represents the wind speed occurring 20 feet (6.1 m) above the vegetation's canopy as expressed in miles per hour. The default wind speed is 5 miles per hour (8.1 km/hr).

Tip*: Make sure that you have entered the wind speed you want to model or the default value will be used automatically.*

Next enter the wind direction (fig. 7-11). There are two options for entering wind direction. Check the *Uphill* box if you want to maximize potential fire behavior on any particular site. Alternatively, uncheck the

Uphill box if you would rather enter an azimuth in degrees for the wind direction.

***Tip**: Enter the direction from which the wind is blowing from in degrees.*

Lastly, select an appropriate percentage value for Foliar Moisture Content (fig. 7-11). Foliar moisture content usually ranges between 80 and 130 percent. Typical conditions are commonly represented by a value of 100 percent foliar moisture content.

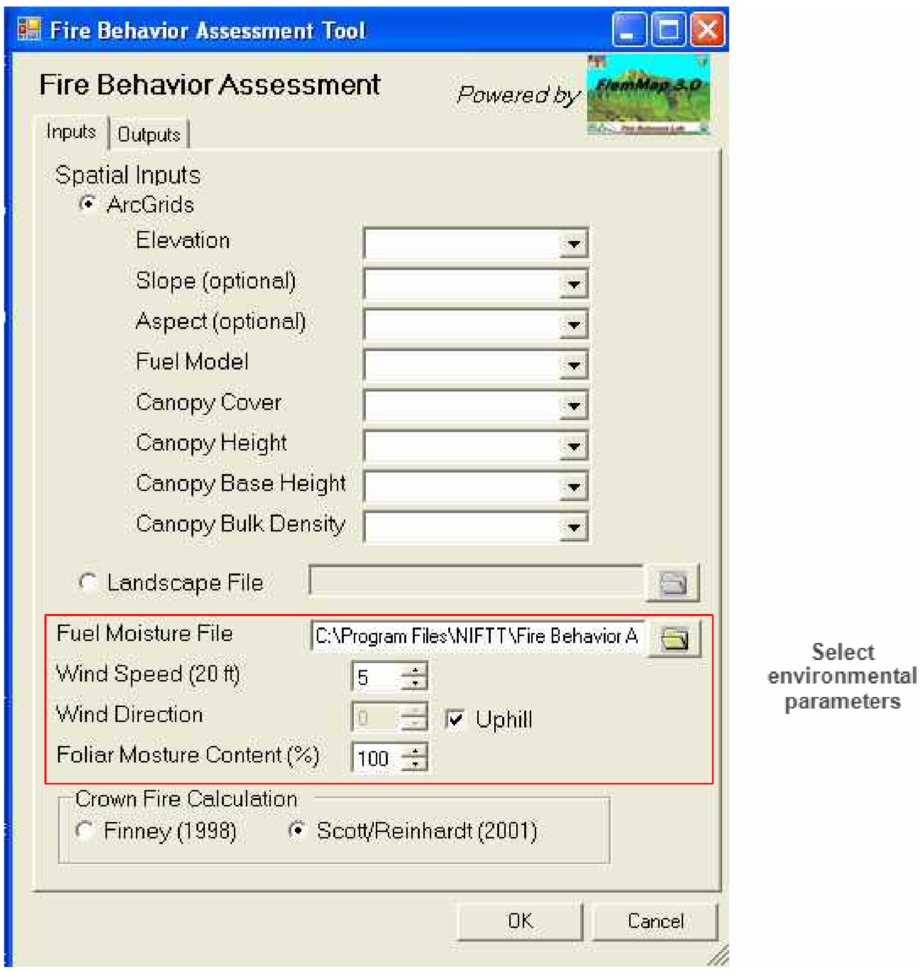


Figure 7-11. Selecting environmental parameters.

7.2.4 Selecting crown fire calculations

Two different algorithms are available for modeling the transition between passive and active crown fire. The primary difference between the two is that the Scott and Reinhardt (2001) equation will result in more active crown fire relative to the Finney (1998) equation. Select the radio button to the left of the algorithm that you wish to use.

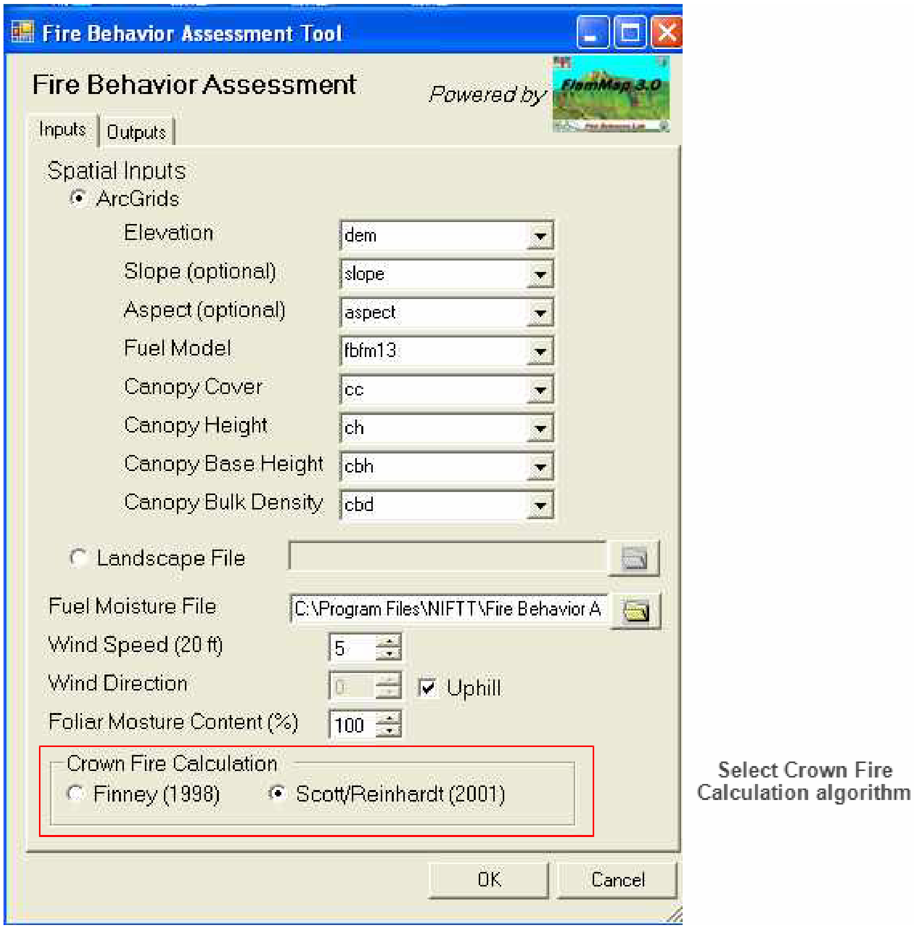


Figure 7-12. Selecting the Crown Fire Calculation algorithm.

***Note**: Important--do not click **OK** until you have completed the "Outputs" tab.*

7.2.5 Selecting output layers

Next, select the FBAT outputs of your choice. Click on the **Outputs** tab at the top of the *Fire Behavior Assessment* dialog box as shown in figure 7-13:

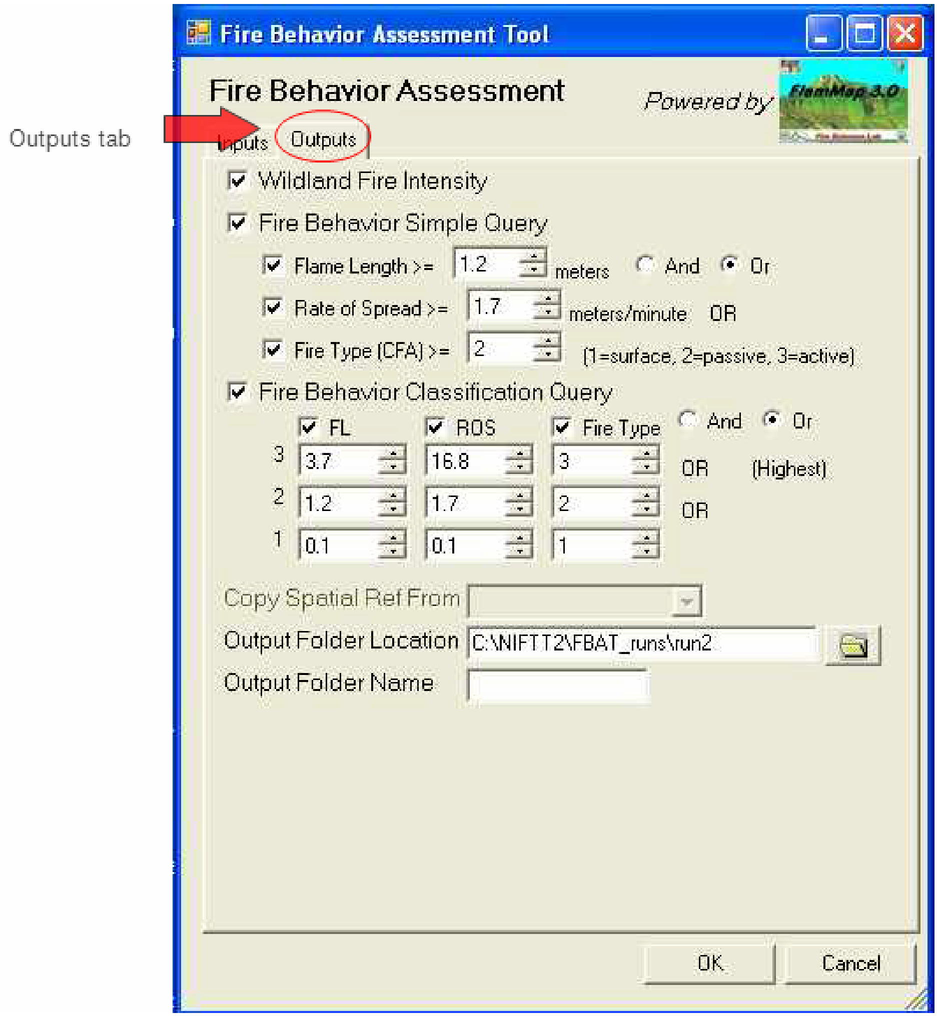


Figure 7-13. Outputs tab on Fire Behavior Assessment dialog box.

The *Outputs* dialog box has four primary functions:

1. Selecting the optional output layers
2. Designing the Simple and Classification queries
3. Copying the spatial reference from an existing layer
4. Selecting a location and name for the output folder

7.2.6 Selecting outputs

Three types of optional outputs are available with FBAT: (1) Wildland Fire Intensity, (2) Fire Behavior Simple Query, and (3) Fire Behavior Classification Query. (See Chapter 5 for more information on FBAT output). All optional outputs are selected by default. Simply uncheck the boxes to the left of the outputs that are not desired, as shown in figure 7-14:

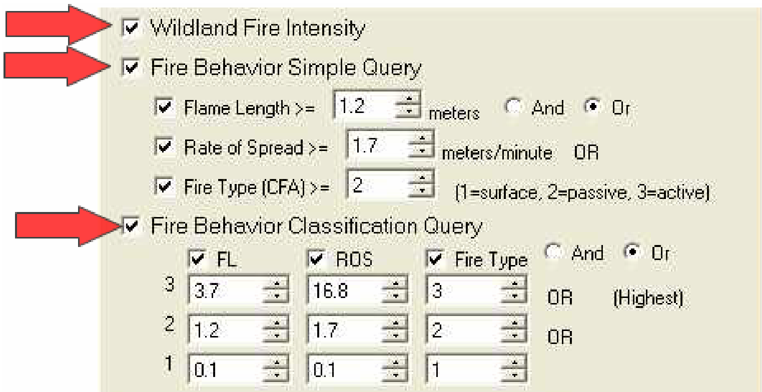


Figure 7-14. Selecting optional outputs.

If none of the optional outputs are selected, FBAT will derive only flame length (FL), flame length class, rate of spread (ROS), rate of spread class, fireline intensity, and fire type.

7.2.7 Designing queries

If the Fire Behavior Simple Query or Classification Query is selected, the user must then complete three general steps for designing a query.

1. First, identify fire behavior characteristics of interest for your query (such as flame length, rate of spread, and fire type). Selecting any combination of the three characteristics is permissible. Select the desired characteristics by checking the box located to the left of the characteristics you wish to use (fig. 7-15).

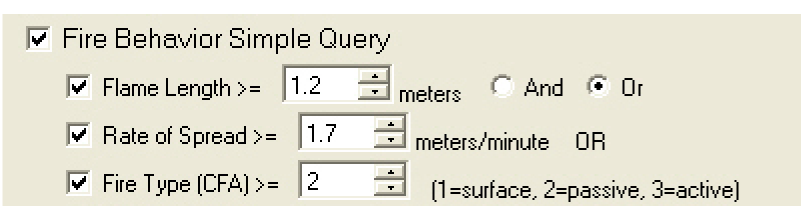


Figure 7-15. Selecting fire behavior characteristics to use with the Simple Query.

2. Next, specify whether the query will use an AND or an OR conditional statement. An AND conditional statement requires that all conditions of the query be met, whereas an OR conditional statement requires that only one of the conditions be met. FBAT uses the OR conditional statement as a default. Select the appropriate conditional statement by checking the AND or OR radio buttons located to the right of the dialog box.

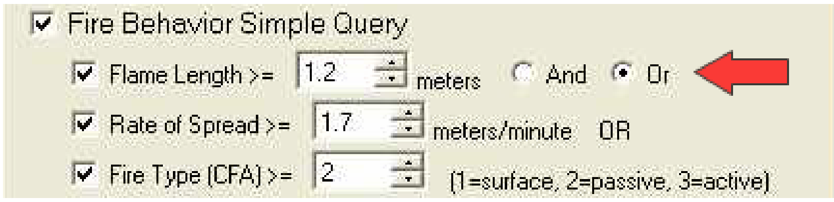


Figure 7-16. Specifying whether the query will use an AND or an OR conditional statement.

***Tip**: Be careful when selecting the conditional statement as the results of the query will vary substantially depending on which conditional statement is used.*

3. Lastly, specify threshold values for each fire behavior characteristic selected. The dialog box contains default threshold values, which are intended to characterize at least a "moderate" fire behavior hazard; the thresholds are the same as those used for deriving the moderate Flame Length Class (greater than 4 ft [1.2m] but less than 12 ft [3.7 m] and the moderate Rate of Spread Class (greater than 5.6 ft/min [1.7m/min] but less than 55 ft/min [16.8 m/min]). Similarly, default thresholds used in the Classification Query were selected so that Class 3 would denote a "high" fire behavior hazard, Class 2 would denote a "moderate" fire behavior hazard, and Class 1 would denote a "low" fire behavior hazard. Any conditions not meeting the specifications of Class 1 would be considered a "very low" fire behavior hazard.

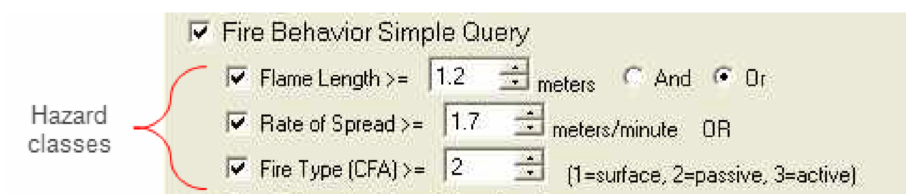


Figure 7-17. Selecting thresholds to derive hazard classes for the Simple Query.

***Note**: Thresholds for flame length and rate of spread, including all default values, must be given in metric units (meters and meters/minute, respectively).*

Simple Query

Recall that the Simple Query was designed to partition an analysis area into two classes: Class 1 represents those conditions that meet or exceed query parameters, and Class 0 represents those conditions that fail to meet query parameters. FBAT users will need to change the default parameters if they do not meet analysis objectives for a particular assessment. The query parameters can be changed by typing the desired threshold directly into the box or by using the spinner to the right of the box to adjust values up or down.

As an example, the Simple Query displayed in figure 7-18 will produce an output layer containing two classes (0 and 1). Class 1 represents areas where potential flame length would exceed 4 ft (1.2 m) OR where potential spread rates would exceed 5.6 ft/min (1.7 m/min) OR where potential fire type would likely be passive or active crown fire. Class 0 would apply to those areas that do not meet the minimum requirements of Class 1.

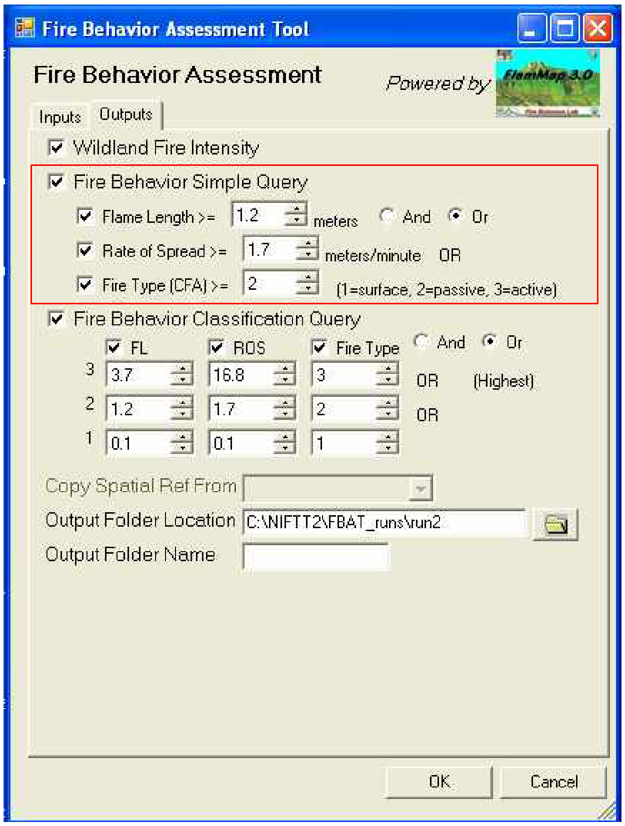


Figure 7-18. Example of completed Fire Behavior Simple Query.

Classification Query

The Classification Query is designed so that Class 3 denotes "high" fire behavior; Class 2 "moderate" fire behavior, and Class 1 "low" fire behavior. Thresholds entered in the dialog box represent the minimum thresholds for a particular class. When selecting threshold values, start either from the top with Class 3 and then work down to Class 1, or start from the bottom with Class 1, and then work up to Class 3. The query parameters can be changed by typing the desired threshold value directly into the box or by using the spinner located to the right of the box to adjust values up or down.

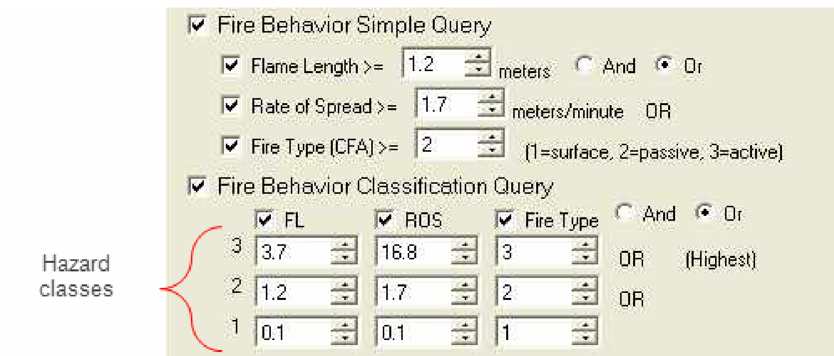


Figure 7-19. Selecting thresholds to derive hazard classes for the Classification Query.

As an example, the Classification Query shown in figure 7-20 produces an output layer with four hazard classes (0 through 3). Class 3 (high) identifies those areas where potential flame length would exceed 12 ft (3.7 m) OR where potential spread rates would exceed 55 ft/min (16.8 m/min) OR where potential fire type would likely be an active crown fire. Class 2 (moderate) denotes those areas that do not meet the minimum requirements of Class 3, but where potential flame length would exceed 4 ft (1.2 m) OR where potential spread rates exceed 5.6 ft/min (1.7 m/min) OR where fire type would likely be at least a passive crown fire. Class 1 (low) identifies those areas that do not meet the minimum requirements of Class 2, but where flame length would exceed 0.3 ft (0.1 m) OR where spread rates exceed 0.3 ft/min (0.1 m/min) OR where fire type would likely be at least a surface fire. Any other conditions not meeting the minimum requirements of Class 1 would be assigned to Class 0 (very low).

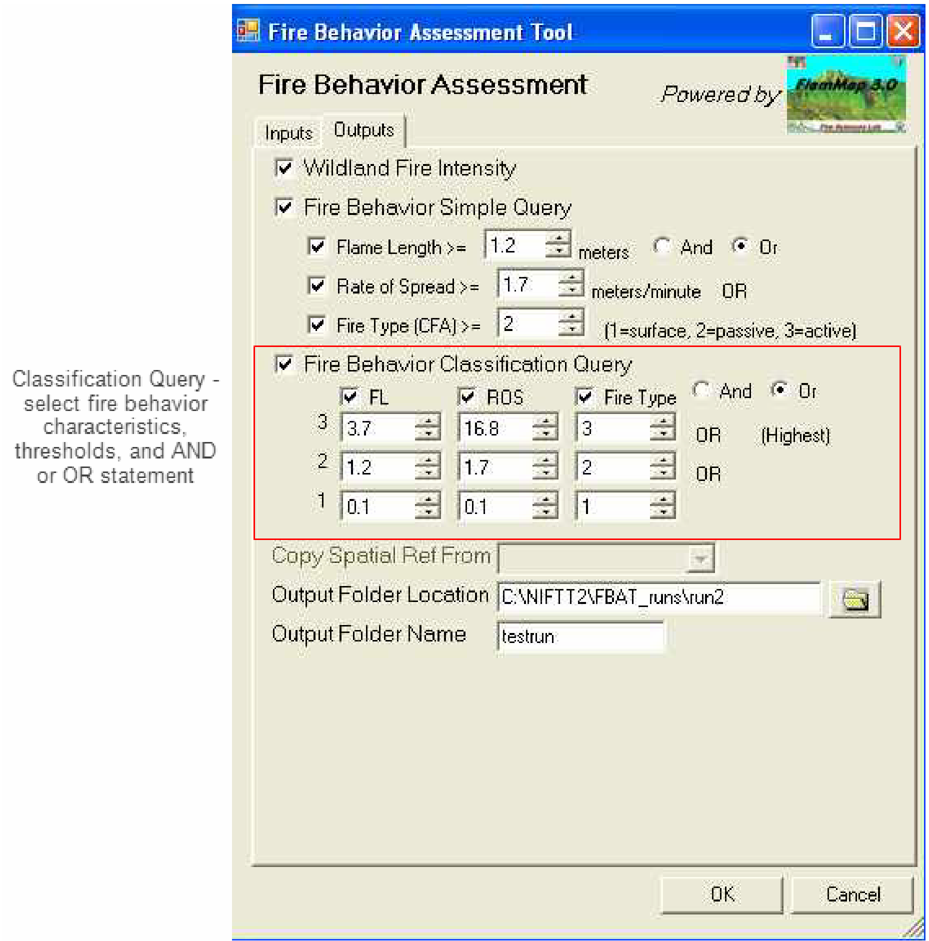


Figure 7-20. Completed Fire Behavior Classification Query.

***Note**: Fire type (CFA) classes are defined as follows:*

1 = surface fire
2 = passive crown fire
3 = active crown fire

7.2.8 Copying a spatial reference

The option of copying a spatial reference (in other words, coordinate system and projection information) from an existing layer becomes available only if the FBAT input includes a previously created landscape file. Since the landscape file itself does not contain any information about spatial references, the user must "inform" FBAT of the appropriate coordinate system and projection needed to derive spatial outputs. If spatial inputs include a pre-existing landscape file, then one of the original spatial layers used to create the landscape file should be selected. This will ensure that the spatial outputs have the same spatial reference as the layers used to create the landscape file.

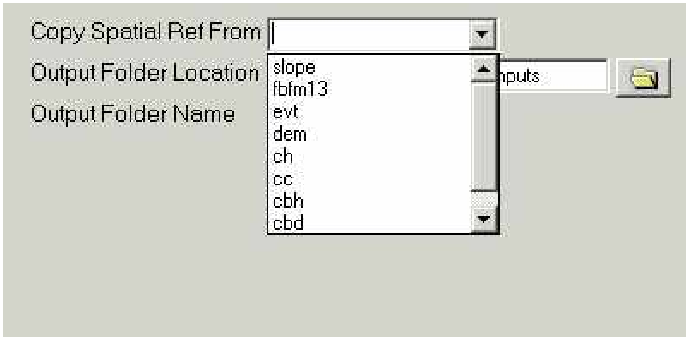


Figure 7-21. Copy Spatial Ref From drop-down menu.

***Tip**: The "Copy Spatial Ref From" drop-down menu (fig. 7-21) is active and available ONLY if the "Landscape File" was selected on the "Inputs" page of the "Fire Behavior Assessment Tool" dialog box (see section 7.2.2 for more information on completing the "Inputs" tab).*

7.2.9 Selecting output location and name of output folder

Select an output path and an appropriate folder name for your run. All of the FBAT outputs are stored in the output folder, which is created automatically. Click on the browse button to the right of the *Output Folder Location* box and navigate to an existing folder of your choice. Next, enter an Output Folder Name for your FBAT run. The folder will be located in the pathway identified as shown in figure 7-22.

Figure 7-22. Selecting output location and name of output folder.

***Tip**: If an "Output Folder" already exists, it will be overwritten.*

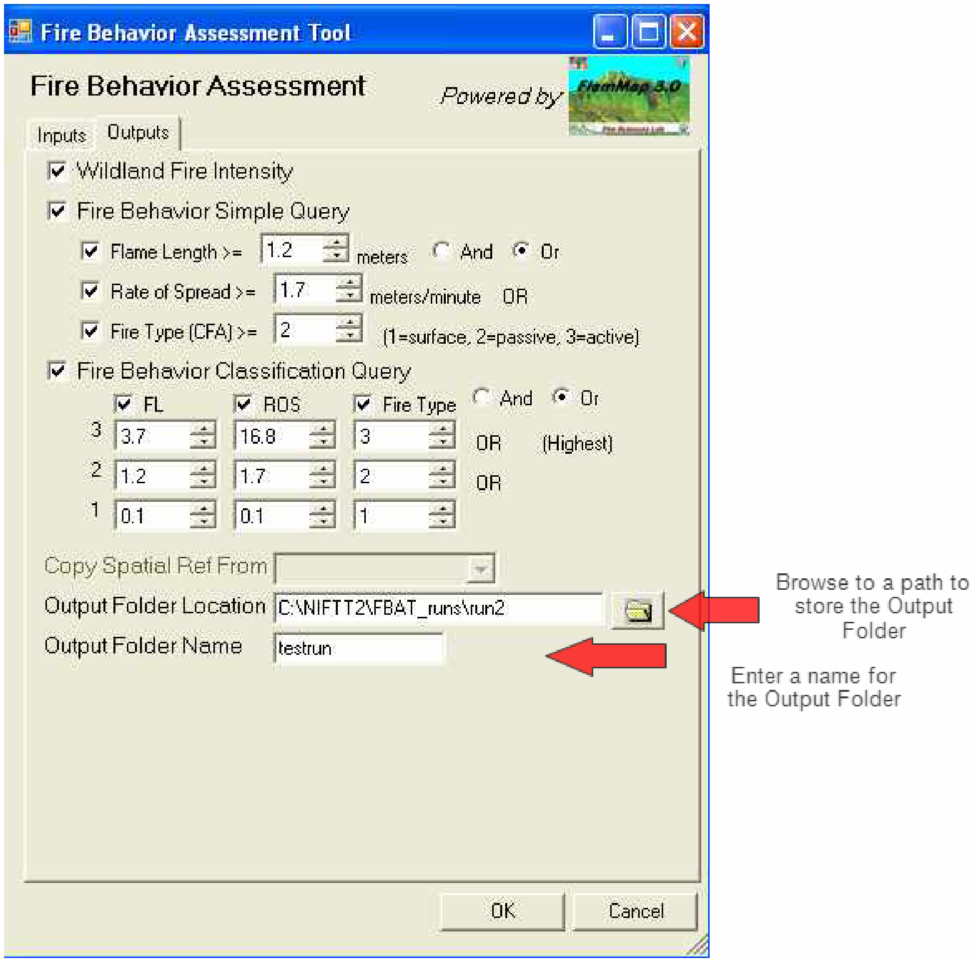


Figure 7-23. Selecting output folder name and location.

After having completed both the *Inputs* and *Outputs* dialog boxes (fig. 7-23), click **OK**. FBAT will now begin processing and will take a few minutes to run. FBAT has three main processing steps: (1) creating the landscape file, (2) initiating FlamMap and deriving fire behavior characteristics, and (3) deriving results for the Simple and Classification queries.

The individual output layers will appear in your ArcMap Table of Contents and the FBAT user interface will disappear automatically when the FBAT run is complete (fig. 7-24).

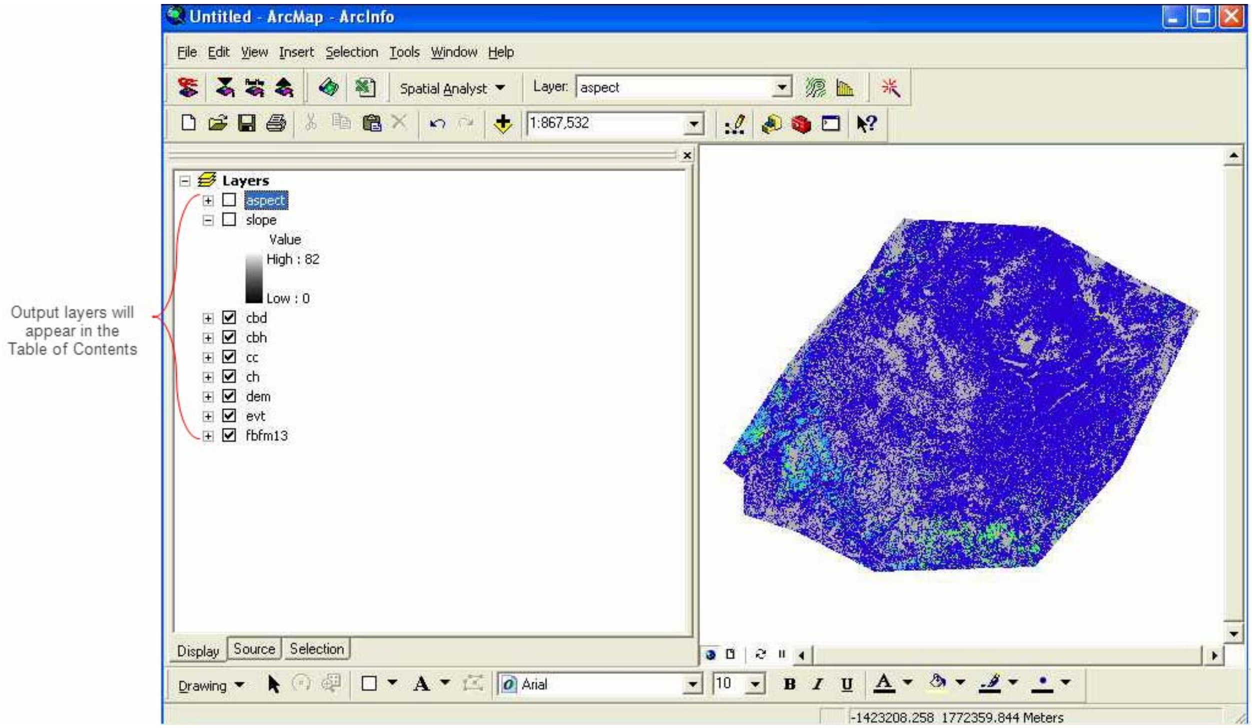


Figure 7-24. FBAT output layers in Table of Contents.

> ***Note**: FBAT version 1.3.0 automatically generates maximum spotting distance, which appears as an output layer in the Table of Contents (fig. 7-25).*

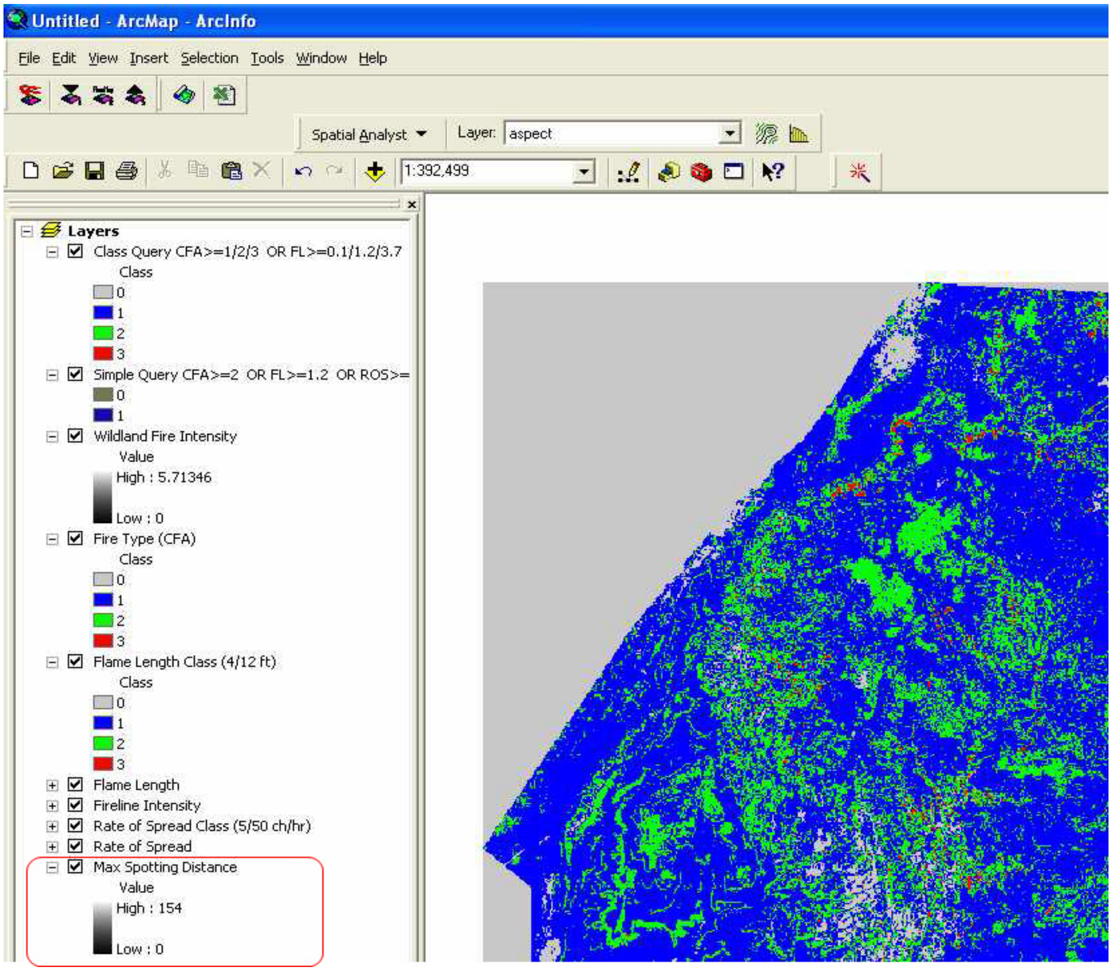


Figure 7-25. FBAT version 1.3.0 generates maximum spotting distance automatically.

***Tip**: FBAT documents the input and output parameters used in a file named "param.txt," which can be found in your "Output Folder Location" folder.*

We recommend that users save their ArcMap project as soon as the FBAT run has finished. Saving the ArcMap project will preserve the label and color schemes for each output layer.

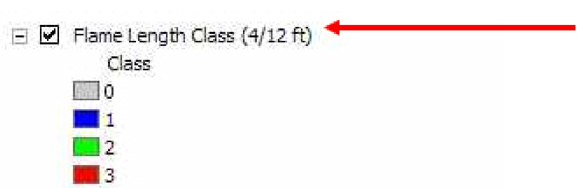


Figure 7-26. Example flame length classification legend from ArcMap Table of Contents.

***Note**: The names of the output layers that appear within ArcMap's Table of Contents are descriptive labels; they are NOT the layer names that will appear in the output folder (specifically, the "Output Folder Name" you identified in the "Output Folder Location"). (See* table 5-1 *for the layer names as they will appear in ArcCatalog). Moreover, the thresholds used to derive ArcMap's legend for the classified outputs (flame length class and rate of spread class) and query outputs can be identified in the "param.txt" file located within the "Output" folder.*

Chapter 8: Generating a Landscape File

The second icon on the FBAT toolbar generates a landscape (LCP) file, but does not run FlamMap to simulate fire behavior. This utility was added to FBAT for those who would like to create a landscape file for later use with FlamMap or FARSITE.

Figure 8-1. Icon for generating a landscape file.

8.1 What is a landscape file?

A landscape file is a binary file comprised of a header and a body of short integers for each of the themes it contains. The header contains information on the bounds of the area, the resolution of the cells, and the units of the themes. The Landscape (LCP) File contains the five basic rasterized data themes needed to run FlamMap or FARSITE: elevation, slope, aspect, fuel model, and canopy cover. The landscape file may include optional files for stand height, crown base height, canopy bulk density, coarse woody fuel, and duff loading. Optional parameters not provided in a raster file will be constant across the entire landscape as set in FlamMap's Inputs tab of the Run dialog box. Because this is the same landscape file format used in FARSITE version 4 and beyond, landscape files generated in either application are interchangeable. To use an FBAT-generated landscape file in FlamMap or FARSITE, the user must ensure that the unit settings in the data layers are the same as those required for FBAT.

8.2 Steps for generating a landscape file

1. Start ArcMap and create a new project by selecting **A new empty map**.

2. Next, load input layers into your ArcMap project by clicking on the **Add Data** icon:

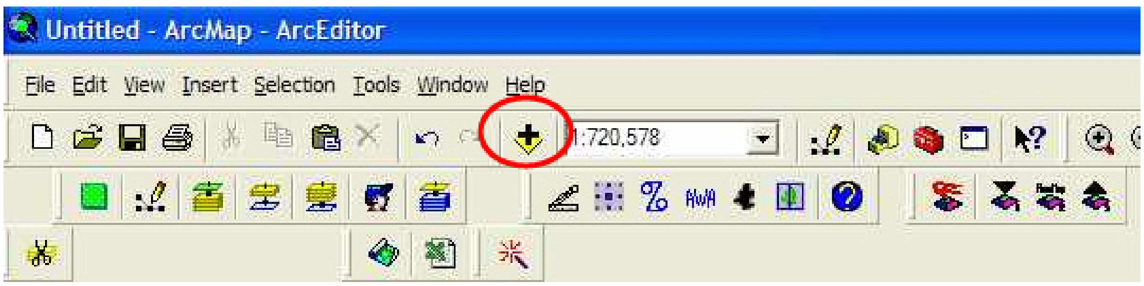


Figure 8-2. Add Data icon.

3. Navigate to the directory where your data layers are stored and add the following eight input layers: elevation, slope, aspect, fire behavior fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density. These eight layers provide the direct input for FBAT.

***Tip**: At this point, you may see several "Create pyramids" dialog boxes similar to the box shown in figure 8-3. Click No to speed up processing. If you do not want to see this box again, put a check in the lower left-hand corner to disable it.*

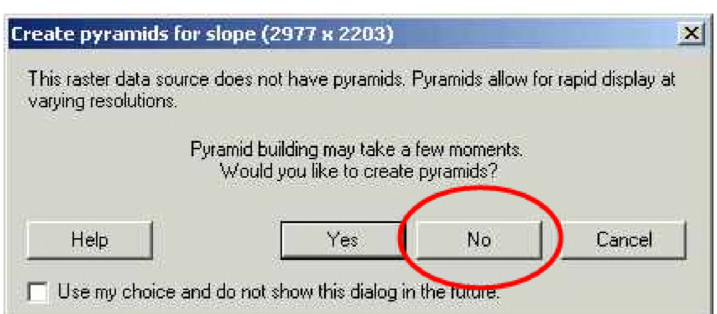


Figure 8-3. Create pyramids dialog box.

4. Ancillary layers can also be added at this time. Layers such as cities, roads, streams, wildland-urban interface, ownership, and other files can often be useful for interpretation and description, as well as for consideration of management implications.

5. If desired, rename the data frame as shown in figure 8-4 with a slow double-click on the default name Layers and save your project.

***Note**: You do not need to include the extension ".mxd" when naming your project.*

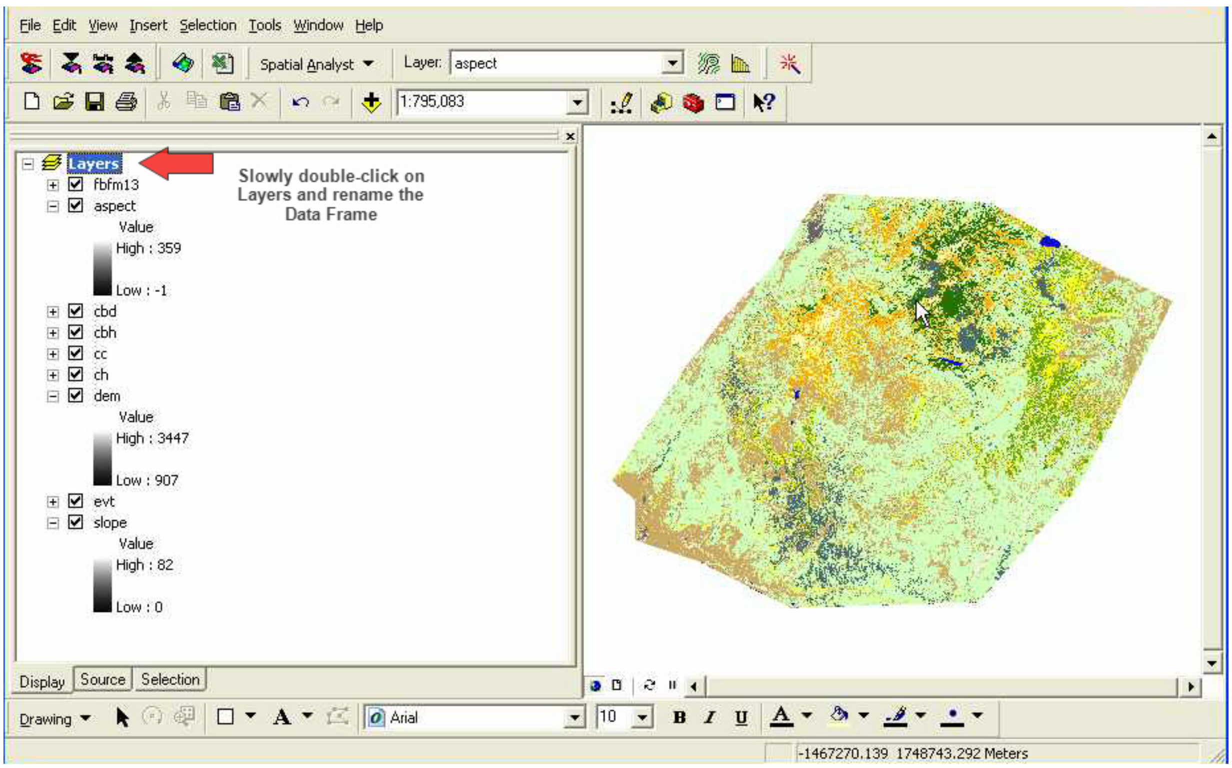


Figure 8-4. Renaming the data frame (if desired).

8.3 Selecting input layers

To generate a landscape file, you will need to add the following eight spatial layers:

- Elevation
- Slope
- Aspect

- Fire Behavior Fuel Model
- Canopy Cover
- Canopy Height
- Canopy Base Height
- Canopy Bulk Density

***Note**: All eight input layers must have the same spatial extents and coordinate system to successfully generate a landscape file. Also, remember that the input layers must be expressed in the appropriate units (see table 3-1).*

After you have finished loading the input layers into ArcMap, click on the **Generate Landscape (LCP) File** icon located second from the left on the FBAT toolbar:

Figure 8-5. Generate Landscape (LCP) File icon.

Selecting this command will open the *Landscape (LCP) File Creation* dialog box as shown in figure 8-6.

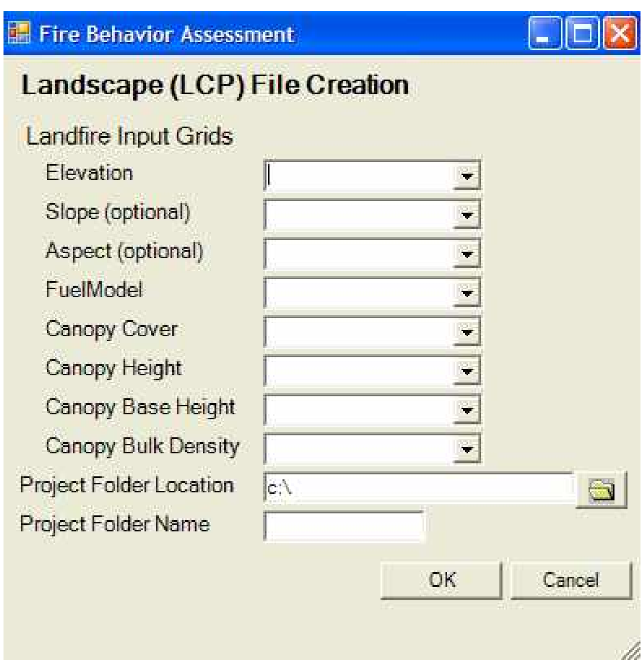


Figure 8-6. Landscape (LCP) File Creation dialog box.

First, select the appropriate input layers from the drop-down menu located to the right of each layer (fig. 8-7). Clicking on the drop-down menu will display all raster layers that are currently loaded in your ArcMap project.

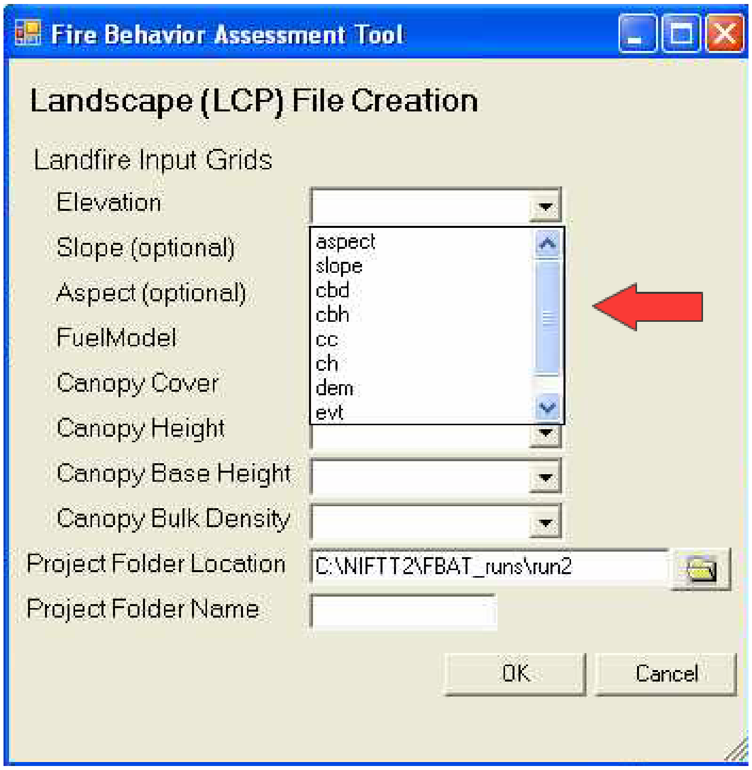


Figure 8-7. Selecting input layers.

> ***Note**: "Slope" and "Aspect" layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive slope and aspect layers from the elevation layer. However, slope may be calculated incorrectly if your data contains pixels with a value of "-9999," which denotes that those pixels lack data. In addition, the elevation layer will not always be named "elev." In some data sources it will be named "dem," an abbreviation for Digital Elevation Model.*

Next, select a Project Folder Location by using the browse button located to the right of the box to navigate to the appropriate location.

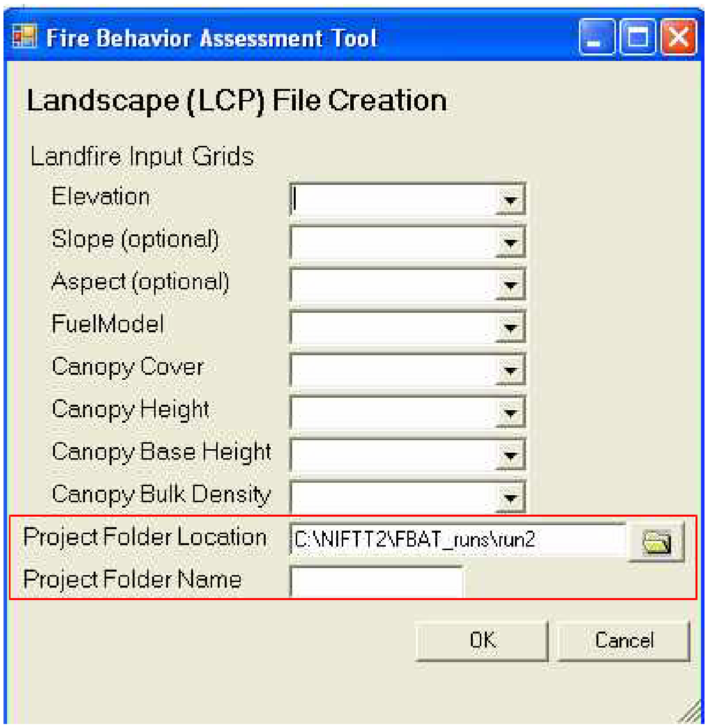


Figure 8-8. Selecting a project folder location.

Enter a folder name for storing the landscape file in the Project Folder Name box.

Click **OK** to generate the landscape file.

> ***Tip***: *The only indication that the LCP file has been created is that the "LCP File Creation" dialog box disappears automatically. This is not an error.*

Your landscape (LCP) file has been created, along with a param.txt file, and is ready for use in FlamMap or FARSITE. Verify that the LCP file has been generated by checking for the file in the project folder that was specified above in figure 8- 8.

Chapter 9: Launching FlamMap

Chapter 9 explains how to use the FBAT command Run FlamMap. The FBAT command that runs FlamMap was added so FlamMap can be opened from the ArcMap platform. This function will prove useful for those who want to compare FBAT outputs to FlamMap outputs and for those who want to run some of FlamMap's more advanced applications that cannot be run using FBAT alone (such as MTT and TOM). See Appendix B for more information on this subject.

Click the third icon from the left on the FBAT toolbar as shown in figure 9-1 to open FlamMap:

Figure 9-1. Icon for launching FlamMap.

> ***Note**: The FlamMap application must be installed separately for this command to work. To learn more about downloading FlamMap, see Appendix B.*

At this point, you will see the following screen:

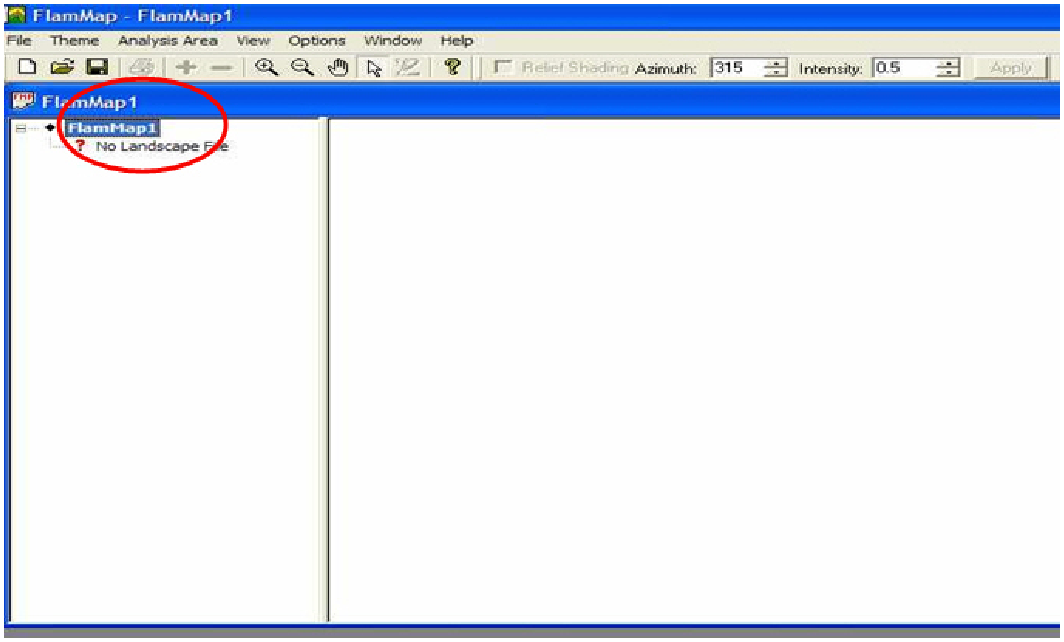


Figure 9-2. FlamMap application.

FlamMap is now available for use (see Appendix B).

To work with the FlamMap tutorial, open FlamMap and from the Toolbar, and select **Help > Contents > Tutorial**. The following screen will open:

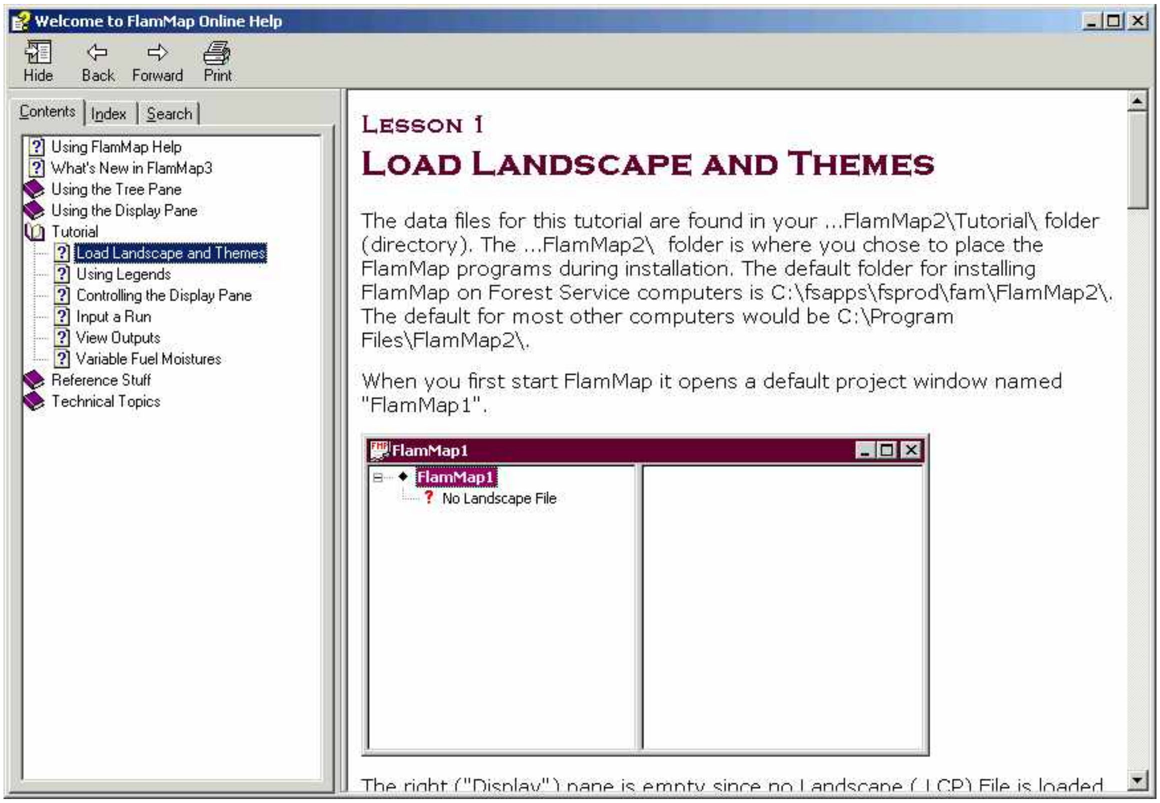


Figure 9-3. FlamMap tutorial.

Chapter 10: Generating FBAT outputs

10.1 Selecting inputs
10.2 Copying a spatial reference
10.3 Selecting project folder location and name
10.4 FBA metrics tab
10.5 FBA queries tab

The FBAT command to generate outputs (Generate FBAT outputs) is typically used to adjust Simple and Classification query parameters for an existing FBAT run. This command does not build a new landscape file, nor does it rerun FlamMap. Do not use this command if you plan to change any of the inputs to FlamMap.

To begin, click on the last icon on the FBAT toolbar as shown in figure 10-1:

Figure 10-1. Icon for generating FBAT outputs.

Selecting this icon will open the dialog box displayed in figure 10-2. This dialog box has three tabs: *Inputs*, *FBA Metrics*, and *FBA Queries*.

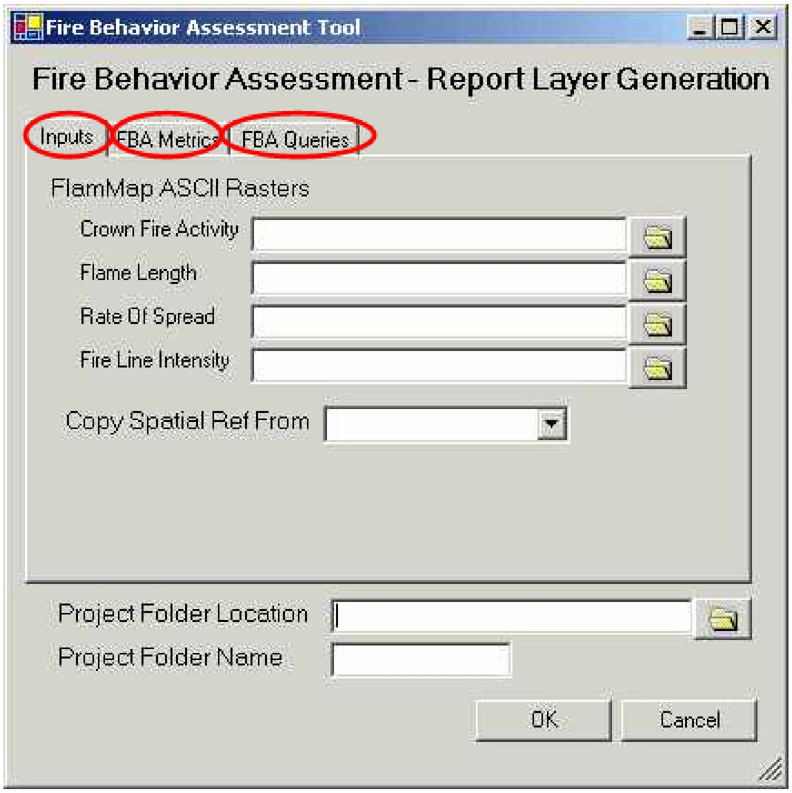


Figure 10-2. *Fire Behavior Assessment – Report Layer Generation* dialog box.

10.1 Selecting inputs

First, make sure that the *Inputs* tab is selected (fig. 10-3). FBAT requires that input layers be in ASCII format. The ASCII-formatted layers can be found in the Results folder of previous FBAT runs and are denoted as *FlamMap.CFR, FlamMap.FML, FlamMap.ROS*, and *FlamMap.FLI* for crown fire activity (CFA), flame length, rate of spread, and fireline intensity, respectively.

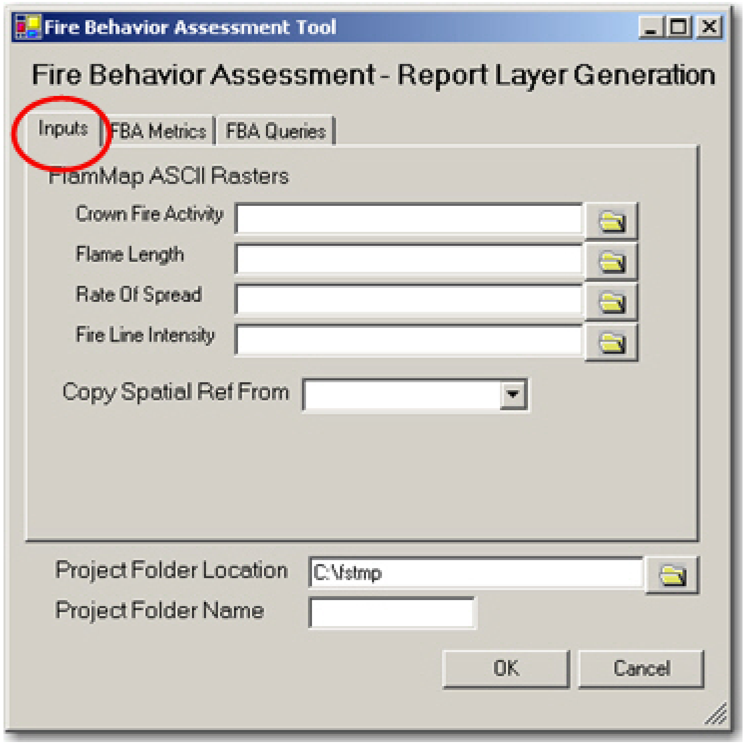


Figure 10-3. Selecting Inputs tab.

Click on the browse button to the right of the required input layer as shown in figure 10-4 and navigate to the output folder of a previous FBAT run.

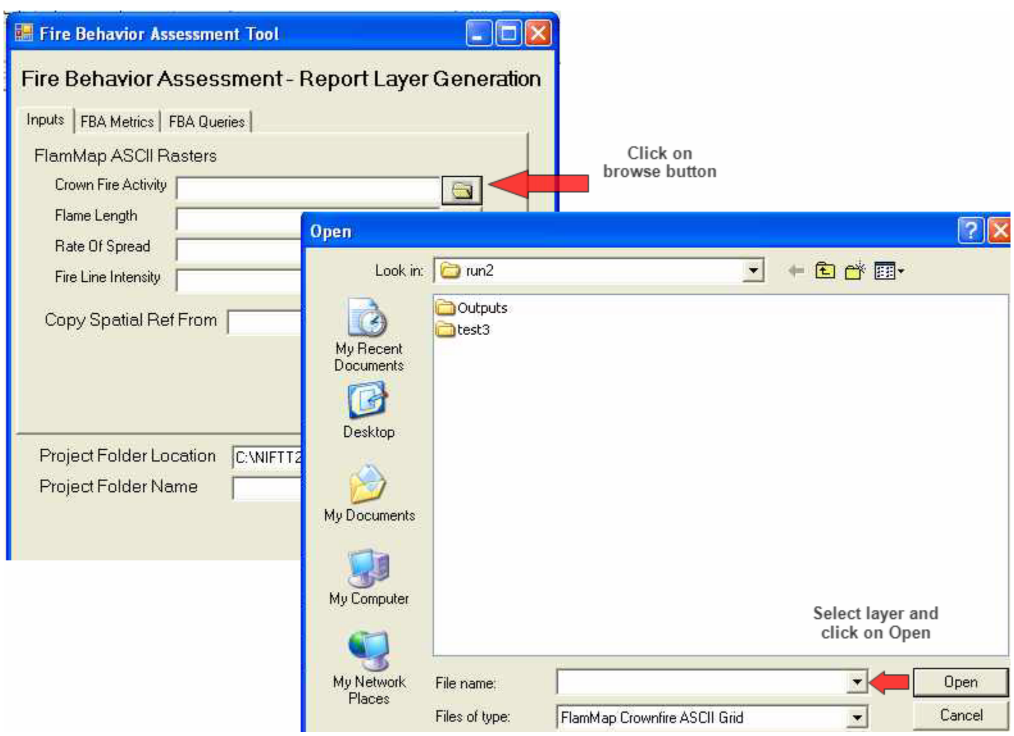


Figure 10-4. Navigating to Outputs folder.

You can choose between the following four default layers: F*lamMap.CFR, FlamMap.FML, FlamMap.ROS*, or *FlamMap.FLI.* Only one of these layers, the correct choice, will be available for each parameter. You must include all four input layers even if some of those layers will not be used in your modified query(s).

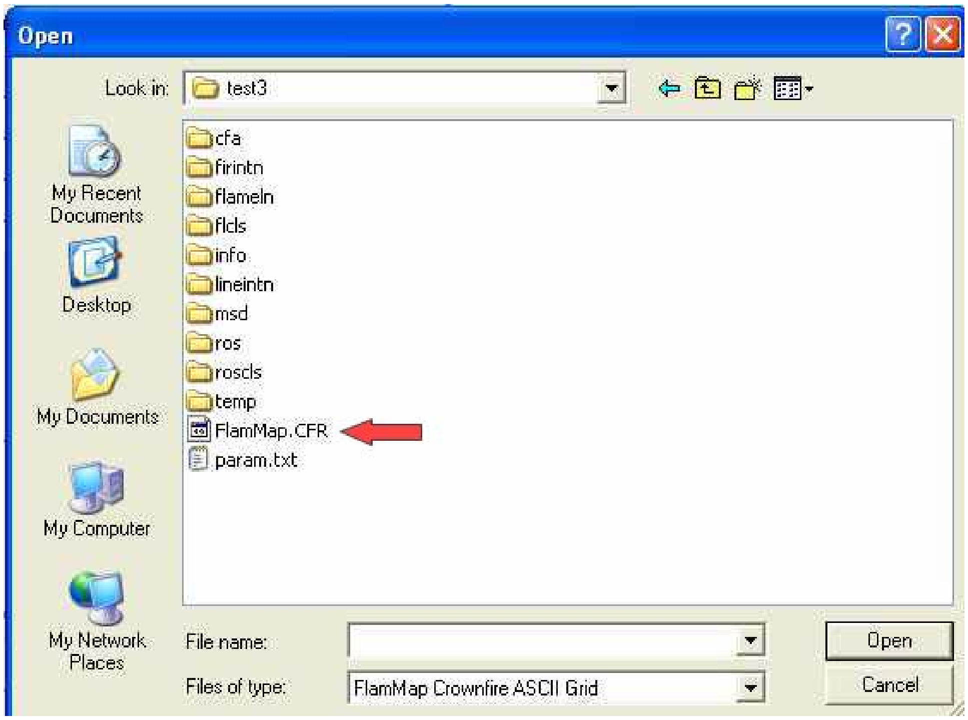


Figure 10-5. Example of default input layer for Crown Fire Activity.

10.2 Copying a spatial reference

ASCII files do not contain a spatial reference (coordinate system and projection information). You will therefore need to select a layer with the appropriate spatial reference from your ArcMap Table of Contents. The option of copying a spatial reference from an existing layer becomes available only if your FBAT input includes previously created files. We recommend that you select one of the layers used to generate your landscape file.

To load layers into ArcMap, follow these steps:

1. Start ArcMap.

2. Next, load input layers into your ArcMap project by clicking on the **Add Data** icon, as shown in figure 10-6:

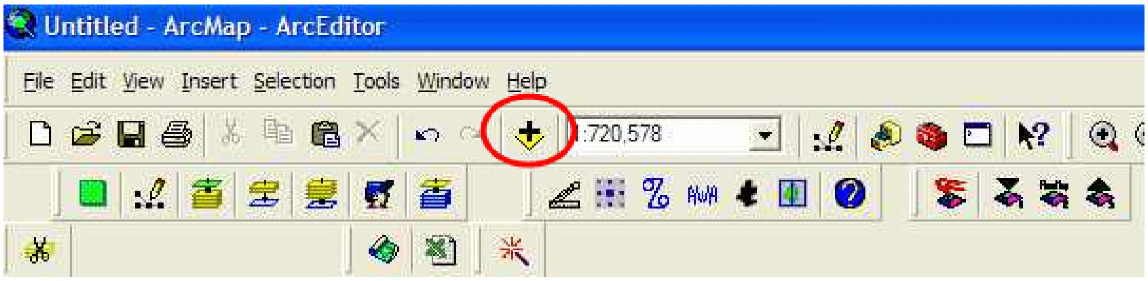


Figure 10-6. **Add Data** icon.

3. Navigate to the directory where your data layers are stored and add the following eight input layers: elevation, aspect, slope, fire behavior fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density. These eight layers provide the direct input for FBAT.

   ***Tip**: At this point, you may see several "Create pyramids" dialog boxes. Click on No to speed up processing. If you do not want to see this box again, put a check in the lower left-hand corner to disable it.*

4. Once these layers have been added to ArcMap's Table of Contents, click on the drop-down menu to select a layer with an appropriate spatial reference, as shown in figure 10-7.

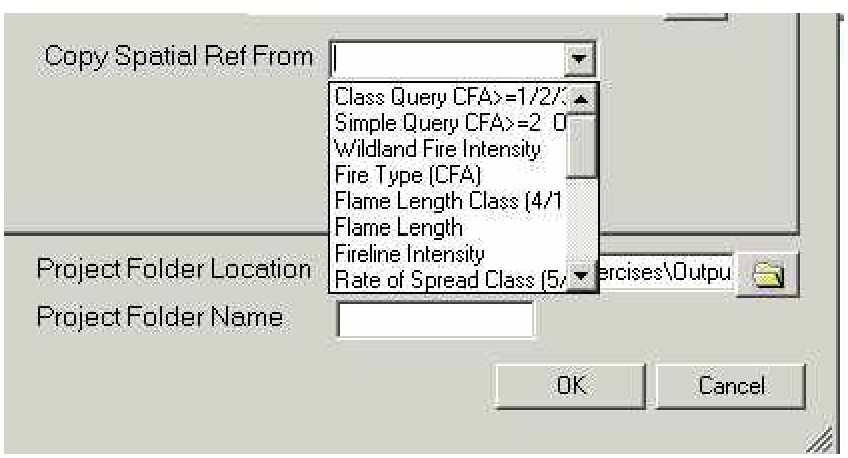


Figure 10-7. Selecting a layer with an appropriate spatial reference.

The *Copy Spatial Ref From* drop-down menu will not be populated if you do not have layers already loaded into ArcMap. If you fill out all of the FlamMap ASCII Rasters boxes and click **OK** to run the Generate FBAT outputs without first loading files into ArcMap, you will see the error message shown in figure 10-8:

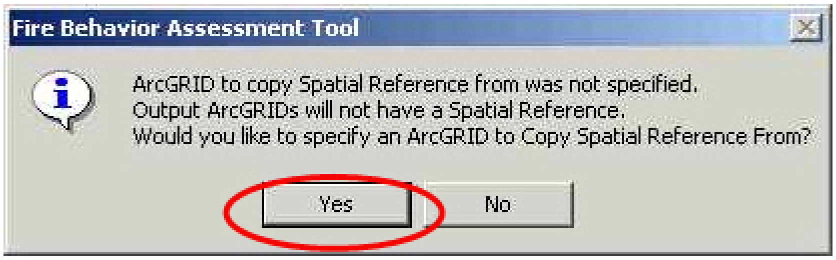


Figure 10-8. Output ArcGRIDs error message indicating need to specify a spatial reference.

> ***Note**: Clicking on "Yes" (fig. 10-8) will not automatically generate a drop-down menu in the "Copy Spatial Ref from" box (fig.10-7). You will need to add the layers as described above.*

Once the layers are present in ArcMap, click on the **Generate FBAT** output icon and again complete the *Inputs* tab as described in section 10.1. You will now be able to select a layer with an appropriate spatial reference from the drop-down menu as shown in figure 10- 7.

10.3 Selecting project folder location and name

FBAT outputs will be stored in the project folder. Use the browse button to the right of the *Project Folder Location* box to navigate to a location where you wish to store the project folder. Type a name for the project folder in the *Project Folder Name* box.

> ***Tip**: Do not click "OK" until you have completed all three tabs of the dialog box.*

Figure 10- 9. Selecting a Project Folder Name and Location.

10.4 FBA Metrics tab

Select the **FBA** (Fire Behavior Assessment) **Metrics** tab to open the dialog box displayed in figure 10-10. This tab allows you to select metrics that you may not have selected in an earlier simulation. Wildland Fire Intensity is currently the only metric available. There is no need to create a new Wildland Fire Intensity metric if it was derived in a previous FBAT run. Check the box to the left of the *Wildland Fire Intensity* metric only if you did not create this layer previously but would like to create it now.

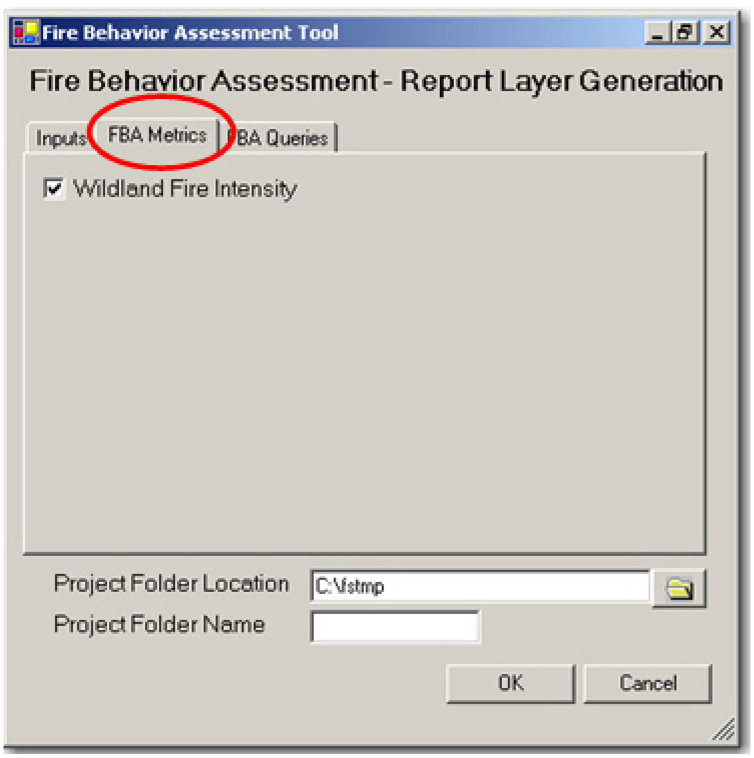


Figure 10-10. Selecting FBA Metrics.

> ***Tip**: Do not click "OK" until you have completed all three tabs of the dialog box.*

10.5 FBA Queries tab

Select the **FBA** (fire behavior assessment) **Queries** tab to open the dialog box displayed in figure 10-11. Check the box to the left of those queries that you would like to rerun. Edit the query parameters (such as *Flame Length, Rate of Spread,* and *Crown Fire Activity*) to match your analysis objectives. (See Chapter 7 for guidance on designing queries).

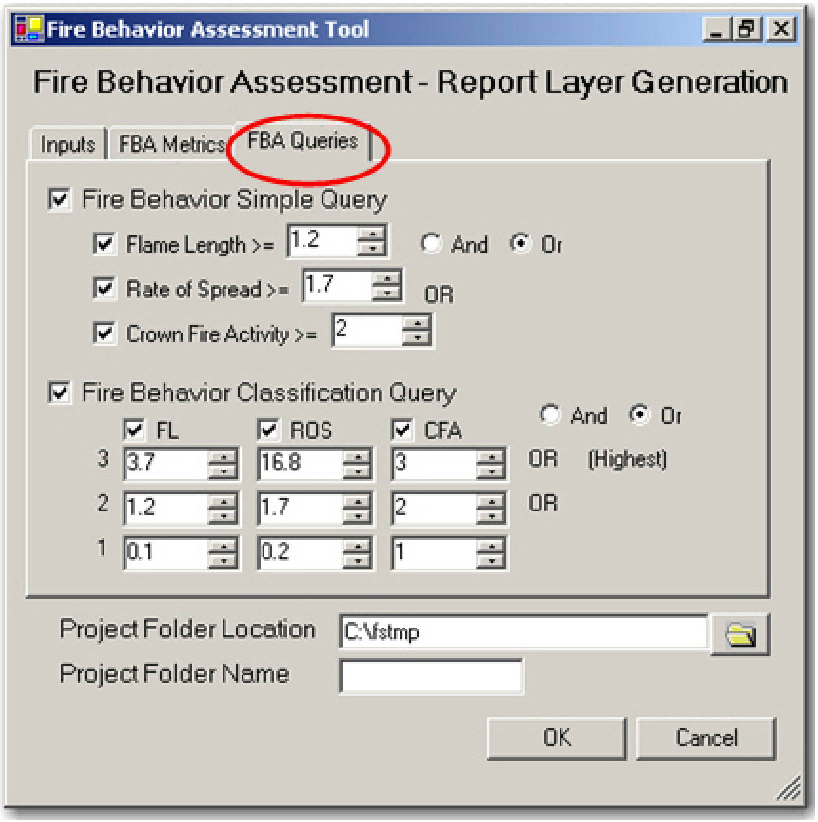


Figure 10-11. Selecting FBA queries.

Click **OK** after providing all of the appropriate information in each of the three dialog boxes. The resulting spatial layers will automatically appear in the ArcMap Table of Contents as well as in your designated project folder.

> ***Note**: The run may take several minutes.*

Chapter 11: Troubleshooting FBAT – Common Errors, Symptoms, and Solutions

> ***Tip**: Make sure that the FBAT version you are using correctly matches your version of ArcGIS. Use FBAT version 1.3.0 only with ArcGIS 9.2*

Perhaps the most common FBAT (and FlamMap) user issue is that modeled potential fire behavior does not coincide with observed fire behavior. The discrepancy between simulated and observed fire behavior can generally be attributed to FBAT input parameters. These parameters can include fuel input data as well as environmental conditions such as wind speed and direction.

Fuel data are often derived from vegetation attributes, which can be poor correlates of fuel characteristics. In addition, accurate identification of the input parameters (such as fuel moisture, wind speed, and wind direction) that result in observed fire behavior can also be problematic. For example, it may be difficult (after the fact) to identify the actual 20-ft wind speed and direction that occurred during an active crown fire.

We recommend that users review Stratton (2006) for guidance on evaluating input data and fire behavior outputs as well as for guidance on calibrating models to observed local fire behavior. The discussion of climatology and fire analysis is particularly useful for identifying appropriate environmental parameters for modeling specific fire scenarios.

The following guidelines can be used if you have doubts regarding the accuracy of your output.

11.1 Evaluating input data

1. **Evaluate the fire behavior fuel model layer**. Does it seem appropriate for your particular analysis scenario? For example, a fuel model layer developed from observations taken during the green-up period will probably not be suitable if you are trying to simulate fire behavior to reflect

conditions during the peak of the fire season. The appropriate fuel model on a given site can vary according to plant phenology as well as with yearly fluctuation in available moisture. In addition, accurate simulation of expected fire behavior is unlikely if the fuel model has been misclassified. For example, crown fire simulation cannot generally be modeled using the Anderson (1982) Fuel Model 8: Closed Timber Litter, which is often characterized under common burning conditions by slow-burning ground fires with low flame lengths.

2. **Evaluate the canopy base height layer**. Canopy base height is a critical variable for determining the transition between surface fire and crown fire. Do the values seem reasonable for your analysis area? Simulating crown fire may be troublesome if the values for canopy base height are too high.

3. **Evaluate the canopy bulk density layer.** Canopy bulk density serves as a critical variable for determining the transition from passive to active crown fire. Do the values seem reasonable for your analysis area? Simulating active crown fire may be troublesome if the values for canopy bulk density are too low.

4. **Evaluate the canopy cover layer.** Canopy cover and effective mid-flame wind speed are inversely related. Thus, dense canopy cover will substantially decrease mid-flame wind speed, which subsequently reduces flame length, which in turn reduces the likelihood of transition from surface fire to crown fire. Be suspicious of canopy cover values exceeding 70 percent (see Scott and Reinhardt [2005]).

5. Evaluate the slope layer. Typically, slope layers are derived from digital elevation models (DEMs). A poor quality DEM can be recognized by the occurrence of "spikes" or "troughs." Using a poor quality DEM to derive a slope layer will result in unrealistic slope values.

   Tip: *Many of the errors discussed above can often be detected by simply viewing the layers and zooming-in when necessary.*

11.2 Evaluating input parameters

1. **Consider which crown fire calculation algorithm you used.** Use of the Scott and Reinhardt (2001) algorithm will increase the amount of active crown fire relative to passive crown fire.

2. **Evaluate the surface fuel moisture file used for the simulation**. Do the fuel moisture values truly reflect the scenario that you were trying to simulate? See Stratton (2006) for a detailed discussion on obtaining fuel moisture parameters from local remote automated weather stations (RAWS).

3. **Evaluate the wind speed and direction used for the simulation**. (See Stratton [2006] for information on how to obtain wind speed and direction parameters). Because FBAT does not currently allow the use of wind vectors, we encourage users to use the uphill" option as this will maximize fire behavior. However, using upslope winds does not adequately simulate actual fire weather. Wind vectors, on the other hand, vary wind speed and direction according to topography to provide a more realistic simulation.

4. **Recognize that FBAT does not allow for fuel moisture conditioning;** therefore, moisture values within a given fuel model do not vary despite differences in elevation, aspect, and canopy cover. This limitation can result in unrealistic fire behavior simulations.

5. **Evaluate the canopy fuel moisture used for the simulation**. Many people use the default of 100 percent. This may underestimate the transition to crown fire during cumulative drought conditions or in areas with short-needled conifer species.

6. **Review the environmental parameters used for your FBAT run**. Open the param.txt file located in the output folder you specified for your simulation. Ensure that a mistake was not made when selecting the fuel moisture file, wind speed, wind direction, and/or foliar moisture content. In addition, check to make sure that you selected the correct input layers. For example, unrealistic simulations may result if you inadvertently used the canopy height layer to represent canopy base height.

   ***Note**: For FBAT to function properly, the analysis area that you select is currently limited to approximately 4 million pixels in size.*

   To report a bug, please contact helpdesk@niftt.gov.

Appendix A: References

Anderson, H. E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 22 p.

Finney, M. A. 1998. FARSITE: fire area simulator; model development and evaluation. Res. Pap. RMRS-RP-4. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Finney, M. A. 2005. The challenge of quantitative risk analysis for wildland fire. Forest Ecology and Management. 211: 97–108.

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Appendix B: Introduction to FlamMap

B.1 About FlamMap

(from http://www.fire.org)

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (such as spread rate, flame length, and fireline intensity) over an entire FARSITE landscape for constant weather and fuel moisture conditions.

FlamMap is widely used by the National Park Service (U.S. Department of the Interior), Forest Service (U.S. Department of Agriculture), and other federal and state land management agencies in support of fire management activities. It is designed for those familiar with fuels, weather, topography, wildfire situations, and the associated terminology. Because of FlamMap's complexity, only those with proper fire behavior training and experience should use the application when outputs are to be used in support of fire and land management decisions.

B.2 Using FlamMap

- FlamMap software creates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) and environmental conditions (dead fuel moistures, mid-flame wind speeds, and solar irradiance) over the entire FARSITE landscape. These raster maps can be viewed in FlamMap or exported for use in a global information system, image, or word processor.

- FlamMap is not a replacement for FARSITE or a complete fire growth simulation model. There is no temporal component in FlamMap. It uses spatial information on topography and fuels to calculate fire behavior characteristics at one instant.

- FlamMap uses the same spatial and tabular data as FARSITE:
  - a Landscape (.LCP) File,
  - Initial Fuel Moistures (.FMS) File,
  - optional Custom Fuel Model (.FMD),
  - optional Conversion (.CNV) File,
  - optional Weather (.WTR) File, and
  - optional Wind (.WND) File.

- FlamMap incorporates the following fire behavior models:
  - Rothermel's 1972 surface fire model,
  - Van Wagner's 1977 crown fire initiation model,
  - Rothermel's 1991 crown fir spread model, and
  - Nelson's 2000 dead fule moisture model.
  - a Landscape (.LCP) File,

- FlamMap runs under Microsoft Windows operating systems (Windows 95, 98, ME, NT, 2000, and XP) and features a graphical user interface.

  ***Note**: FlamMap has not yet been tested with the Microsoft Windows VISTA operating system.*

- Users may need the support of a geographic information system (GIS) analyst to use FlamMap. Rasters must be in the same projection system and pixel size must also match.

- In addition to the usual menus, commands, and toolbar buttons, FlamMap has a hierarchical tree interface that makes it easy to navigate throughout a fire behavior analysis.

- Instead of using the same dead fuel moisture values for all cells of a fuel model, FlamMap has the ability to use weather data so as to estimate dead fuel moisture based on slope, shading, elevation, aspect, and the weather stream.

- Because FlamMap uses fuel moisture values at one point in time, and of course topography does not change, FlamMap is an ideal tool to compare relative fire behavior changes resulting from fuel modifications. However, FlamMap will not simulate temporal variations in fire behavior caused by weather and diurnal fluctuations, nor will it display spatial variations caused by backing or flanking fire behavior. These limitations need to be considered when viewing FlamMap output in an absolute rather than relative sense.

B.3 What's new in FlamMap version 3.0?

FlamMap version 3.0 (FlamMap3) was released in March 2006. Major recent feature additions include support for the Scott and Burgan (2005) Fire Behavior Fuel Models, the Minimum Travel Time fire growth model (described below), and the Treatment Optimization Model (also described below). In addition, a second method for calculating crown fire behavior has been added. All of the features found in FlamMap2 are still available in this newer version.

The Minimum Travel Time (MTT) fire growth model is a two-dimensional fire growth model. It calculates fire growth and behavior by searching for the set of pathways with minimum fire spread times from point, line, or polygon ignition sources. In theory, the results are identical to those of the wave-front expansion simulation technique used in FARSITE with the exception that all weather and fuel moisture conditions are held constant over time in MTT but allowed to vary in time in FARSITE.

The Treatment Optimization Model's (TOM) calculations rely on the MTT calculations to identify major fire travel routes, and then the model attempts to efficiently block these routes with fuel treatments. Given target weather conditions, the model will select the fuel treatments that best reduce fire growth rates.

> ***Tip**: See "What's New in FlamMap3" in online help for more information on these features.*

B.4 Downloading FlamMap

To download FlamMap, go to http://www.fire.org and click on **FlamMap > Downloads >** FlamMap3Setup.msi.

FlamMap3Setup.msi (6.4 MB) is a Windows installer module containing all files as well as Help and Tutorial data. Download this file to a temporary directory and install by using the Add/Remove Programs control panel or by simply double-clicking.

> ***Note**: The msi file referenced above requires the latest version of Windows Installer. During the installation process, you will be notified if your system does not contain the most recent Windows Installer distribution from Microsoft, and your computer system will attempt to update Windows Installer from Microsoft's website.*

If you select the full installation package as shown above, you will get the FlamMap install, a helpful tutorial with sample data, as well as full on-line help.

Appendix C: Off the Richter: magnitude and intensity scales for wildland fire

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Introduction

Quantitative scales of wildland fire magnitude and intensity are needed to assess and publicly communicate the unbiased potential of wildland fire to cause effects—harm, damage, and ecological change. Such scales already exist for earthquakes (Richter Scale and Mercalli Scale), hurricanes (Saffir-Simpson Scale), tornadoes (Fujita Scale), and even near-Earth objects (Torino Impact Hazard Scale). Standard quantitative scales of wildland fire magnitude and intensity would (1) set a standard for communicating important fire characteristics to the public, and (2) provide a context for public understanding of the potential for a fire to cause harm or damage (see Binzel 1997).

The magnitude of a natural event like wildland fire—its potential to cause effects—is a function of energy release rate. Magnitude is a measure of an event as a whole; a high-magnitude event has great potential as a whole to cause harm or damage. That potential is not necessarily uniform. Some parts of a high-magnitude event have little potential to cause effects—the rear of a large fire, for example—whereas other parts have great potential. The potential for causing effects at any particular place is measured as intensity, the rate of energy release at that place and time. Magnitude and intensity are measures of potential to cause effects; actual effects are also a function of exposure—the presence of susceptible values in a hazardous situation. A high-magnitude event can cause no damage if no susceptible values are exposed to it.

A wildland fire intensity scale

Byram (1959) defines fireline intensity (IB) is the rate of heat release per unit length of fire front (kW · m-1), regardless of flame front depth. IB is a fundamental fire characteristic variable containing "…about as much information about a fire's behavior as can be crammed into one number" (Van Wagner 1977).

$$I_B = H * w_f * \left(R/60 \right) \quad [1]$$

where *H* is the low heat of combustion (kJ · kg-1), *wf* is the load of fuel consumed in the flaming fire front (kg · m-2), and R is the linear rate of spread (m · min-1). *IB* can be estimated or simulated for any spatially explicit landscape element on a past or future fire. The resulting values of IB span nearly five orders of magnitude, from less than 10 kW m-1 for a slow-spreading fire in light fuel to more than 100 000 kW m-1 for a fast-spreading fire in heavy fuel. This very large range of IB makes communication and interpretation difficult. As a simple scale for communication with the media and public, I propose to use the common logarithm of *IB (kW · m-1)* as a scaled measure of wildland fire intensity (I)

$$I = Log_{10}\left(I_B\right) \quad [2]$$

For the range of IB noted above, *I* ranges from less than 1 to just greater than 5 (six classes).

A wildland fire magnitude scale

The rate of energy release of a fire as a whole is termed total fire flux (Catchpole and others 1982). Total fire flux, ∫IB, is the integral of fireline intensity around the perimeter of a fire. If a fire perimeter is broken down into n segments of uniform IB, then ∫IB (kW) is the sum-product of IB and segment length for all segments around the perimeter. Total fire flux can also be calculated as (Catchpole and others 1982)

$$\int I_B = \left(\frac{dA/dt}{60} \right) H w_f \quad [3]$$

where *dA/dt* is the rate of fire area increase (m2 · min-1). For example, if a fire's area is known at two points in time, average area growth rate is simply the difference in area divided by the time interval. For an elliptical fire in uniform conditions

$$dA/dt = 2\pi abt \quad [4]$$

where *t* is the time (min) since start of point-source fire growth, and

$$a = \frac{R_{head}}{1 + \sqrt{1 - L_B^{-2}}}$$ [5]

$$b = \frac{a}{L_B}$$ [6]

where *Rhead* is the linear rate of fire spread in the heading direction and *LB* is the length-to-breadth ratio of the fire. Andrews (1986) estimated LB as a simple function of effective mid-flame wind speed (Ue).

$$L_B = 1 + 0.155 * U_e$$ [7]

for Ue measured in km · h-1. It is not necessary to know t explicitly (which requires an unrealistic assumption of constant fire growth conditions throughout the time period) as long as current fire size is known, because for an elliptical fire the effective time required to achieve a given size is

$$t = \sqrt{A/\pi ab}$$ [8]

and therefore

$$dA/dt = \sqrt{4\pi abA}$$ [9]

where *A* is the area (m2) of the fire.

Like IB, total fire flux ranges over many orders of magnitude. An incipient fire of 1 m2 with LB = 1.0 that consumes 0.1 kg · m-2 in the flaming front and spreads at 0.5 m · min-1 produces 55 kW (IB = 15 kW · m-1 around all portions of the perimeter). In contrast, a 100 000 ha fire of LB = 4.0 that consumes 4.0 kg · m-2 in the flaming front and spreads 100 m · min-1 at the head produces a theoretical 3.5 billion kW (with corresponding IB = 125 000 kW · m-1, and I = 5.1). Because of the huge theoretical range of ∫IB, and to satisfy the need for a simple measurement for communication with the media and public, I propose to use the common logarithm of total fire flux (kW) as a scaled measure of wildland fire magnitude (M), and to categorize magnitude by factors-of-ten.

$$M = Log_{10}\left(\int I_B\right)$$ [10]

For the range of total fire flux noted above, M ranges from less than 1 for an incipient fire to greater than 9 for a large, fast-growing fire in heavy fuel (resulting in ten classes).

Summary and Conclusions

The magnitude and intensity scales defined here standardize the measurement and communication of two important fire characteristics with the public: intensity of any portion of a fire and its magnitude as a whole. Like the Richter Scale for earthquake magnitude, the wildland fire scales are logarithmic, which minimizes the effects of measurement error and fully exposes the wide range of variability of both IB and ∫IB. The intensity scale relates to a particular point on a fire's perimeter at a particular time; it can be mapped for a past or potential fire. The magnitude scale applies to the whole fire at a particular point in time.

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