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ArcFuels10 Tutorial Supplemental Information

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ArcFuels10 Tutorial - Supplemental Information

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Abstract

ArcFuels10 is a toolbar implemented in an ArcMap interface which leverages pre-existing programs. This supplemental information document is intended for users who require more information about the Forest Vegetation Simulator and the Fire and Fuels Extension, FlamMap 5, FireFamily Plus, and Landscape Treatment Designer programs. These four programs are leveraged by ArcFuels10 and a familiarity will enhance understanding of the ArcFuels10 process and tools. In addition, basic ArcMap information to help less advanced users is included. The information within this document is not intended to be all inclusive; readers are encouraged to refer to the individual program websites, help guides, and tutorials.

Keywords: ArcMap, FlamMap 5, FireFamily Plus, Forest Vegetation Simulator, Landscape Treatment Designer

Contents

1. Introduction

ArcFuels10 is a custom toolbar designed for use with ArcMap (fig. 1-1). The ArcMap framework helps users incorporate data from a variety of sources to address project-specific issues that typify many fuel treatment projects. ArcFuels10 provides a logical flow from stand to landscape analyses of vegetation, fuel, and fire behavior, using a number of different models (table 1). Of the models leveraged by ArcFuels10, the Forest Vegetation Simulator (FVS, Crookston and Dixon 2005) and the Fire and Fuels Extension to FVS (FFE-FVS, Rebain 2010), Stand Visualization System (SVS, McGaughey 1997), and FlamMap (Finney 2006) are the most used. This document will provide information about FVS/FFE-FVS, FlamMap (version 5), and FireFamily Plus (Main et al. 1990); SVS is not included because it is only used for the graphical display capabilities.

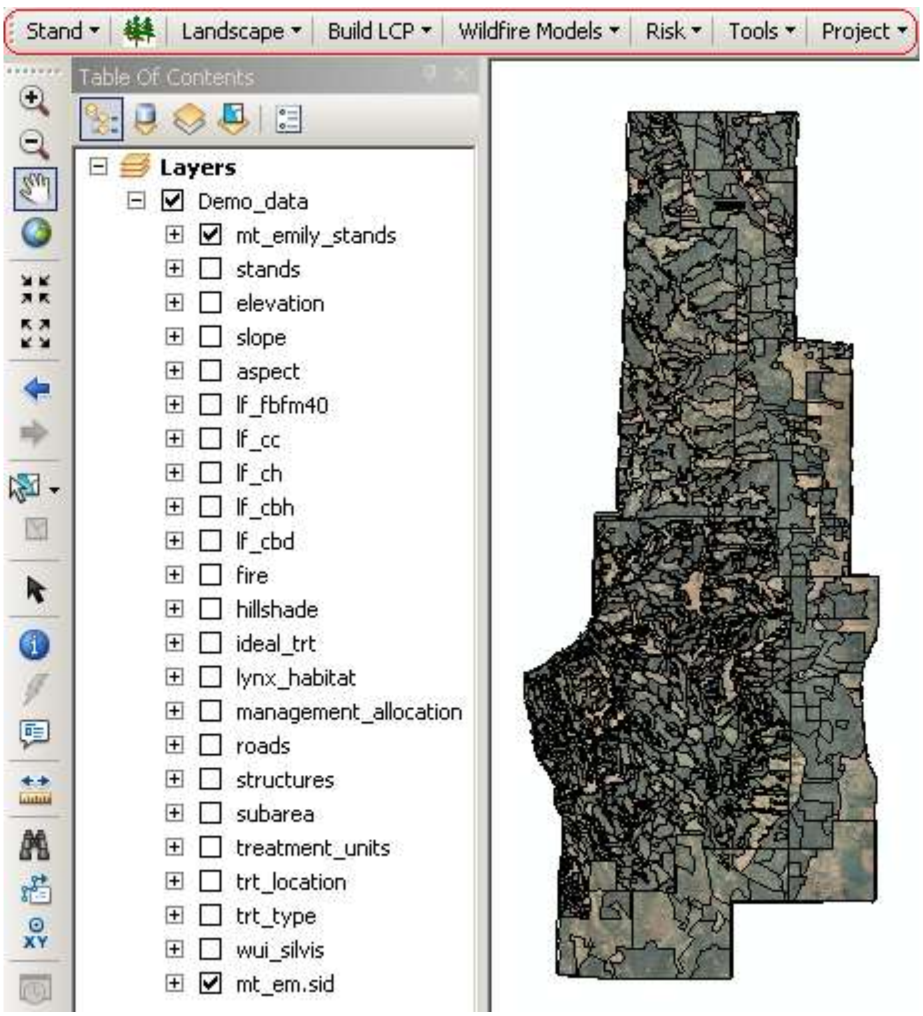


Figure 1-1—ArcFuels10 toolbar (outlined in red) within ArcMap with the supplied ArcFuels demonstration data loaded.

Tutorial conventions

This Tutorial uses the following conventions:

References to sections within the Tutorial are in ***bold italic*** text. For example, “See the ***Start-up Errors*** section below if ArcFuels10 does not open properly.”

Menu selections, buttons, form names and tab names are in **bold** text. For example, “Select the **Wildfire Models** button then select FlamMap from the drop-down list.”

Text within forms or tabs is shown in *italics*. For example, “Select <u>elevation</u> from the *Stand Polygon Layer* drop-down list.”

Pre-existing data, either within the demonstration data or data created during a prior exercise are <u>underlined</u>. For example, “Select <u>elevation</u> from the *Stand Polygon Layer* drop-down list.”

Commands or text you type from the keyboard are show in “quotes.” For example, “Enter “fm_8” in the text box to name the new grid you are creating.”

“Click” refers to pressing the primary mouse button (usually the left mouse button).

“Double-click” refers to pressing the primary mouse button twice.

“Right click” refers to clicking the secondary mouse button.

When a string of steps is used they are in bold text and connected with an arrow (→). For example, “Add the GIS layer file for the demonstration data in ArcMap (**File→Add Data**).”

Keyboard combinations are shown separated by a hyphen (-), this means that both keys need to be pressed in unison for the function to work. For example, “The VBA editor can be opened at any time by pressing Alt-F11.”

Capitalization is used to emphasize important steps. For example “MAKE SURE THE FOLDERS ARE NOT FURTHER NESTED.”

2. Forest Vegetation Simulator and the Fire and Fuels Extension

This section is meant to be a brief introduction to FVS and FFE-FVS. For more thorough tutorials, webinars, and information about FVS training courses please visit the FVS webpage (http://www.fs.fed.us/fmsc/fvs/training/index.shtml).

FVS is typically run through the Suppose graphical user interface (available at: http://www.fs.fed.us/fmsc/fvs/software/suppose.php) with specific text file inputs. However, FVS has also been linked to other software such as Access. ArcFuels10 has leveraged these links and created a different interface for running FVS with a spatial component. The ArcFuels interface and tutorials are found in the ArcFuel10 Tutorial. A Suppose tutorial will not be included, rather the User Guide and Tutorial includes general information about FVS and FFE-FVS.

Program Overview

FVS is an individual tree, distance independent, growth and yield model that is used to model forest stand dynamics overtime (Crookston and Dixon 2005). FVS is used extensively in the U.S. by federal agencies, private landholders, and universities. FVS and the available extensions (see below for a complete list) are used to summarize current stand conditions, model future stand conditions, simulate silvicultural prescriptions including costs associated, model fuel treatment prescriptions, model wildfire events and compute the resulting fire effects, determine suitability of wildlife habitat, estimate insect hazard, predict change under future climate scenarios and much more.

Within FVS the stand is the basic unit of management; however, many thousands of stands can be run through the model. Tree growth and mortality can be run hundreds of years into the future with FVS (the limit in ArcFuels10 is 49 cycles).

FVS starts by reading stand and tree data, then calibrates based on the input data and reports on initial conditions (i.e. tree density, fuel loading, etc.) for each stand (fig. 2-1). Next, treatment prescriptions or other management activities are read into the program and applied at the appropriate time. The stand is grown forward accounting for tree mortality and regeneration. Metrics related to the treatments applied and stand structure information are output. If more than one stand is run through FVS this process repeats until all stands have been simulated.

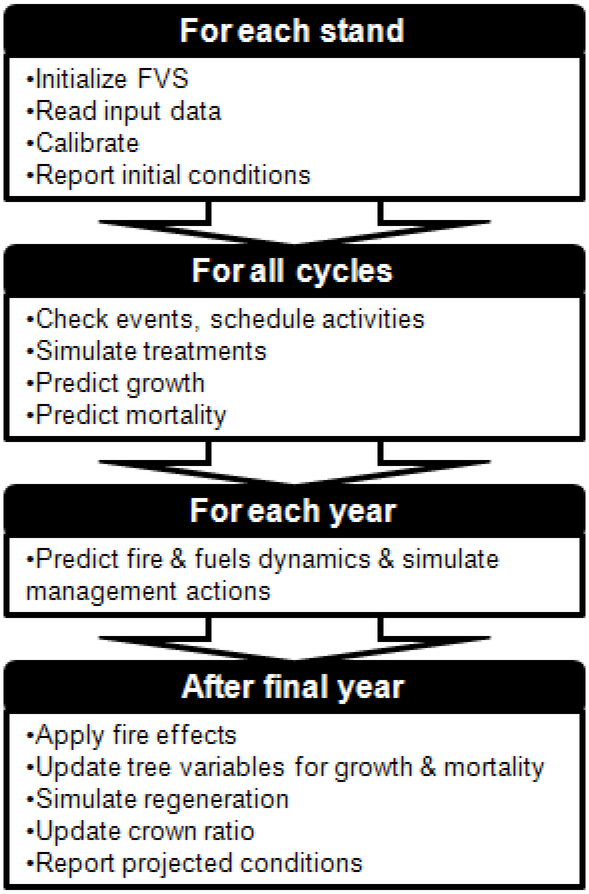


Figure 2-1—Simplified FVS program flow for a FFE-FVS fuel treatment run.

Extensions

In addition to the FVS base model there are many extensions available for use with FVS. The extensions include:

- Cover & shrubs
- Economics extension
- Regeneration & establishment
- Fire and fuels extension (FFE)
- Parallel processing extension (PPE)
- Douglas-fir beetle
- Douglas-fir tussock moth
- Dwarf mistletoe
- Mountain pine beetle
- White pine blister rust impact
- Western root disease
- Western spruce budworm
- Climate extension

The only extensions available for all variants (described below) are the economics extension and the fire and fuels extension. The ***ArcFuels10 Tutorial*** only includes the use of the fire and fuels extension. To learn more about the other extensions go to: http://www.fs.fed.us/fmsc/fvs/whatis/index.shtml.

Variants

Tree growth, mortality, and volume equations differ within FVS based on the dominant tree species within 20 regions of the U.S. (fig. 2-2). Each of these regions is called a "variant." Within each variant only specific tree species, habitat types, dominant vegetation groups, etc. are available and applicable. In addition to unique growth, mortality, and volume equations within FVS, equations specific to extensions vary. For example, in FFE moderate and extreme fuel moisture conditions are different between variants to best represent the fire environment for the geographic location.

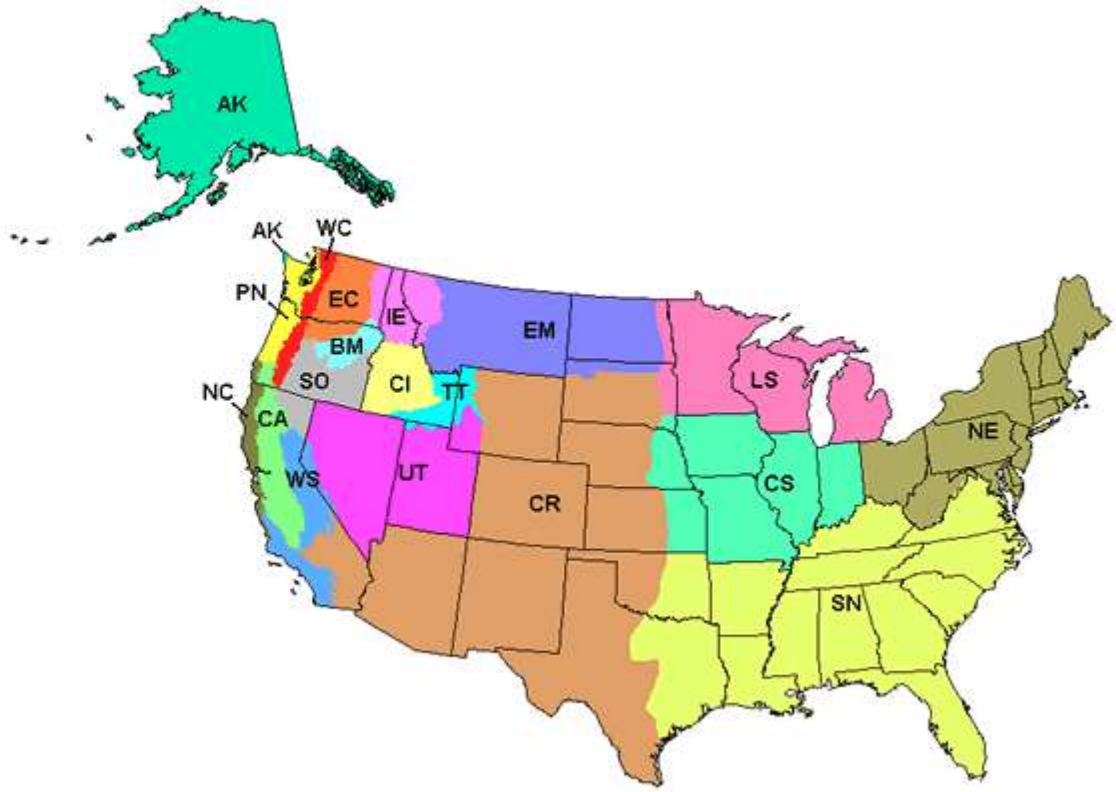


Figure 2-2—Map of FVS variants from the FVS webpage: http://www.fs.fed.us/fmsc/fvs/whatis/index.shtml.

The demonstration data included with the ArcFuels10 download includes the Blue Mountain (BM) variant. Before working with your FVS data in ArcFuels10 be sure to download the proper variant files (http://www.fs.fed.us/fmsc/fvs/software/variantinstaller.php).

Input Data

Data sources—

FVS requires information about the stand and the trees within. For ArcFuels10, this needs to be in an FVS-ready database (fig. 2-3, tables 2-1 and 2-2). At a minimum, stand information must include a unique identifier, the area of the stand, the inventory year, topographic information (slope, aspect, elevation), inverse plot size (for smaller trees), the diameter at breast height (DBH) breakpoint between small and large trees, basal area factor, and the number of plots which are input into the FVS_StandInit table (fig. 2-3). If multiple plots were sampled within a stand, plot information must also include a unique identifier, the inventory year, topographic information (slope, aspect, elevation), the diameter at breast height (DBH) breakpoint between small and large trees, and basal area factor which are input into the FVS_PlotInit table (fig. 2-3). Tree information must include a unique identifier, species, DBH, history (live or dead code), and number of trees represented by the species-DBH-mortality combination which are input into the FVS_TreeInit table (fig. 2-3). However, the more information supplied, the more accurate the modeled outputs will be. For a full list of all the input data possible see the FVS Essentials Guide (Dixon 2003).

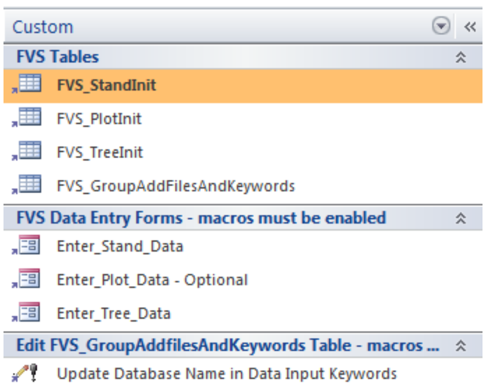


Figure 2-3—The FVS database structure showing the input data tables (FVS_StandInit, FVS_PlotInit, and FVS_TreeInit).

Data can be obtained through Forest Inventory Analysis (FIA) or the FSVeg database for national forest lands (http://www.fs.fed.us/fmsc/fvs/software/data.shtml). It can be created from field inventory such as common stand exams monitoring plots. A blank FVS database has been supplied with the demonstration data (C:\arcfuels\data\Blank_FVS_database.mdb) for creation from field data (fig. 2-3). Another option is if your data is in FFI (FIREMON/FEAT Integrated, http://www.frames.gov/partner-sites/ffi/ffi-home/) you can export an FVS-ready database.

FVS database data tables—

Table 2-1 through 2-3 list the input FVS database data table attributes including which attributes are required to run FVS. A blank FVS database was included with the demonstration data (C:\arcfuels\data\Blank_FVS_database.mdb); however, check the FVS page for updated versions before starting new projects.

Table 2-1—The FVS_StandInit and FVS_PlotInit tables house information about the stand characteristics. The FVS_StandInit is a required table; FVS_PlotInit is optional and is only used when multiple plots exist in a given stand.

Metric	Description
Stand_ID*	Stand identification code
StandPlot_ID*†	Plot identification code
Variant	The two character variant identification code
Inv_Year*	The stand's inventory year
Groups	A list of Grouping codes separated by spaces, tabs, carriage returns, or newlines
AddFiles	A list of Addfile names (kcp) – ArcFuels has its own version of this see the tutorial
FVSKeywords	A list of FVS keywords – ArcFuels has its own version of this see the tutorial
Latitude	Latitude in degrees of the stand's location
Longitude	Longitude in degrees of the stand's location
Region	USDA-FS Region code
Forest	USDA-FS National Forest code
District	USDA-FS District code
Compartment	USDA-FS Compartment code
Location	Location Code representing the Region/Forest/District/Compartment
Ecoregion	Bailey's Ecoregion code, used in the Southern variant
PV_Code	PV_Code identifies the potential vegetation
PV_Ref_Code	Potential vegetation reference code for the PV_Code
Age	Stand age in years
Aspect	Aspect in degrees
Slope	Slope in percent
Elevation	Stand elevation represented in 100's of feet for all variants except AK were it is elevation in 10's of feet
ElevFt	Elevation in feet When specified, ElevFt takes precedence over Elevation
Basal_Area_Factor*	Basal area factor corresponding to BAF in FVS (required if variable radius plot)
Inv_Plot_Size*	The inverse of the small-tree fixed area plot (required if fixed radius plot)
Brk_DBH*	Breakpoint DBH in inches between large and small tree plots

* This data is required to run FVS. Although not all data is required the more data input the more accurate the outputs.

†This is only used if you have plots within the a stand

Table 2-1 continued

Metric	Description
Num_Plots	Number of plots in stand
NonStk_Plots	Number of non-stockable plots in the stand
Sam_Wt	Sampling weight used to compute the average yield tables and other weighted averages
Stk_Pcnt	Stockable percent
DG_Trans	Diameter growth translation code
DG_Measure	Diameter growth measurement period
HTG_Trans	Height growth translation code
HTG_Measure	Height growth measurement period
Mort_Measure	Mortality measurement period
Max_BA	Maximum basal area
Max_SDI	Maximum stand density index
Site_Species	Site species code
Site_Index	Site index
Model_Type	Model type code, may be used in CR variant
Physio_Region	Physiographic region code
Forest_Type	FIA Forest type code
State	FIA state code
County	FIA county code
Fuel_Model	Fire behavior fuel model
Fuel_0_25_H or _S	Initial ton/ac of 0 to 0.25 in hard/sound fuel
Fuel_25_1_H or _S	Initial ton/ac of 0.25 to 1 in hard/sound fuel
Fuel_1_3_H or _S	Initial ton/ac of 1 to 3 in hard/sound fuel
Fuel_3_6_H or _S	Initial ton/ac of 3 to 6 in hard/sound fuel
Fuel_6_12_H or _S	Initial ton/ac of 6 to 12 in hard/sound fuel
Fuel_12_20_H or _S	Initial ton/ac of 12 to 20 in hard/sound fuel
Fuel_20_35_H or _S	Initial ton/ac of 20 to 35 in hard/sound fuel
Fuel_35_50_H or _S	Initial ton/ac of 35 to 50 in hard/sound fuel
Fuel_gt_50_H or _S	Initial tons per acre of greater than 50 inch hard/sound fuel
Fuel_Litter	Initial tons per acre of litter
Fuel_Duff	Initial tons per acre of duff
Photo_Ref	Photo series reference number
Photo_Code	Photo code

* This data is required to run FVS. Although not all data is required the more data input the more accurate the outputs.

†This is only used if you have plots within the a stand

Table 2-2—The FVS_TreeInit table houses information about individual trees.

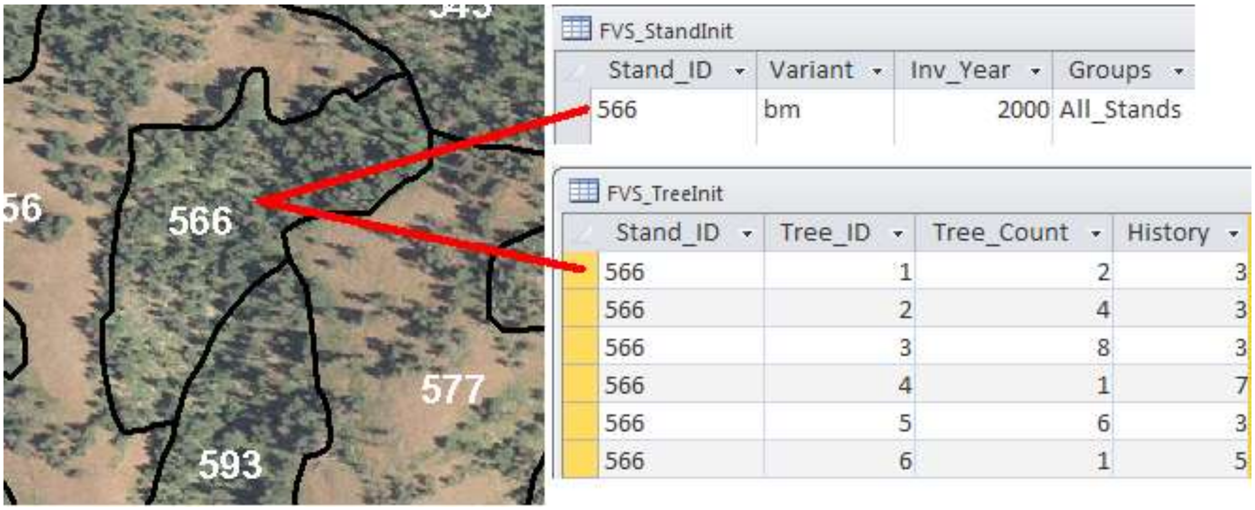
Metric	Description
Stand_ID*	Same as Stand_ID in FVS_StandInit/PlotInit
StandPlot_ID*†	Same as StandPlot_ID in FVS_PlotInit
Plot_ID*†	Plot identification
Tree_ID	Tree identification code (tag #)
Tree_Count	Tree count
History	History code 0-5 are live trees, 6-7 died during mortality observation, 8-9 died before mortality observation period
Species*	Tree species code, can be the FVS alpha code, FIA code or USDA plant symbol
DBH*	Diameter at breast height
DG	DBH growth
Ht	Tree height in ft
HTG	Height growth in ft
HtTopK	Height to top kill is the height to the point of the tree of top kill
CrRatio	Crown ratio, if 0-9 then it is considered a crown ratio code, if 10-99 the value is percent live crown
Damage	Damage code
Severity	Severity code corresponding to damage code
TreeValue	Tree value class code 1=desirable, 2=acceptable, 8=non-stockable, other number=live cull
Prescription	Prescription code
Age	Age of the tree record
Slope	Slope where the tree was located in %
Aspect	Aspect where the tree was located in deg
PV_Code	The potential vegetation code where the tree was located
TopoCode	Topography code: 1=bottom, 2=lower, 3=mid slope, 4=upper slope, and 5=ridge top
SitePrep	Site preparation code 1=none, 2=mechanical, 3=burn, and 4=road cuts/road fills/stockable road beds

* This data is required to run FVS. Although not all data is required the more data input the more accurate the outputs.

†This is only used if you have plots within the a stand

Database and spatial linkages for ArcFuels10—

Within ArcFuels10 the linkage between the FVS database and GIS is very important for both the stand and landscape level functionality. Within each of the FVS data tables and the ArcGIS stand shapefile and stand raster there must be a unifying identifier (fig. 2-4).



FVS_StandInit

Stand_ID	Variant	Inv_Year	Groups
566	bm	2000	All_Stands

FVS_TreeInit

Stand_ID	Tree_ID	Tree_Count	History
566	1	2	3
566	2	4	3
566	3	8	3
566	4	1	7
566	5	6	3
566	6	1	5

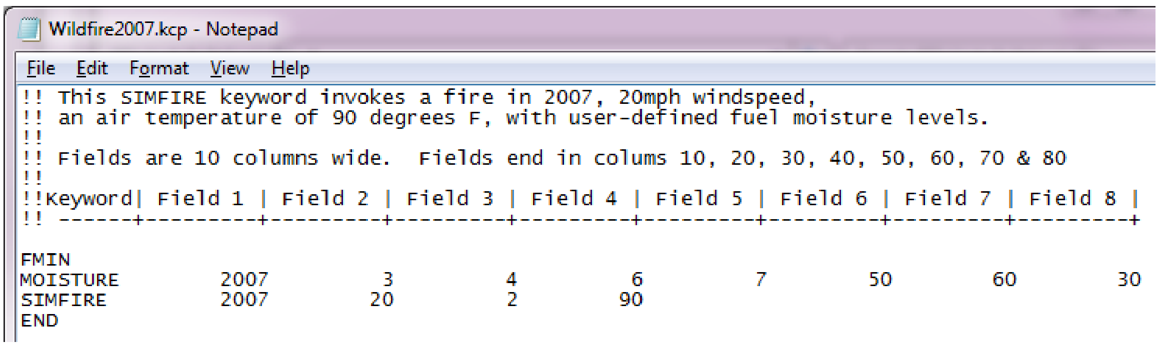
Figure 2-4—Spatial linkage between the stand shapefile and the FVS_StandInit (top right) and FVS_TreeInit (bottom right) data tables within the FVS-ready database for stand 566 and the stand shapefile (left).

It is recommended that the Stand_ID value from the FVS input files be used and linked to the stand shapefile. Whatever is used must be a unique value in the FVS_StandInit table; multiple stands cannot have the same Stand_ID in the FVS_StandInit table.

It is possible to use data that has a one-to-one linkage between stands represented in the FVS-ready database and the stand shapefile, or a one-to-many relationship where there are fewer stands in the database than polygons in the shapefile. When a one-to-many relationship exists the stands in the database are imputed to the various stands in the shapefile which is the case with Most Similar Neighbor (Crookston et al. 2002) and Gradient Nearest Neighbor (Ohmann and Gregory 2002) data. With the one-to-many relationship the Stand_ID will be repeated across the landscape.

Keywords for Fuel Treatments

A keyword system is used to communicate much of the information used by FVS and its extensions. A single keyword record consists of the keyword itself and the associated parameters. Multiple keywords can be strung together in a “KCP” file (fig. 2-5); which is the format required for running keywords in ArcFuels10. The Suppose software can be used to generate KCP files or the supplied KCP files can be altered with a text editing program.


Wildfire2007.kcp - Notepad
File Edit Format View Help
```
!! This SIMFIRE keyword invokes a fire in 2007, 20mph windspeed,
!! an air temperature of 90 degrees F, with user-defined fuel moisture levels.
!!
!! Fields are 10 columns wide.  Fields end in colums 10, 20, 30, 40, 50, 60, 70 & 80
!!
!!Keyword| Field 1 | Field 2 | Field 3 | Field 4 | Field 5 | Field 6 | Field 7 | Field 8 |
!! ------+---------+---------+---------+---------+---------+---------+---------+---------+

FMIN
MOISTURE        2007         3         4         6         7        50        60        30
SIMFIRE         2007        20         2        90
END
```

Figure 2-5—Example KCP file provided with the ArcFuels10 demonstration data. The KCP models a wildfire in 2007 with user specified moisture parameters.

There are some rules to creating keyword files that must be followed in order for keywords to function. The keyword always begins in the first column of the keyword record and up to seven additional parameter fields on the record may be used. The number is dependent on the keyword itself. Each parameter field consists of 10 columns. Depending on the type (alphabetic or numeric) or if a decimal point is included, the location of the parameter matters within the 10 column field. If integer values are used (no period) they must be right justified.

A few useful FVS keywords for fuel treatments are described below for demonstration purposes. Users should read the FVS Keyword Guide (Van Dyck and Smith-Mateja 2000), FFE-FVS Manual (Rebain 2010), and FVS Event Monitor Guide (Crookston 1990) for a complete explanation. The parameter headings can be found in this material.

Thinning Keywords—

THINSDI thins to a stand density index target. In the example below, all species in the stand were thinned from below to 35% of the residual SDI and the cutting efficiency is 90% with no diameter limits.

THINSDI 2000 .35 0.90 0 0.0 999.0 1

THINBBA thins from below to a desired basal area. In the example below, all species in the stand were thinned from below in 2000 to 150 ft^2/ac throughout all diameter and height ranges at 95% efficiency.

ThinBBA 2000 150 0.95 0.0 999.0 0.0 999.0

SPECPREF sets a removal preference, by species, for subsequent simulated thinning. This affects the order in which trees are selected for removal when a harvest is implemented. Positive values favor removal and negative values favor retention. For example, the keyword set below sets a removal priority to three tree species. These priorities favor retention of ponderosa pine (PP), Douglas-fir (DF), and western larch (WL) whenever a thinning is implemented. The retention priorities are weighted such that PP is most heavily favored for retention, followed by DF, followed by WL.

SPECPREF 0 PP -100

SPECPREF 0 DF -50

SPECPREF 0 WL -20

FFE Specific Keywords—

FMIN signals the start of the FFE keywords and **END** signals the end of the FFE keywords. All other FFE keywords must appear between the FMIN-END pair. You may code several FMIN-END pairs and you may have one or many FFE keywords between each pair.

FUELMOVE keyword moves dead and downed fuel between fuel size classes to simulate fuel treatments. The following set of FUELMOVE keywords removes from the stand 90% of fuels from size classes 3, 4, and 5 in 2002.

FUELMOVE 2002 3 0 0 .9 999 0

FUELMOVE 2002 4 0 0 .9 999 0

FUELMOVE 2002 5 0 0 .9 999 0

MOISTURE is used to set the moisture levels for each fuel size class. If this keyword is used, the user must specify moisture levels for all size classes (there are no defaults). When the **MOISTURE** keyword is used it overrides the moisture category from the **SIMFIRE** keyword. In the example below, the fuel moisture is set for 2007. One-hr fuel moisture is 3%, 10-hr is 4%, 100-hr is 6%, 1000-hr is 7%, duff is 20%, live herbaceous is 60%, and live woody is 90%.

MOISTURE 2007 3 4 6 7 20 60 90

SIMFIRE signals that a fire and its effects should be simulated. The following **SIMFIRE** keyword invokes a fall fire in 2003, with dry fuel conditions, 8 mph windspeed, and air temperature of 70 ˚F where the whole stand is burned and mortality is calculated.

SIMFIRE 2003 8 1 70 1 100 4

Other Useful Keywords—

COMPUTE allows you to define up to 200 variables expressed as functions of Event Monitor variables, constants, and variables previously defined using the **COMPUTE** feature. The **COMPUTE** option can be scheduled for specific years, and the value of variables may depend on an event.

SPMCDBH returns to the user one for the following trees per acre, basal area, total cubic volume, merchantable cubic foot volume, total board foot volume, quadratic mean diameter, average height, percent cover, average mistletoe rating, stand density index, species specific average diameter growth per acre, tree value class, tree status, and range of diameter and height. The example below returns the quadratic mean diameter of recent mortality trees which are at least 10 in DBH and at least 40 ft tall.

SPMCDBH(5,0,0,10,999,40,999,1)

Output Descriptions and Units

ArcFuels10 has many hardwired keywords included in every FVS simulation. Some of these can be turned on or turned off by setting the FVS options within the appropriate form. For more information about the forms and options see the ArcFuel10 Tutorial. ***Tables 2-3*** through ***2-13*** contain all the output units for hardwired results tables from FVS runs. For units specific to other keywords see the FVS literature.

Table 2-3—Output units for the FVS_Cases table (default output with ArcFuels10).

Metric	Description	Units
Stand_CN	Stand_CN from FVS database	n/a
StandID	Stand ID from FVS database	n/a
MgmtID	Management ID from FVS database	n/a
KeywordFile	Location of output keyword file	n/a
SamplingWt	Area of stand - from FVS database	ac
Variant	FVS variant used	n/a
RunDateTime	Time and date of FVS run	n/a

Table 2-4—Output units for the FVS_Summary table (default output with ArcFuels10).

Metric	Description	Units
Age	Stand age	yr
Tpa	Tree density	trees/ac
BA	Basal area	ft^2/ac
SDI	Stand density index	n/a
CCF	Crown competition factor	%
TopHt	Top height	ft
QMD	Quadratic mean diameter	in
TCuFt	Total cubic feet	ft^3/ac
MCuFt	Merchantable cubic feet	ft^3/ac
BdFt	Board foot volume	bd ft
RTpa	Tree density removed	trees/ac
RTCuFt	Total cubic feet removed	ft^3/ac
RMCuFt	Merchantable cubic feet removed	ft^3/ac
RBdFt	Total board feet removed	bd ft
ATBA	Basal area, after treatment	ft^2/ac
ATSDI	Stand density index, after treatment	n/a
ATCCF	Crown competition factor, after treatment	%
ATTopHt	Top height, after treatment	ft
ATQMD	Quadratic mean diameter, after treatment	in
PrdLen	Period length	years
Acc	Accretion	ft^3/ac/yr
Mort	Mortality	ft^3/ac/yr
MAI	Stand mean annual increment	in/yr
ForTyp	Forest type	n/a
SizeCls	Stand size class	n/a
StkCls	Stand stocking class	n/a

Table 2-5—Output units for the FVS_StrClass (structure class) table (default output with ArcFuels10).

Metric	Description	Units
Removal_Code	Removal code	n/a
Stratum_X_DBH	Nominal diameter at breast height, Stratum X	in
Stratum_X_Nom_Ht	Height of the tallest tree, Stratum X	ft
Stratum_X_Lg_Ht	Nominal height of trees, Stratum X	ft
Stratum_X_Sm_Ht	Height of the shortest tree, Stratum X	ft
Stratum_X_Crown_Base	Canopy base height, Stratum X	ft
Stratum_X_Crown_Cover	Canopy cover, Stratum X	%
Stratum_X_Species_X	Primary species, Stratum X	n/a
Stratum_X_Species_2	Secondary species, Stratum X	n/a
Stratum_X_Status_Code	Status, Stratum X	n/a
Number_of_Strata	Number of valid strata	n/a
Total_Cover	Total canopy cover in all strata	%
Structure_Class	Structure class: ground (BG), stand initiation (SI), stem exclusion (SE), understory reinitiation (UR), young forest multistrata (YM), old forest single stratum (OS), or old forest multistrata (OM)	n/a

Table 2-6—Output units for the FVS_Fuels table (default output with ArcFuels10).

Metric	Description	Units
Surface_Litter	Litter fuel load	ton/ac
Surface_Duff	Duff fuel load	ton/ac
Surface_lt3	Small surface fuel (1, 10, 100-hr, less than 3 in diameter) load	ton/ac
Surface_ge3	Large surface fuel (1000-hr, greater or equal to 3 in diameter) load	ton/ac
Surface_3to6	Large surface fuel (3 to 6 in diameter) load	ton/ac
Surface_6to12	Large surface fuel (6 to 12 in diameter) load	ton/ac
Surface_ge12	Large surface fuel (greater or equal to 12 in diameter) load	ton/ac
Surface_Herb	Herbaceous fuel load	ton/ac
Surface_Shrub	Shrub fuel load	ton/ac
Surface_Total	Total fuel load (surface, herb, and shrub)	ton/ac
Standing_Snag_lt3	Standing dead fuels (snags and branches) less than 3 in diameter	ton/ac
Standing_Snag_ge3	Standing dead fuels (snags and branches) greater or equal to 3 in diameter	ton/ac
Standing_Foliage	Standing live tree foliage	ton/ac
Standing_Live_lt3	Standing live trees (bole and branches) less than 3 in diameter	ton/ac
Standing_Live_ge3	Standing live trees (bole and branches) greater or equal to 3 in diameter	ton/ac
Standing_Total	Total standing fuel mass (live and dead)	ton/ac
Total_Biomass	Total of all standing wood and surface fuels	ton/ac
Total_Consumed	Total amount of fuel consumed (does not include live trees)	ton/ac
Biomass_Removed	Total harvested wood (live and dead), and surface fuels removed via FUELMOVE	ton/ac

Table 2-7—Output units for the FVS_PotFire (potential fire behavior) table (default output with ArcFuels10).

Metric	Description	Units
Surf_Flame_Sev	Surface fire flame length, severe conditions	ft
Surf_Flame_Mod	Surface fire flame length, moderate conditions	ft
Tot_Flame_Sev	Surface and/or crown fire flame length, severe conditions	ft
Tot_Flame_Mod	Surface and/or crown fire flame length, moderate conditions	ft
Fire_Type_Sev	Fire type severe condition: surface, passive or active crown fire	n/a
Fire_Type_Mod	Fire type moderate condition: surface, passive or active crown fire	n/a
PTorch_Sev	Probability of torching; moderate condition	n/a
PTorch_Mod	Probability if torching, severe condition	n/a
Torch_Index	Torching index, 20ft wind speed required to cause torching of some trees, severe condition	mph
Crown_Index	Crowing index, 20ft wind speed required for to cause active crown fire, severe condition	mph
Canopy_Ht	Canopy height	ft
Canopy_Density	Canopy bulk density	kg/m^3
Mortality_BA_Sev	Total basal area killed, severe condition	ft^2/ac
Mortality_BA_Mod	Total basal area killed, moderate condition	ft^2/ac
Mortality_VOL_Sev	Total tree volume killed, severe condition	ft^3/ac
Mortality_VOL_Mod	Total tree volume killed, moderate condition	ft^3/ac
Pot_Smoke_Sev	Smoke produced, particles greater than 2.5 microns, severe condition	ton/ac
Pot_Smoke_Mod	Smoke produced, particles greater than 2.5 microns, moderate condition	ton/ac
Fuel_ModX	Fire behavior fuel model X selection	n/a
Fuel_WtX	Fire behavior fuel model X weight	%

Table 2-8—Output units for the FVS_Compute table. This is a table specific to ArcFuels that contains some potential fire behavior information and data required to build landscape files (default output with ArcFuels10).

Metric	Description	Units
SEV_FLAM	Flame length, severe condition	ft
MOD_FLAM	Flame length, moderate condition	ft
CC	Canopy cover	%
FML	Fuel model	n/a
CH	Canopy height	ft
CBH	Canopy base height	ft
CBD	Canopy bulk density	kg/m^3
YR	Simulation year	n/a

Table 2-9—Output units for the FVS_BurnReport table (only produced when a fire is simulated).

Metric	Description	Units
One_Hr_Moisture	1-hr time lag fuel moisture	%
Ten_Hr_Moisture	10-hr time lag fuel moisture	%
Hundred_Hr_Moisture	100-hr time lag fuel moisture	%
Thousand_Hr_Moisture	1000-hr time lag fuel moisture	%
Duff_Moisture	Duff moisture	%
Live_Woody_Moisture	Live woody plant moisture	%
Live_Herb_Moisture	Live herbaceous plant moisture	%
Midflame_Wind	Midflame wind speed based on 20ft wind input and canopy cover	mph
Slope	Slope of the stand	%
Flame_length	Flame length used to calculate mortality	ft
Scorch_height	Scorch height based on the flame length	ft
Fire_Type	Fire type: surface fire, passive crown fire, or active crown fire	n/a
FuelModlX	Fire behavior fuel model X selection	n/a
WeightX	Fire behavior fuel model X weight	%

Table 2-10—Output units for the FVS_Consumption table (fuel consumption from fire, only produced when a fire is simulated).

Metric	Description	Units
Min_Soil_Exp	Mineral soil exposure	%
Litter_Consumption	Litter consumed	ton/ac
Duff_Consumption	Duff consumed	ton/ac
Consumption_lt3	1, 10, and 100-hr fuels consumed	ton/ac
Consumption_ge3	Large surface fuels (greater or equal to 3 in diameter) consumed in the simulated fire	ton/ac
Consumption_3to6	Large surface fuels (3 to 6 in diameter) consumed	ton/ac
Consumption_6to12	Large surface fuels (6 to 12 in diameter) consumed	ton/ac
Consumption_ge12	Large surface fuels (greater or equal to 12 in diameter) consumed	ton/ac
Consumption_Herb_Shrub	Herbs and shrubs consumed	ton/ac
Consumption_Crowns	Tree crowns consumed from scorching	ton/ac
Total_Consumption	Total all fuel types consumed	ton/ac
Percent_Consumption_Duff	Duff consumed	%
Percent_Consumption_ge3	Large surface fuels greater or equal to 3 in diameter consumed	%
Percent_Trees_Crowning	Crown fraction burned: surface fire = 0; active crown fire = 100; passive crown fire is between 0 and 100	%
Smoke_Production_25	Smoke produced, particles greater than 2.5 microns ($PM_{2.5}$)	ton/ac
Smoke_Production_10	Smoke produced, particles greater than 10 microns (PM_{10})	ton/ac

Table 2-11—Output units for the FVS_Mortality table (tree mortality from fire, only produced when a fire is simulated).

Metric	Description	Units
Species	Two letter tree species code	n/a
Killed_class1	Trees killed by fire in class 1 (default 0 to 5 in DBH)	trees/ac
Total_class1	Trees before fire in class 1 (default 0 to 5 in DBH)	trees/ac
Killed_class2	Trees killed by fire in class 2 (default 5 to10 in DBH)	trees/ac
Total_class2	Trees before fire in class 2 (default 5 to10 in DBH)	trees/ac
Killed_class3	Trees killed by fire in class 3 (default 10 to 20 in DBH)	trees/ac
Total_class3	Trees before fire in class 3 (default 10 to 20 in DBH)	trees/ac
Killed_class4	Trees killed by fire class 4 (default 20 to30 in DBH)	trees/ac
Total_class4	Trees before fire in class 4 (default 20 to 30 in DBH)	trees/ac
Killed_class5	Trees killed by fire in class 5 (default 30 to 40 in DBH)	trees/ac
Total_class5	Trees before fire in class 5 (default 30 to 40 in DBH)	trees/ac
Killed_class6	Trees killed by fire in class 6 (default 40 to50 in DBH)	trees/ac
Total_class6	Trees before fire in class 6 (default 40 to50 in DBH)	trees/ac
Killed_class7	Trees killed by fire in class 7 (default greater or equal to 50 in DBH)	trees/ac
Total_class7	Trees before fire in class 7 (default greater or equal to 50 in DBH)	trees/ac
Bakill	Total basal area killed by fire	ft^2/ac
Volkill	Total tree volume killed by fire	ft^3/ac

Table 2-12—Output units for the FVS_Carbon and FVS_Hrv_Carbon (harvested) carbon (C) tables (only produced when the C outputs are selected).

Metric	Description	Units
Aboveground_Total_Live	Total aboveground live tree C	ton/ac
Aboveground_Merch_Live	Total aboveground merchantable tree C	ton/ac
Belowground_Live	Total belowground live C (roots)	ton/ac
Belowground_Dead	Total belowground dead C (roots)	ton/ac
Standing_Dead	Total aboveground dead tree C	ton/ac
Forest_Down_Dead_Wood	Total down dead woody fuel (1, 10, 100, 1000-hr) C	ton/ac
Forest_Floor	Total litter and duff C	ton/ac
Forest_Shrub_Herb	Total herb and shrub C	ton/ac
Total_Stand_Carbon	Total stand C - all live and dead pools	ton/ac
Total_Removed_Carbon	Total C removed by treatment	ton/ac
Carbon_Released_From_Fire	C in fuel consumed by fire	ton/ac
Products	Merchantable C stored in products	ton/ac
Landfill	Merchantable C stored in landfills	ton/ac
Energy	Merchantable C emitted with energy capture	ton/ac
Emissions	Merchantable C emitted without energy capture	ton/ac
Merch_Carbon_Stored	Merchantable C stored - products and landfill	ton/ac
Merch_Carbon_Removed	Merchantable C removed	ton/ac

Table 2-13—Output units for the FVS_TreeList and FVS_CutList tables (only produced when the outputs are selected).

Metric	Description	Units
PrdLen	Length of the projection cycle	yr
TreeID	Tree identification code	n/a
TreeIndex	A sequential index number assigned to the tree records as they are processed by FVS	n/a
Species	Tree species code, FVS alpha, FIA, or USDA plant code	n/a
TreeVal	Tree value, 1=desirable, 2=acceptable, 8=non-stocked, all other= live cull	n/a
SSCD	Special status code	n/a
PtIndex	Point (or plot) index	n/a
TPA	Trees per acre represented by the record	trees/ac
MortPA	Trees per acre represented by the record that died that cycle	trees/ac
DBH	Diameter at breast height	in
DG	DBH growth	in
Ht	Total height	ft
HtG	Height growth	ft
PctCr	Percent live crown	%
CrWidth	Crown width	ft
MistCD	Mistletoe rating code	n/a
BA Pctile	Basal area percentile	n/a
PtBAL	Point basal area in larger trees	ft^2/ac
TCuFt	Total cubic foot volume per tree	ft^3
MCuFt	Merchantable cubic foot volume per tree	ft^3
BdFt	Board feet	ft^3
MDefect	Merchantable cubic foot defect percent	%
BDefect	Merchantable board foot defect percent	%
TruncHt	Truncated height - height to the point of breakage or top-kill	ft
EstHt	Estimated height	ft
ActPt	Actual point (or plot) number from input	n/a
Ht2TDCF	Height to the merchantable cubic foot top diameter	ft
Ht2TDBF	Height to the merchantable board foot top diamete	ft

Using the Parallel Processing Extension (PPE)

The FVS Parallel Processing Extension (PPE, Crookston and Stage 1991) is a useful extension for landscape planning with FVS. It simulates multiple stands in a parallel fashion, i.e., the simulation is completed for all stands each time period before cycling to the next time period. PPE can model multiple, spatially explicit treatment constraints and priorities at the stand scale for a given landscape.

For example, if a comparison is desired of two treatment strategies, one where stands are selected for treatment based on their tree density, and another based on the proximity to structures. Presume also that six treatment levels are desired where 0, 5, 10, 20, 30, and 40% of the landscape is treated. These scenarios are simulated with the MSPOLICY keyword to set the priority treatment variable, and the total treatment constraint. The priority variable can be a FVS event monitor variable or a variable read from the stand database. Sample priority data are included in the stand database in the homedens field.

On the ArcFuels10 **Run FVS** form (**ArcFuels toolbar→Landscape→Run FVS**) select the **FVS Inputs** tab and select the PPE_ReadVariablesFromStandDatabase.kcp from within the PPE folder which is inside the KCPs folder in the data folder of the ArcFuels directory to read in the homedens data (fig. 2-6). Open PPE_ReadVariablesFromStandDatabase.kcp; the KCP file reads the homedens variable from the stand input table and sets a FVS compute table equal to the variable. The subsequent commands make a compute variable to echo the database contents into the FVS output database (fig. 2-7).

Select the **FVS Options** tab, enter "hdens" into the priority text box and set the proportion to "0.2", then click the **Run PPE** button (fig. 2-6). The resulting run will treat 20% of the landscape (about 200 stands) and prioritize the treatments according to the distance to homes. This can be repeated for the other percentages (i.e. 5, 10, 30 and 40%) mentioned above.

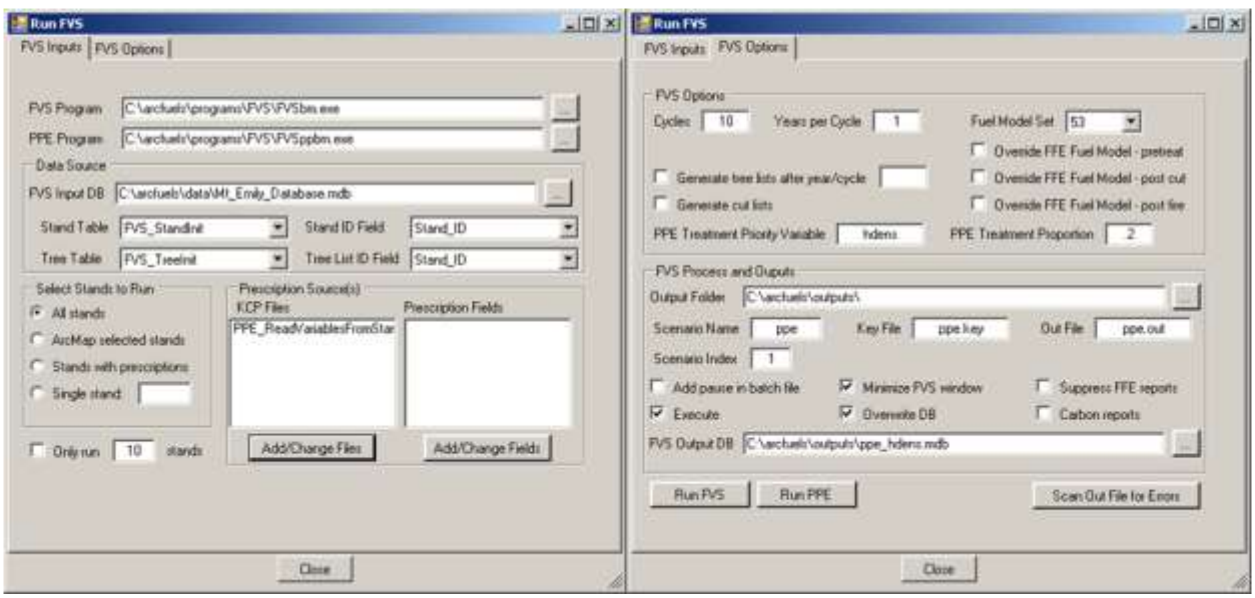


Figure 2-6—Run FVS form set up for a PPE run that treats about 20% of the landscape.

```
Database
DSNIN
C:\arcfuels\data\Mt_Emily_Database.mdb
SQLIN              1
SELECT homedens FROM stands
WHERE stand_cn = '%stand_cn%'
EndSQL

End

compute     0
hdens = homedens
end
```

Figure 2-7—KCP for reading the homedens data from the database for a PPE run.

To use an event monitor variable as the treatment priority, declare the variable in a COMPUTE statement, i.e., make a new variable and set it equal to a pre-defined FVS event monitor variable. The statement below defines and sets the variable CBSDI to the values of the FVS variable BSDI, which is the before-thin stand density index.

COMPUTE 0

CBSDI= BSDI

END

It is also possible to create more elaborate treatment priority schemes using external programs. Coding a '1' in the last field of the MSPOLICY field instructs FVS-PPE to stop execution at each cycle and execute a user-supplied program called "computepriority." FVS-PPE expects this latter program to generate an ASCII file containing treatment priorities. Prior to stopping the user can write the current state of FVS variables to an Access database to be read by "computepriority." An example application of this system can be found in Finney et al. (2007).

3. Fire Climate/Weather Data & FireFamily Plus

In order to model fire behavior, climate or fire weather is needed. NEXUS (Scott 1999), BehavePlus (Heinsch and Andrews 2010), FlamMap, and FARSITE (Finney 1998) all require fuel moisture (1-hr, 10-hr, 100-hr, live herbaceous, live woody) and wind speed. In NEXUS and BehavePlus the user types in these data, whereas FlamMap and FARSITE use an ASCII file (fuel moisture file, FMS) that defines the live and dead fuel moistures. Because FlamMap and FARSITE are landscape-level fire simulation models, the initial fuel moistures can be conditioned using hourly weather data. Fuel moisture conditioning results in more realistic fire behavior outputs because fuel moistures will be calculated based on weather, topography, and shading for each pixel in the landscape using the initial fuel moistures as a starting point. The files needed for fuel moisture conditioning can be quickly created in FireFamily Plus.

This section is meant to be a brief introduction on FireFamily Plus (FFP, version beta 4.1) highlighting the programs ability for creating fire weather files for use in FlamMap 5. There are many functions within FFP that will not be discussed. For more information about the program the FFP Version 4 User's Guide is provided in the optional docs folder (C:/arcfuels/docs/ FFP41_Users_Guide.pdf) or from their website (http://www.firemodels.org/index.php/firefamilyplus-software/firefamilyplus-downloads). In addition to options in FFP to create weather files needed, alternative methods are described below.

Program Overview

The FFP program is used to analyze weather data, climatology, and fire occurrence data for long term fire management plans. The FFP program will generate Pocket Cards for firefighter safety and supports many of the climatology data requirements for fire growth projections using FlamMap.

FireFamily Plus uses data from remote automated weather stations (RAWS) and fire occurrence data. It can use both daily observations and hourly data. Data is available from a number of sources: Fire and Aviation Management Web Applications (FAMWEB, https://fam.nwcg.gov/fam-web/) provides daily and limited hourly weather data and fire occurrence data; Western Regional Climate Center (WRCC, http://www.raws.dri.edu/) provides hourly weather, a password is needed for data more than 30 days old; and MesoWest (http://mesowest.utah.edu/index.html) provides hourly weather data, an account is needed to download more than one day at a time. The FAMWEB and WRCC data are provided in a format ready to import into FFP, MesoWest does not.

Tutorial

The tutorial will demonstrate how to download weather data from the FAMWEB website using the Kansas City Fire Access Software (KCFAST) option. Please note daily data can also be downloaded from the state data fire and weather data option on the FAMWEB website. The key differences between the state data and the KCFAST data is KCFAST is current to the day whereas state data is through the previous year, and state data does not include any hourly observations. Similarly hourly data can be obtained from WRCC or MesoWest but both websites require passwords to download older data and additional steps for import into FFP. However, if you need hourly weather that is older than about 2 years, use one of those sites instead of KCFAST.

Obtaining fire weather and occurrence data and importing it into FFP—

This exercise will demonstrate how to download fire weather data for a single RAWS from the FAMWEB website using the Kansas City Fire Access Software (KCFAST) option and how to import it into FFP. FAMWEB State Data will be used to download fire occurrence data.

The closest RAWS is not always the best one to choose. The RAWS(s) used should represent the climatological conditions (i.e. slope position, aspect, elevation, fuel model type, weather patterns) as best as possible. In addition, the rule-of-thumb is to have at least 10 years of data available, 20 years is even better, and 30 years is considered to be statistically complete. The LAGRANDE1 station has data from 2002-present, whereas the EDEN and J-RIDGE have data from 1985-present (fig. 3-1). The RAWS used for demonstration purposes will be EDEN (fig. 3-1).

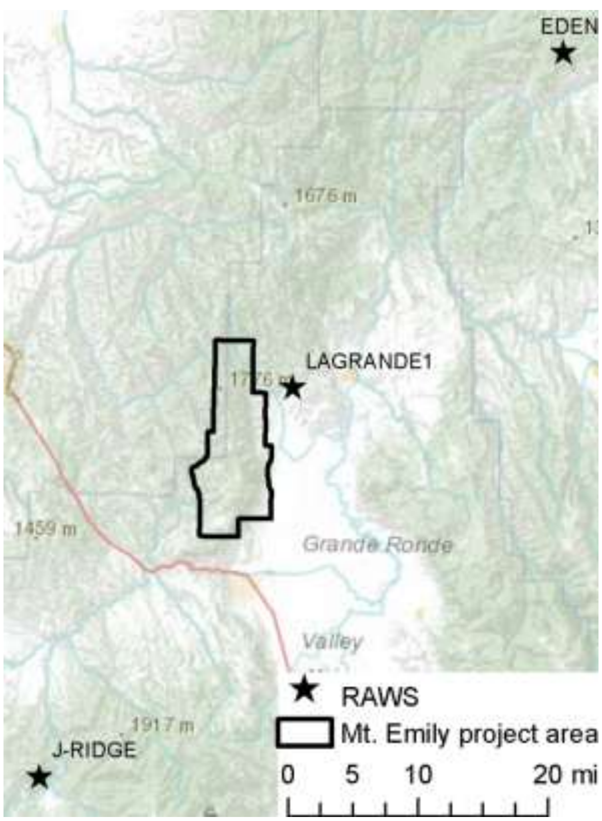


Figure 3-1—RAWS near the Mt. Emily project area.

For detailed information and instructions for choosing the most appropriate RAWS see Lesson 3 in the S-495 online course materials (http://www.frames.gov/partner-sites/niftt/training/nwgc-training-courses/).

1) Go to the National Fire and Aviation Management webpage (FAMWEB): https://fam.nwcg.gov/fam-web/ and click on **KCFAST** on the left hand side menu bar (fig. 3-2).

Figure 3-2—FAMWEB website homepage menu bar.

a) This will open a new window for the KCFAST home page (fig. 3-3).

Figure 3-3— KCFAST website homepage.

b) Click on **Weather** then **Data Extract** then **Historical** on the left hand side menu bar to open the **Historical Fire Weather Extract** page (fig. 3-4).

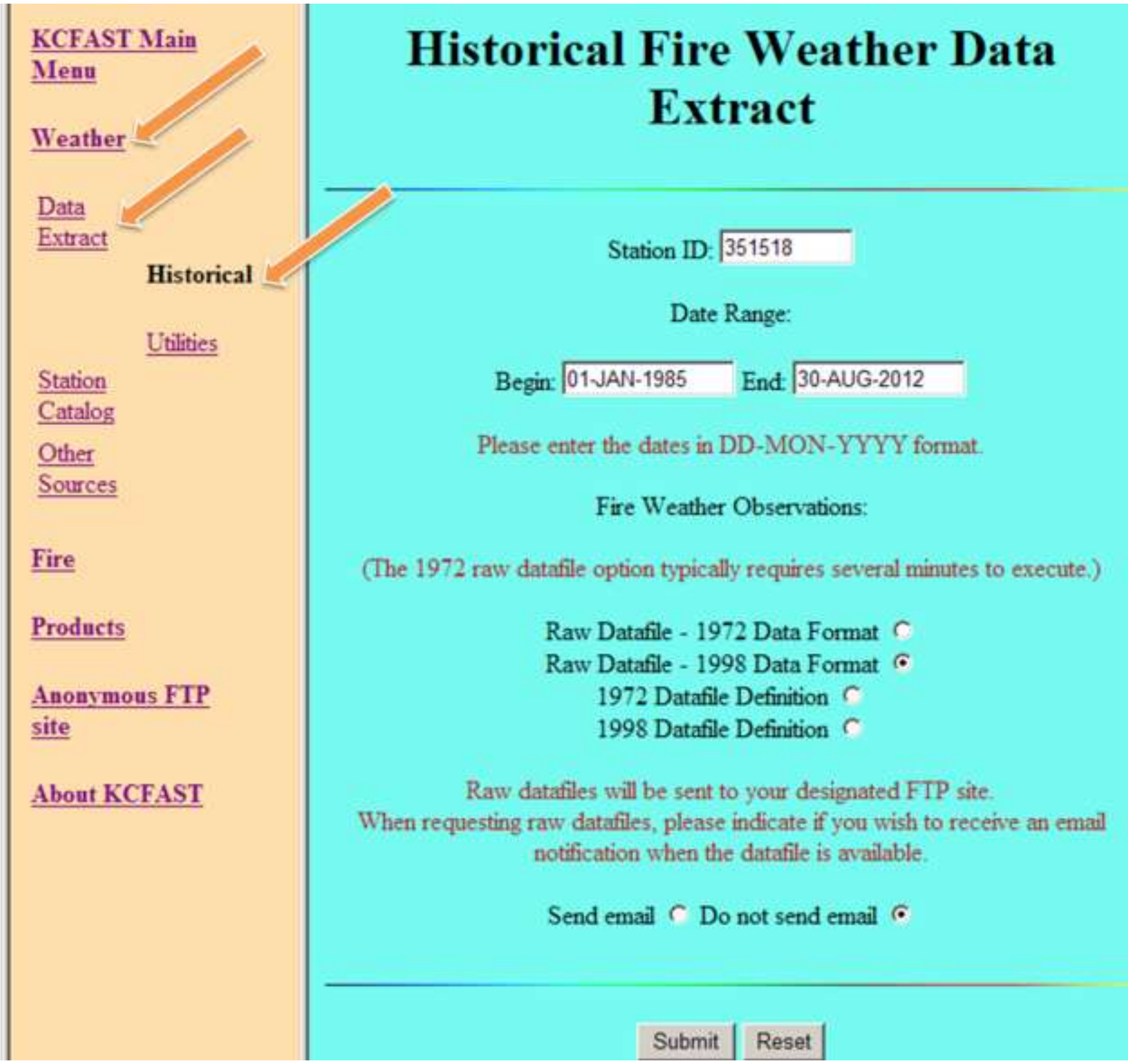


Figure 3-4—KCFAST Historical Fire Weather Extract page.

i) *Station ID*: type "351518" in the text box. This is the station identification number for the Eden RAWS.

ii) *Begin*: type "01-JAN-1985" in the text box. The data spans from 1985 until present for this RAWS.

iii) *End*: type "30-AUG-2012" or todays date in the text box. The KCFAST data is updated daily.

iv) *Fire weather observations*: select the *Raw Datafile – 1998 Format* option. This returns data in the *.fw9 format which is readable by FFP. The 1998 format includes daily observation throughout the time period downloaded, and hourly observations for the past three years.

v) Select the *Do not send email* option.

vi) Click **Submit** and a new window will open noting the file name and the ftp address where the data will be placed (fig. 3-5). You may want to write down the file name and the ftp so you can reference it later. You will retrieve all the data at once in ***Step 2***.

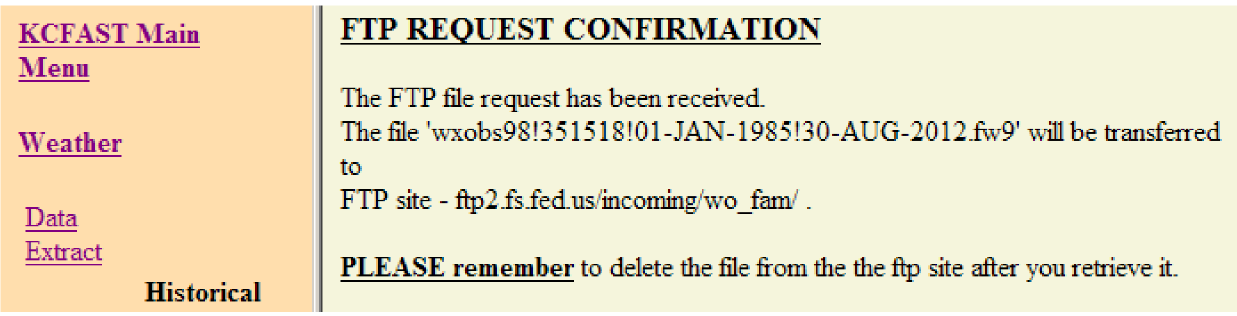


Figure 3-5—File name and ftp site window.

If you do not know the station ID for a particular RAWS or what RAWSs are near your project area, the WRCC website has a map with all the stations noting both the name and ID.

c) Return to the **Historical Fire Weather Extract** page (fig. 3-4).

i) *Station ID*: type “351518” in the text box.

ii) *Begin*: type “01-JAN-1985” in the text box.

iii) *End*: type “30-AUG-2012” or todays date in the text box.

iv) *Fire weather observations*: select the *Raw Datafile – 1972 Format* option. This returns data in the *.fwx format which is readable by FFP. The 1972 format only includes daily observation throughout the time period downloaded.

v) Select the *Do not send email* option.

vi) Click **Submit** and a new window will open noting the file name and the ftp address where the data will be placed (see fig. 3-5 for an example). Again, take note of the file name and the ftp. You will retrieve all the data at once in ***Step 2***.

d) Click on **Station Catalog** then **Station Information** on the left hand side menu bar to open the **Weather Station Information** page (fig. 3-6).

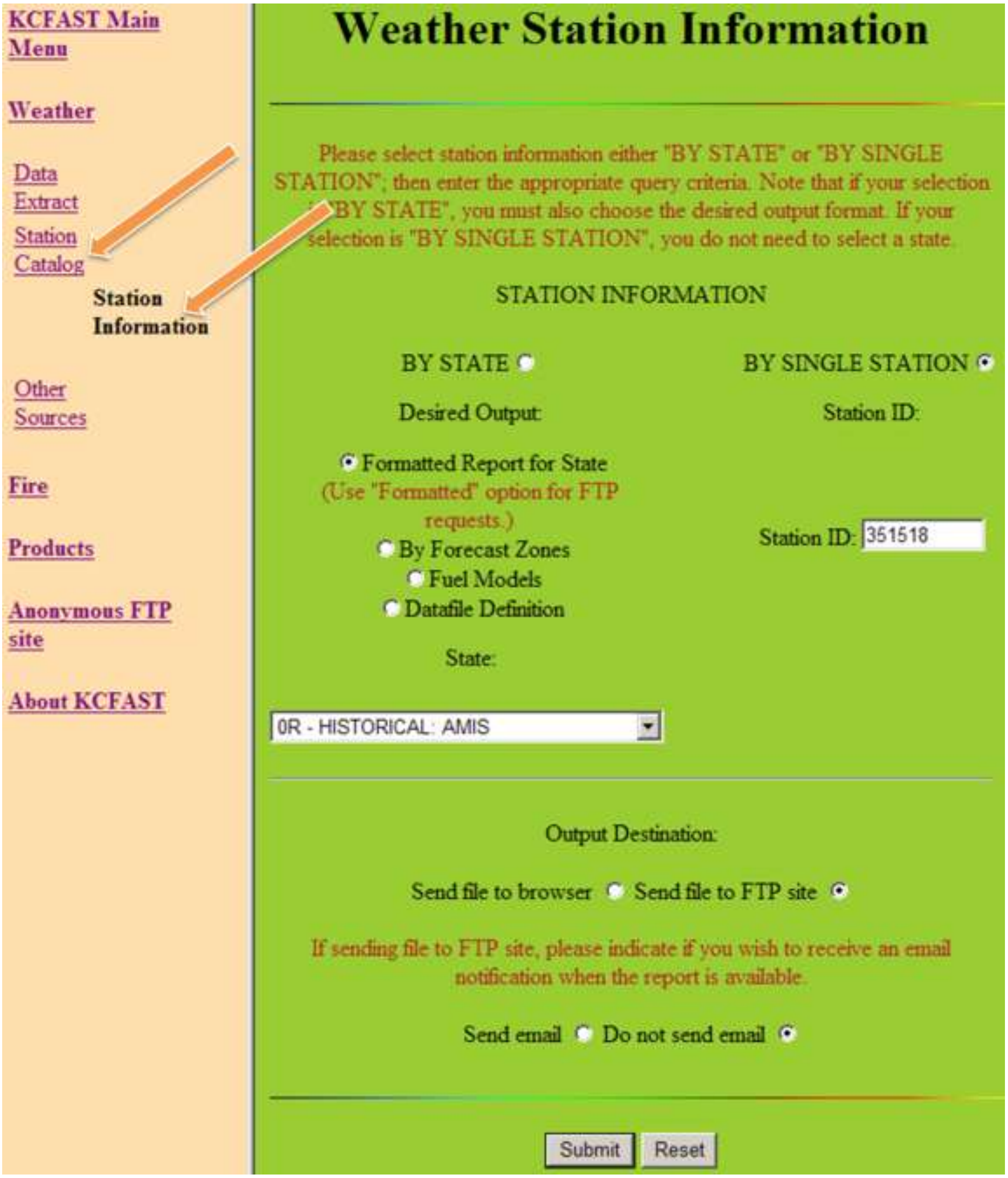


Figure 3-6—KCFAST Weather Station Information page.

i) Select the *By Single Station* option.

ii) *Station ID*: type "351518" in the text box.

iii) Select the *Send file to FTP site* option.

iv) Select the *Do not send email* option.

v) Click **Submit** and a new window will open noting the file name and the ftp address where the data will be placed (see fig. 3-5 for an example). Again, take note of the file name and the ftp. You will retrieve all the data at once in ***Step 2***.

2) Open a new Windows Explorer window and type the ftp address (ftp://ftp2.fs.fed.us/incoming/wo_fam/) in the *Address* bar then click the **Go** button (white arrow in the green box) to the right (fig 3-7). It is easier to find the files requested using Windows Explorer than the ftp site through Internet Explorer because you can sort the data.

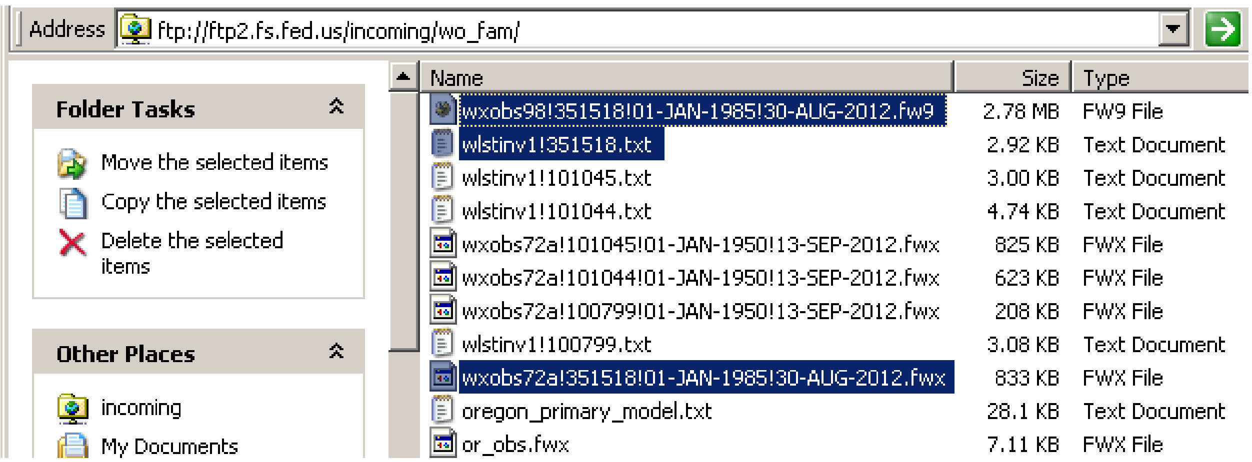


Figure 3-7—Data on the FAMWEB ftp site, with the files for the Eden RAWS highlighted.

If your windows explorer window does not look like figure 3-7, change the view to "Detailed." Windows XP ***main menu bar→View→Detailed****, Windows 7* ***change view icon→Detailed****.*

a) Sort the data by the *Date Modified* (**click on the heading**) to move the most recently requested files to the top of the list and find the three files requested: wxobs98!351518!01-JAN-1985!30-AUG-2012.fw9, wxobs72a!351518!01-JAN-1985!30-AUG-2012.fwx, and wlstinv1!351518.txt. If they are not there yet wait a couple of minutes and then refresh the window.

b) Cut and paste the files into the outputs folder in the ArcFuels directory. Close the ftp site window after the files have transferred.

3) Go to the National Fire and Aviation Management webpage (FAMWEB): https://fam.nwcg.gov/fam-web/ and click on **Wildland Fire Related Links** and then **Fire and Weather Data** on the left hand side menu bar (fig. 3-8).

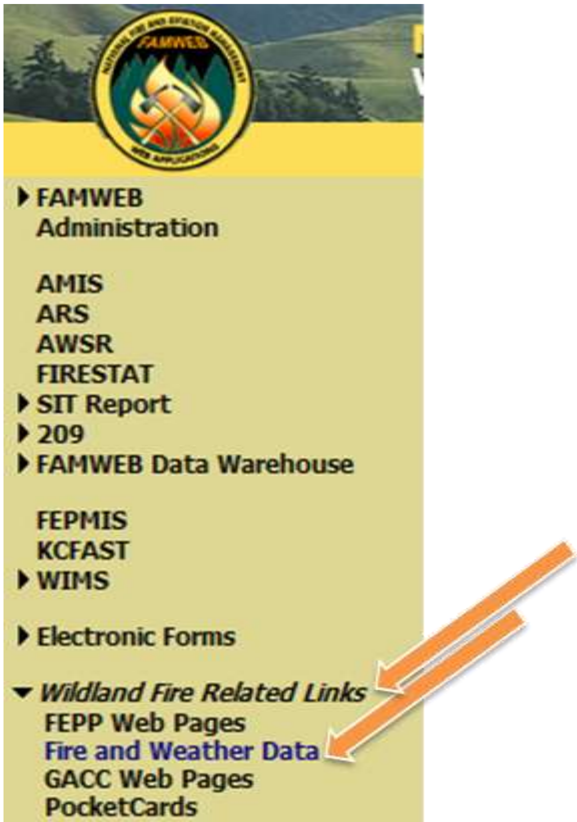


Figure 3-8—FAMWEB fire and weather data.

a) This will open a new window for the **Fire & Weather Data**, click on **State Data** on the left hand side of the window (fig. 3-9).

Figure 3-9—Selecting the State Data option.

b) Select Oregon from the drop-down list, then click on **Fires-FS** (fig. 3-10).

Figure 3-10—Selecting Oregon and jumping to the Forest Service fire data.

When gathering your own data if the Fires-FS option is not available for your state scroll down the main page until you see the Fire Occurrences Files box and proceeded to step c.

c) Scroll down until you see the Umatilla and Wallowa-Whitman National Forests, these are the two that the Mt. Emily project area is on (fig-3-11).


Fire Occurrence Files

Agency	Unit Identifier	Unit Name	Fire Data
FS	ORSUF	Siuslaw National Forest	flnfmas2!0612!1950!2011.raw
FS	ORUMF	Umatilla National Forest	flnfmas2!0614!1950!2011.raw
FS	ORUPF	Umpqua National Forest	flnfmas2!0615!1950!2011.raw
FS	ORWWF	Wallowa-Whitman National Forest	flnfmas2!0616!1950!2011.raw
FS	ORWIF	Willamette National Forest	flnfmas2!0618!1950!2011.raw
FS	ORWNF	Winema National Forest	flnfmas2!0620!1950!2011.raw

Figure 3-11—List of fire occurrence files for the state of Oregon.

i) Right-click on flnfmas2!0614!1950!2011!raw and select **Save Target As...** from the menu that opens. Save the file in the outputs folder in the ArcFuels directory.

ii) Right-click on flnfmas2!0616!1950!2011!raw and select **Save Target As...** from the menu that opens. Save the file in the outputs folder in the ArcFuels directory.

d) Close Internet Explorer.

4) Open FFP via the ArcFuels10 tool bar (**ArcFuels10 toolbar→Wildfire Models→FireFamily Plus**, fig. 3-12).

Figure 3-12—FireFamily Plus startup screen.

5) Create a new FFP database (**FFP→File→New**); name it “EdenRAWS.mdb” and save it in the outputs folder in the ArcFuels directory (fig. 3-13).

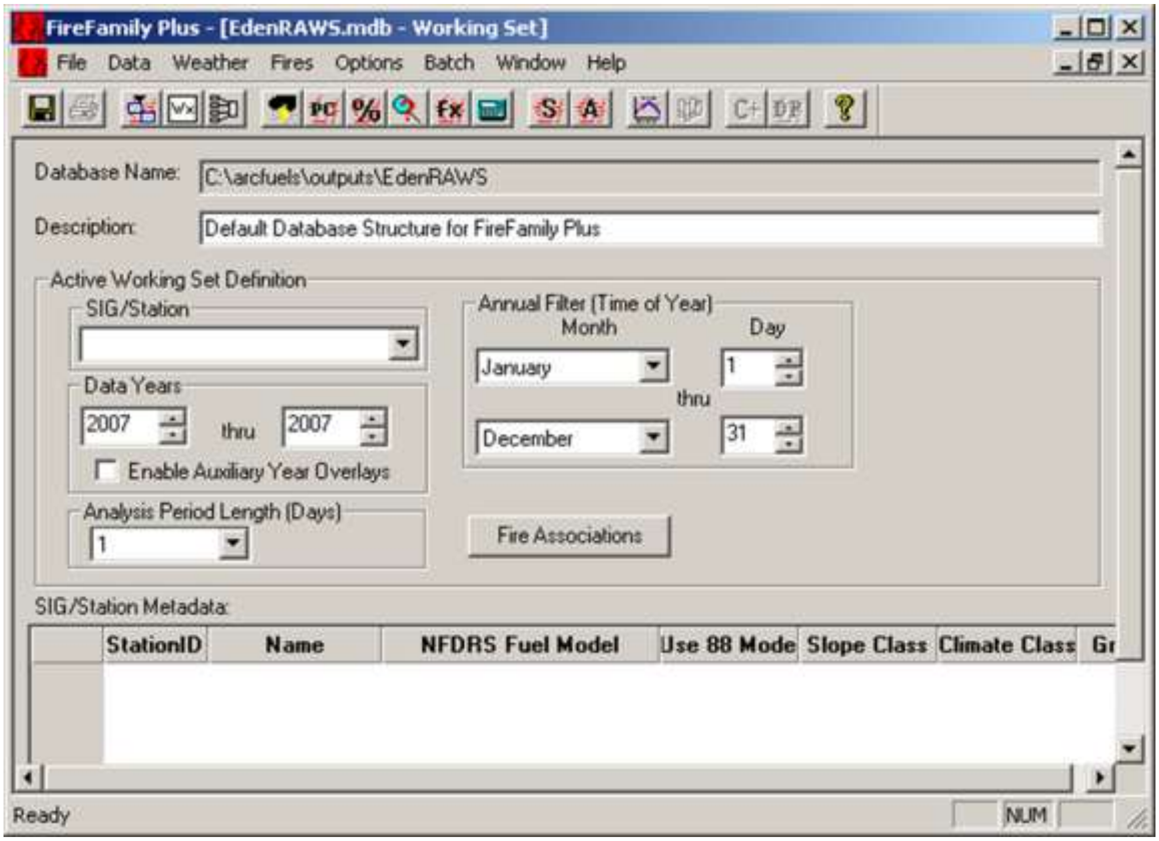


Figure 3-13—FFP home screen for Eden RAWS.

6) Import the station information and fire weather data by opening the **Import Fire and Weather Data** form (**FFP menu bar→Data→Import**, fig. 3-14).

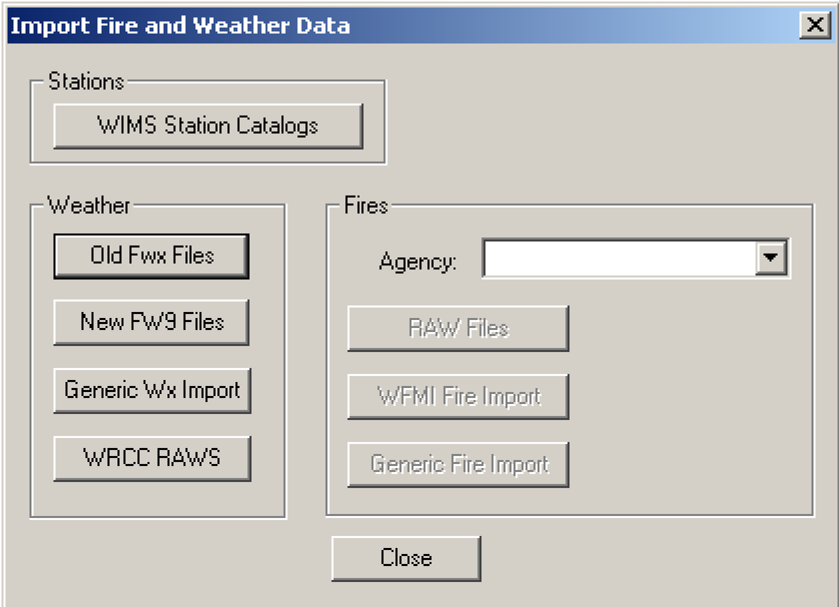


Figure 3-14—Import Fire and Weather Data form.

a) First the station information will be imported. Click the **WIMS Station Catalogs** button. Navigate to and open the wlstinv1!351518.txt file from the outputs folder in the ArcFuels directory. After the import is complete a window will open indicating it is done and if any errors were found (fig. 3-15). Click **Close** to close the window.

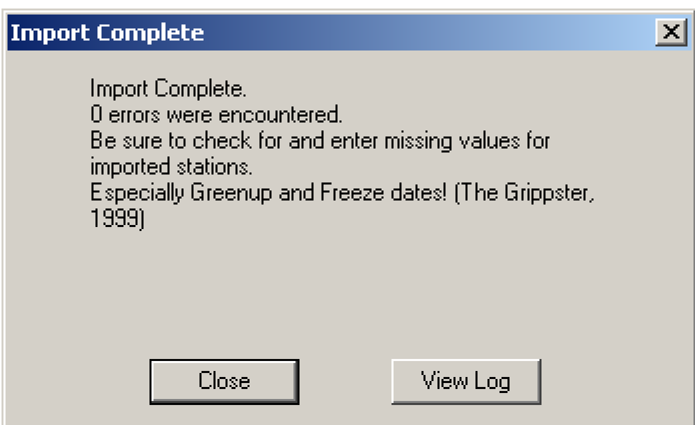


Figure 3-15—Import Complete window.

b) Next the weather data will be imported. Click the **Old Fwx Files** button. Navigate to and open the wxobs72a!351518!01-JAN-1985!30-AUG-2012.fwx file from the outputs folder in the ArcFuels directory. A progress window will open and when import is complete a window will open indicating it is done (fig. 3-16). Click **Close** to close the window.

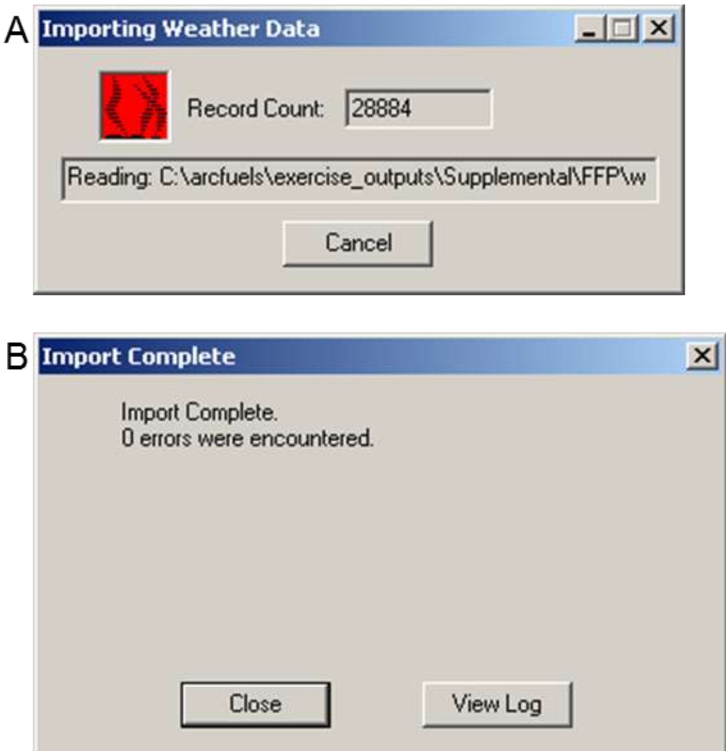


Figure 3-16—Progress meter (A) and completion (B) windows.

c) Click the **New FW9 Files** button. Navigate to and open the wxobs98!351518!01-JAN-1985!30-AUG-2012.fw9 file from the outputs folder in the ArcFuels directory. A progress window will open and when import is complete a window will open indicating it is done (see fig. 3-12 for an example). Click **Close** to close the window.

*If errors were encountered, click the **View Log** button to see what the errors were and then correct them. For detailed information about fire weather and tutorials for downloading data and correcting errors see Lesson 3 in the S-495 online course materials (http://www.frames.gov/partner-sites/niftt/training/nwgc-training-courses/).*

d) Finally, the fire occurrence data will be imported, under *Fires* select USFS from the drop-down list to the right of *Agency* (fig. 3-17).

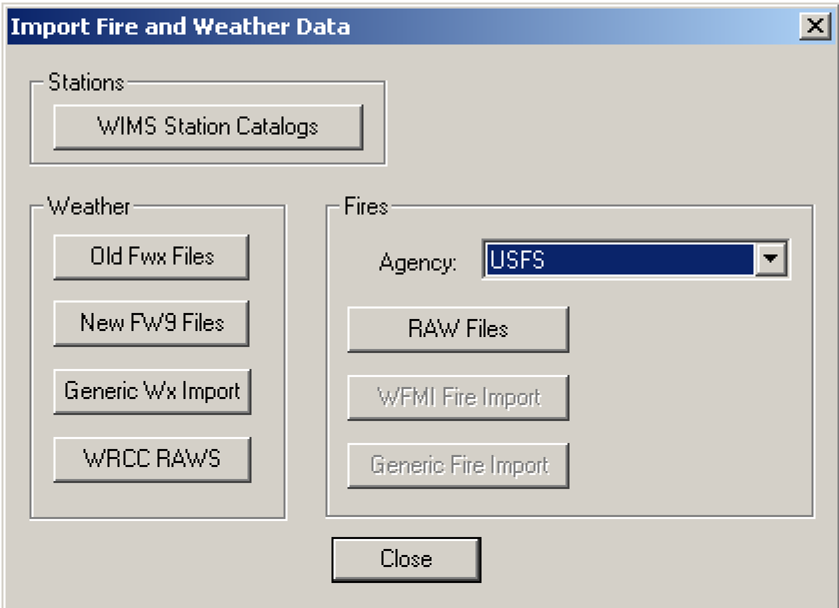


Figure 3-17—Importing past fire data.

i) Click **RAW Files** and navigate to and open the flnfmas2!0614!1950!2011.raw file from the outputs folder in the ArcFuels directory. A progress window will open and when import is complete a window will open indicating it is done (fig. 3-18a). Click the **View Log** button to view the import information and see what the new Fire SubUnits are (fig. 3-18b). Click **Close** to close the **Import Error Log** window and again to close the **Import Complete** window.

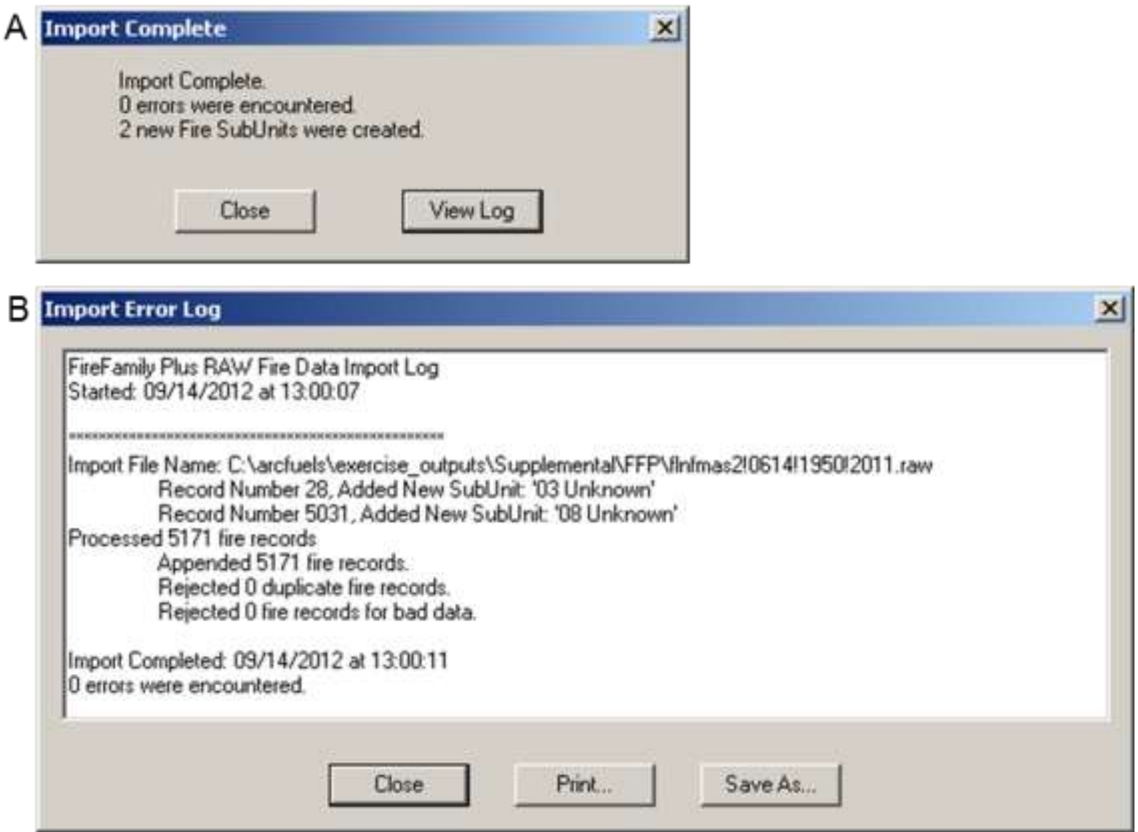


Figure 3-18—Import Complete (A) and Import Error Log (B) windows for the Umatilla fire occurrence data.

ii) Click **RAW Files** and navigate to and open the flnfmas2!0616!1950!2011.raw file from the outputs folder in the ArcFuels directory. A progress window will open and when import is complete a window will open indicating it is done. Click the **View Log** button to view the import information and see what the new Fire SubUnits are. Click **Close** to close the **Import Error Log** window and again to close the **Import Complete** window.

e) Click close to close the **Import Fire and Weather Data** form.

7) Next you will look at the imported weather data.

a) Under *Active Working Set Definition* and then *SIG/Station* select 351518 – EDEN from the drop-down list (fig. 3-19). This will populate the *Data Years* and *SIG/Station Metadata*.

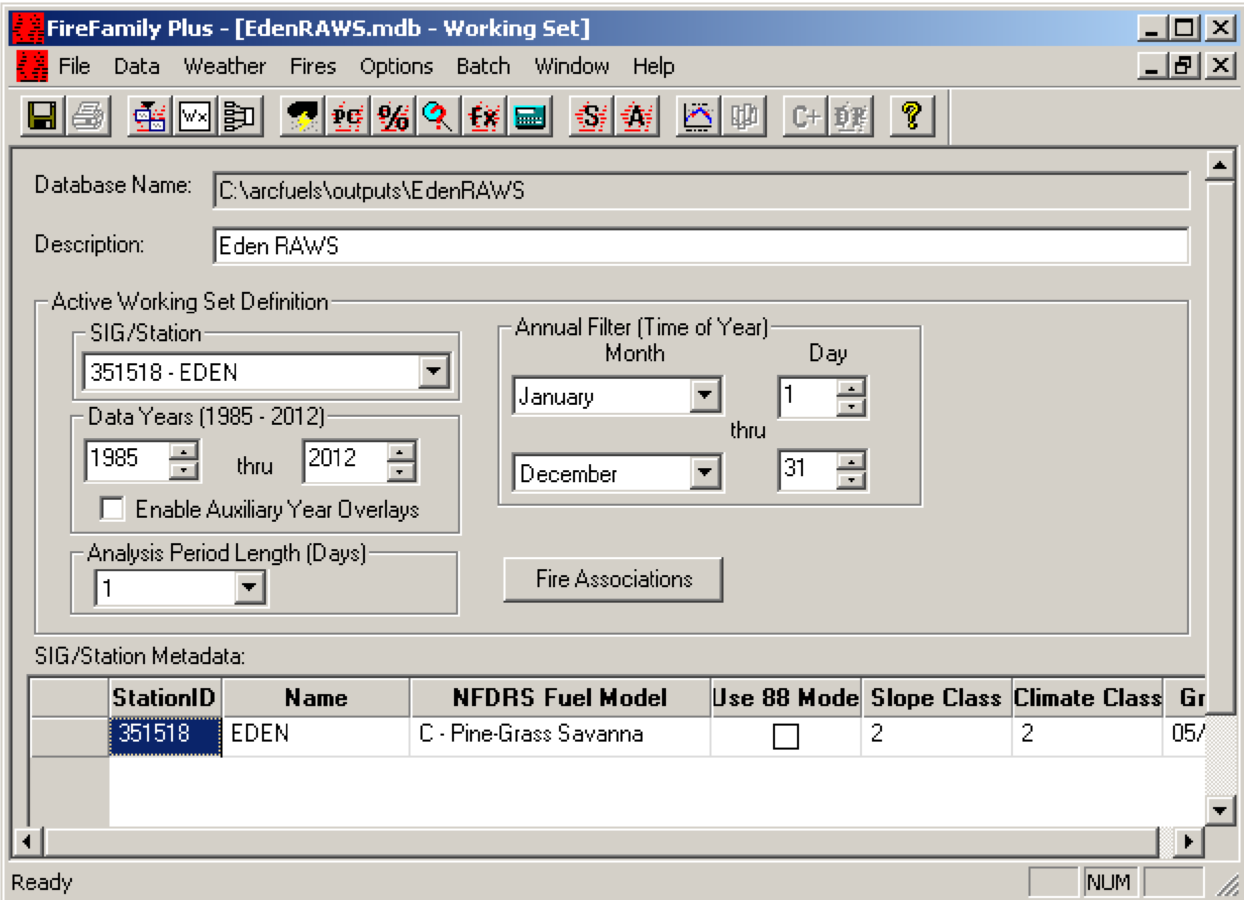


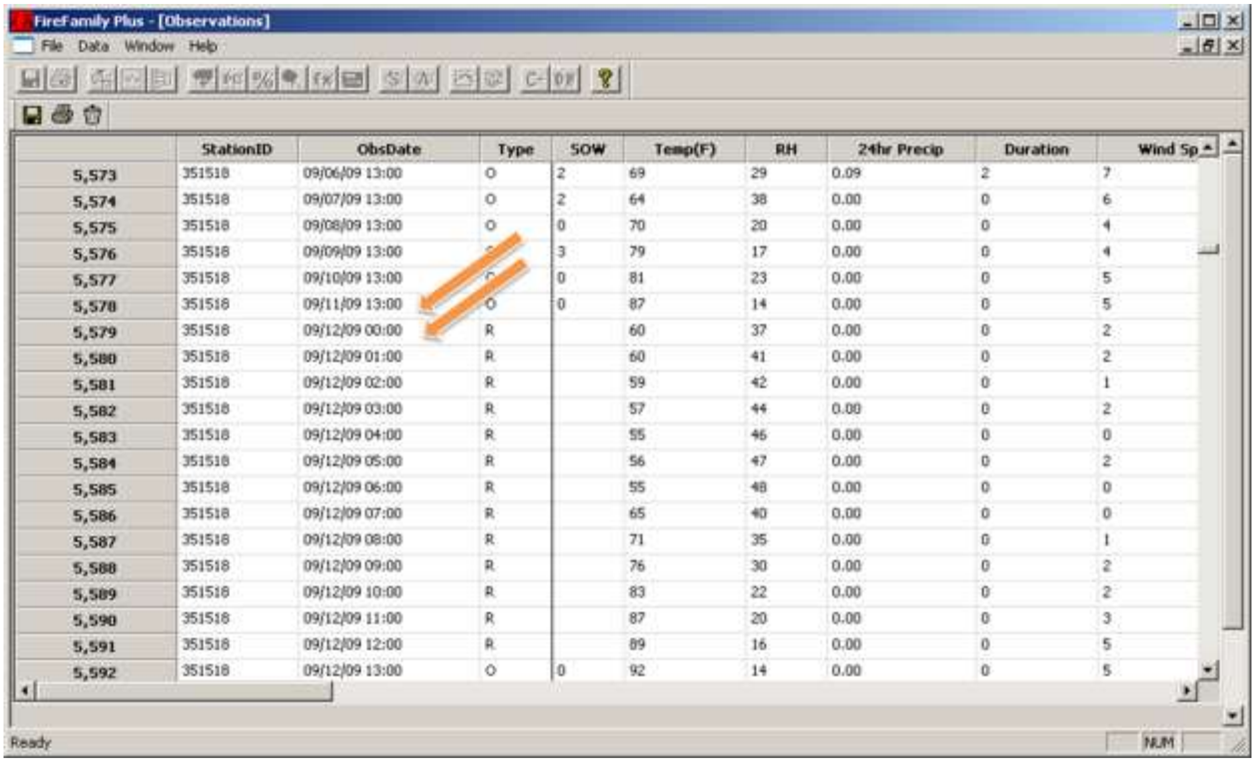
Figure 3-19—Main FFP page with the EDEN RAWS selected.

b) *Data Years (1985 – 2012)*: shows the span of the data available, before the import it was simply *Data Years* (see fig 3-13). Type "1985" thru "2012" in the appropriate text boxes, which will allow you to work with data for all the years for the station.

c) *Annual Filter (Time of Year)*: this allows you to define the season of data you want to look at or use for analysis. Leave the default January 1 thru December 31 for now.

d) Under *SIG/Station Metadata* is the station information, this is what was in the wlstinv1!351518.txt file. Information includes the NFRDS Fuel Model, station elevation and slope position, green-up and freeze dates, etc. Scroll to the right to see all the information.

e) To see the imported weather observations **FFP menu→Weather→View Observations→All** (fig. 3-20). Scroll to the right to see all the data options, and scroll down to see all the dates imported. To see where the hourly data starts go to 9/12/09, this is 2 years prior to the download date. This will depend on when the data was requested, for the tutorial the data was requested on 9/12/12. Close the observations window when you are done exploring.



	StationID	ObsDate	Type	SOW	Temp(F)	RH	24hr Precip	Duration	Wind Sp
5,573	351518	09/06/09 13:00	O	2	69	29	0.09	2	7
5,574	351518	09/07/09 13:00	O	2	64	38	0.00	0	6
5,575	351518	09/08/09 13:00	O	0	70	20	0.00	0	4
5,576	351518	09/09/09 13:00	[illegible]	3	79	17	0.00	0	4
5,577	351518	09/10/09 13:00	[illegible]	0	81	23	0.00	0	5
5,578	351518	09/11/09 13:00	O	0	87	14	0.00	0	5
5,579	351518	09/12/09 00:00	R		60	37	0.00	0	2
5,580	351518	09/12/09 01:00	R		60	41	0.00	0	2
5,581	351518	09/12/09 02:00	R		59	42	0.00	0	1
5,582	351518	09/12/09 03:00	R		57	44	0.00	0	2
5,583	351518	09/12/09 04:00	R		55	46	0.00	0	0
5,584	351518	09/12/09 05:00	R		56	47	0.00	0	2
5,585	351518	09/12/09 06:00	R		55	48	0.00	0	0
5,586	351518	09/12/09 07:00	R		65	40	0.00	0	0
5,587	351518	09/12/09 08:00	R		71	35	0.00	0	1
5,588	351518	09/12/09 09:00	R		76	30	0.00	0	2
5,589	351518	09/12/09 10:00	R		83	22	0.00	0	2
5,590	351518	09/12/09 11:00	R		87	20	0.00	0	3
5,591	351518	09/12/09 12:00	R		89	16	0.00	0	5
5,592	351518	09/12/09 13:00	O	0	92	14	0.00	0	5

Figure 3-20—Imported fire weather observations pointing out the daily versus hourly data.

8) Finally you will look at the fire occurrence data. This data can be used to assess the fire season duration and to see what notable fires have occurred near your analysis area. Because the Mt. Emily project area spans two National Forests we will include data from both.

   a) Open the **Select Fires for Summary for Station 351518** form (**FFP menu→ Fires→Associations**, fig. 3-21).

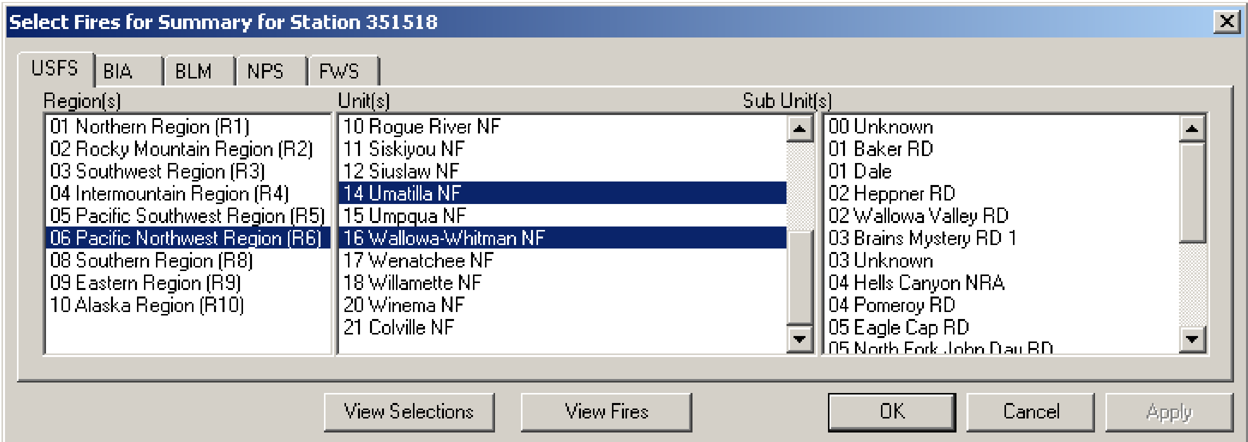
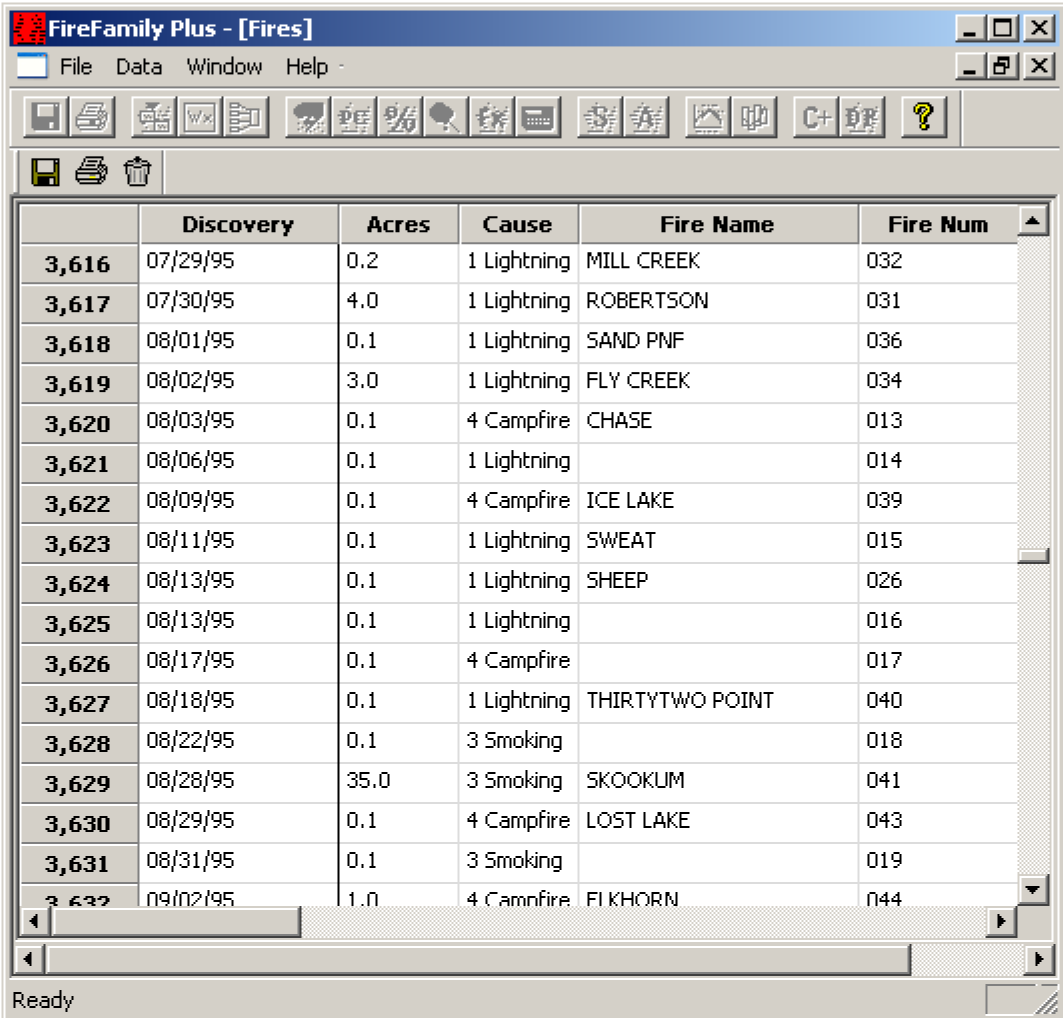


Figure 3-21—Setting the fire associations.

      i) Select the **USFS** tab then under *Regions* select 06 Pacific Northwest Region (R6), under *Units* select 14 Umatilla NF and 16 Wallowa-Whitman NF. The *Sub Unit(s)* will auto-populate.

      ii) Click **View Fires** to open a windows with a list of all the fires on the Umatilla and Wallowa-Whitman National Forests from 1985 to 2011 (fig. 3-22).

      iii) With the fire list window open scroll up and down and to the right to look at what information is available (fig 3-22). Close the fire list window when you are done looking at it.



	Discovery	Acres	Cause	Fire Name	Fire Num
3,616	07/29/95	0.2	1 Lightning	MILL CREEK	032
3,617	07/30/95	4.0	1 Lightning	ROBERTSON	031
3,618	08/01/95	0.1	1 Lightning	SAND PNF	036
3,619	08/02/95	3.0	1 Lightning	FLY CREEK	034
3,620	08/03/95	0.1	4 Campfire	CHASE	013
3,621	08/06/95	0.1	1 Lightning		014
3,622	08/09/95	0.1	4 Campfire	ICE LAKE	039
3,623	08/11/95	0.1	1 Lightning	SWEAT	015
3,624	08/13/95	0.1	1 Lightning	SHEEP	026
3,625	08/13/95	0.1	1 Lightning		016
3,626	08/17/95	0.1	4 Campfire		017
3,627	08/18/95	0.1	1 Lightning	THIRTYTWO POINT	040
3,628	08/22/95	0.1	3 Smoking		018
3,629	08/28/95	35.0	3 Smoking	SKOOKUM	041
3,630	08/29/95	0.1	4 Campfire	LOST LAKE	043
3,631	08/31/95	0.1	3 Smoking		019
3,632	09/02/95	1.0	4 Campfire	ELKHORN	044

Figure 3-22—Fires on the Umatilla and Wallowa-Whitman National Forests from 1985 to 2011.

b) Open the fire summary graphics (**FFP menu→Fires→Summary→General →View Fires**, fig. 3-23).

i) With the fire summary window open look at the various graphics created. The upper left quadrant (A) is the total number of fire and acres burned by year. The largest acreage year was 2007, and the year with the most fires was 1896. The upper left hand quadrant (B) is the percentage of fires that occur in each month. This can be used to determine the fire season. Based on the fires present July and August are the peak fire months with June, September and October also experiencing quite a few fires. The bottom graphics include the percentage of fires by fire size class (C), the percentage of fires by fire cause class (D), and the percentage of fires per fire-day that tax suppression resources (E). The majority of the fires in the record are small (class A= <0.25 ac) and are causes by lightning (1=lightning). For this data set the majority of the time a fire occurs it is the only fire to happen on that day (1,047 fires out of 2,070 fire days) the remainder are multi-fire days with 152 of the fire days having 10 or more fires (E). Close the fire summary window when you are done looking at it.

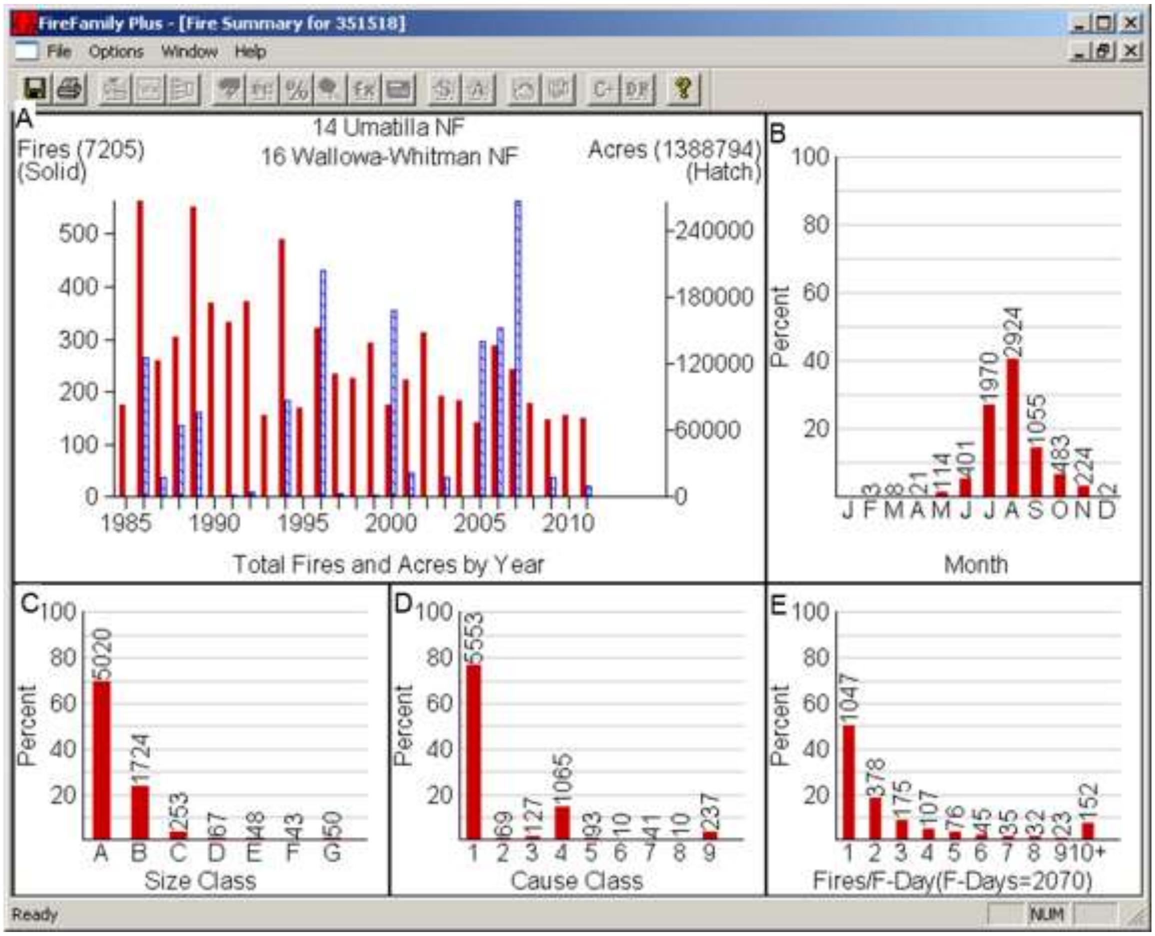


Figure 3-23—Fire summary charts.

Using FFP to complete a wind analysis for FlamMap—

FireFamily Plus can be used to complete a wind analysis to define the wind speed and wind direction for modeling in FlamMap5. When modeling fire behavior you need to think about what part of the day your fire is likely to spread and what winds are likely to affect it during that period. If there is a prevalent known pattern such as winds out of the south west it is fine to use that rather than run FFP.

1) On the home FFP screen, the *Active Working Set Definition* will be updated to represent the fire season for the wind analysis (fig. 3-24).

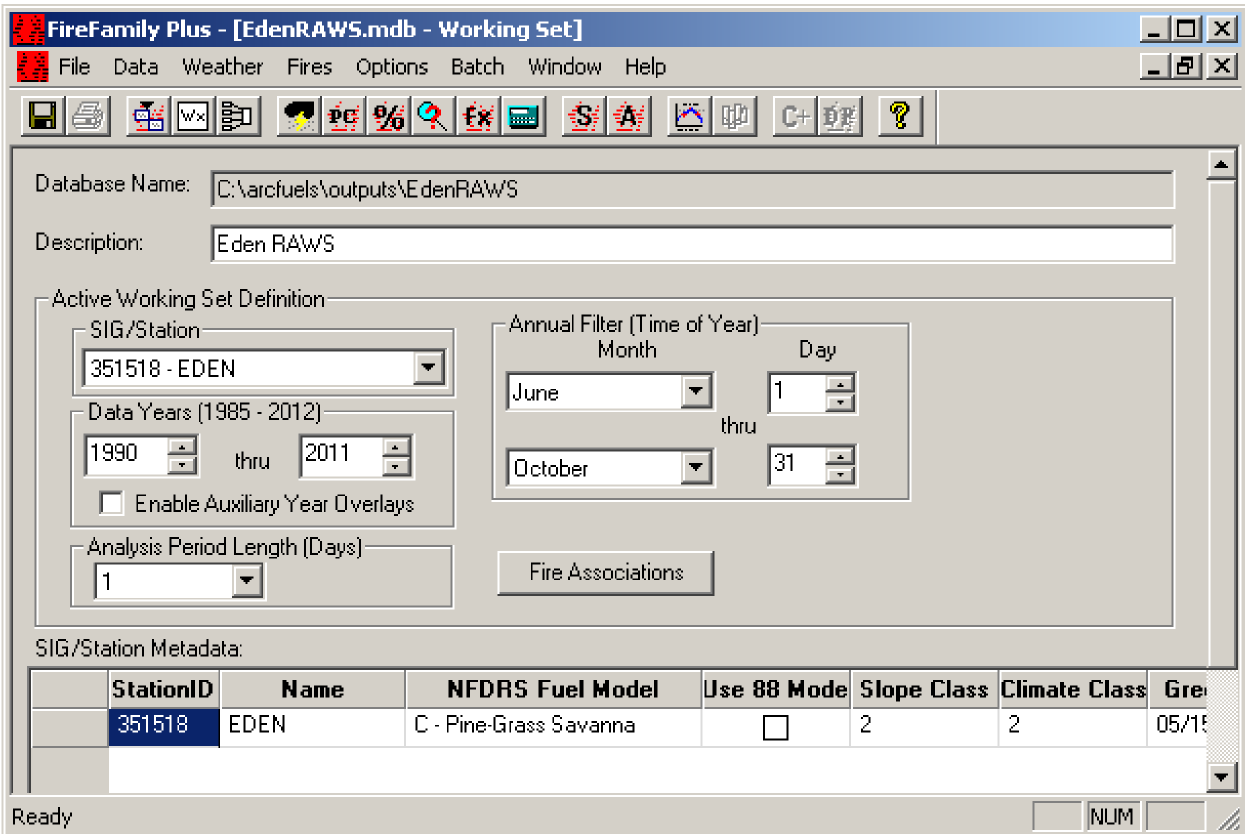


Figure 3-24—Main FFP page with the EDEN RAWS selected.

a) *Data Years (1985 – 2012)*: type "1990" thru "2011" in the appropriate text boxes. The choice of years is to include only years data is available for the whole fire season (2011) and to match the data available from WRCC (starts in 1990) for a comparison of findings.

b) *Annual Filter (Time of Year)*: select June 1 thru October 31 using the appropriate drop-down menus and spin boxes. Based on the fire summary graph this is a good approximation of the fire season for the given RAWS.

2) Open the **Wind report options** form (**FFP menu bar→Weather→Winds**, fig. 3-25).

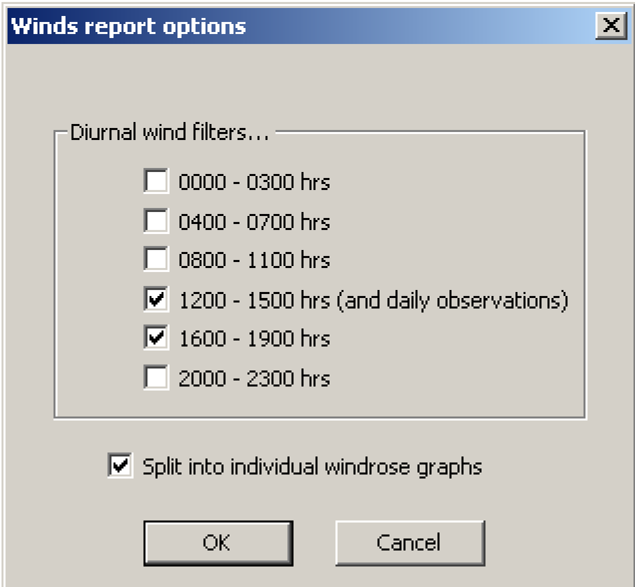


Figure 3-25—Setting the wind report options.

a) Select the *1200-1500 hrs (and daily observations)* and *1600-1900* options. This will select the daily observations from 1990-2009, and the hourly from dates available from 2009-2011. The wind during hours between 1200 and 1900 are most important to fire growth for this situation, so we will only look at these winds for fire behavior.

b) Click **OK** to run the analysis. Several tiled output windows will appear.

c) Look at the **Wind Rose – Combined hourly periods** window (fig. 3-26). This summarizes the frequency of wind speed category by direction in a graphical form. There is a definite trend of winds coming from the south to southwest for this time period and those winds having the highest speeds. The strongest winds (13-19 mph) occur from the south, but they rarely occur.

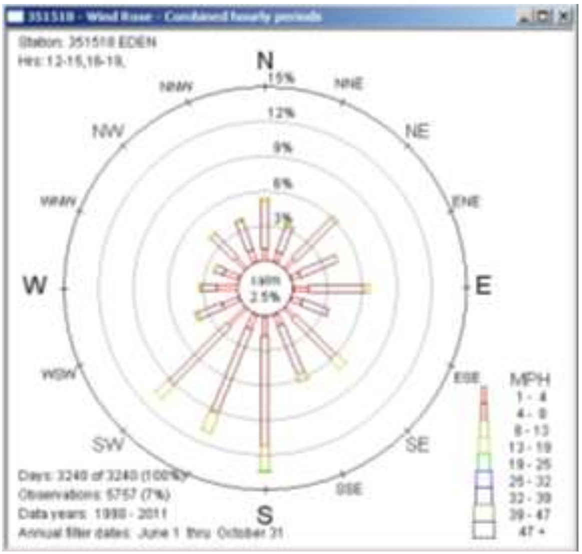


Figure 3-26—Wind rose for June 1 to October 31 from noon to 1900.

d) Look at the **Wind Frequency Table**, scroll down to the **Combined Hours: 12-15, 16-19,** section (fig. 3-27). This summarizes the frequency of wind speed category by direction in a tabular form. Winds never exceed 13-19 mph, and the majority of the time winds are between 4-8 mph (66.7 % of the time). The most typical wind occurrence is 4-8 mph out of the south (9.5 % of the time).

351518 - Wind Frequency Table

Combined Hours: 12-15, 16-19,

MPH	Direction																
Range	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
1-4	1.1	0.9	1.2	0.8	1.3	1.0	1.1	1.0	1.7	1.3	2.1	1.5	1.9	1.5	1.4	1.1	20.7
4-8	4.2	2.4	4.8	3.6	4.9	2.5	4.9	4.6	9.5	8.0	7.2	2.4	1.4	0.9	2.8	2.8	66.7
8-13	0.3	0.2	0.4	0.0	0.4	0.0	1.2	0.8	2.2	1.8	1.6	0.3	0.1	0.0	0.2	0.2	9.6
13-19	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.4
19-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47 +	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (%)	5.5	3.5	6.4	4.4	6.6	3.5	7.3	6.5	13.5	11.1	10.9	4.2	3.4	2.3	4.3	4.0	97.5
Calm (<1)																	2.5
Ave Speed (MPH)	4.1	4.5	4.9	4.5	4.9	4.1	5.5	5.3	5.7	5.6	5.2	4.2	3.6	3.1	4.2	4.4	4.9

5757 total observations used out of a possible 77760 (7%)
3240 days (3240 w/ complete wind dirs - 100%)

Figure 3-27—Wind frequency report for June 1 to October 31 from noon to 1900. The majority of the time (66.7%) the wind is between 4-8 mph, and the most common winds are from the south also between 4 and 8 mph (9.5%).

3) Close all the windows from the wind run.

Using WRCC data to complete a wind analysis for FlamMap—

The WRCC website also has the ability to generate wind rose graphs and tables using their hourly weather data. This can be very useful and fast especially for exploring how time of day affects wind patterns when hourly data is not imported into FFP. We will run the same assessment as in the ***Using FFP to complete a wind analysis for FlamMap*** exercise above.

1) Go to the WRCC hourly RAWS web page: http://www.raws.dri.edu/ (fig. 3-28).

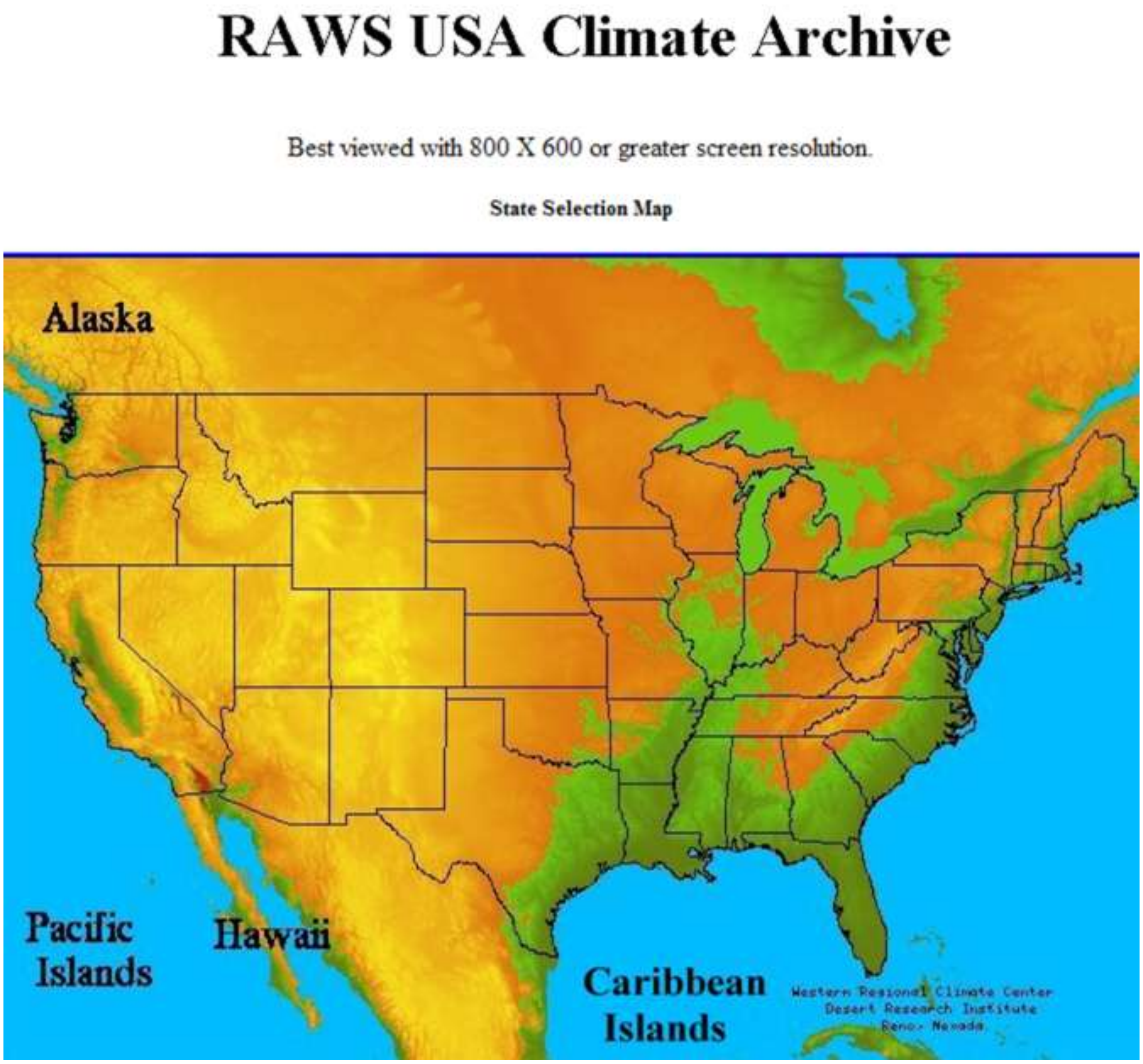


Figure 3-28—WRCC home page for hourly RAWS data.

2) Click on the state of Oregon, then find the Eden RAWS and click on it to access the data (fig. 3-29).

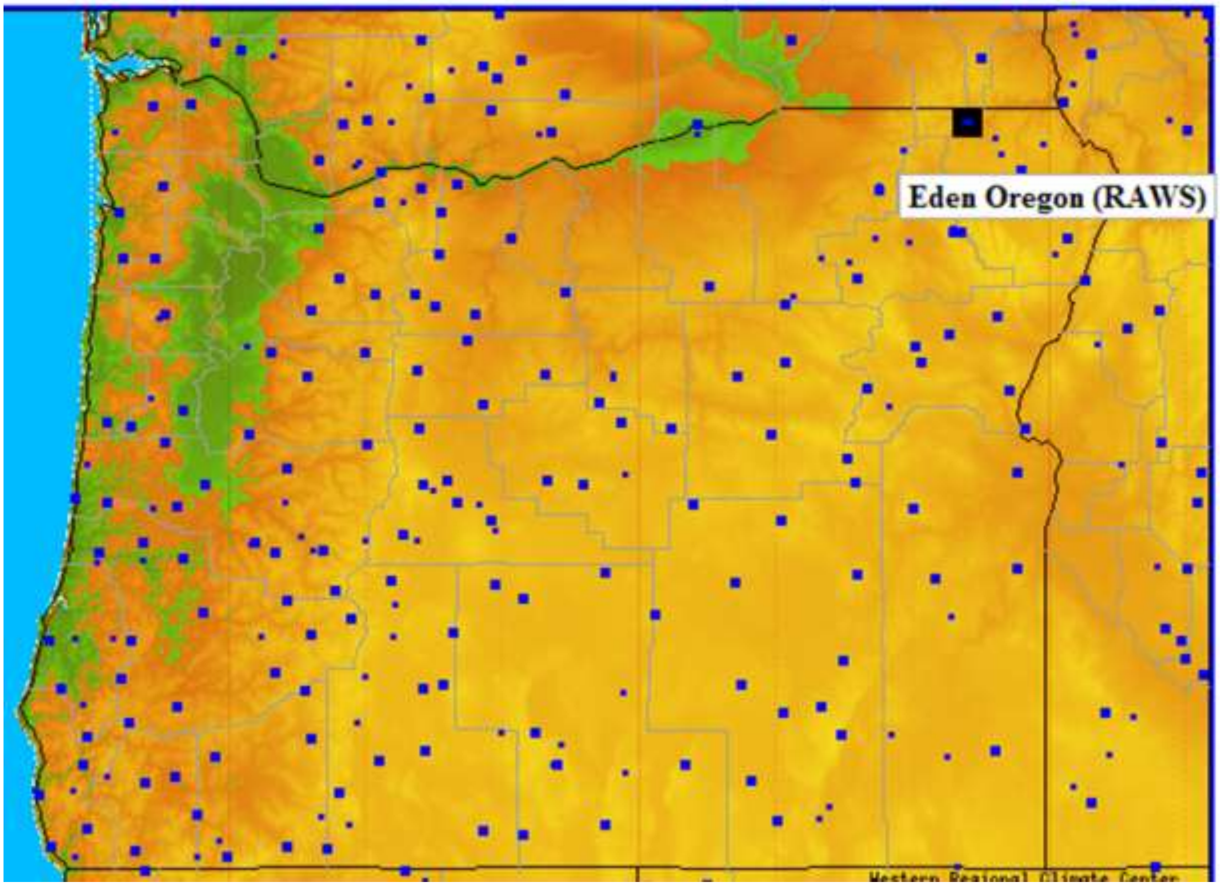


Figure 3-29—RAWS station in Oregon.

3) On menu bar on the left-hand side click on **Wind Rose Graph and Tables** (fig. 3-30).

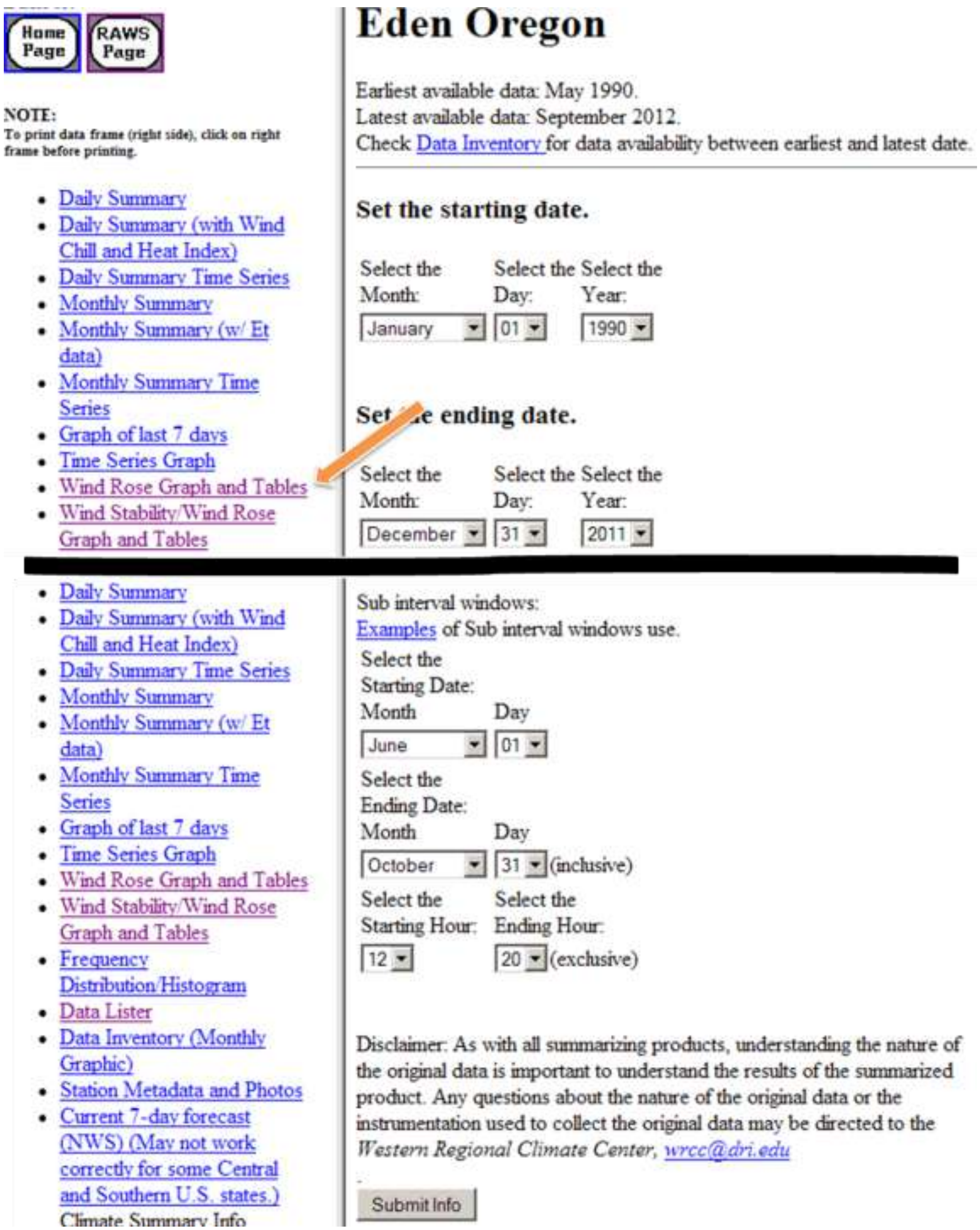


Figure 3-30—Setting up the wind run with WRCC data from their webpage.

a) *Set the starting date*: select January 1 1990 using the drop-down lists.

b) *Set the ending date*: select December 31 2011 using the drop-down lists.

c) Scroll down to the bottom of the page leaving all the rest of the defaults as is until you reach the settings for the *Sub interval windows*.

d) *Starting date*: select June 1 using the drop-down lists.

e) *Ending date*: select October 31 using the drop-down lists.

f) *Starting hour*: select 12 using the drop-down list.

g) *Ending date*: select 20 using the drop-down list.

h) Click **Submit Info**.

i) Look at the wind rose (fig. 3-31) how does it compare to the one created in FFP? The south to southwest winds are still the most frequent, but with this data winds out of the southwest are more prevalent and stronger than out of the south.

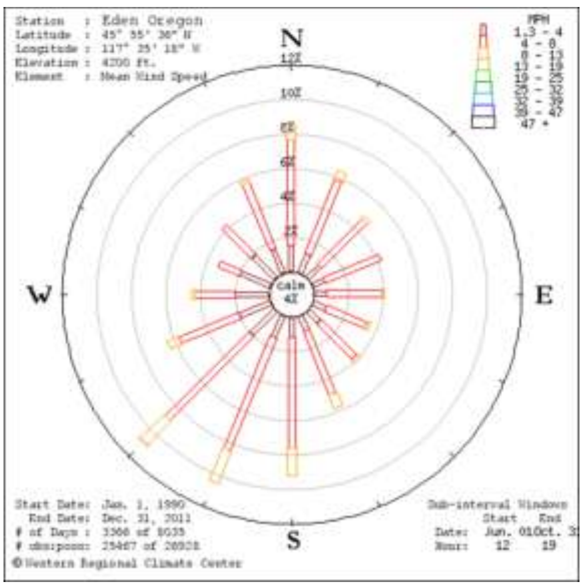


Figure 3-31—Wind rose for June 1 to October 31 from noon to 1900 using WRCC hourly data.

j) Look at the **Wind Frequency Table** how does it compare to the one created in FFP? The distribution of wind speeds is very similar between the two data sets. With the WRCC hourly data the most prevalent wine is from the SSW again at 4-8 mph (64.7%).

Eden Oregon - Wind Frequency Table (percentage)

Latitude : 45° 55' 36" N
Longitude : 117° 35' 18" W
Elevation : 4200 ft.
Element :

Start Date : Jan. 1, 1990
End Date : Dec. 31, 2011
# of Days : 3366 of 8035
obs : poss : 25467 of 80784

Sub Interval Windows	Start	End
Date	Jun. 01	Oct. 31
Hour	12	19

(Greater than or equal to initial interval value and Less than ending interval value.)

Range (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
1.3 - 4	1.5	1.2	1.0	0.7	0.7	0.8	0.9	1.0	1.2	1.3	1.9	1.9	1.9	1.8	1.8	1.5	21.1
4 - 8	6.1	4.6	3.7	3.5	3.1	2.5	2.9	3.9	6.4	7.1	6.9	3.7	2.3	1.4	2.4	4.1	64.7
8 - 13	0.8	0.5	0.2	0.1	0.2	0.2	0.3	0.8	1.6	2.0	1.9	0.7	0.2	0.0	0.1	0.3	9.8
13 - 19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.4
19 - 25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 - 32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 - 39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 - 47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47 -	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total(%)	8.4	6.3	4.8	4.3	4.0	3.6	4.1	5.7	9.2	10.5	10.8	6.3	4.4	3.2	4.3	5.8	95.9
Calm (<1.3)																	4.0
Ave Speed	5.2	5.1	4.7	4.7	5.0	4.8	4.9	5.4	5.8	5.8	5.6	4.9	4.1	3.7	4.0	4.7	4.9

Figure 3-32—Wind frequency report for June 1 to October 31 from noon to 1900 using WRCC hourly data.

4) Close Internet Explorer.

Using FFP to create the WND and WTR files for FlamMap—

Dead fuel moisture conditioning results in more realistic fire behavior outputs because fuel moistures will be calculated based on weather, topography, and shading for each pixel in the landscape using the initial fuel moistures as a starting point. FFP can be used to create wind (WND) and weather (WTR) files required for dead fuel moisture conditioning in FlamMap. Hourly data is needed to create the WND and WTR files. In the example you will create the files for the month of August in 2012. Another option would be to use data leading up to a known large historic fire.

1) On the home FFP screen, the *Active Working Set Definition* will be updated to represent the month of August for 2012 for the hourly data analysis (fig. 3-33).

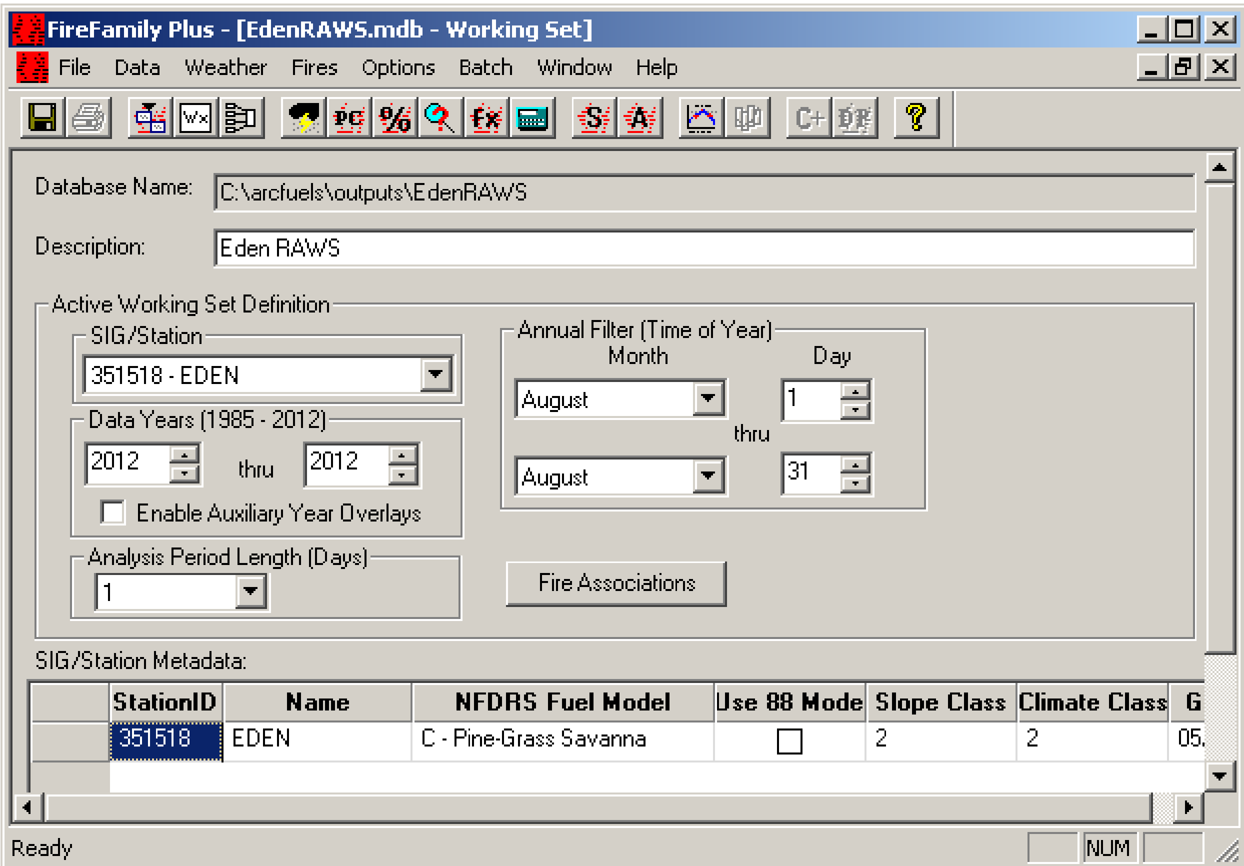


Figure 3-33—Main FFP page with the EDEN RAWS selected for August 2012.

a) *Data Years (1985 – 2012)*: type “2012” thru “2012” in the appropriate text boxes.

b) *Annual Filter (Time of Year)*: select August 1 thru August 31 using the appropriate drop-down menus and spin boxes.

2) Open the **Generate FarSite Data Files** form (**FFP menu bar→Weather→Hourly Data Analysis→FarSite Exports**, fig. 3-34).

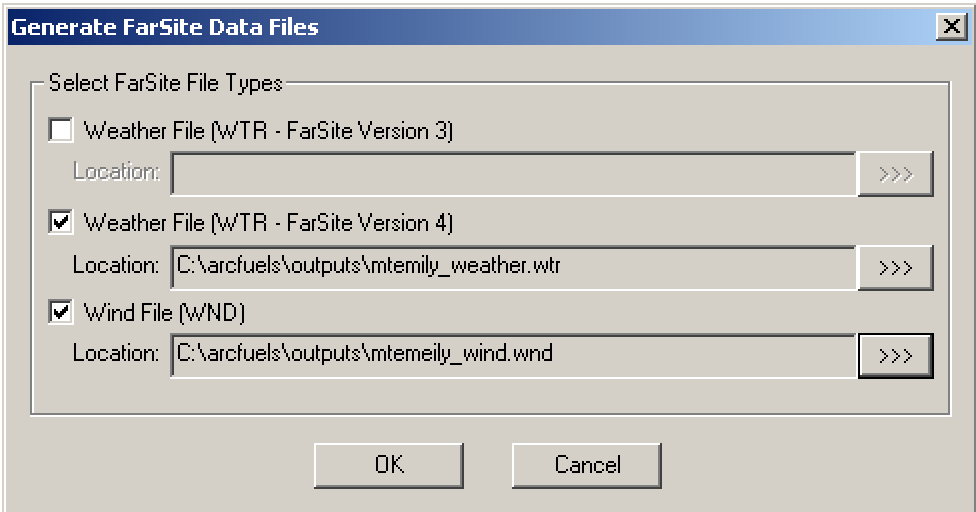


Figure 3-34—Generating FarSite Data Files form.

a) Select the *Weather File (WTR-FarSite Version)* option. Click the >>> button to navigate to the outputs folder in the ArcFuels directory and save the WTR file as "mtemily_weather."

b) Select the *Wind File (WND)* option. Click the >>> button to navigate to the outputs folder in the ArcFuels directory and save the WND file as "mtemily_wind."

c) Click **OK** to create the files.

3) Look at the WND file (fig. 3-35). This file contains wind speed and direction and cloud cover percent for every hour in the month of August. Specifically the headers are:

Month Day Hour Speed Direction Cloud Cover

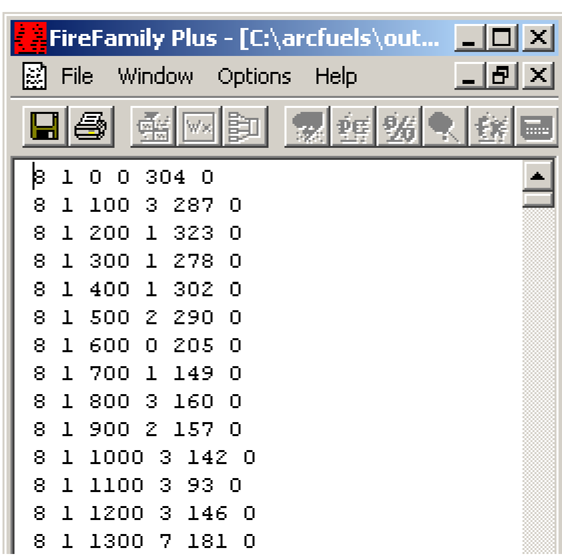


Figure 3-35—The WND file created in FFP for use with FARSITE and FlamMap.

4) Look at the WTR file (fig. 3-36). This file contains minimum and maximum temperature and relative humidity, precipitation amount and duration for each day in the month of August. Specifically the headers are:

Month Day Precip Hr1 Hr2 Temp1 Temp2 RH1 RH2 Elev rt1 rt2

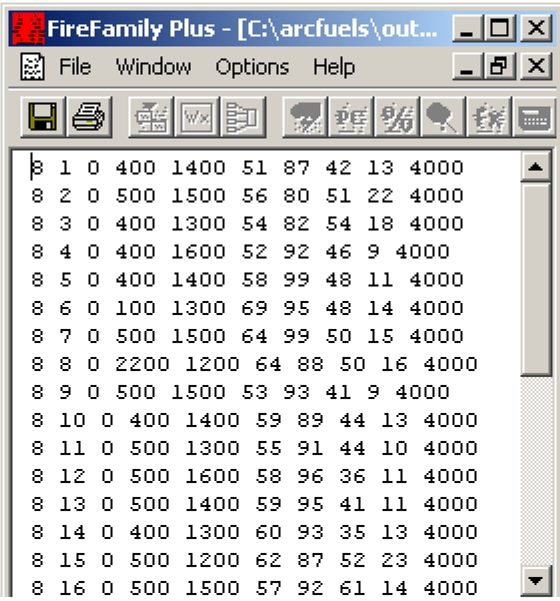


Figure 3-36—The WTR file created in FFP for use with FARSITE and FlamMap.

a) *Precip* is the daily rain amount specified in hundredths of an inch.

b) *Hr1* is the hour for the minimum temperature.

c) *Hr2* is the hour for the maximum temperature.

d) *Temp1* is the minimum temperature in degrees Fahrenheit.

e) *Temp2* is the maximum temperature in degrees Fahrenheit.

f) *RH1* is the maximum relative humidity in percent.

g) *RH2* is the minimum relative humidity in percent.

h) *Elev* is the elevation of the RAWS station in feet.

i) *rt1* is the beginning of the rain event, only recorded of *Precip* is greater than 0.

j) *rt1* is the end of the rain event, only recorded of *Precip* is greater than 0.

5) Close FFP.

Downloading recent WND and WTR files from NWS—

Another option available for obtaining WND and WTR files is to download them from the National Weather Service (NWS) Fire Weather webpage. WND and WTR files are created for any point by interactively clicking on a map. The files produced are for the past week starting from the time you request the data.

1) Go to the National Weather Service (NWS) Fire Weather webpage (fig. 3-37): http://www.srh.noaa.gov/ridge2/fire/

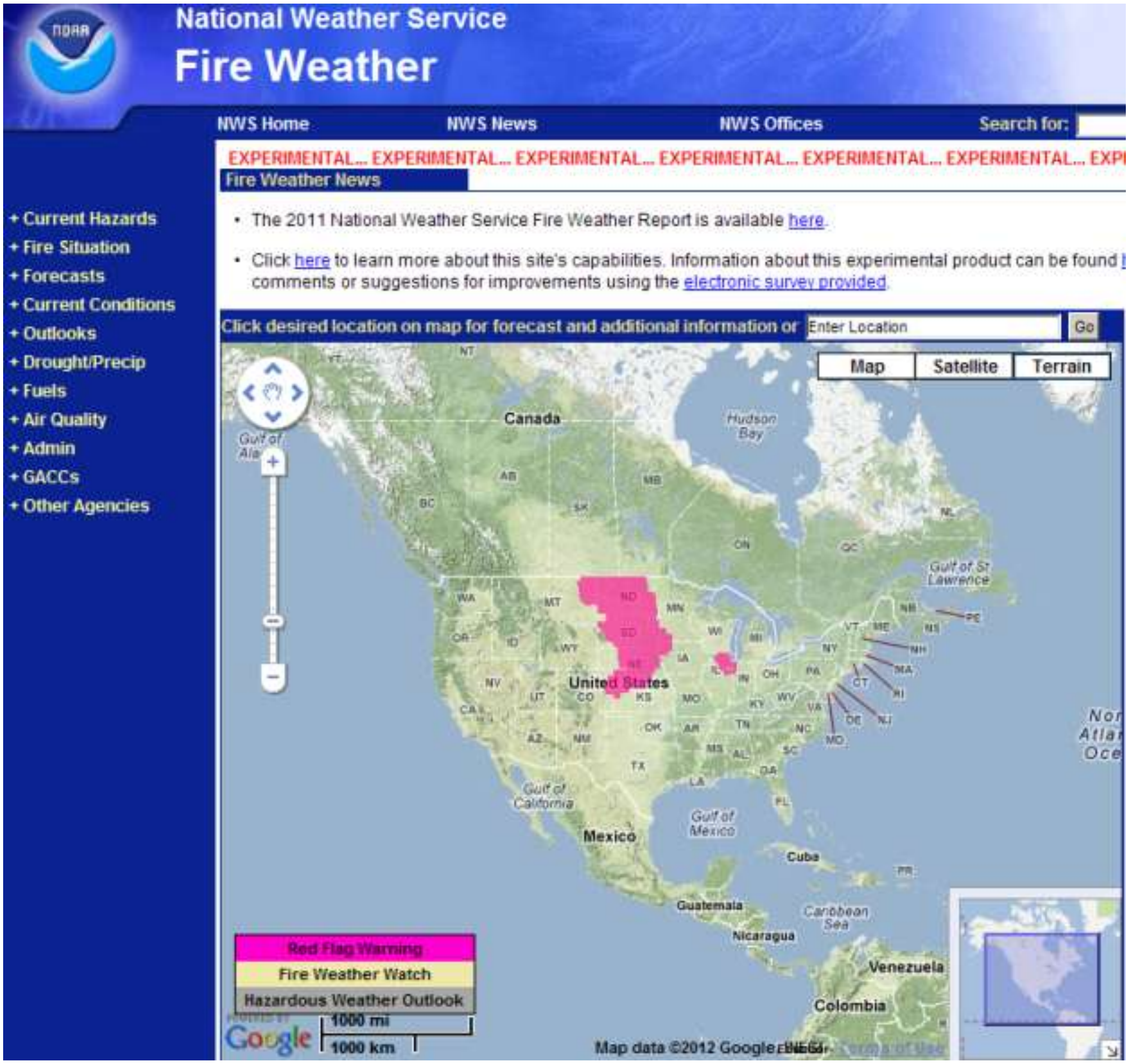


Figure 3-37— National Weather Service (NWS) Fire Weather webpage.

2) Zoom into north eastern Oregon and click on the map near the Mt. Emily project area which is just north of La Grande (fig. 3-38).

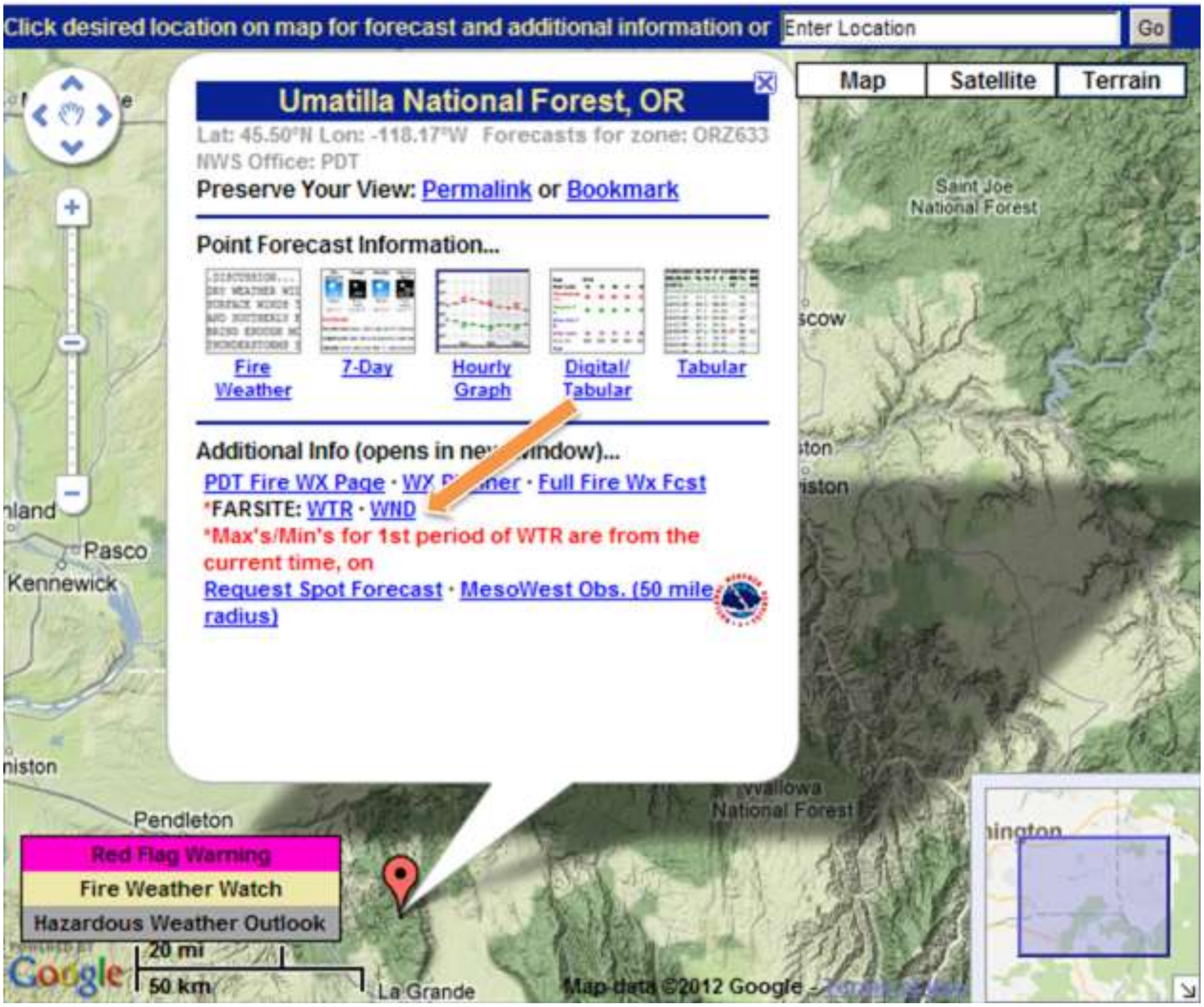


Figure 3-38—Pop-up window for the clicked on location on the map and the link to the WTR and WND files highlighted.

If you click on a slightly different location you will get the weather for that location.

3) Click on the **WTR** link to the right of FARSITE in the pop-up window (see fig. 3-38). This will open a new browser window with the WTR data for the past week (fig. 3-39).


```
09 20 00 2300 1500 50 79 30 14 4704
09 21 00 0500 1500 41 80 30 13 4704
09 22 00 0500 1500 39 82 33 12 4704
09 23 00 0600 1500 49 77 31 13 4704
09 24 00 0600 1500 51 74 36 20 4704
09 25 00 0600 1500 50 72 41 26 4704
09 26 00 0600 1400 49 71 48 25 4704
```

Figure 3-39—WTR data for the past week from the NWS.

a) To use this data in FlamMap it needs to be saved as a *.txt file (**Internet Explorer main menu→File→Save As**) then be converted to a *wtr file. Navigate to and save the file as "mtemily_weather_nws" as a text file (*.txt) in the outputs folder of the ArcFuels directory (fig. 3-40).

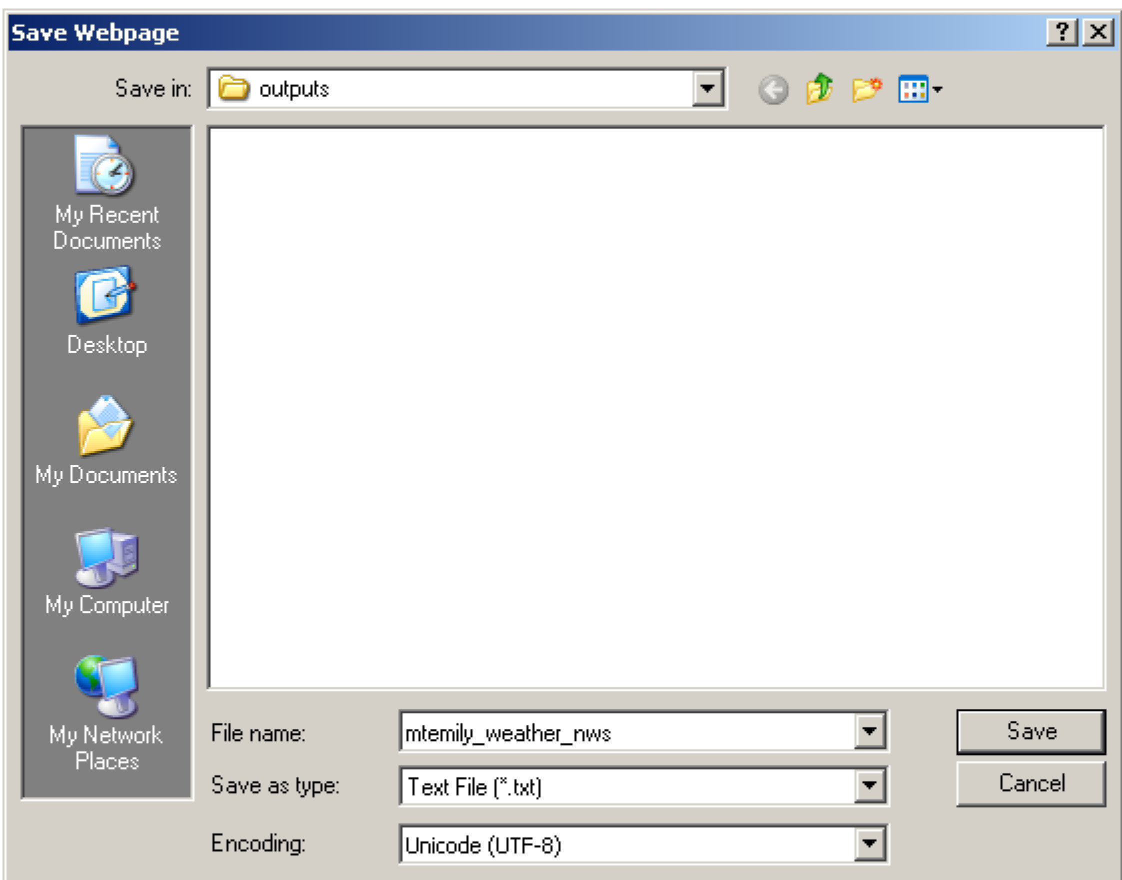


Figure 3-40—Saving the data as a text file.

b) Open the outputs folder in the ArcFuels directory. Find the mtemily_weather_nws.txt file right-click on the file and select **Rename** from the menu that opens. Change the txt extension to “wtr.” A warning window will open, click **OK** to close the window and change the extension (fig. 3-41).

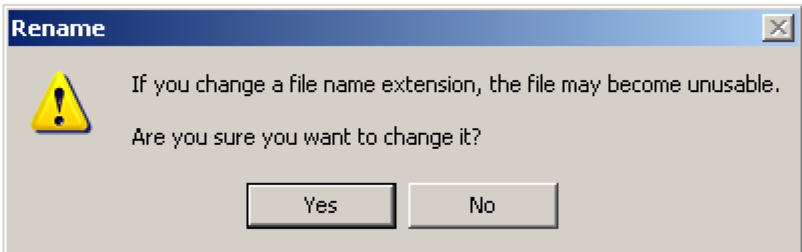


Figure 3-41—File extension rename warning window.

4) Click on the **WND** link to the right of FARSITE in the pop-up window (see fig. 3-38). This will open a new browser window with the WND data for the past week (fig. 3-42).

09 19 1300 2 200 8
09 19 1400 3 320 8
09 19 1500 3 320 8
09 19 1600 3 320 8
09 19 1700 3 290 2
09 19 1800 3 290 2
09 19 1900 3 290 2
09 19 2000 3 10 2

Figure 3-42—WND data for the past week from the NWS.

a) To use this data in FlamMap it needs to be saved as a *.txt file then be converted to a *wnd file. Follow the steps outlined for the WTR file but name the file “mtemily_wind_nws” and change the txt extension “wnd.”

5) Close Internet Explorer.

4. FlamMap 5

This section is meant to be a brief introduction FlamMap 5. There are many functions within FlamMap 5 that will not be discussed. The purpose is to have the user gain a foundation of FlamMap 5 skills for use with ArcFuels10. For more thorough tutorials download the program and help file from the FlamMap 5 website (http://www.firemodels.org/index.php/national-systems/flammap).

Program Overview

FlamMap 5 (Finney 2006) is a spatially explicit landscape fire behavior mapping and modeling system that describes potential fire behavior with a constant fire environment (static weather and fuel moisture). The fact that the fire environment is held constant makes FlamMap 5 the ideal tool for landscape-level fire behavior assessment for fuel treatment planning. It is possible to see the effect of changes to fuels on fire behavior without the additional unknown of weather affects.

FlamMap 5 has two methods of modeling potential fire behavior: basic fire behavior, and minimum travel time (MTT, Finney 2002). In the first type of simulation, basic fire behavior is calculated by independently burning each pixel on the landscape. Primary modeled outputs include rate of spread, flame length, fireline intensity, and crown fire activity. In the second type of simulation, discrete wildfire(s) are simulated using the two-dimensional MTT fire growth algorithm. MTT calculations assume independence of fire behavior among neighboring cells but are dependent on the ignition locations, resolution of calculations, and simulation time. The MTT algorithm replicates fire growth by Huygens' principle where the growth and behavior of the fire edge is modeled as a vector or wave front (Knight and Coleman 1993). This method results in less distortion of fire shape and response to temporally varying conditions than techniques that model fire growth from cell-to-cell on a gridded landscape (Finney 2002). Specifically, a rectangular lattice of a defined resolution (preferable scaled to the input data) is used to determine fire spread or travel time between each node (cell size based on the input variables), fuel moisture, wind speed, and wind direction. In addition to the fire spread, fire behavior is stored for each node (Finney 2002). Minimum travel time is determined starting at the ignition location for all adjacent nodes until the minimum cumulative travel time is determined. Primary outputs for a single fire are rate of spread, arrival time, fire intensity, and flow paths. When multiple random fires are ignited, burn probability, flame length probability, plus ignition location and resulting fire perimeters are available.

Both basic fire behavior and MTT calculations are derived from the same lineage of systems that model one-dimensional behavior as part of a spreading line fire (Albini 1976, Anderson et al. 1982, Rothermel 1972, 1991, Van Wagner 1977, 1993). For more detailed information about the calculations see the FlamMap 5 help guide supplied with the program.

In addition to the fire behavior outputs, FlamMap 5 also has the Treatment Optimization Model (TOM, Finney 2007). TOM utilizes MTT fire behavior calculations, predetermined fire ignition (point, line or area), fuel moisture and wind information, and two LCPs. The first LCP represents the current conditions, and the second an "ideal" landscape. The ideal landscape represents post-treatment conditions, with treatments occurring wherever they are possible (not just desired). TOM then simulates fire across both landscapes and places treatment block (user defined size) in the most optimal location to slow fire spread. The output is a treatment grid consisting of 0s and 1s with the most optimal treatment pattern given the availability to be treated and the proportion of land allowed to be treated.

As with any modeling system, there are known limitations with FlamMap 5 (Cruz and Alexander 2010). Having an understanding of these limitations is important before using any model.

Input data—

FlamMap 5 requires a landscape (LCP) file, wind speed and wind direction information, and a fuel moisture file (FMS) to run. Additional optional files include a custom fuel model file (FMD), wind vector files (direction and speed), and weather (WTR) and wind (WND) files for fuel moisture conditioning.

Landscape File (LCP)

The LCP is a binary file that contains spatially explicit information about the topography and fuel characteristics of a landscape (fig. 4-1). The LCP is comprised of five layers at a minimum (elevation, slope, aspect, fuel model, and canopy cover) and ideally eight (addition of canopy base height, canopy height, and canopy bulk density), and infrequently 10 (addition of duff loading and course woody fuels). This LCP file is identical to the one used in FARSITE. It is possible to create the LCP in both FARSITE and FlamMap 5, but this will not be discussed, rather see the ArcFuels10 Tutorial to learn how to build the LCP using ArcFuels10.

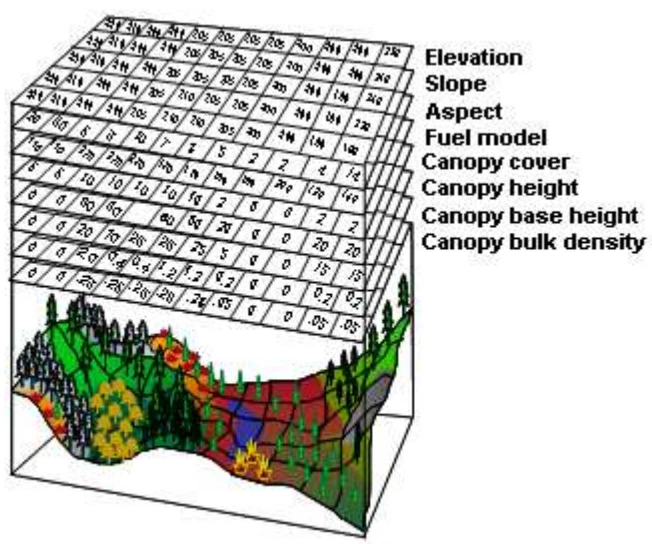


Figure 4-1—FlamMap 5 LCP file adapted from Finney 2006.

Wind speed and wind direction

Wind speed and wind direction will be dependent on the fire scenario desired. Winds can either blow uphill or downhill (based on the input topographic themes in the LCP) or from a set direction (i.e. out of the south west). Wind speed can be selected using a program such as FireFamily Plus to characterize a given percentile condition, or can be determined using expert opinion. FlamMap 5 can also create wind vectors using WindNinja (Forthofer et al. 2009, available at: http://www.firemodels.org/index.php/research-systems/windninja) or if already obtained, wind direction and speed ASCII files can be used.

Fuel moisture file (FMS)

The FMS file is an ASCII text file that contains the fuel moisture for 1-hr, 10-hr, and 100-hr timelag fuel classes, as well as live herbaceous and live woody fuels for all fuel models present (fig. 4-2). The FMS file can now be created in FlamMap 5.

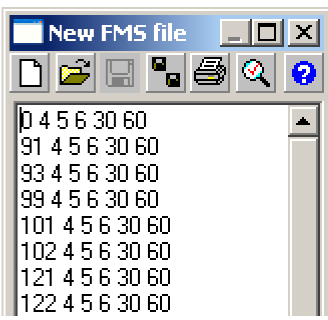


Figure 4-2—Example FMS file.

Custom fuel model file (FMD)

The optional FMD is an ASCII text file that describes custom fuel model(s). The description includes data on fuel loading, surface area to volume ratio, fuel bed depth, moisture of extinction, and heat content of live and dead fuels (fig. 4-3).

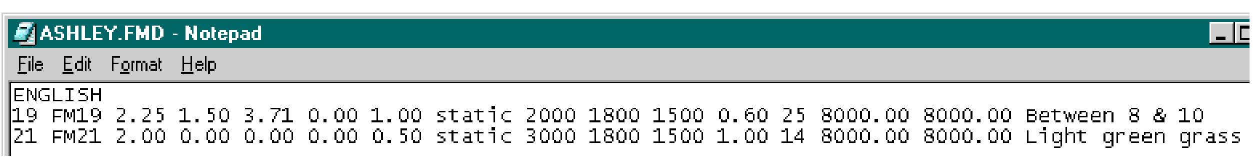


Figure 4-3—Example FMD file.

Wind (WND) and weather (WTR) files

Dead fuel moisture conditioning uses the optional WND and WTR files in addition to topography and shading, to condition dead fuel moistures. The WND file is an ASCII text file including hourly information (by date) on wind speed, wind direction, and cloud cover. The WTR file is an ASCII text file containing daily maximum and minimum temperate and relative humidity, precipitation duration and quantity, and the elevation of the weather observations.

For more information about the WND and WTR files please see section 3***. Fire Climate/Weather Data & FireFamily Plus*** in this document.

FlamMap interface—

Main FlamMap screen

FlamMap 5 can be opened from within ArcFuels10, or directly from your computer if you have downloaded and installed the program. From the ArcFuels10 toolbar, click on **Wildfire Models,** then select **FlamMap** from the drop-down list. This will open the FlamMap 5 interface (fig. 4-4).

The left pane is called the "tree" pane, and the right is the "display" pane (fig. 4-8). Within the tree pane, each "section" is indicated by a diamond to the left of the text, and each section can be expanded using the boxed "+" symbol, or collapsed using the boxed "-" symbol when there are multiple data layers or options within a section.

Figure 4-4—FlamMap 5 interface.

FlamMap runs form

The **Inputs** tab (fig. 4-5) is where a run can be named, the fuel moisture files are loaded, the wind information is input, canopy characteristics are defined, and fuel moisture settings are defined. A fuel moisture file must be loaded to run FlamMap 5. In addition, if custom fuel models are used in the theme, a custom fuel model file must also be used. The pencil icon to the right of the files can be used to open a loaded file, verify the contents, update the file as needed, and save the file. Winds can be blowing uphill, downhill, from a defined direction, or from wind vectors with a user defined speed. If the LCP does not have information about the canopy height, canopy base height, and/or canopy bulk density, a single constant value for the entire landscape can be defined under the *Canopy Characteristics* heading. It is recommended that spatially explicit information characterizing these canopy characteristics is used for more accurate crown fire behavior modeling. In addition, foliar moisture (water content of conifer foliage) is set in this section. For more information about foliar moisture content in North American conifers, see Keyes 2006. If conditioning the dead fuel moistures, the WND and WRT files need to be loaded. Then the conditioning period (days and time) need to be set.

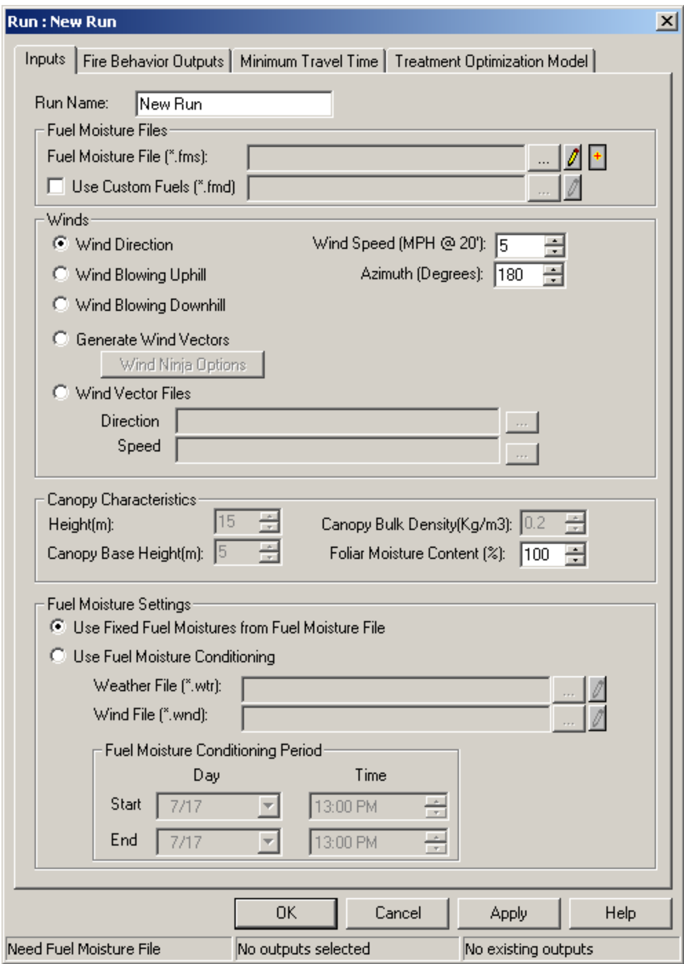


Figure 4-5—Inputs tab for a FlamMap 5 run.

The **Fire Behavior Outputs** tab (fig. 4-6) is used to calculate the basic fire behavior outputs, and set the crown fire calculation method and computer memory set up for MTT and TOM runs. The number of processors used defaults to the number of processors your computer has. The *Crown Fire Calculation Method* can be set based on Finney (1998) methods which are identical to FARSITE, or Scott/Reinhardt (2001) methods. When using the Finney (1998) method it is recommended that canopy bulk density values derived using a 15 ft running mean window (Scott and Reinhardt 2001), as is the case with FFE-FVS, should be doubled. The other differences have to do with how active and passive crown fire spread is modeled. Active crown fire is reduced to account for spotting being modeled separately with the Finney (1998) method, and passive crown fire is scaled to the crown fraction burned using the Scott/Reinhardt (2001) method. The *Output Grids* and *Non-Fixed Fuel Moisture Outputs* are the optional outputs available. The *Non-Fixed Fuel Moisture Outputs* are only created when fuel moisture conditioning is completed with WND and WTR files. The outputs are summarized in tables 4-1 and 4-2. The other *Options* control the spread direction for calculating the fire behavior characteristics.

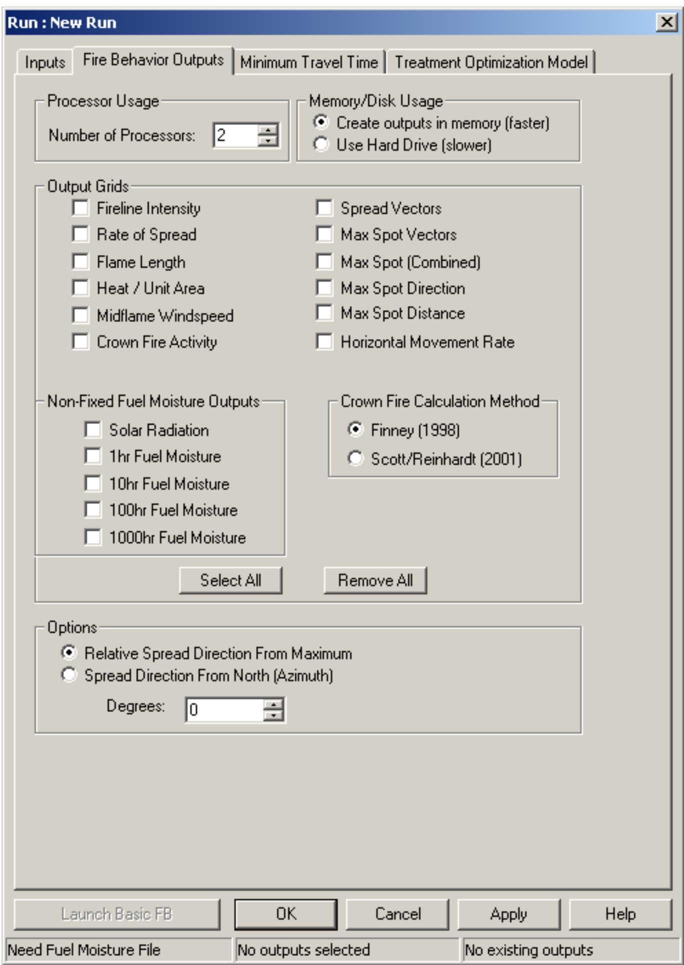


Figure 4-6—Fire Behavior Outputs tab for a FlamMap 5 run.

Table 4-1—Basic fire behavior output grids from FlamMap 5.

Output grid	Possible units	Description
Fireline intensity	kW/m, BTU/ft/sec	Rate of heat energy released per unit time per unit length of fire front
Rate of spread	m/min, ft/min, chains/hr	Horizontal distance that the flame zone moves per unit of time
Flame length	m, ft	Distance from the ground at the leading edge of the flame to tip of the flame
Heat/unit area	kJ/m^2, BTU/ft^2	Total amount of heat released per unit area as the flaming front of the fire passes
Midflame windspeed	k/hr, mph	The speed of the wind measured at the midpoint of the flames
Crown fire activity	categorical	Fire type: 0=no fire; 1= surface fire; 2=passive crown fire; 3=active crown fire
Spread vectors	n/a	A combination of the maximum spread direction and rate of spread grids displayed as an arrow
Max spot vectors	n/a	A combination of the maximum spread direction and rate of spread grids displayed as an arrow for spot fires
Max spot (combined)	class	
Max spot direction	deg	Direction of the maximum spotting distance
Max spot distance	m, ft	Distance of the maximum spotting range
Horizontal movement	m/min, ft/min, chains/hr	The rate of spread (slope basis) transformed to a horizontal projection

Table 4-2—Non-fixed fuel moisture outputs from FlamMap 5.

Output grid	Possible units	Description
Solar radiation	W/m^2	The amount of sunlight exposed to the fuels
1-hr fuel moisture	fraction	Moisture content of 1-hr timelag fuels (fuels with diameter $< ¼$ in including the litter layer)
10-hr fuel moisture	fraction	Moisture content of 10-hr timelag fuels (fuels with diameter $\geq ¼$ in but $<$ 1in)
100-hr fuel moisture	fraction	Moisture content of 100-hr timelag fuels (fuels with diameter $\geq$ 1 in but $<$ 3 in)
1000-hr fuel moisture	fraction	Moisture content of 1000-hr timelag fuels (fuels with diameter $>$ 3 in)

The **Minimum Travel Time** tab (fig. 4-7) is used to calculate the MTT fire behavior outputs. Available outputs will vary depending on the type of ignition used; a set ignition (created within FlamMap 5, or in ArcMap and loaded) versus random ignitions, or those from a fire list file. When a set ignition is used, outputs available for selection are: rate of spread, influence, arrival time, fire intensity, and ignition grids, as well as flow paths, major paths, and arrival time contours (table 4-3). When random ignitions or ignitions from a fire list file are used, a burn probability grid, flame length probability (FLP) file, fire size list, and fire perimeters are created (table 4-3).

Resolution of calculations dictates how often the calculations are completed, and what the output resolution of the grids selected will be. It is advised that the user chooses a multiple of the input resolution (i.e. if the input grid resolution is 30 m, then choose 30 m, 60 m, 90 m etc. for the calculations). Simulation time can be set for a defined time (often a single burn period such as 6 hr or 360 min), or left to run until every pixel has burned. The interval for the minimum travel paths controls how FlamMap 5 outputs the major paths.

This is also where the spotting probability is set for any calculations that involve MTT. This includes the Treatment Optimization Model which is described below.

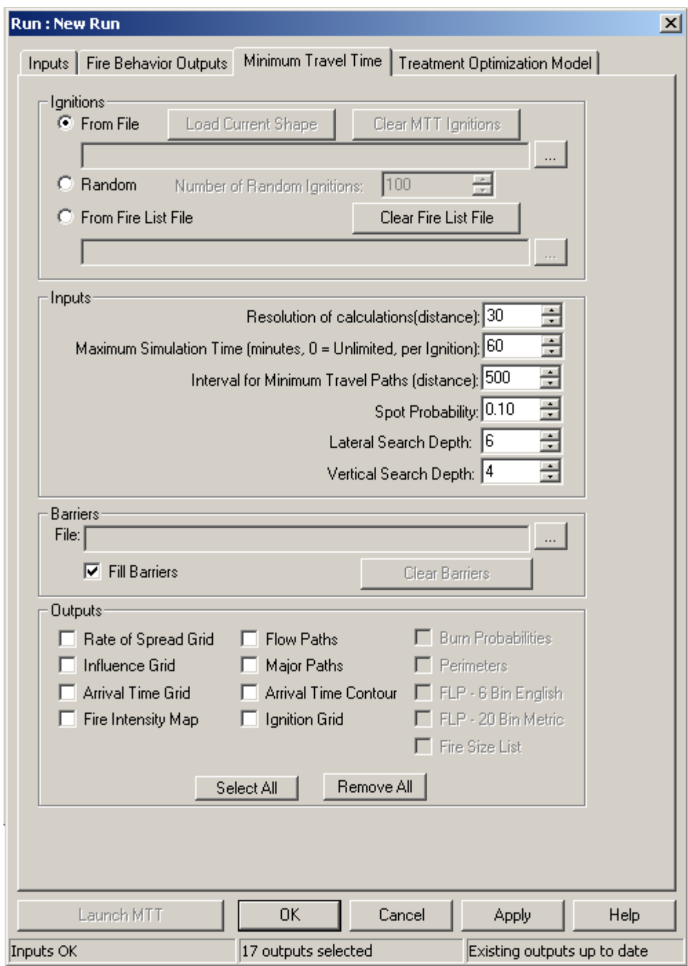


Figure 4-7—Minimum Travel Time tab for a FlamMap 5 run.

Table 4-3—Minimum travel time outputs.

Output	Possible units	Description
Rate of spread grid	m/min, ft/min, chains/hr	Spread rate of the fire as it encountered each node along the minimum travel time path
Influence grid	n/a	Logarithm of the number of nodes burning as a result of burning through that particular node
Arrival time grid	min	The elapsed time when the fire arrived at each node – fire progression
Fire intensity map	kW/m, BTU/ft/sec	Fireline intensity of each node burned by the fire as it follows the minimum travel time path
Flow paths	n/a	Minimum travel time pathways among all nodes
Major paths	n/a	Flow paths identified at the user-specified interval for MTT flow
Arrival time contour	n/a	Contour representation of the MTT Arrival Time grid (default contour interval is the maximum value of the MTT Arrival Time grid divided by 10)
Ignition grid	n/a	Grid file of the ignition points, lines or areas used in the MTT run.
Burn probability	fraction	Fraction of the number of fires that encountered each node
Perimeters	n/a	Shapefile of final fire perimeter from random or fire size list file ignitions
FLP 6 bin English	n/a	Text file that contains information about burn probability and fire intensity for each point for 6 fire intensity levels (FIL1–FIL5 are 2 ft increments and FIL6 >12 ft)
FLP 20 bin metric	n/a	Text file that contains information about burn probability and fire intensity for each point for 20 0.5 m fire intensity levels
Fire size list	n/a	Text file with information about the location of each ignition and the final fire size (in acres)

The **Treatment Optimization Model** tab (fig. 4-8) is used to determine the optimal fuel treatment pattern to slow the forward progression of fire using existing conditions and ideal landscape for a defined fire ignition. Inputs include: a fire ignition (created in FlamMap 5 or ArcMap), resolution of calculations (see the **MTT** tab), the ideal landscape, and treatment specifications. Maximum treatment dimension is the maximum linear dimension of any treatment allowed. The number of iterations/treatment level sets the number of iterations for the model to run; more iterations increase computing time for minimal benefits. The treatment fraction is the fraction of the entire landscape, not just the available lands that can be treated. Outputs include the treatment opportunities grid (a positive value indicated the ideal landscape has a slower rate of spread, and a 0 is no difference), and the treatment grid (a 0/1 grid identifying where TOM suggests treatments). In addition, the same outputs as the MTT (table 4-3) calculations are available for a fixed ignition.

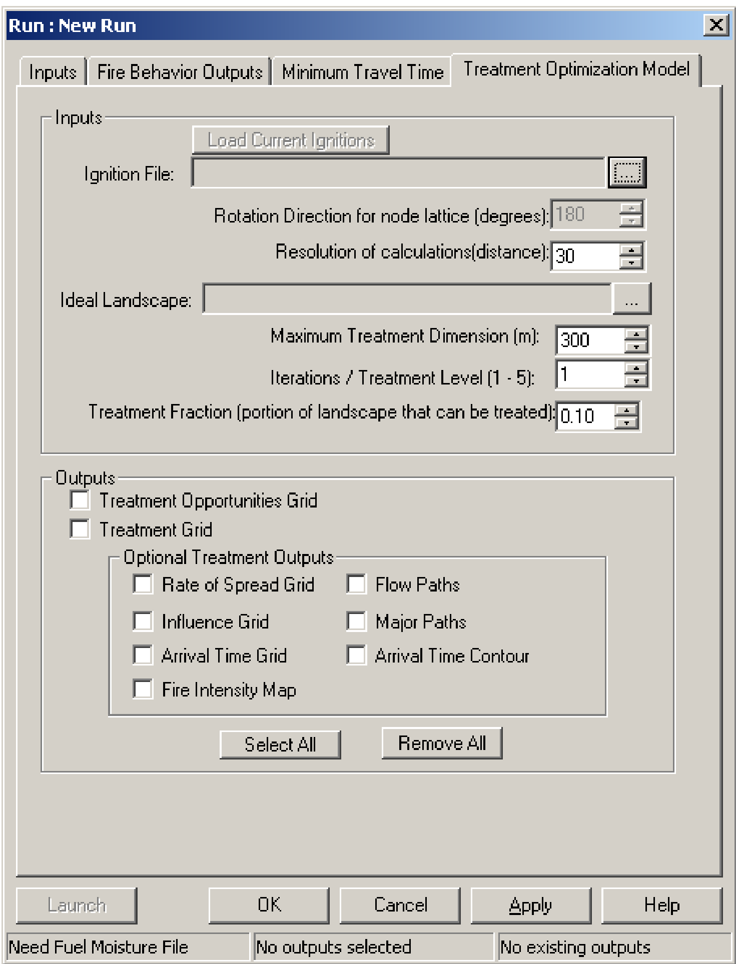


Figure 4-8—Treatment Optimization Model tab for a FlamMap 5 run.

Tutorial

In this tutorial we will cover some of the basics within FlamMap 5. As mentioned before, this is not an all-inclusive tutorial. It is highly recommended that you complete the tutorial provided with the FlamMap 5 program to learn all the functionality within the program. All of the exercises will use the landscape file lf_notreat.lcp (C:\arcfuels\outputs if you have competed the ArcFuels10 Tutorial exercises or C:\arcfuels\exercise_outputs\3_Landscape). Each exercise will build upon the last one, so it is recommended to do them all in order.

Loading and critiquing a LCP file—

1) Open FlamMap5 (**ArcFuels10 toolbar→Wildfire Models→FlamMap**, fig. 4-9).

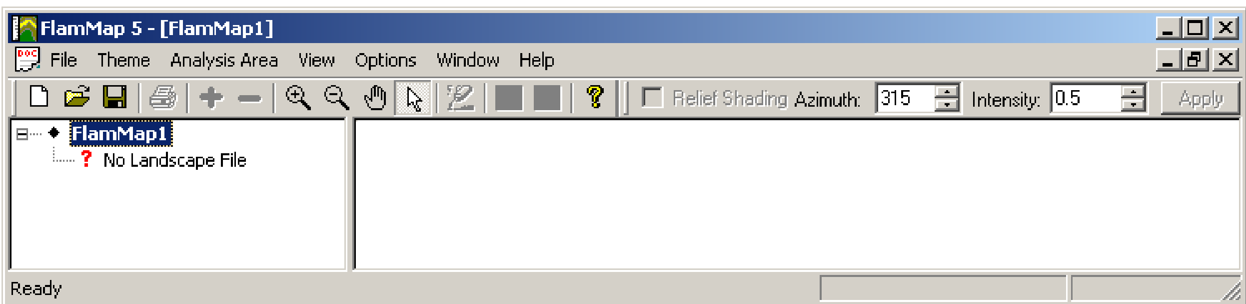


Figure 4-9—New FlamMap run window.

2) Double-click **? No Landscape File** in the tree pane and navigate to the lf_notreatment.lcp file (C:\arcfuels\outputs if you have competed the ArcFuels10 Tutorial exercises or C:\arcfuels\exercise_outputs\Tutorial).

    a) Notice there are now more sections in the tree pane (fig. 4-10). The Themes section includes all the layers within the loaded LCP file. FlamMap 5 automatically expands this section and has the fuel model layer displayed. The layer shown in the display pane is the active theme selected, which is indicated by the landscape icon to the left of the name; the non-active themes have a magnifying glass to the left. To change the active theme, click on the magnifying glass or name of the theme to display.

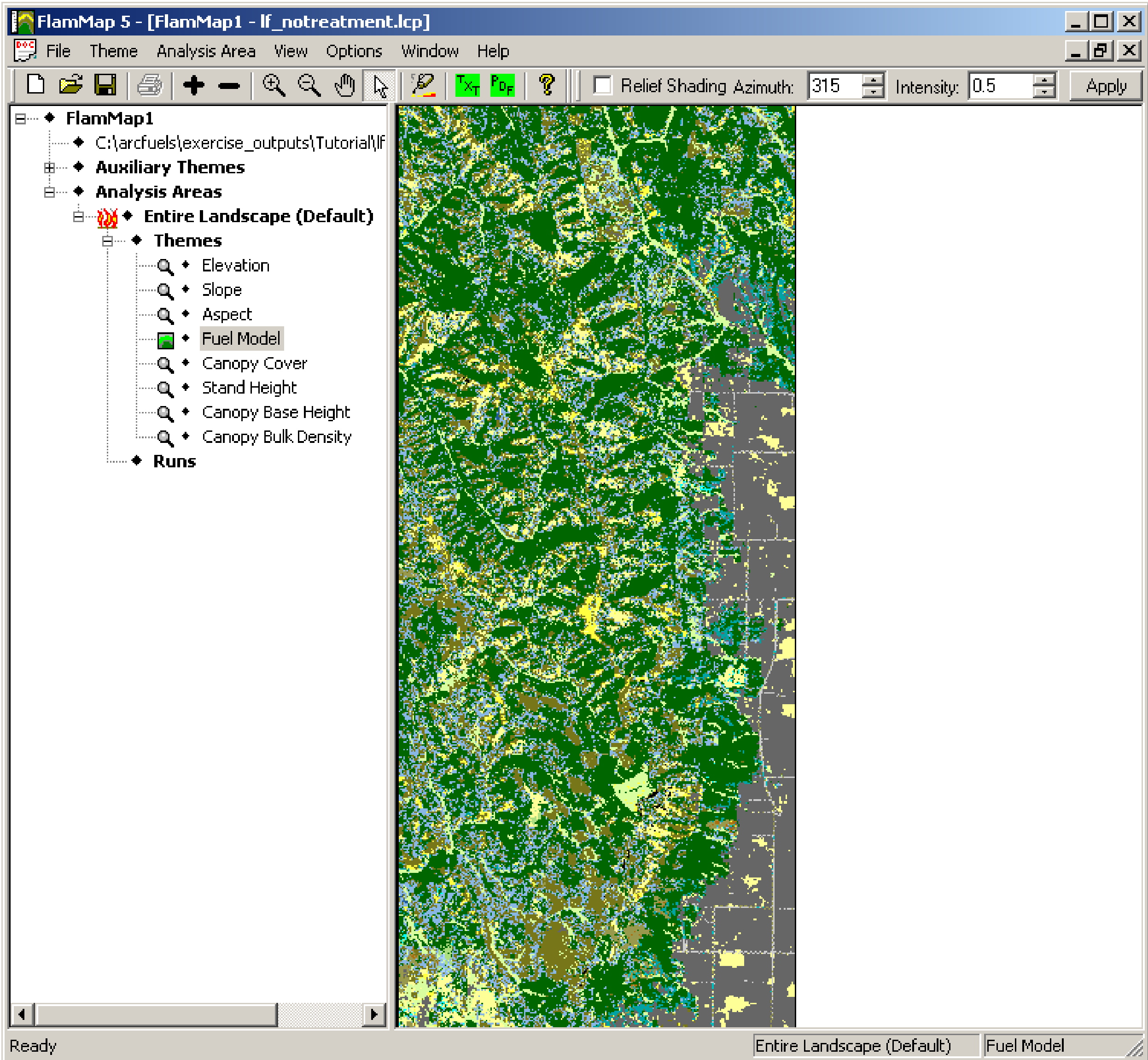


Figure 4-10—No treatment alternative LCP loaded with the fuel model theme displayed.

3) To create a text file critique of the LCP, click the green **TXT** button on the FlamMap toolbar (fig. 4-10). The text file includes information about the extent and resolution of the LCP, the themes present with their units and ranges, a distribution of each theme, and fuel model specific distributions of the remaining themes (fig. 4-11).

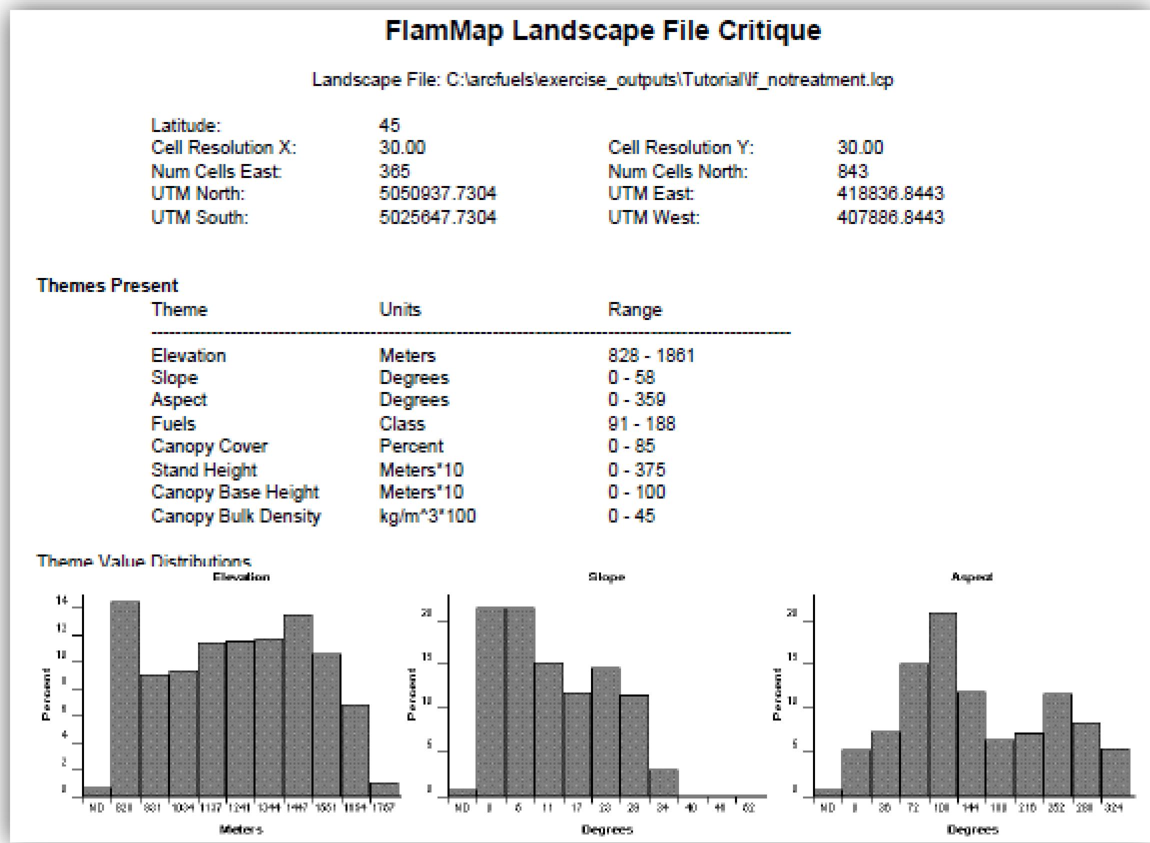
```
FlamMap Landscape File Critique
Landscape File: C:\arcfuels\exercise_outputs\Tutorial\lf_notreatment.lcp
  Latitude: 45
  Cell Resolution X: 30.00  Cell Resolution Y: 30.00
  Num Cells East: 365 Num Cells North: 843
  UTM North: 5050937.730421
  UTM South: 5025647.730421
  UTM East: 418836.844335
  UTM West: 407886.844335

Themes present
  Theme                Units      Range
  --------------------------------------------------------
  Elevation            Meters    828 - 1861
  Slope               Degrees    0 - 58
  Aspect              Degrees    0 - 359
  Fuel                  Class    91 - 188
  Canopy Cover        Percent    0 - 85
  Stand Height      Meters*10    0 - 375
  Base Height       Meters*10    0 - 100
  Bulk Density    kg/m^3*100     0 - 45


Elevation distribution
  Elevation                Frequency        Percent      Overall Percent
  ---------------------------------------------------------------------
      828 -    931        44487     14.56    14.46
      931 -   1034        27764      9.08     9.02
     1034 -   1137        28643      9.37     9.31
     1137 -   1241        35296     11.55    11.47
     1241 -   1344        35543     11.63    11.55
     1344 -   1447        35877     11.74    11.66
     1447 -   1551        41554     13.60    13.50
     1551 -   1654        32473     10.62    10.55
     1654 -   1757        20961      6.86     6.81
     1757 -   1861         3048      1.00     0.99
       No Data             2049      0.67     0.67
```

Figure 4-11—Text file LCP critique.

4) To create a PDF critique of the LCP, click the green **PDF** button on the FlamMap toolbar (fig. 4-10). The PDF includes information about the extent and resolution of the LCP, the themes present with their units and ranges, histograms of the themes comprising the LCP, maps of each theme with a legend, and histograms of the remaining themes for each fuel model (fig. 4-12).



FlamMap Landscape File Critique

Landscape File: C:\arcfuels\exercise_outputs\Tutorial\lf_notreatment.lcp

Latitude:	45		
Cell Resolution X:	30.00	Cell Resolution Y:	30.00
Num Cells East:	365	Num Cells North:	843
UTM North:	5050937.7304	UTM East:	418836.8443
UTM South:	5025647.7304	UTM West:	407886.8443

Themes Present

Theme	Units	Range
Elevation	Meters	828 - 1861
Slope	Degrees	0 - 58
Aspect	Degrees	0 - 359
Fuels	Class	91 - 188
Canopy Cover	Percent	0 - 85
Stand Height	Meters*10	0 - 375
Canopy Base Height	Meters*10	0 - 100
Canopy Bulk Density	kg/m^3*100	0 - 45

Theme Value Distributions

Figure 4-12— PDF LCP critique.

Changing the display and/or units of a theme and saving a theme—

Changing the display and/or units of a theme is useful for better understanding your data. This is most useful after completing a FlamMap 5 run. Saving the individual themes is necessary for further mapping and analysis in ArcGIS. As with changing the display and units, this is more important for fire modeled outputs than the input LCP file themes.

To change the display of the fuel model theme right-click on the Fuel Model theme, and then select **Properties** from the menu. The **Create/Modify Legend** window will open (fig. 4-13).

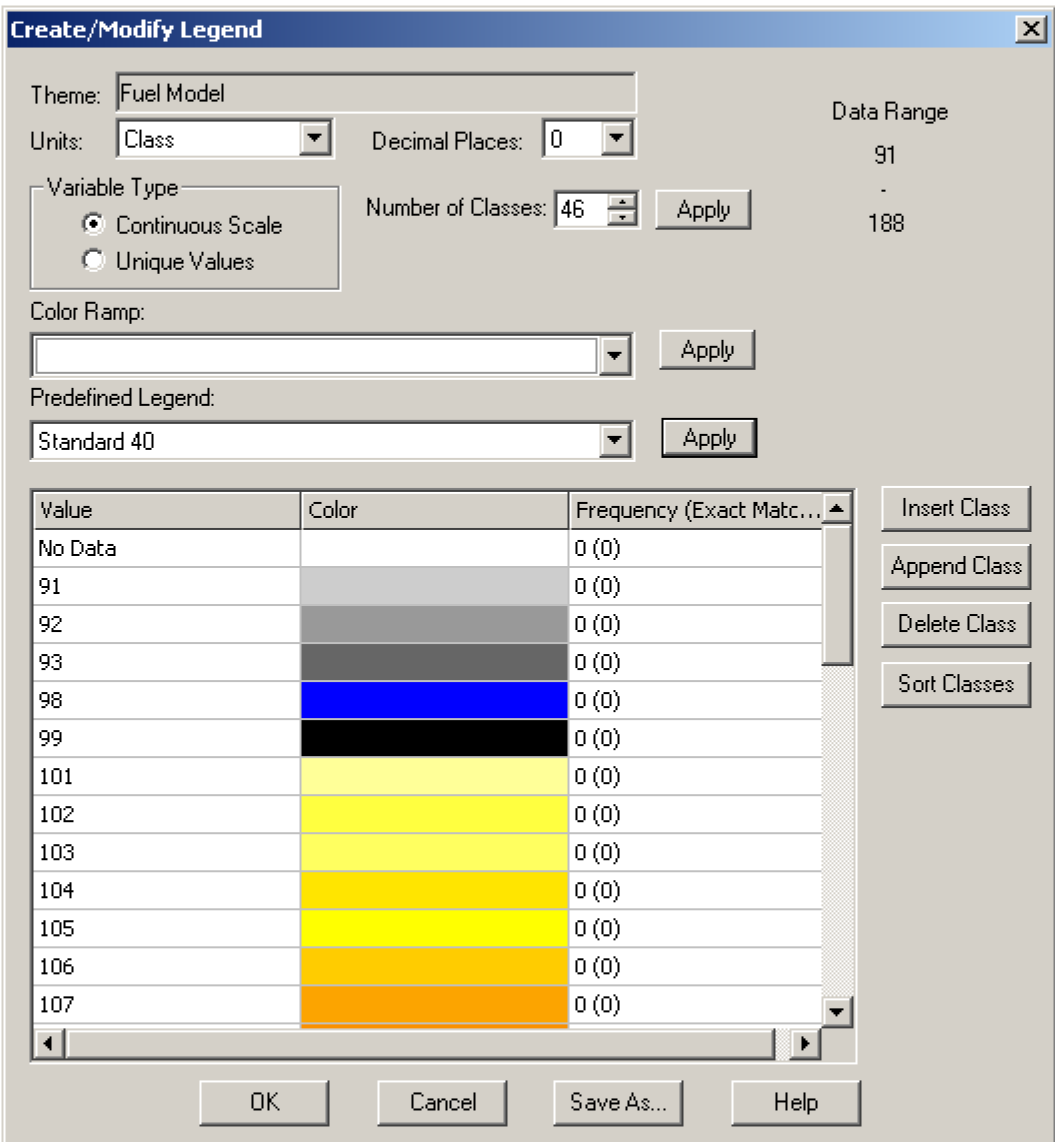


Figure 4-13—Create/Modify Legend window for the fuel model theme.

Theme: this is the theme you are changing.

Units: the available units are listed in the drop-down list. Because the theme is the fuel model, the only choice is Class.

Decimal Places: this is the number of decimal places used to categorize and display the data.

Number of Classes: you can choose the number of classes you would like your data to be displayed in.

Variable Type: this will depend on the data type; most will be Continuous Scale.

Color Ramp: all the options are shown in the drop-down list.

Predefined Legend: if there are common preexisting options, they will be in the drop-down list. It is also possible to create and save custom ones (see the FlamMap 5 help guide for more information).

You can also insert, append, delete, and sort classes using the **Insert Class**, **Append Class**, **Delete Class**, and **Sort Classes** buttons.

1) Change the display to the supplied fuel model legend.

   a) *Predefined Legend*: select Standard 40 from the drop-down list, then click **Apply**.

   b) Click **OK** to close the form and apply the changes.

*You must click **Apply** for the changes to take effect.*

If you change the display of a theme using a Predefined Legend the data saved will still be continuous, not categorical, however the units of the Predefined Legend will be maintained.

2) To change the units and number of classes of the canopy base height theme, right-click on the Canopy Base Height theme, and then select **Properties** from the menu. The **Create/Modify Legend** window will open (fig. 4-14).

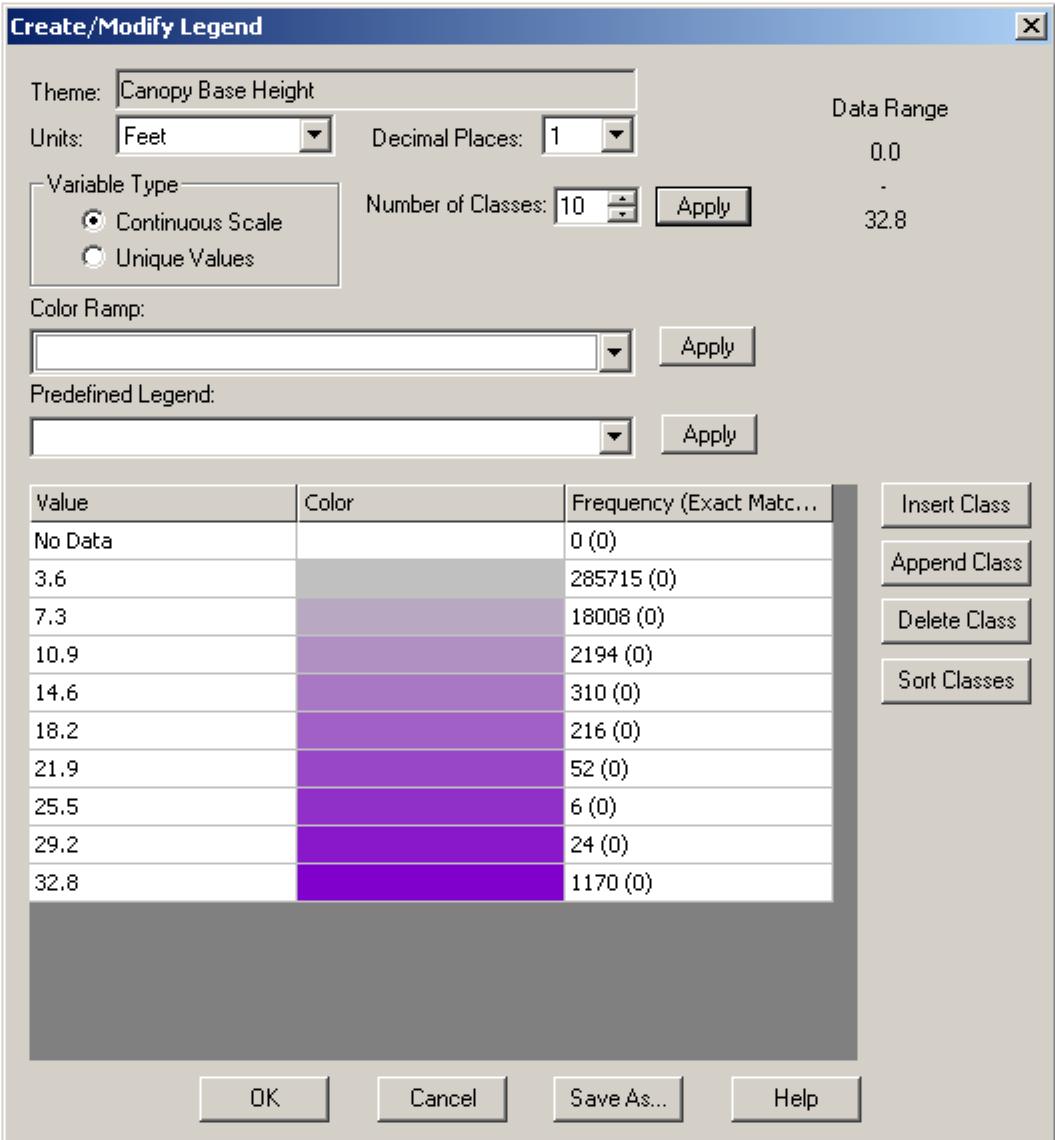


Figure 4-14—Changing the units and class number for canopy base height.

a) *Units*: select Feet from the drop-down list.

b) *Number of Classes*: type "10" in the text box. Then click **Apply** to apply the change.

c) Click **OK** to close the form and apply the changes.

3) To save the canopy base height theme with the new units, right-click on the Canopy Base Height theme, and then select **Save As** from the new menu.

a) Navigate to the outputs folder in the ArcFuels directory, and save the file as an ASCII file named "cbh_ft" (fig. 4-15). File type options include: ASCII, BMP, JPEG, GIF, TIFF, PNG). The default is an ASCII file that can be easily converted to a grid using ArcFuels10.

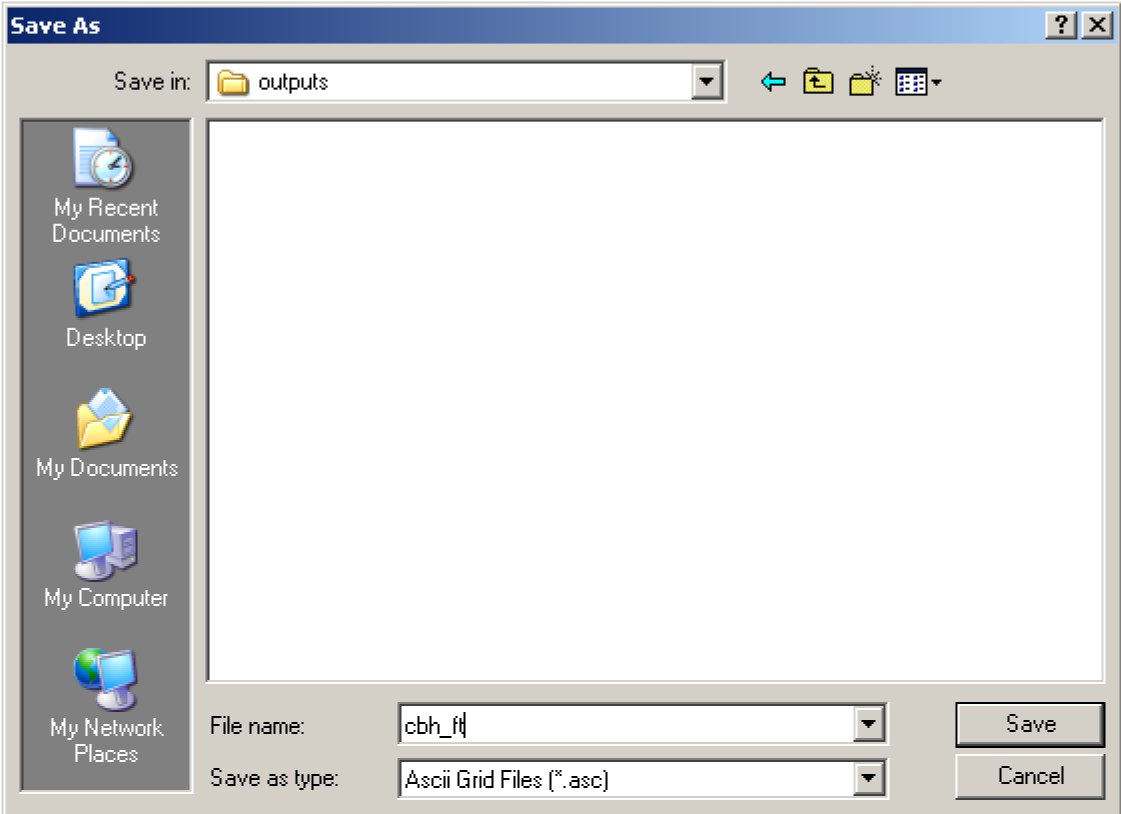


Figure 4-15—Saving a theme for further use in ArcMap.

It is highly recommended to save your individual theme outputs after completing runs in FlamMap5. You can also save your FlamMap session but it does not always reopen. Any time changes are made to input file paths or file names FlamMap cannot reopen old runs.

Creating a FMS file in FlamMap5—

To create a FMS using FlamMap5, the live and dead fuel moisture content tables from Scott and Burgan (2005) will be used to set the values (table 4-4). The FMS file assigns initial live and dead fuel moisture values by fuel model. The moistures are the same for each fuel model regardless of the location on the landscape.

Table 4-4—Live and dead fuel moisture content (percent) adapted from Table 3 and Table 4 in Scott and Burgan (2005).

Parameter	Very Low	Low	Moderate	High
1-hr (%)	3	6	9	12
10-hr (%)	4	7	10	13
100-hr (%)	5	8	11	14
Woody (%)	30	60	90	120
Herbaceous (%)	60	90	120	150

1) To create a new run, double-click **Runs** in the tree pane. This will add a **New Run** theme to the **Runs** section in the tree pane. The FlamMap 5 **Runs** form consists of four tabs: **Inputs**, **Fire Behavior Outputs**, **Minimum Travel Time**, and **Treatment Optimization**. See the ***FlamMap run interface*** section above for more detail about each of the tabs.

2) Go to the **Inputs** tab, and click the red and yellow plus button to the right of *Fuel Moisture file (*.fms)* (fig. 4-16).

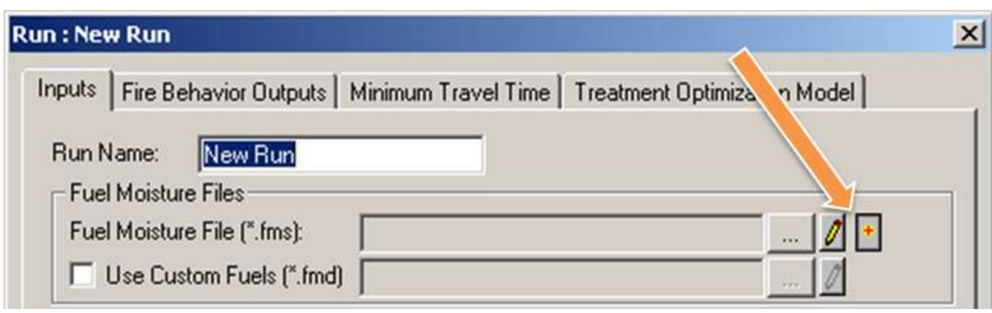


Figure 4-16—Location of the button to create a new FMS file.

3) The **Set Default Fuel Moistures** form will open (fig. 4-17). Set the fuel moisture values to the <u>Very Low</u> values from table 4-4.

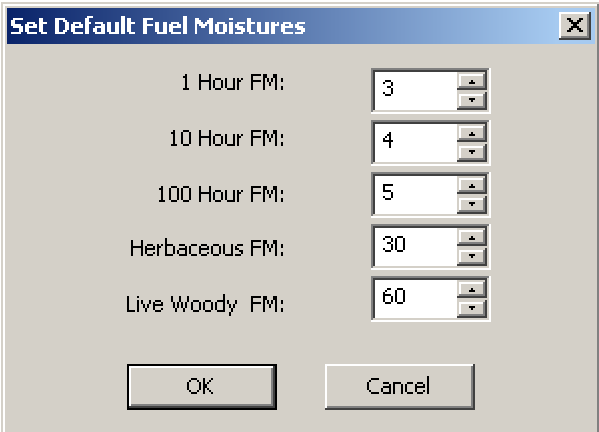


Figure 4-17—Set Default Fuel Moistures form set for the Very Low fuel moisture scenario.

a) Click **OK** to create the FMS file (fig. 4-18). The created FMS file will be specific to the loaded LCP, only including entries for the fuel models present.

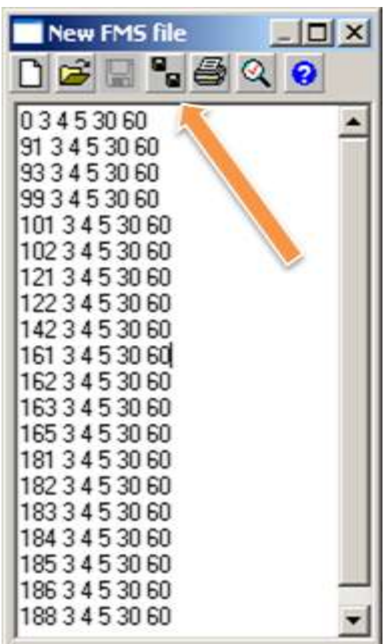


Figure 4-17—FMS file and arrow indicating where the “Save As” button is located.

b) Click the “Save As” or double disk button to save and load the new FMS file, and save the file as “lf_notreatment_very_dry” in the outputs folder of the ArcFuels directory.

c) Close the FMS file.

Dead fuel moisture conditioning in FlamMap5—

Dead fuel moisture conditioning results in more realistic fire behavior outputs because fuel moistures are calculated based on weather, topography, and shading for each pixel in the landscape. This creates geographic variation across the landscape. The FMS file is used to define the initial fuel moistures (FMS) as a starting point. Fuel moisture conditioning only affects dead fuels, it does not affect the live herbaceous or live woody fuel moistures; those remain unchanged across the landscape and are the same as defined in the FMS for each fuel model. Fuel moisture conditioning uses WND and WTR files where all the WTR information is used, and only the cloud cover is used from the WND file. Cloud cover along with canopy cover (from the LCP) is used to calculate shading.

If FFP is used to create the WND file, the cloud cover percent is 0 if there was no rain, and 100 if there was rain. If there was no rain but clouds were present, try to include estimates of cloud cover.

1) With the previous run open, name the run "15:00 Conditioning" in the text box to the right of *Run Name* (fig. 4-18).

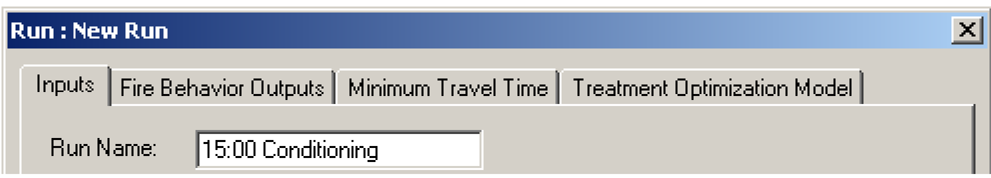


Figure 4-18—Run Name box.

2) Select the *Use Fuel Moisture Conditioning* option on the **Inputs** tab (fig. 4-19).

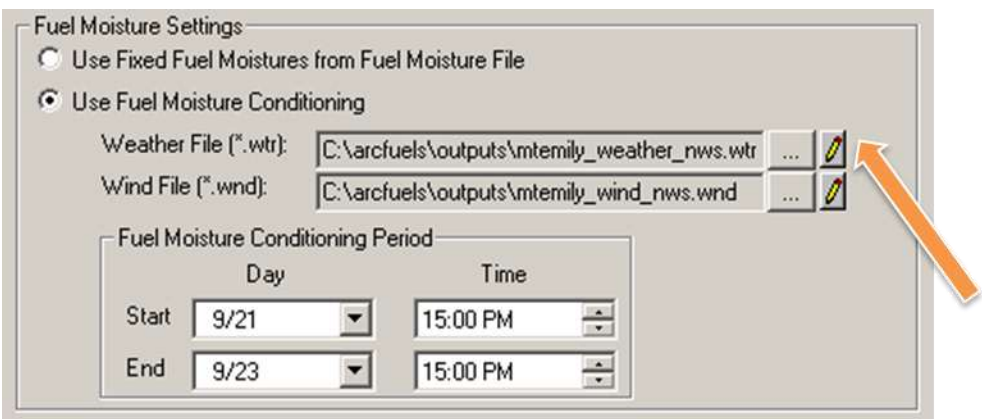


Figure 4-19—Fuel moisture setting portion of the Inputs tab of a FlamMap5 run.

a) Navigate to and add the WND and WTR files downloaded from the NWS webpage. These are located in the outputs folder if you completed the ***Downloading recent WND***

and WTR files from NWS exercise. Or, they are located in the optional download exercise outputs folder (C:\arcfuels\exercise_outputs\Supplemental\Weather).

3) Click the pencil icon to the right of the *Weather File* (see the orange arrow in fig. 4-18) to open the WTR file (fig. 4-20). The pencil icon is available for the FMS, WND, and WTR files; and is used to open, view, and edit these files. Looking at the file, there appears to be a slight cooling trend (lower temperatures and higher relative humidity) starting on September 24th. For the conditioning period, September 20 – 23 will be used to capture the hotter drier period.

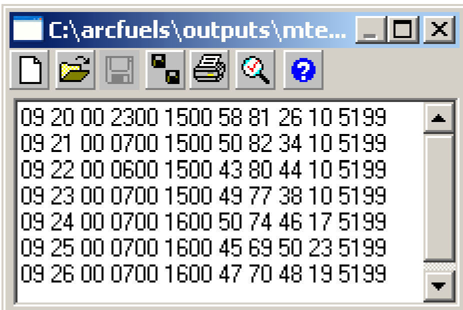


Figure 4-20—The WTR file.

   a) Close the WTR file to return to the **Inputs** tab.

4) Set the *Fuel Moisture Conditioning Period* (see fig. 4-19).

   a) *Start Day*: select 9/21 from the drop-down list. Do not worry if the year on the calendar is incorrect.

   b) *End Day*: select 9/23 from the drop-down list.

   c) *Start and End Time*: using the arrows, set the time to 15:00 PM. The FlamMap default is to set the time to the current hour. For example, if you are start a run at 9:25 in the morning, the modeled start and end times would both be automatically set to 09:00 AM.

   d) Click **Apply** to apply these settings.

5) Select the **Fire Behavior Outputs** tab (fig. 4-21).

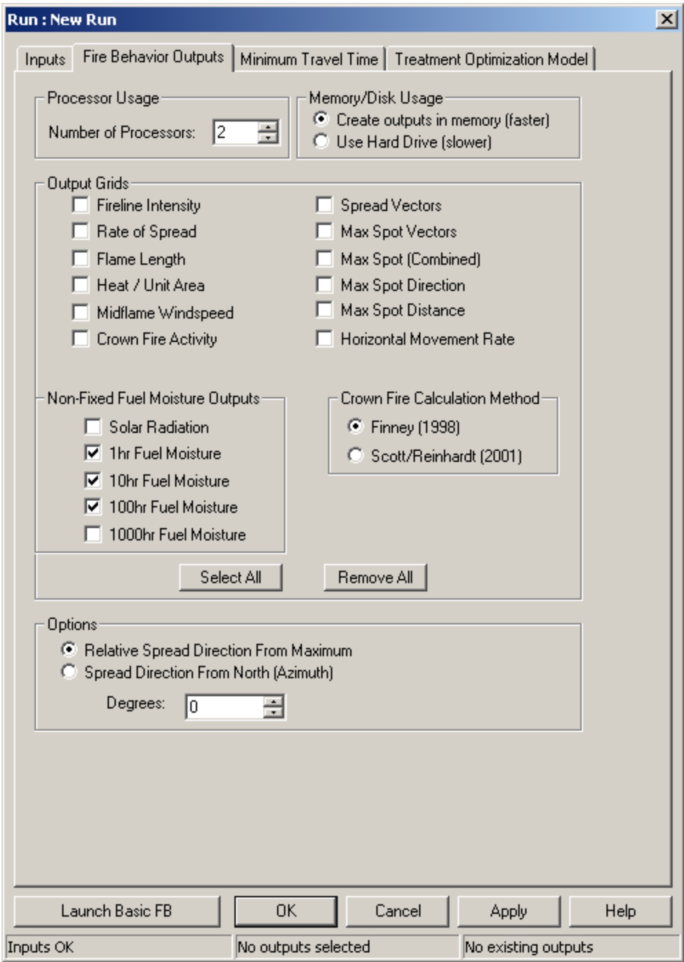


Figure 4-21—Fire Behavior Outputs tab setup to output fuel moistures.

a) Leave the defaults for the *Processor Usage* and *Memory/Disk Usage* sections.

b) Under the *Non-Fixed Fuel Moisture Outputs* section select: *1hr Fuel Moisture*, *10hr Fuel Moisture*, and *100hr Fuel Moisture*.

c) Click **Apply,** then click **Launch Basic FB**.

d) A FlamMap progress meter window will open once the run has started, and it will let you know when the execution is complete (fig. 4-22). Click **Ok** to close the meter.

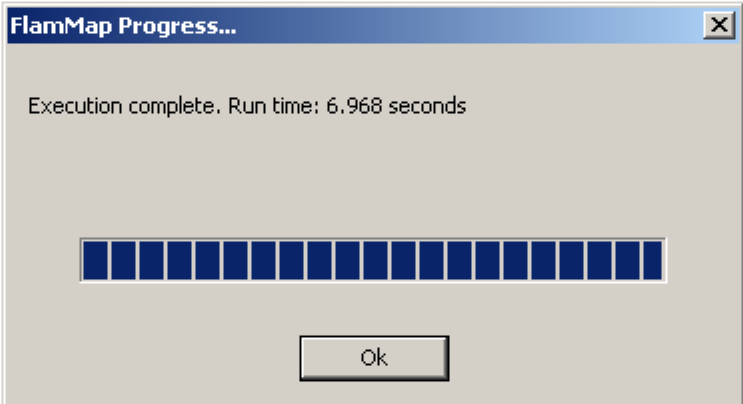


Figure 4-22— FlamMap progress meter window stating the execution is complete.

e) Click **OK** to close the **Run** form and return to the main FlamMap window.

*If **Launch Basic FB** is not available the FMS is most likely missing, return to the **Inputs** tab and load lf_notreatment_very_dry.fms.*

6) Under the Runs section, expand the 15:00 Conditioning run in the tree pane (fig. 4-23). Display the 1hr Fuel Moisture theme, and open the legend (double-click in the theme name). Notice the units are fractions rather than percentage, so a 0.03 fraction is 3% moisture. Remember the 1hr fuel moisture in the FMS file was 3% across the board, which is represented by orange in figure 4-23. Look at the map and think about why the fuel moistures changed where they did. Look at different themes from the LCP if that helps. Is it possible to have fuel moisture of 0? Hint: take a look at the fuel model layer. Look at the 10-hr and 100-hr fuel moistures themes as well.

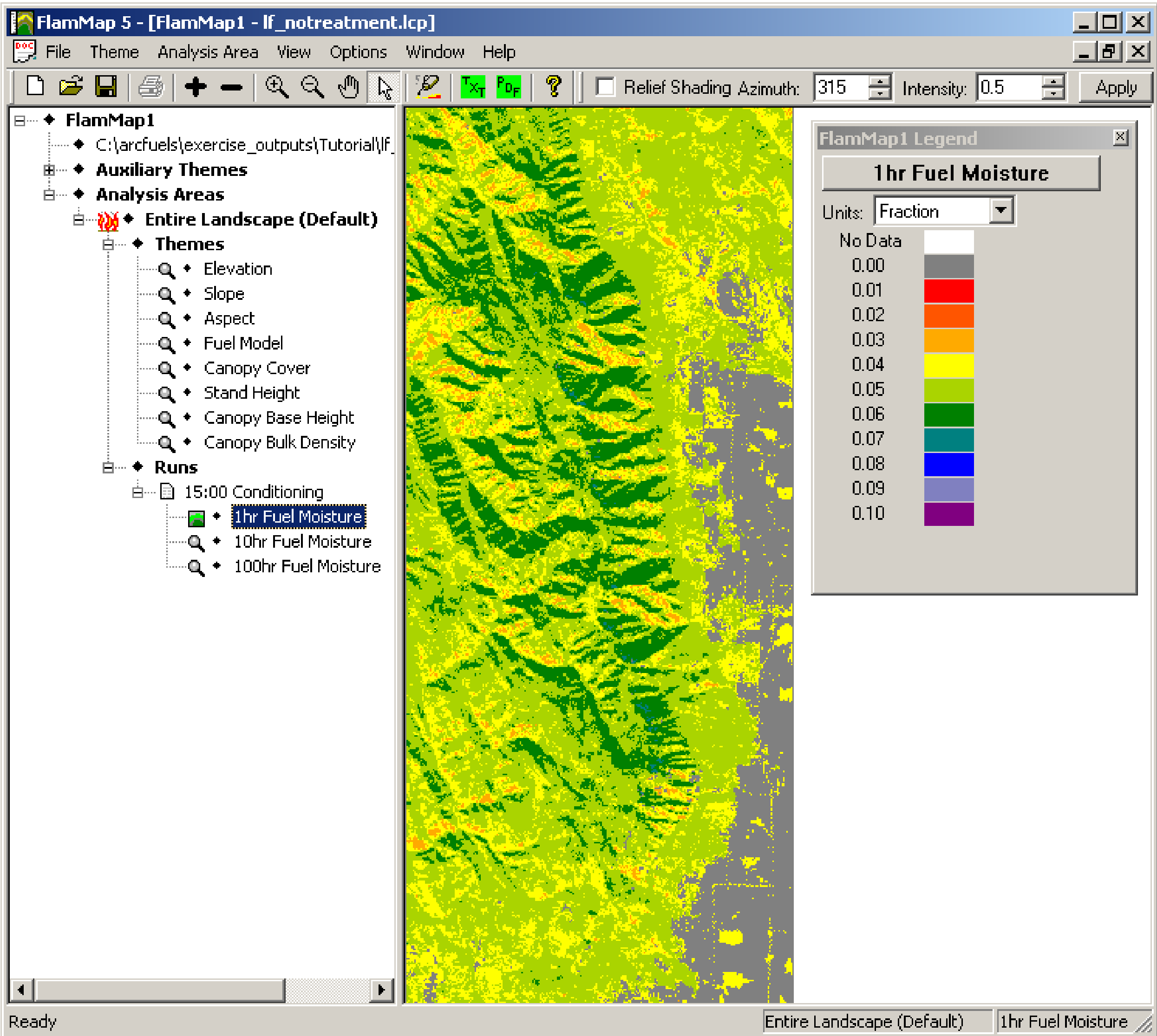


Figure 4-23—One-hour fuel moisture values after conditioning for 15:00 PM.

7) To better understand how the start and ending times affect fuel moisture, you are going to repeat the run for 06:00 AM. In FlamMap5 you can copy an existing run to use the prior settings as a starting point. You will be doing this for a run that will be named “06:00 Conditioning.” Right-click on the 15:00 Conditioning run, and select **Copy** from the menu. This will open a new **Run** form (fig. 4-24).

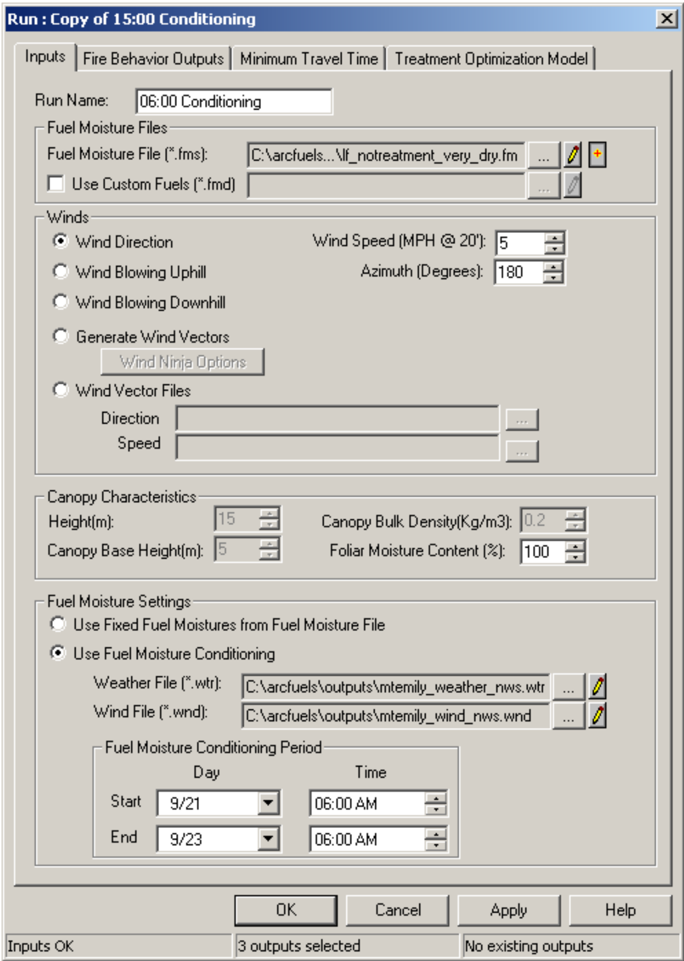


Figure 4-24—Inputs tab for the 06:00 fuel moisture conditioning run.

a) *Run Name*: type “06:00 Conditioning” in the text box.

b) *Fuel Moisture Conditioning Period Time*: type “06:00 AM” in the *Start* and *End* boxes.

c) Leave everything else the same and click **Apply**.

8) Select the **Fire Behavior Outputs** tab (see fig. 4-21). Ensure the *1hr Fuel Moisture*, *10hr Fuel Moisture*, and *100hr Fuel Moisture* options are selected, then click **Launch Basic FB.**

a) Click **Ok** to close the **FlamMap Progress....** window.

b) Click **OK** to close the **Run** form and return to the main FlamMap window.

9) Under the Runs section, expand the 06:00 Conditioning run in the tree pane (fig. 4-25). Display the 1hr Fuel Moisture theme, and open the legend if you closed it. All of the values are greater than 10%. Look at the 10-hr and 100-hr fuel moistures themes as well.

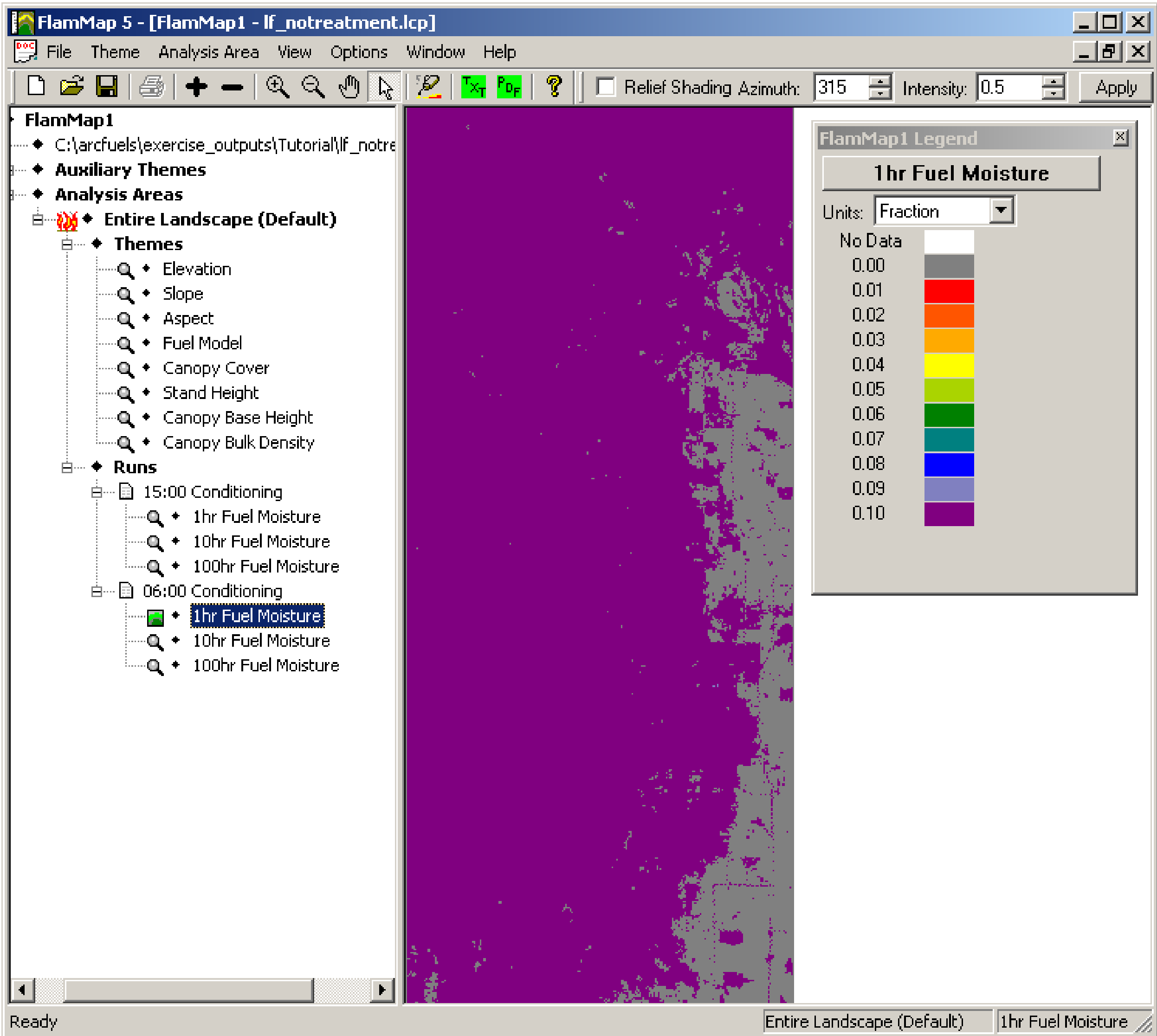


Figure 4-25—One-hour fuel moisture values after conditioning for 06:00 AM.

a) Close the legend.

Modeling basic fire behavior outputs with and without wind vectors—

This exercise will teach you how to model basic fire behavior outputs. Two runs will be completed: one with, and one without wind vectors.

FlamMap5 now incorporates the WindNinja (Forthofer et al. 2009) program. WindNinja is a program that computes spatially varying wind for wildland fire modeling. WindNinja needs elevation and dominant vegetation data, and initial wind speed and direction. Within FlamMap5 the LCP supplies the elevation data, and WindNinja uses the canopy and fuels information in the landscape file to infer the vegetation drag information required. The initial wind speed and direction are also inputs for FlamMap5 and are used by WindNinja. For more information about WindNinja, and to download it, visit the WindNinja website: http://www.firemodels.org/index.php/research-systems/windninja.

You will build upon the last exercise, and will use the 15:00 Conditioning run as a starting point. If you have not completed the last exercise, do so now.

1) Right-click on the 15:00 Conditioning run, and select **Copy** from the menu. This will open a new **Run** form (fig. 4-26).

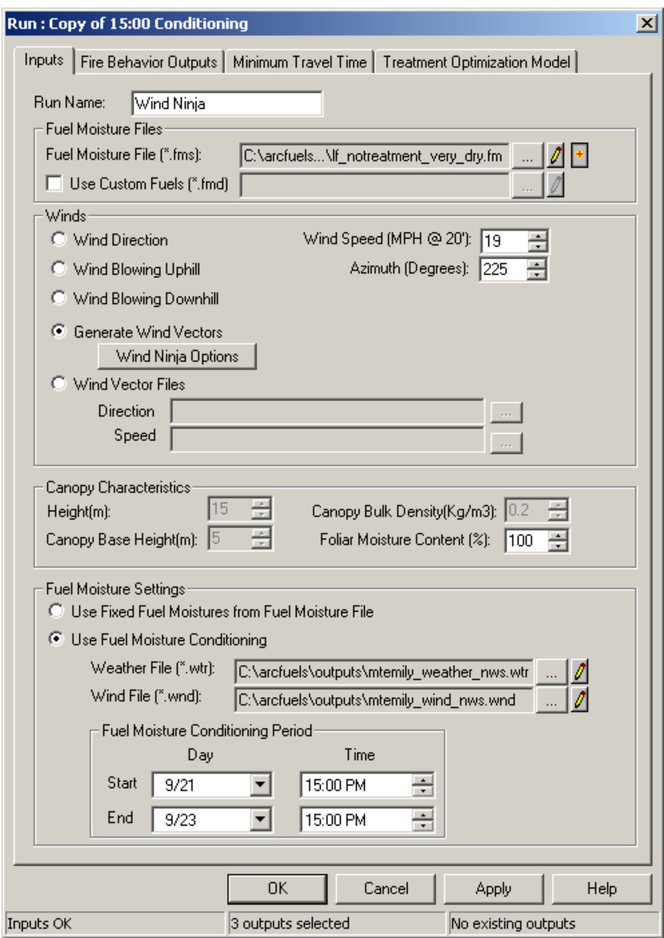


Figure 4-26—Inputs tab for the WindNinja run.

a) *Run Name*: type “WindNinja” in the text box.

b) *Fuel Moisture File*: verify lf_notreatment_very_dry.fms is still loaded.

c) *Use Custom Fuels (*fmd)*: do not select this option.

d) *Wind Speed (MPH @20’)*: type “19” in the text box. This is the maximum wind observed during the wind analysis exercises in the ***3. Fire Climate/Weather Data & FireFamily Plus*** section.

e) *Azimuth (Degrees)*: type “225” in the text box. This is the dominant wind direction observed during the WRCC wind analysis exercise in the ***3. Fire Climate/Weather Data & FireFamily Plus*** section.

f) Select the *Generate Wind Vectors* option, then click **Wind Ninja Options** (fig. 4-27).

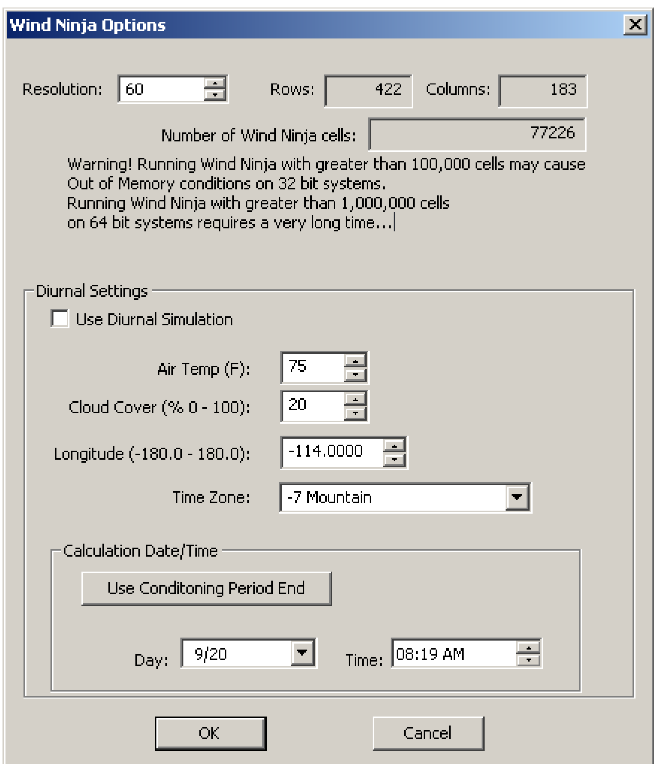


Figure 4-27—Wind Ninja Options window.

i) *Resolution*: type “60” in the text box. Choose a resolution that is a multiple of the input pixel size (30m for most data). The finer the resolution the longer the run will take.

ii) *Diurnal Settings*: do not select this option. For detailed information about the *Diurnal Settings* in WindNinja refer to the program’s tutorials.

iii) Click **OK** to save the settings and return to the **Run** form.

g) *Foliar Moisture Content (%)*: leave the default 100% value.

h) Select the *Use Fuel Moisture Conditioning* option, verify the WND and WTR files are loaded, and the *Fuel Moisture Conditioning Period* is from 9/21 15:00 PM to 9/23 15:00 PM.

i) Click **Apply**.

2) Select the **Fire Behavior Outputs** tab (fig. 4-28).

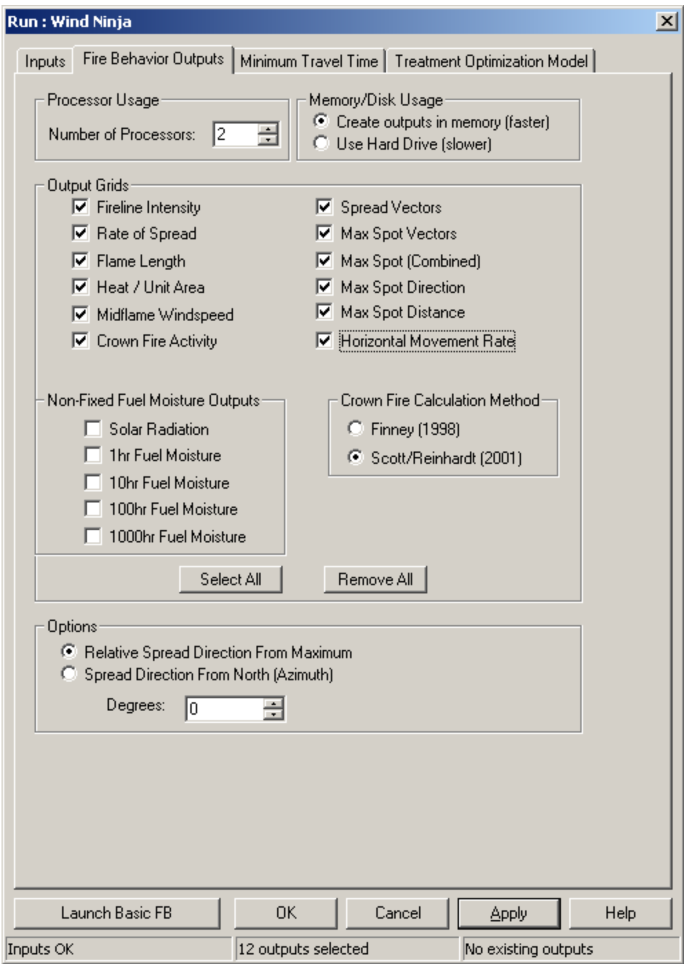


Figure 4-28—Fire Behavior Outputs tab setup to output rate of spread, flame length, crown fire activity and spread vectors.

a) Leave the defaults for the *Processor Usage* and *Memory/Disk Usage* sections.

b) *Output Grids*: select all of the fire behavior outputs.

c) *Non-Fixed Fuel Moisture Outputs*: do not select any of these options.

d) *Crown Fire Calculations Method*: select the *Scott/Reinhardt (2001)* option.

e) Click **Apply,** then click **Launch Basic FB**.

f) Click **Ok** to close the **FlamMap Progress....** window after the execution is complete.

g) Click **OK** to close the **Run** form and return to the main FlamMap window.

3) Under the Runs section, expand the WindNinja run in the tree pane (fig. 4-29). Display the Rate of Spread theme, and open the legend (double-click on the theme name). Turn off the Wind Vectors and Max Spot Vectors themes (double-click on the theme name). The Spread Vectors are the purple arrows and blue green Xs. The length of the arrow indicates the spread speed; longer arrows indicate faster fire spread. Look at the other themes.

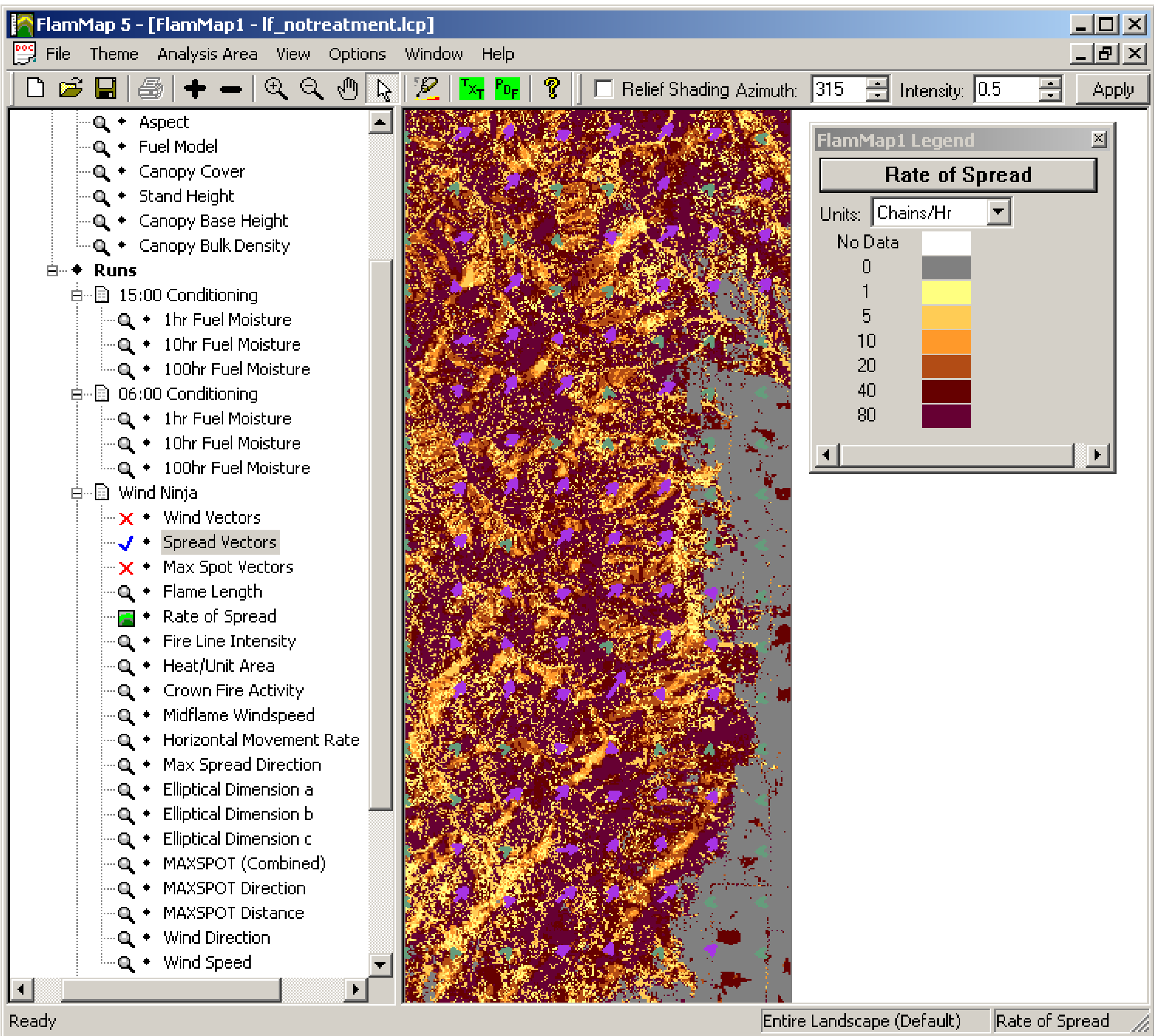


Figure 4-29—Rate of spread with wind vectors from a basic fire behavior run using WindNinja.

*If the Wind Vectors are hard to see you can change the display properties by right-clicking on the theme and selecting **Properties** from the menu.*

10) To better understand how WindNinja affect wind flow patterns and fire behavior, a second run will be completed without wind vectors. Right-click on the Wind Ninja run, and select **Copy** from the menu. This will open a new **Run** form (see fig. 4-26). Make the changes specified below.

   a) *Run Name*: type "Set Winds" in the text box.

   b) Select the *Wind Direction* option.

   c) Click **Apply**.

11) Select the **Fire Behavior Outputs** tab (see fig. 4-28). Verify the same options are selected.

   a) Click **Apply,** then click **Launch Basic FB**.

   b) Click **Ok** to close the **FlamMap Progress....** window after the execution is complete.

   c) Click **OK** to close the **Run** form and return to the main FlamMap window.

12) Under the Runs section, expand the Set Winds run in the tree pane (fig. 4-30). Display the Rate of Spread theme, and open the legend (double-click on the theme name). Turn off the Max Spot Vectors theme (double-click on the theme name).

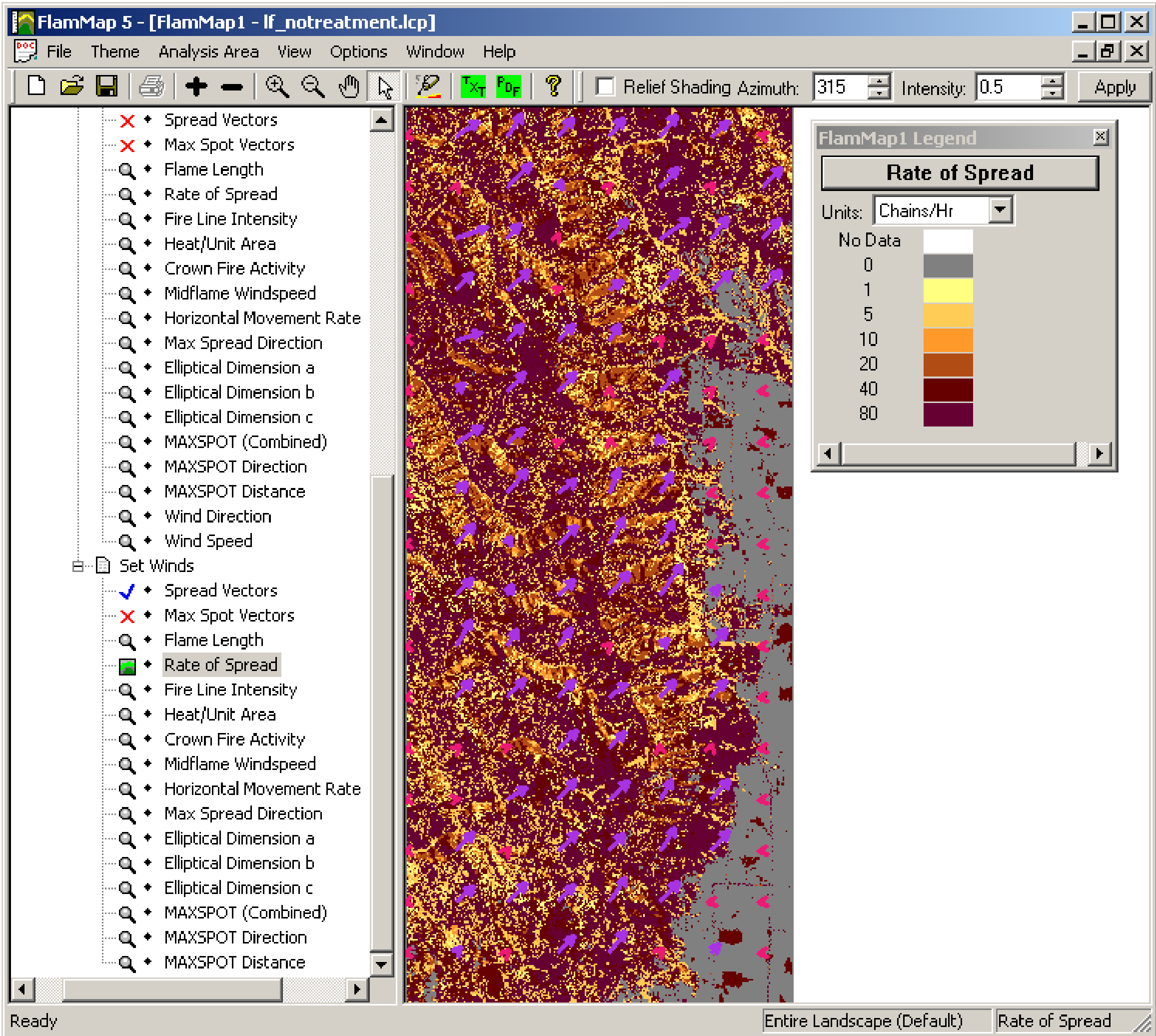


Figure 4-30—Rate of spread with wind vectors from a basic fire behavior run using set winds.

a) Close the legend.

13) Turn off any vector themes from the run (i.e. Spread Vectors), and display the Fuel Model theme.

How is rate of spread affected? What about the spread vectors? The changes are not drastic, but the rate of spread is faster with the set windspeeds. To see the differences it is helpful to click the Rate of Spread theme under each run to toggle back and forth between the two outputs. Similarly, the Spread Vectors can be turned on and off, or both can be turned on.

The default modeled fire behavior units are metric (i.e. m, kW/m). If you would like to save the themes in English units (i.e. ft, mph), you must change the units before you save the theme.

Running minimum travel time (MTT) for a single ignition—

This exercise will teach you how to model minimum travel time (MTT) outputs for a single ignition. This exercise will demonstrate how to create an ignition in FlamMap 5, and how to use it for the MTT run.

You will build upon the last exercise, and will use the Wind Ninja run as a starting point. If you have not completed the last exercise, do so now.

1) Select the drip torch button on the FlamMap5 menu bar. The drip torch button is a toggle button, and remains activated until you select another button such as the arrow button on the toolbar. This is similar to the pan tool in ArcMap. It is activated when you mouse over the map and see a drip torch.

    a) A left-click of the mouse followed by a right-click of the mouse will put down a point ignition. This can be repeated to have multiple point ignitions.

    b) Two successive left-clicks with the mouse followed by a right-click will create a single line.

    c) Three or more left-clicks followed by a right-click will create an area ignition, connecting the points with a line, and then connecting the first and last click location.

2) Play around a bit making various types of ignitions (fig. 4-30).

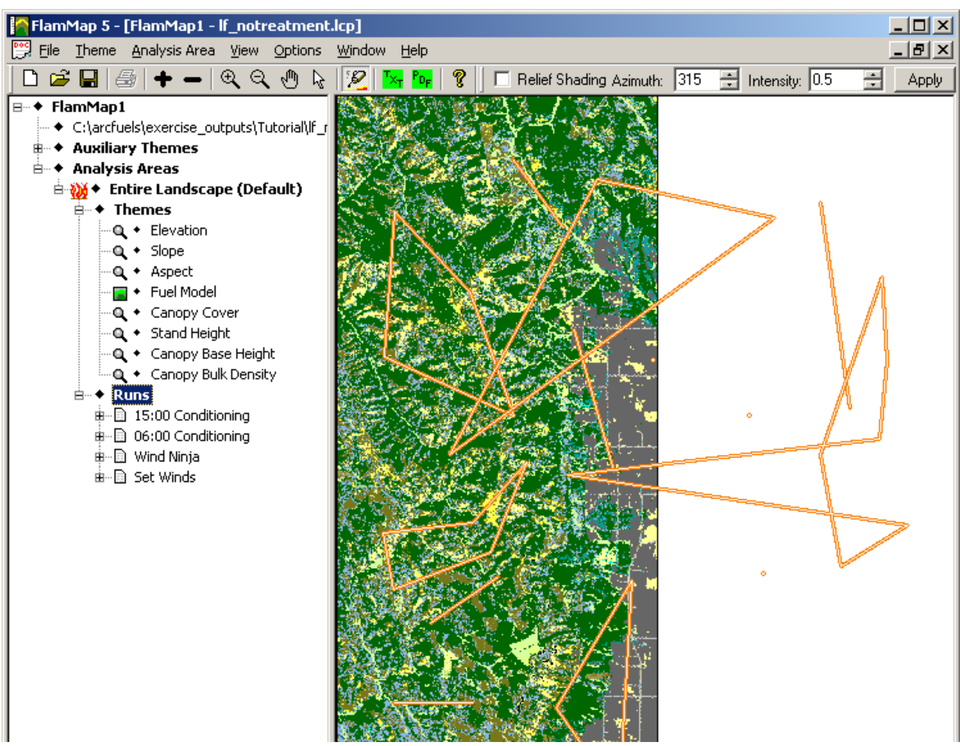


Figure 4-30—Ignitions created in FlamMap5 with the drip torch tool.

3) Clear all the ignitions you just created (**FlamMap5 menu→Options→Shape→Clear**).

4) Create a single line ignition in the southwest quadrant of the landscape. After you are finished, turn off the drip torch tool by selecting the arrow tool.

5) Right-click on the Wind Ninja run, and select **Copy** from the menu. This will open a new **Run** form (fig. 4-31).

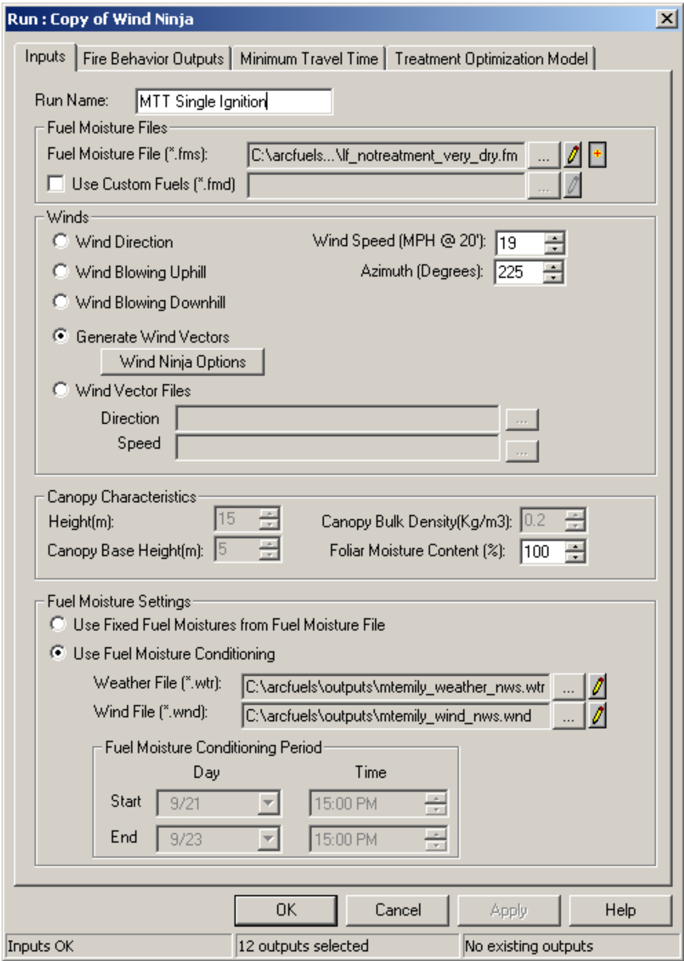


Figure 4-31—MTT Single Ignition inputs.

a) *Run Name*: type "MTT Single Run" in the text box.

b) Verify the remaining settings were kept.

6) Select the **Fire Behavior Outputs** tab (see fig. 4-32).

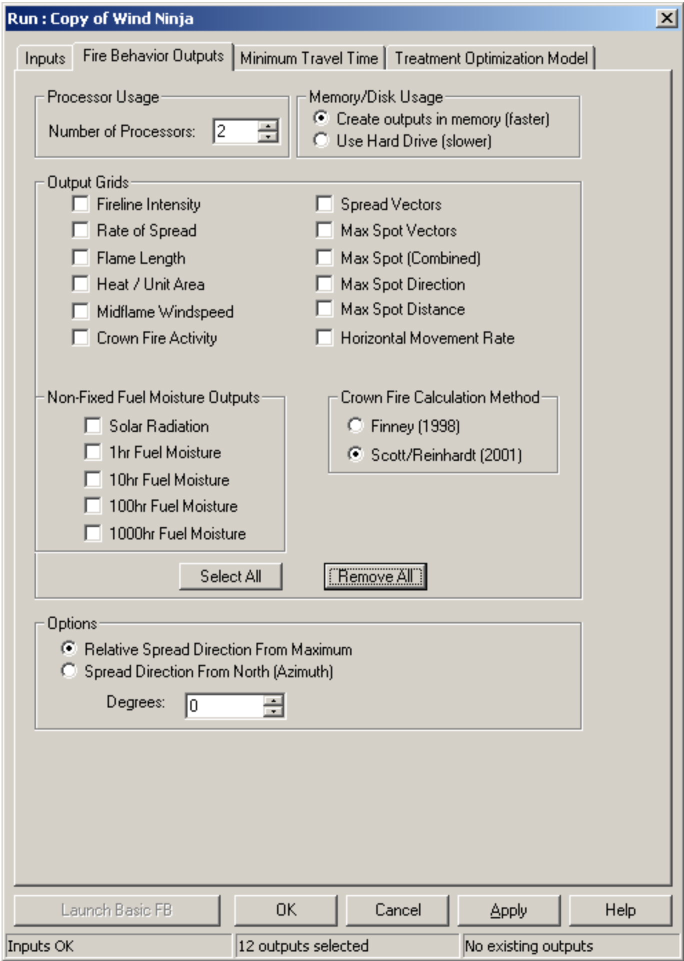


Figure 4-32—MTT single ignition fire behavior outputs options.

a) Click **Remove All**.

b) Verify the remaining settings were kept.

c) Click **Apply**.

7) Select the **Minimum Travel Time** tab (fig. 4-33).

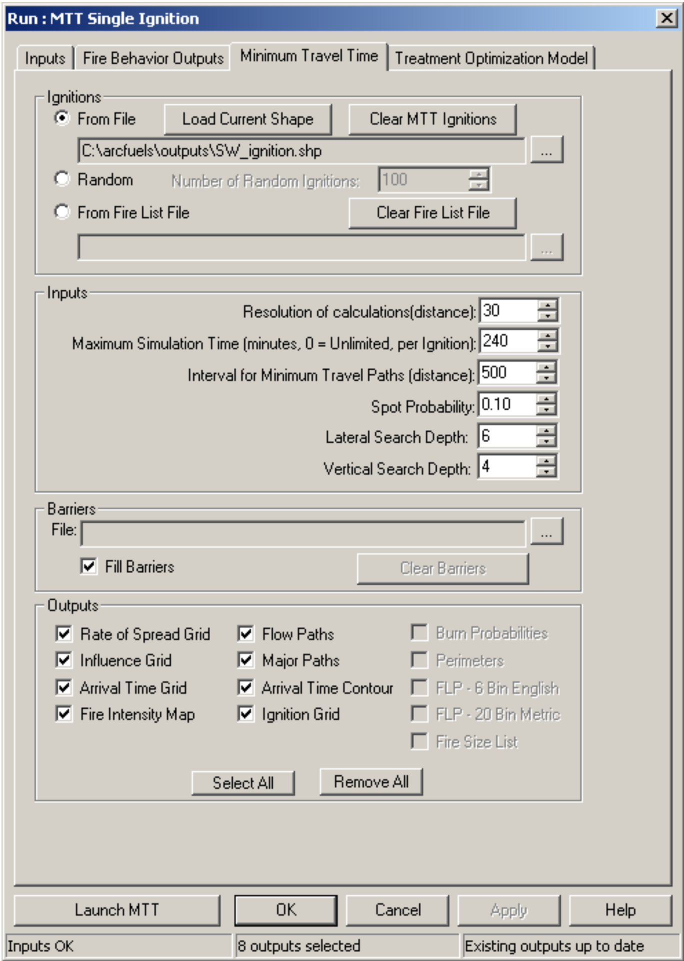


Figure 4-33—MTT single ignition MTT options.

a) Under *Ignitions*, select the *From File* option, and then click **Load Current Shape**. You will be prompted to save the file; save it as “SW_ignition” in the outputs folder of the ArcFuels directory (fig. 4-44).

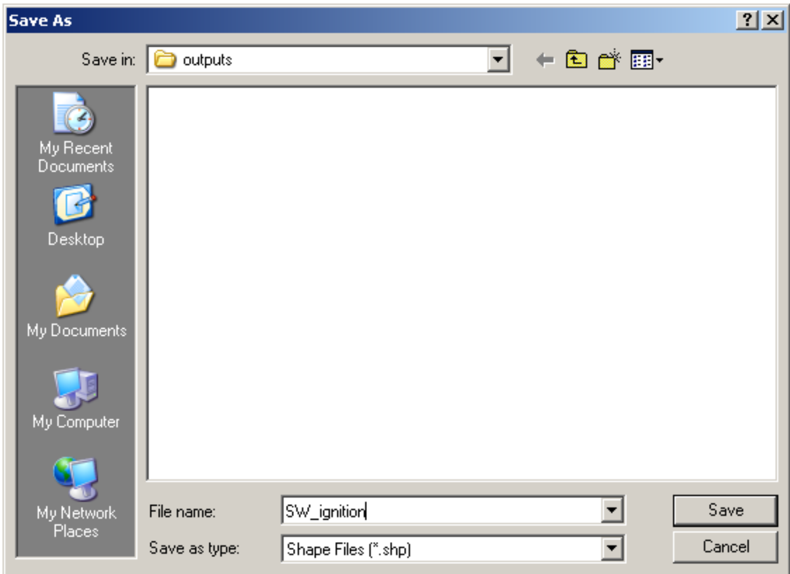


Figure 4-44—Saving the ignition.

b) *Resolution of calculations (distance)*: type "30" in the text box. This defines the resolution that calculations are completed, and the output resolution. The finer the resolution, the longer a run will take. The value should be a multiple of the input data (.i.e. 30, 60, 90, etc.).

c) *Maximum Simulation Time (minutes, 0 = Unlimited, per Ignition)*: type "240" in the text box to run a 4 hr simulation.

d) *Interval for Minimum Travel Paths (distance*): keep the default "500" value.

e) *Spot Probability*: keep the default "0.10" value.

f) *Lateral Search Depth*: keep the default "6" value.

g) *Vertical Search Depth*: keep the default "4" value.

h) Under *Outputs*, click **Select All** to select all of the available outputs.

i) Click **Apply**.

j) Click **Launch MTT**.

k) Click **Ok** to close the **FlamMap Progress....** window after the execution is complete.

l) Click **OK** to close the **Run** form and return to the main FlamMap window.

8) Under the Runs section, expand the MTT Single Ignition run in the tree pane. Zoom into the fire and display the MTT Major Flow Paths and Minimum Travel Time Ignition over the MTT Arrival Time (fig. 4-45).

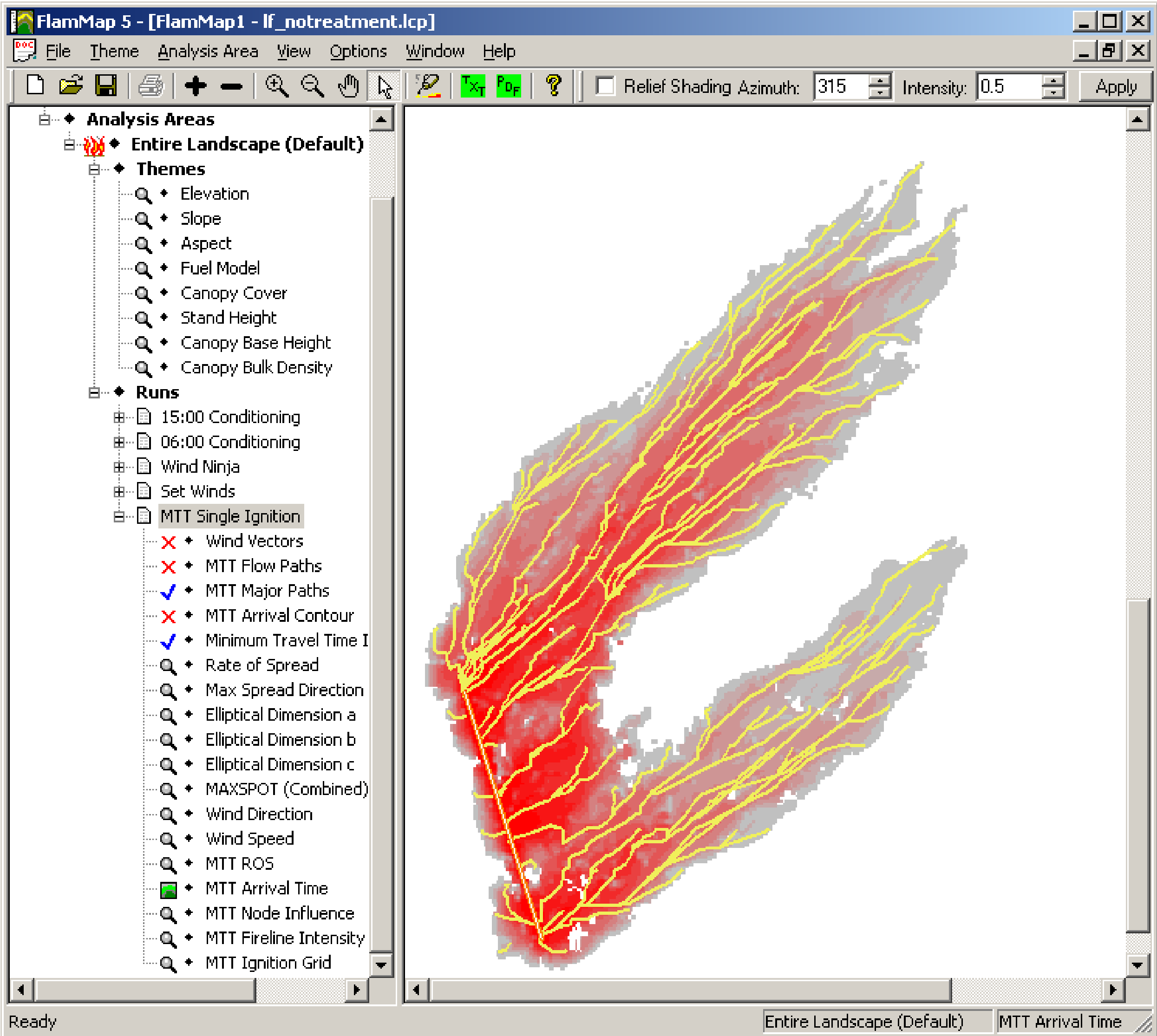


Figure 4-45—MTT fire arrival and major flow paths.

a) Turn on and off all the themes, and explore the outputs.

9) Return to a full screen view (**FlamMap5 menu→View→Full View**).

10) Clear the ignition you created (**FlamMap5 menu→Options→Shape→Clear**).

11) Turn off any vector themes from the run (i.e. Spread Vectors), and display the Fuel Model theme.

The MTT major flow paths are a good way to visualize fire spread. Longer lines indicate faster moving fire. The MTT major flow paths are valuable outputs for comparing the effectiveness of fuel treatments (fig. 4-46). The paths are a good way to visualize what the fuel treatments do to the forward progression of fire. Figure 4-46 shows that the treatments that are narrow (perpendicular) to the fire spread are virtually ineffective at slowing the fire, whereas wider treatments often stop the fire progression quickly.

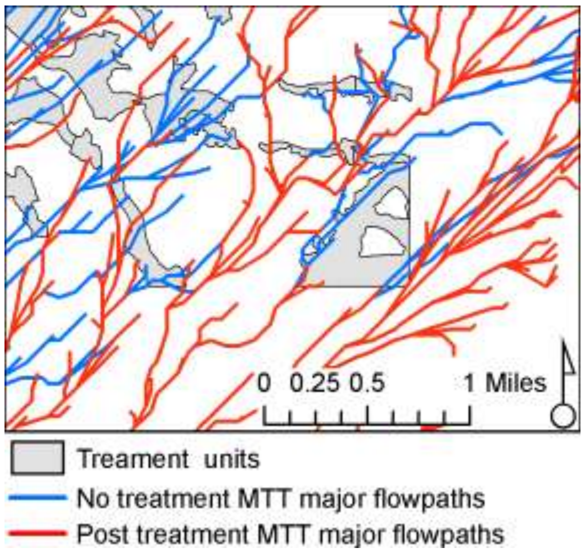


Figure 4-46—MTT fire Major Paths for the no treatment alternative (blue), and post-treatment alternative (red), with the treatment units in gray. This is one way to display how treatment units affect modeled fire spread. As the flow paths reach the treatment units post-treatment, they typically stop at the edge of the unit or find a different path through. Narrower treatment units are not as effective at stopping or slowing the forward progression of the modeled fire.

Running minimum travel time (MTT) for a multiple random ignitions—

In this exercise MTT will be used again. But this time, randomly placed ignitions will be used to create a burn probability map. You will build upon the last exercise, and use the MTT Single Ignition run as a starting point. If you have not completed the last exercise, please do so now.

1) Right-click on the MTT Single Ignition run, and select **Copy** from the menu. This will open a new **Run** form (fig. 4-47).

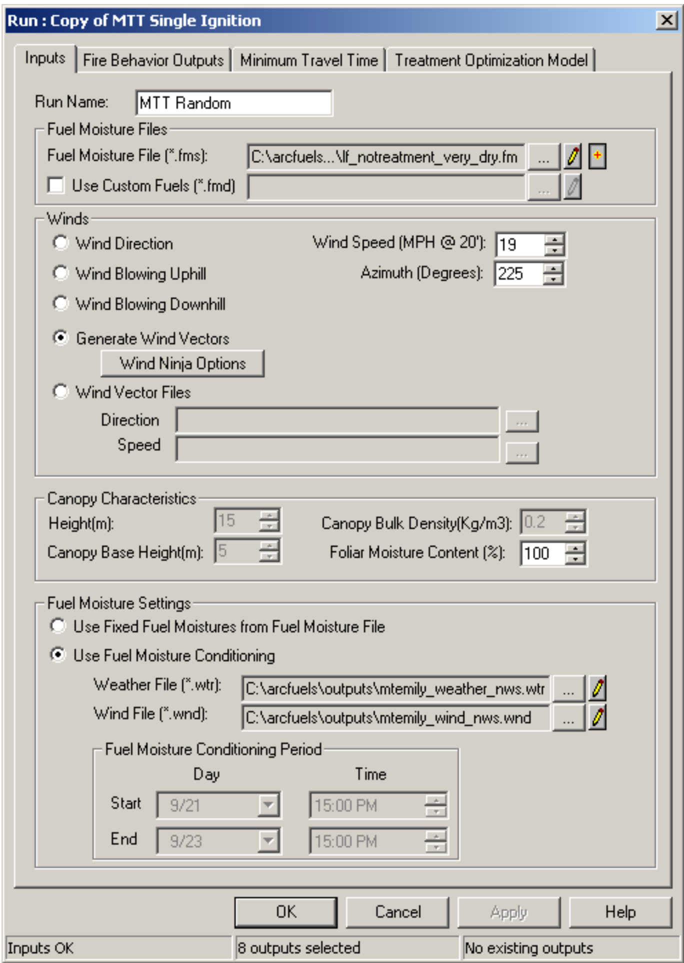


Figure 4-47—MTT Random inputs.

a) *Run Name*: type "MTT Random" in the text box.

b) Verify the remaining settings were kept.

2) Select the **Fire Behavior Outputs** tab (see fig. 4-48).

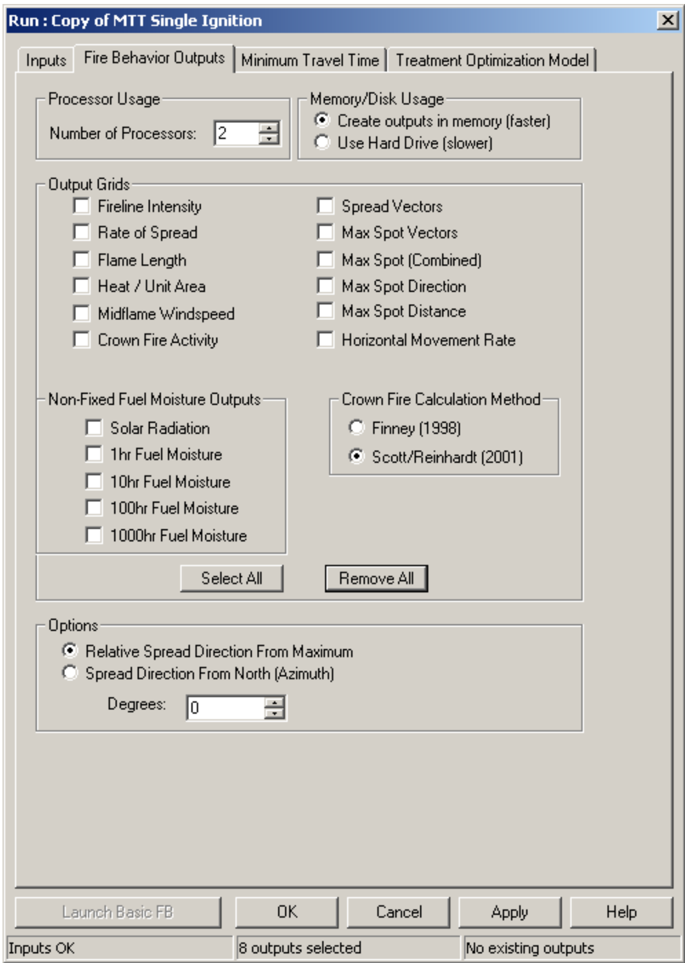


Figure 4-48—MTT random fire behavior outputs options.

a) Click **Remove All**.

b) Verify the remaining settings were kept and then click **Apply**.

3) Select the **Minimum Travel Time** tab (fig. 4-49).

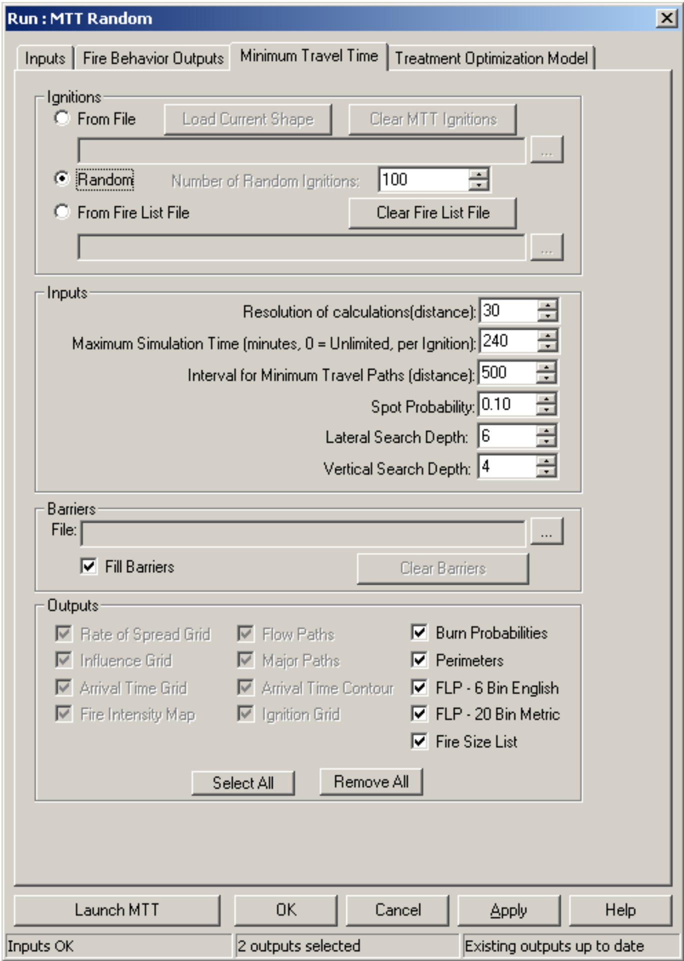


Figure 4-49—MTT random ignition MTT options.

a) Under *Ignitions*, click **Clear MTT Ignitions,** then select the **Random** option, and set the number of ignitions to be “100.”

b) *Resolution of calculations (distance)*: type “30” in the text box.

c) *Maximum Simulation Time (minutes, 0 = Unlimited, per Ignition)*: type “240” in the text box to run a 4 hour simulation.

d) *Interval for Minimum Travel Paths (distance*): keep the default “500” value.

e) *Spot Probability*: keep the default “0.10” value.

f) *Lateral Search Depth*: keep the default “6” value.

g) *Vertical Search Depth*: keep the default “4” value.

h) Under *Outputs*, click **Select All** to select all of the available outputs.

i) Click **Apply**.

j) Click **Launch MTT**.

k) Click **Ok** to close the **FlamMap Progress....** window after the execution is complete.

l) Click **OK** to close the **Run** form and return to the main FlamMap window.

4) Under the Runs section, expand the MTT Random run in the tree pane (fig. 4-50). Show the MTT Perimeters over the Burn Probability theme. Change the properties of each to make the map more informative and easier to see. In figure 4-50 the MTT Perimeters were changed to black 1 pt lines, and the Burn Probability color ramp was changed to the rainbow option.

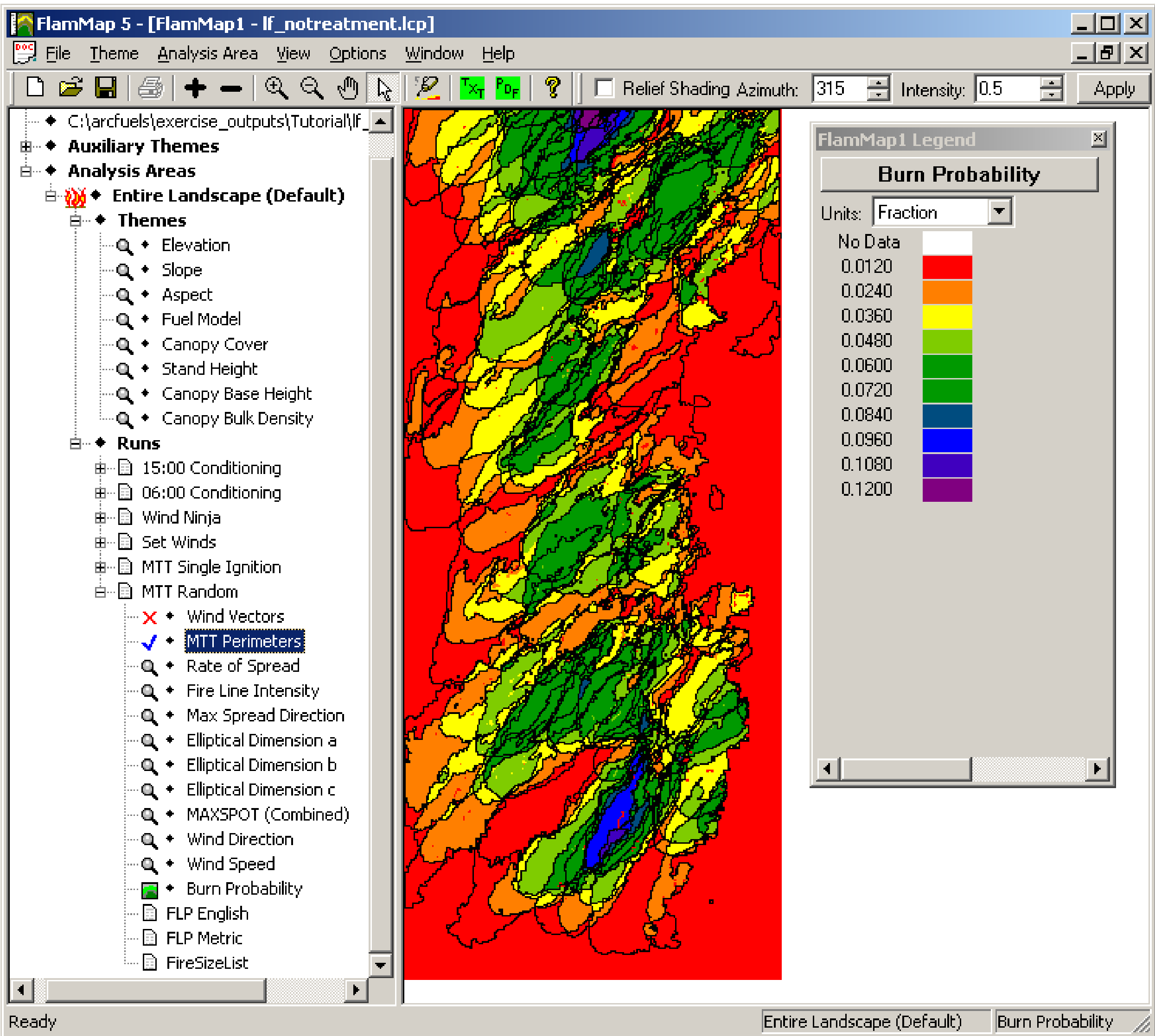
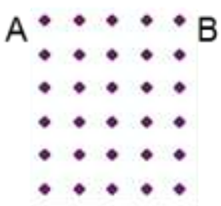


Figure 4-50—MTT Perimeters

In addition to the MTT Perimeters output new to FlamMap5 are the FLP English, FLP Metric, and Fire Size List.

A FLP file is a gridded text file that contains information about burn probability and fire intensity for each point (fig. 4-51a). The spacing of the points is user defined within FlamMap5. A metric FLP file contains 20 fire intensity levels (FILs). A FIL is a measure of fire behavior and is based flame length. Each of the 20 FIL is representative of a 0.5 m increment, so FIL1 is 0-0.5 m, FIL2 is 0.5-1 m, and FIL20 is >9.5 m. An English FLP contains 6 FILs. The FLP file is also referred to as the conditional burn probability, because it includes information on the intensity of any point on the landscape, given a fire occurs. The sum value of the FIL categories is 1, where the value within each FIL is the probability of the fire burning at that intensity (flame length, fig. 4-51b).



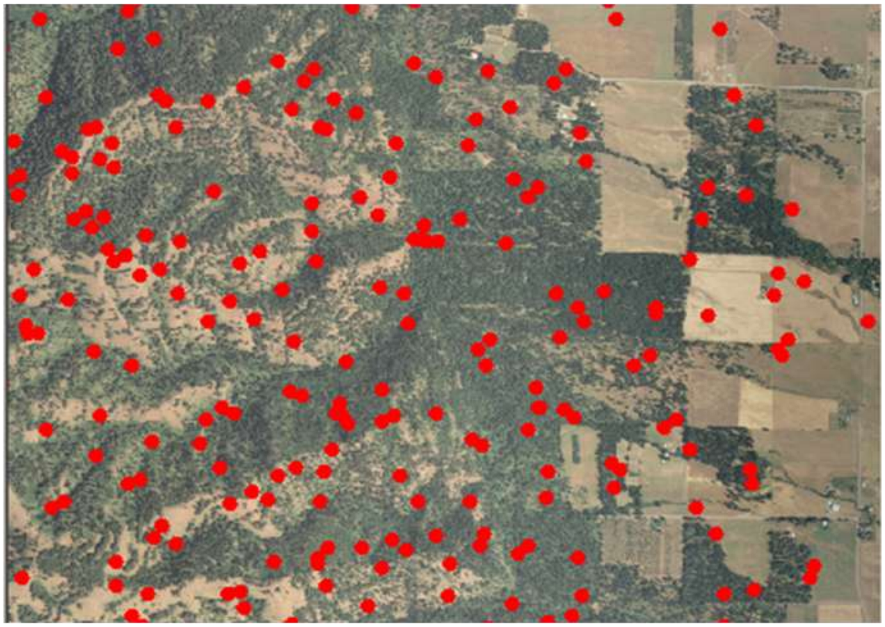
B

FID	Shape *	XPos	YPos	PBurn	FIL1	FIL2	FIL20
0	Point	407931.844335	5050892.73042	0.0052	0.307692	0.692308	0
1	Point	408021.844335	5050892.73042	0.0056	0	0.928571	0
2	Point	408111.844335	5050892.73042	0.007	0	0.942857	0
3	Point	408201.844335	5050892.73042	0.0088	0	0	0
4	Point	408291.844335	5050892.73042	0.0094	0	0.978723	0
5	Point	408381.844335	5050892.73042	0.0108	0.092593	0.759259	0

Figure 4-51—Metric FLP converted to a shapefile (A) and attributes table (B).

A Fire Size List (FSL) is a point text, with information about the location of each ignition and the final fire size (in acres), for all randomly ignited fires in FlamMap5 (fig. 4-52). The FIRE_NUM attribute in the FSL shapefile directly correlates the FIRE_NUM attribute in the fire perimeters file.

A



B

ExpectedLossFSL

	FID	Shape *	FIRE_NUM	XStart	YStart	FireSize
▸	0	Point	0	415072.436703	5039990.81434	1789.38891
	1	Point	1	411445.20774	5027425.63618	7876.113381
	2	Point	2	416185.902485	5045012.82065	2119.645253
	3	Point	3	412570.517519	5036571.56837	5460.238196
	4	Point	4	413267.834372	5035550.48166	4895.800084
	5	Point	5	415538.984214	5032469.26812	2920.266689

Figure 4-52—Fire Size List converted to a shapefile (A) and attributes table (B) overlaid on aerial imagery of the Mt. Emily project area.

For more information about how to convert and use the FLP and Fire Size List outputs for wildfire risk assessments, refer to the ***ArcFuels10 Tutorial***.

Running the Treatment Optimization Model (TOM) in FlamMap 5—

The Treatment Optimization Model (TOM) is an automated approach to the landscape design of treatments, which relies on the Minimum Travel Time calculations to identify major fire travel routes and to impede them with fuel treatments. Given a proportion of the landscape that can be treated, TOM finds the specific treatment areas that reduce fire growth rates the most for the given treatment amount. TOM is however a computationally intensive process, and runs can take days. With the right set of parameters however, it is possible to see how the program works with runs less than an hour.

TOM requires two landscapes: the ideal, and the untreated. The ideal has every possible treatment implemented on the landscape. The user inputs the two landscapes, and the proportion of the landscape that can be treated. The primary output is an ASCII file with suggested treatment locations. TOM does not apply treatments to the suggested area; this must be completed in another program such as ArcGIS. ArcFuels10 has specific tools created for using the TOM treatment grid to apply treatments to build the treated LCP for further modeling in FlamMap.

You will be using the no treatment LCP created in the ***ArcFuels10 Tutorial Exercise 17,*** and the TOM alternative LCP as the ideal treatment LCP created in ***ArcFuels10 Tutorial Exercise 18***. The TOM alternative LCP treated about 66% of the landscape treating all available lands.

1) In FlamMap5, open a new run window (**FlamMap5 menu→File→New**, fig. 4-53).

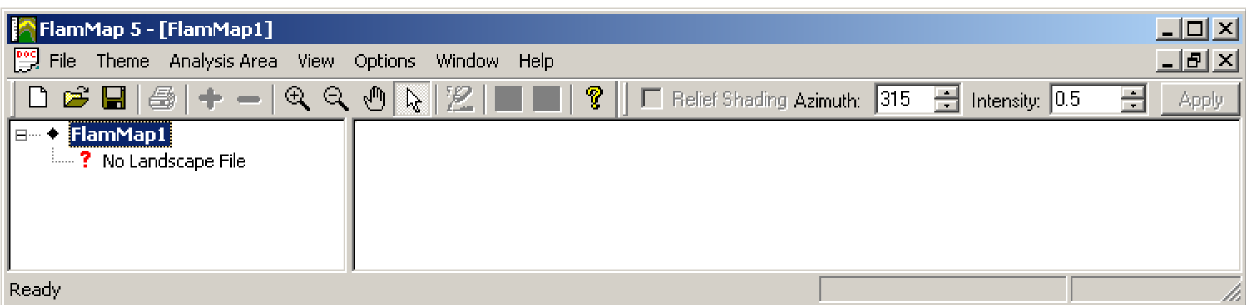


Figure 4-53—New FlamMap run window.

a) Double-click **? No Landscape File** in the tree pane, and navigate to the fvs_alt0_notreatment.lcp file (C:\arcfuels\outputs if you have competed the ArcFuels10 Tutorial exercises or C:\arcfuels\exercise_outputs\Tutorial, fig. 4-54).

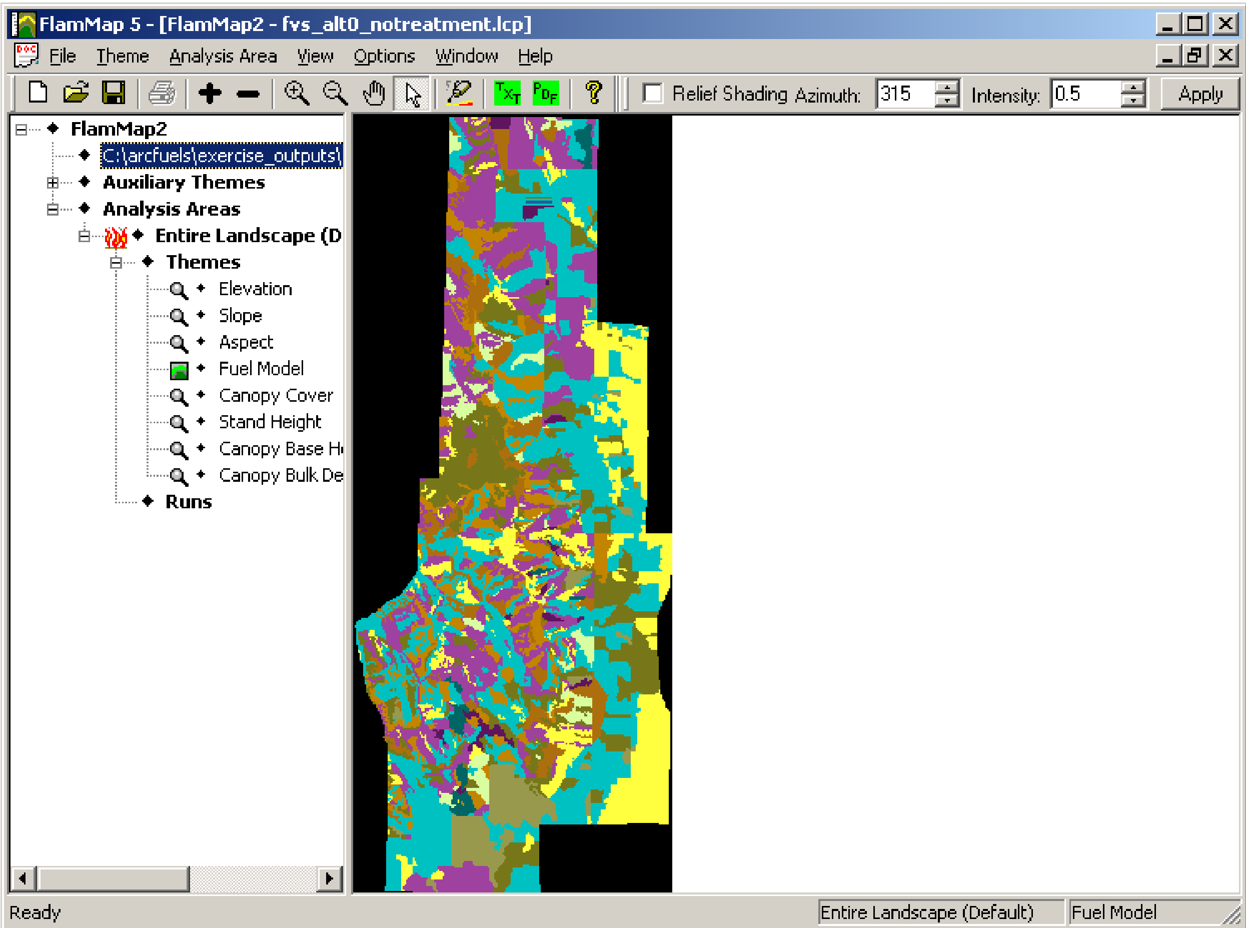


Figure 4-54—No treatment landscape from FVS data.

2) To create a new run, double-click **Runs** in the tree pane, and go to the **Input** tab of the **Run** form (fig. 4-55).

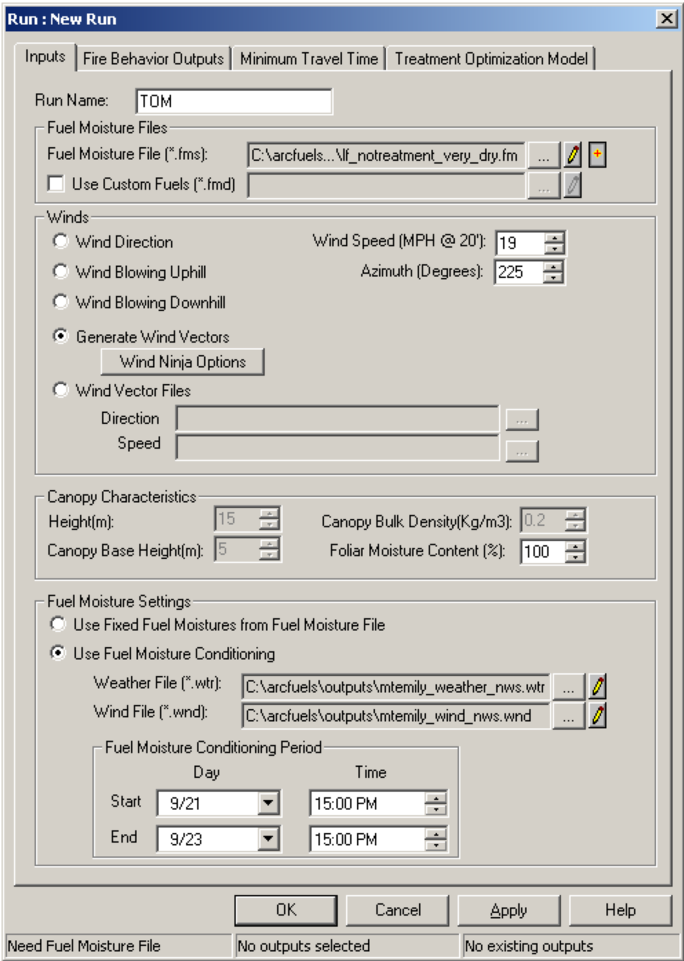


Figure 4-56—FlamMap 5 Inputs form for the TOM run.

a) *Run Name*: type "TOM" in the text box.

b) *Fuel Moisture File*: navigate to, and add the lf_notreatment_very_dry.fms file from the outputs folder of the ArcFuels directory.

c) *Use Custom Fuels (*fmd)*: do not select this option.

d) *Wind Speed (MPH @20')*: type "19" in the text box.

e) *Azimuth (Degrees)*: type "225" in the text box.

f) Select the *Generate Wind Vectors* option and then click **Wind Ninja Options** (fig. 4-58).

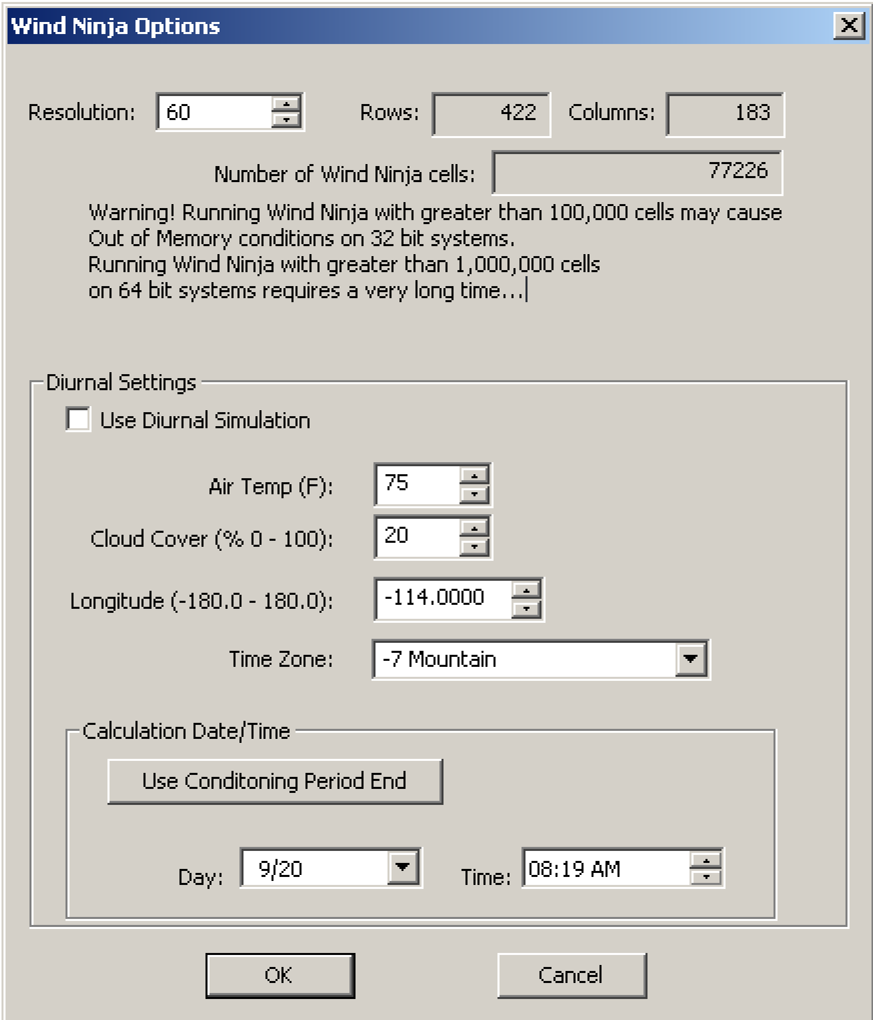


Figure 4-58—Wind Ninja Options window.

i) *Resolution*: type "60" in the text box. Choose a resolution that is a multiple of the input pixel size (30m for most data). The finer the resolution, the longer the run will take.

ii) *Diurnal Settings*: do not select this option. For detailed information about the *Diurnal Settings* in WindNinja, refer to the program's tutorials.

iii) Click **OK** to save the settings and return to the **Run** form.

g) *Foliar Moisture Content (%)*: leave the default 100% value.

h) Select the *Use Fuel Moisture Conditioning* option.

i) *Weather File (*wtr)*: navigate to and add the <u>mtemeily_weather_nws.wtr</u> file from the outputs folder of the ArcFuels directory.

j) *Weather File (*wnd)*: navigate to and add the mtemeily_wind_nws.wnd file from the outputs folder of the ArcFuels directory.

k) Set the *Start Day* to 9/21 and the *End Day* to 9/23. Set the *Start Time* and *End Time* to 15:00 PM.

l) Click **Apply**.

3) Select the **Fire Behavior Outputs** tab (fig. 4-59).

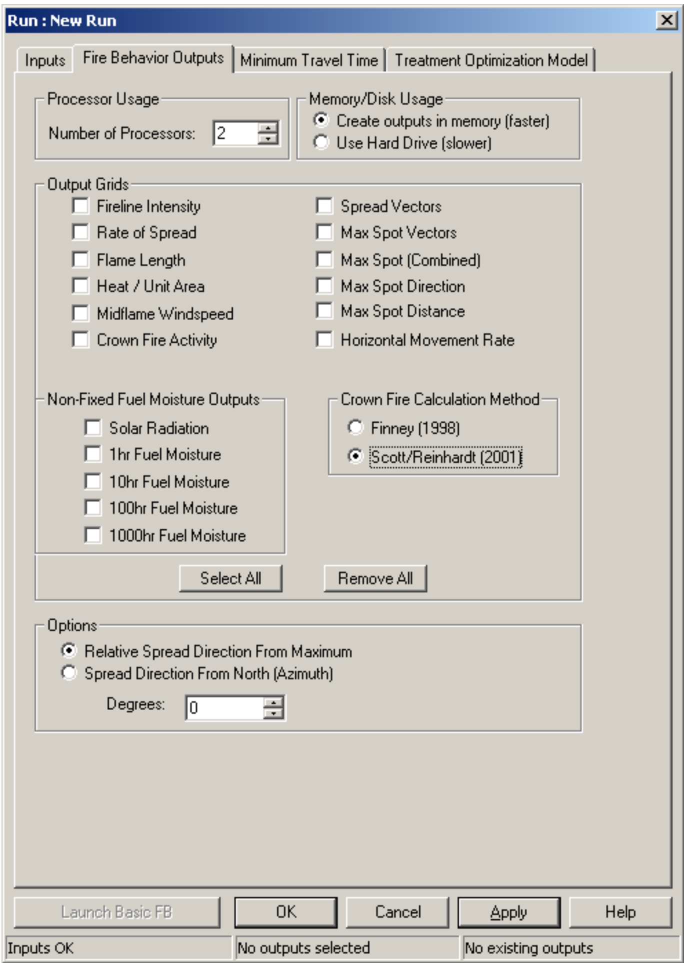


Figure 4-59—TOM fire behavior outputs options.

a) Under *Crown Fire Calculation Method*, select the *Scott/Reinhardt (2001)* option.

b) The remainder of the options and settings should remain the defaults.

c) Click **Apply**.

4) Select the **Minimum Travel Time** tab (fig. 4-60).

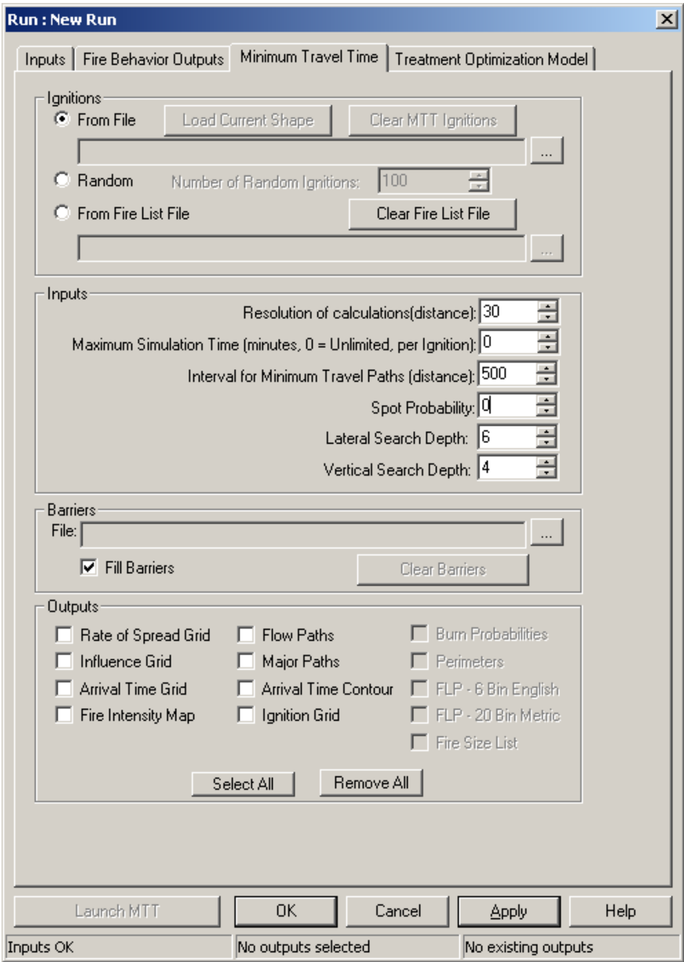


Figure 4-60—Setting the spotting probability on the MTT tab.

a) *Spot Probability*: type “0” in the text box. Just like the *Crown Fire Calculation Method* is set on the **Fire Behavior Outputs** tab, the *Spot Probability* is set on the **Minimum Travel Time** tab, even if outputs from either tab are not created. Setting the *Spot Probability* to zero will speed up the computing time for TOM.

b) Click **Apply**.

5) Select the **Treatment Optimization** tab (fig. 4-61).

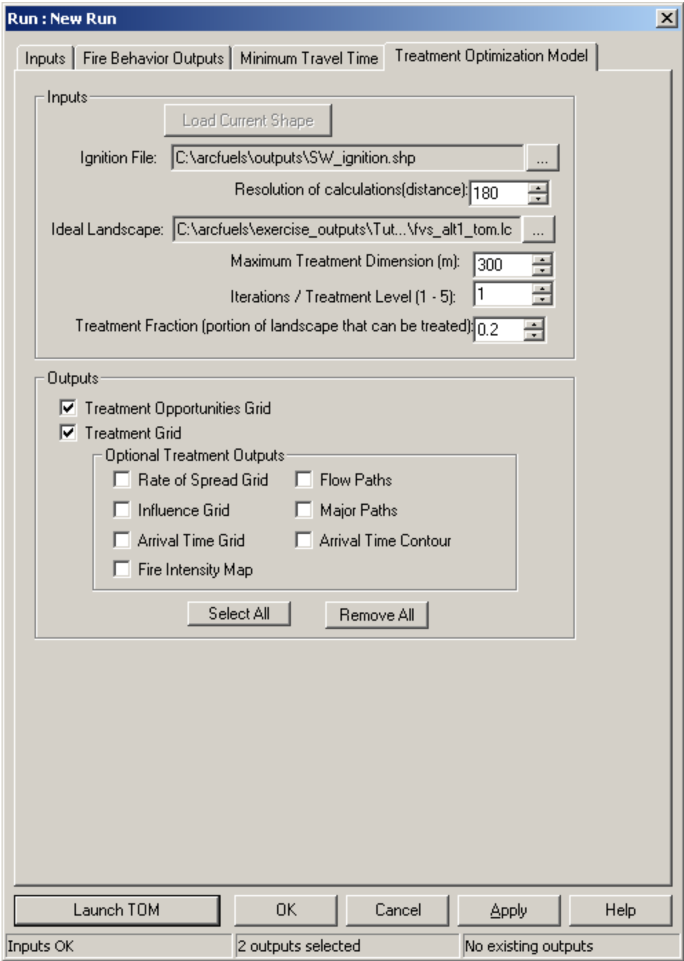


Figure 4-61—Treatment Optimization Model (TOM) options tab in FlamMap.

a) *Ignition File*: navigate to and open SW_ignition.shp from the outputs folder in the ArcFuels directory.

b) *Resolution of calculations (distance)*: type "180" in the text box. This should always be a multiple of the input data.

c) *Ideal Landscape*: navigate to and open fvs_alt1_tom.lcp (C:\arcfuels\outputs if you have competed the ArcFuels10 Tutorial exercises or C:\arcfuels\exercise_outputs\Tutorial).

d) *Maximum Treatment Dimension (m)*: keep the default "300" value.

e) *Iterations/Treatment Level (1*-5): keep the default "1" value.

f) *Treatment Fraction (portion of the landscape that can be treated)*: type "0.20" in the text box.

g) Under *Outputs* select the *Treatment Grid* and *Treatment Opportunities Grid*. The *Treatment Grid* is a 0/1 grid where 1s indicate treatment is suggested and 0 means it is not. The *Treatment Opportunities Grid* is a grid where fire behavior for the two LCPs (ideal landscape and current conditions) is compared and can be -1, 0, or 1.

h) Click **Apply**.

i) Click **Launch TOM**. Now is a great time to take a break... the run can take 30-60 min to complete.

j) Click **Ok** to close the **FlamMap Progress....** window after the execution is complete.

k) Click **OK** to close the **Run** form and return to the main FlamMap window.

6) Under the Runs section, expand the TOM run in the tree pane. Display the TOM Treat Opportunities theme, and open the legend (fig. 4-62). The TOM Treat Opportunities theme compares the fire behavior for the two LCPs. If the value is 1, the rate of spread is less in the ideal landscape. If the value is -1, the rate of spread is greater in the ideal landscape. And areas with a zero value indicate no difference in the rate of spread between the LCPs. TOM will only select from the areas where the value is 1.

Why might values of -1 exist? If treatments aggressively open the canopy, then midflame windspeed could be higher. If treatments result in a flashier fuel model, the rate of spread might increase. Another possibility is this is a result of the resolution of the calculations. For this simulation, you used 30m resolution input data, and ran TOM at 180 m. A 180 m x 180 m pixel contains 36 30 m x 30 m pixels, but only one value is recorded. It's possible that the average or the majority of those 36 pixels has slower rates of spread or higher rates of spread than the rest; that is what would be displayed as the value for the entire 180 m pixel.

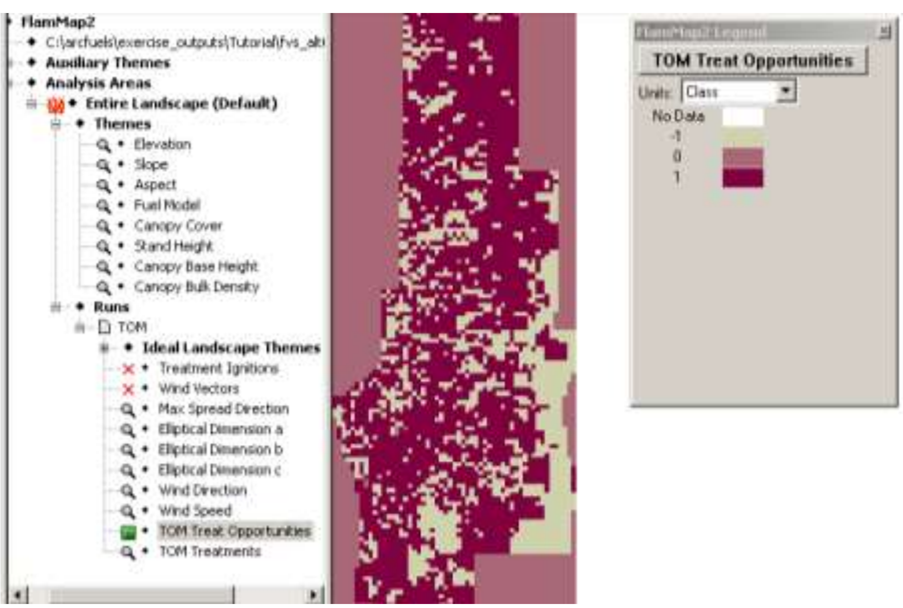


Figure 4-62—The TOM Treatment Opportunities output.

7) Display the TOM Treatments theme (fig. 4-63). The TOM Treatments theme displays the suggested treatment locations (value = 1).

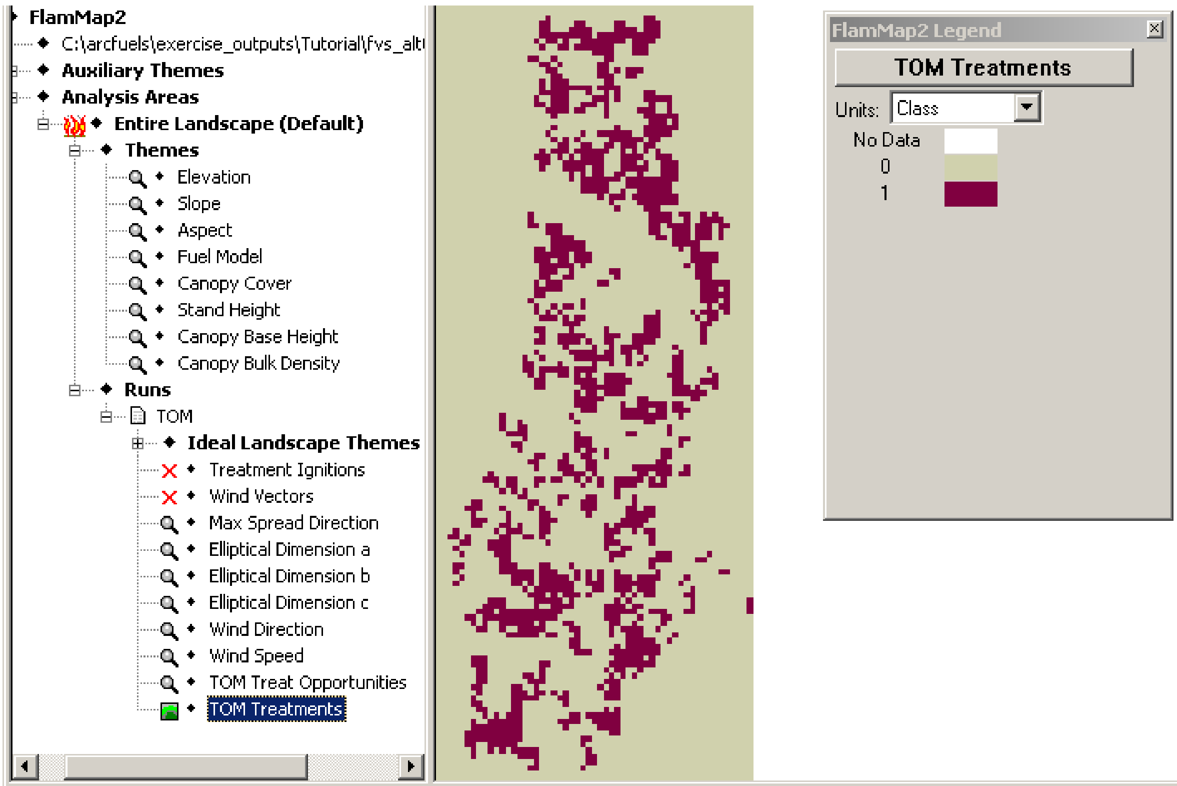


Figure 4-63—The TOM Treatment output.

8) Close FlamMap5. You are done with the tutorial. Congrats!

5. Landscape Treatment Designer (LTD)

This section is meant to be a brief introduction to Landscape Treatment Designer (LTD, version Beta 1.3, Ager et al. 2012). The purpose is to have the user gain basic LTD skills for use with ArcFuels10. For more thorough tutorials, visit the LTD website (www.arcfuels.org/ltd).

Program Overview

The Landscape Treatment Designer (LTD) program is a multi-criteria spatial prioritization and optimization system to help design and explore landscape fuel treatment scenarios. The program fills a gap between fire model programs such as FlamMap, and planning systems such as ArcFuels, in the fuel treatment planning process. The LTD uses inputs on spatial treatment objectives, activity constraints, and treatment thresholds; and then identifies optimal fuel treatment locations with respect to the input parameters (fig. 5-1). The input data represent polygons that are attributed with information about expected fire behavior, and the polygon's overall contribution to one or more landscape management objectives. Four types of output files are generated with each run: (1) a text file containing all the input data with treatment locations indicated, (2) a summary text file of input parameters and output results, (3) a results comma separated file with the input parameters and output results, and (4) a shapefile with an attribute table that identifies patch locations and stands selected for treatments.

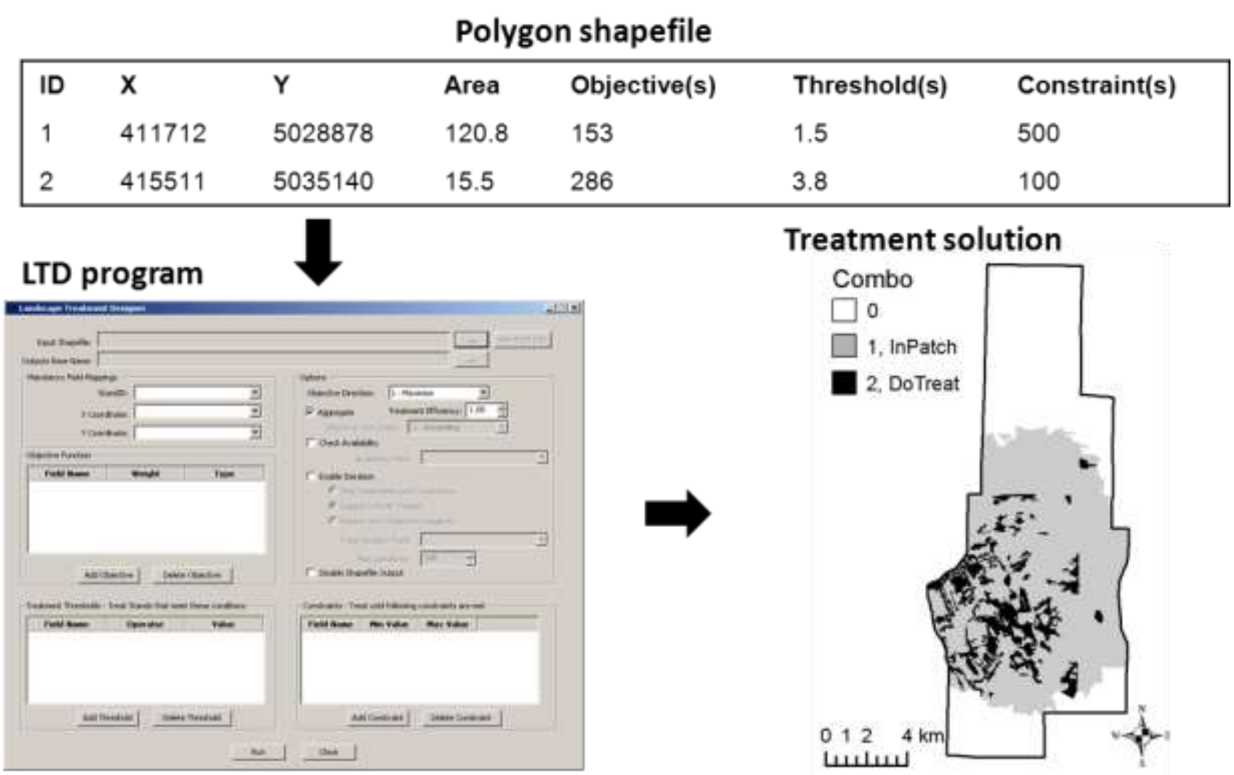


Figure 5-1—Diagram showing the input data and outputs of the LTD program

The LTD GUI interface (hereafter LTD) is comprised of six major parts (fig. 5-2): 1) input and output data, 2) mandatory field mapping, 3) objective function, 4) treatment threshold, 5) constraints, and 6) options. Each part will be described in detail below.

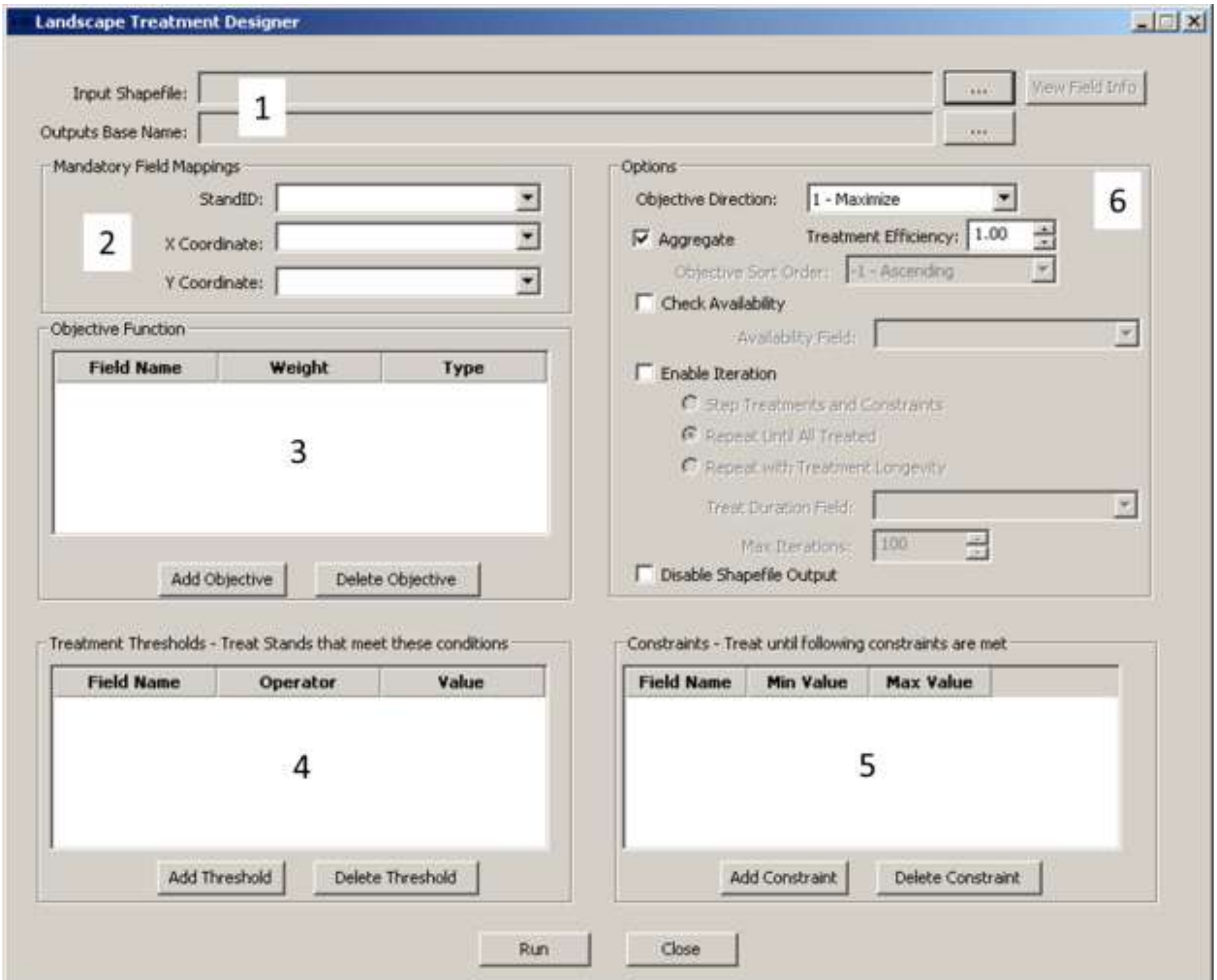


Figure 5-2—LTD GUI interface

LTD interface—

Input and output data

Input data are in the form of an ArcGIS shapefile. Once you have loaded a shapefile into LTD you can see the information from the attributes table using the **View Field Information** button.

There are four output files associated with a LTD run: 1) text file with all the input data with treatment locations indicated (_Points), 2) text file summary of input parameters and output results (_Summary), 3) comma-separated values file summary of input parameters and output results (_Results), and 4) a shapefile attributed with the output solution (_Polys). The *Outputs Base Name* is used to create a single pre-fix name for the above mentioned output files.

Mandatory field mappings

The *Mandatory Field Mappings* are used in LTD to define the unique units or polygons within the input shapefile (typically stands), and their spatial location. The *Stand ID* and X-Y centroids (*X Coordinate* and *Y Coordinate*) must be identified from the loaded shapefile. These auto-populated fields are pull-down enabled; select the correct field from the shapefile attribute table for each option.

Objective function

Objective Functions describe goals of a particular spatial fuel management strategy. Multiple objective functions with different weights and types can be entered. Objective functions for fuel management typically include variables that describe the desired location and stand types for treatments. Example variables include old growth ponderosa pine, distance to road, historic range of variability (HRV) departure indices, slope position, biomass, and fire behavior. When multiple objectives are entered, it is important that they are scaled and valued consistently.

The *Field Name* is the field in the shapefile containing the objective function values which must be numeric.

When multiple objectives are selected, their values are additive when the *Weight* is equal to 1.0 for all objectives (i.e., $\sum \text{Objective}_1 + \text{Objective}_2 + ... + \text{Objective}_n$), and the total value of a stand is used. However, if the *Weight* values are different than 1.0, the solution is not as simple. The objective is multiplied by the weight, and then summed (i.e., $\sum(\text{Objective}_1 * \text{Weight}_1) + (\text{Objective}_2 * \text{Weight}_2) + ... + (\text{Objective}_n * \text{Weight}_n)$). For example, if two objectives are used and their weights are 1.0 and 10.0, respectively, each stand has a value of $\text{Objective}_1 * 1 + \text{Objective}_2 * 10$.

The *Type* option is only available for aggregated treatment solutions (*Aggregate* option selected in the *Options* part). There are three *Types* available: <u>Both</u>, <u>Treat</u>, and <u>Non-Treat</u>. When an objective function variable is assigned a <u>Treat</u> type, the value of the objective is only accrued when the polygon is selected for treatment. When an objective function variable is assigned a <u>Non-Treat</u> type, the value of the objective is only accrued when the polygon is not selected for treatment, but is within the larger treatment patch. Selection of a stand for treatment is covered in the next section.

Treatment threshold

Treatment Thresholds are values which must be met in order for a stand to be selected for treatment. Thresholds are selected from the input shapefile attribute table, and are most often associated with fire behavior, stand conditions, or topography.

The *Field Name* is the field in the shapefile containing the objective function values which must be numeric. *Operator* functions are included to parameterize the treatment thresholds. The operators available are less than (<), less than or equal to (<=), greater than (>), and greater than or equal to (>=). *Value* is the treatment threshold value which must be numeric. The *Min Value*, *Max Value*, and *Step* are available when the *Enable Iteration* and *Step Treatments and Constraints* options are selected. The *Min Value* is the minimum value, the *Max Value* is the maximum value for the threshold, and the S*tep* value sets the increment desired. More information about *Enable Iteration,* and *Step Treatments and Constraints* will be provided in the *Options* section below.

Constraints

Constraints provide parameters for treatment solutions. Multiple constraints are possible with minimum and maximum value inputs. Because treatments solutions often include stands with various constraint values, the *Min Value* and *Max Value* constraint are guides, and are often not met exactly. Area and cost of treatment are two examples of constraints.

The *Field Name* is the field in the shapefile containing the constraint values which must be numeric. *Min Value* is the minimum value, and *Max Value* is the maximum value for the constraint. *Step* is available when the *Enable Iteration* and *Step Treatments and Constraints* options are selected. The S*tep* value sets the increment desired for iterative solutions bounded by the *Min Value* and *Max Value*. More information about *Enable Iteration* and *Step Treatments and Constraints* will be provided in the *Options* section below.

Options

The *Options* are available to customize the LTD runs based on the users' needs. Depending on the *Options* selected, additional choices become available (black text) and non-available (gray text).

Objective Direction can either be 1- Maximized, or 0 - Minimized. Maximizing direction creates a solution where the *Objective Function* is maximized (highest value possible), whereas minimizing creates a solution where the *Objective Function* is minimized (smallest value possible).

Aggregate allows the user to aggregate treatments into spatially explicit patch(s) (checked), or to allow a non-aggregate non-spatially explicit treatment pattern (unchecked). This is dependent on the *Objective Function*, *Treatment Thresholds*, and *Constraints* (fig. 5-3).

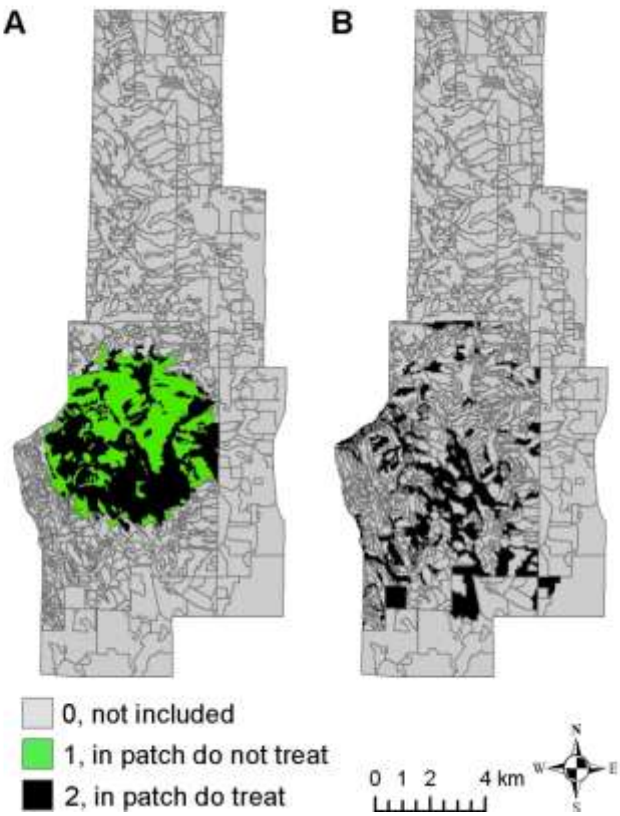


Figure 5-3—Aggregate (A) and non-aggregate (B) treatment solutions.

Treatment Efficiency is a value between 0 and 1, where 1 treats all possible stands. Stands qualified for treatment based on the thresholds are selected at random when the values is <1. For example, if the *Treatment Efficiency* is set to 0.9, only 90% of the stands marked for treatment will be flagged as needing treatment.

Objective Sort Order sorts the data in the input shapefile based on the *Objective Function* specified in -1 - Ascending,0 - StandID, or 1 – Descending. Stands that meet the treatment threshold requirements are selected for treatment based on the sorted *Objective Function* until the constrains are met (fig. 5-4). For example, when -1 – Ascending is selected, the treatment solution starts selecting stands that have the lowest values for the *Objective Function* first. If 1 – Descending is selected, the treatment solution starts selecting stands that have the highest values for the *Objective Function* first. When 0 – StandID is selected, the *Objective Function* is no longer taken into account and stands with smaller StandID values are chosen first. The *Objective Sort Order* is only available for non-aggregated runs; if the *Aggregate* check box is selected it will be grayed out.

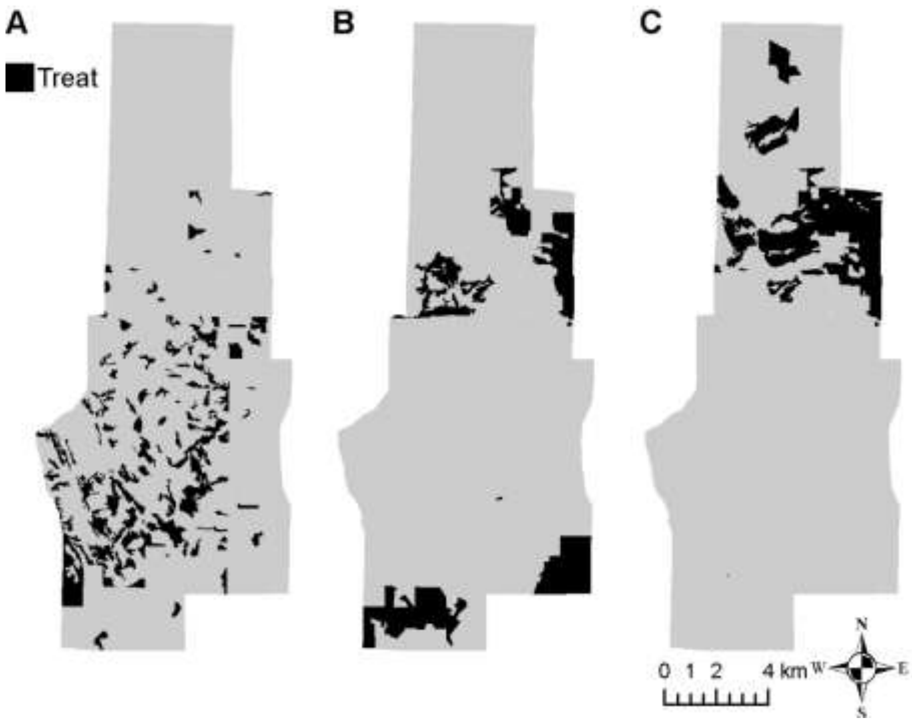


Figure 5-4—The objective sort order affects treatment location. Options include ascending (A), descending (B), and StandID (C).

Check Availability allows the user to only allow treatments in stands which are available for treatments when checked; if not checked, then all stands are used. Within the shapefile a 0/1 integer field indicates stands available for treatment (1), from stands not available (0).The 0/1 integer field is specified from the input data attribute table with *Availability Field* drop-down menu.

Within the *Enable Iteration* option, there are three sub-options: *Step Treatments and Constraints*, *Repeat Until All Treated*, and *Repeat with Treatment Longevity*. *Step Treatment and Constraints* allows the user to iteratively create treatment solutions by stepping either or both the *Treatment Thresholds* and *Constraints*. *Repeat Until All Treated* will create multiple treatment solutions until: 1) all stands have been treated (non-aggregated), 2) are within a patch (aggregated), or 3) until it is not possible to create a solution that meets the treatment thresholds and constraints. *Repeat with Treatment Longevity* uses an additional attribute defining the expected treatment effectiveness duration (*Treat Duration Field*). Once selected for treatment, stands will not become available again until their longevity duration has passed. The time period for each iteration is arbitrary. Because the program could run indefinitely, the user must specify a maximum number of runs (*Maximum Iterations*).

The final option, *Disable Shapefile Output*, is available if the shapefile output is not wanted.

Tutorial

The following exercises will use the Mt. Emily stands shapefile supplied with the ArcFuels10 demonstration data (C:\arcfuels\data\mt_emily_stands.shp).

Simple aggregated treatment plan—

This first example is a simplistic scenario where the goal is to create an aggregated treatment patch which treats about 10% of the landscape. The goal is to locate treatments in stands with large trees when flame lengths exceed 1.2 m (4 ft). The resulting treatment will be a single patch with some stands marked for treatment, and others not.

1) Open Landscape Treatment Designer (LTD) through the ArcFuels10 toolbar (**ArcFuels10 toolbar→Landscape→Landscape Treatment Designer**). For this to work, the LTD program must be linked via the **Project Settings** form. See the ***Setting up ArcFuels10 with the Mt. Emily Demonstration Data*** section of the ***ArcFuels10 Tutorial*** for more detailed instructions (fig. 5-5).

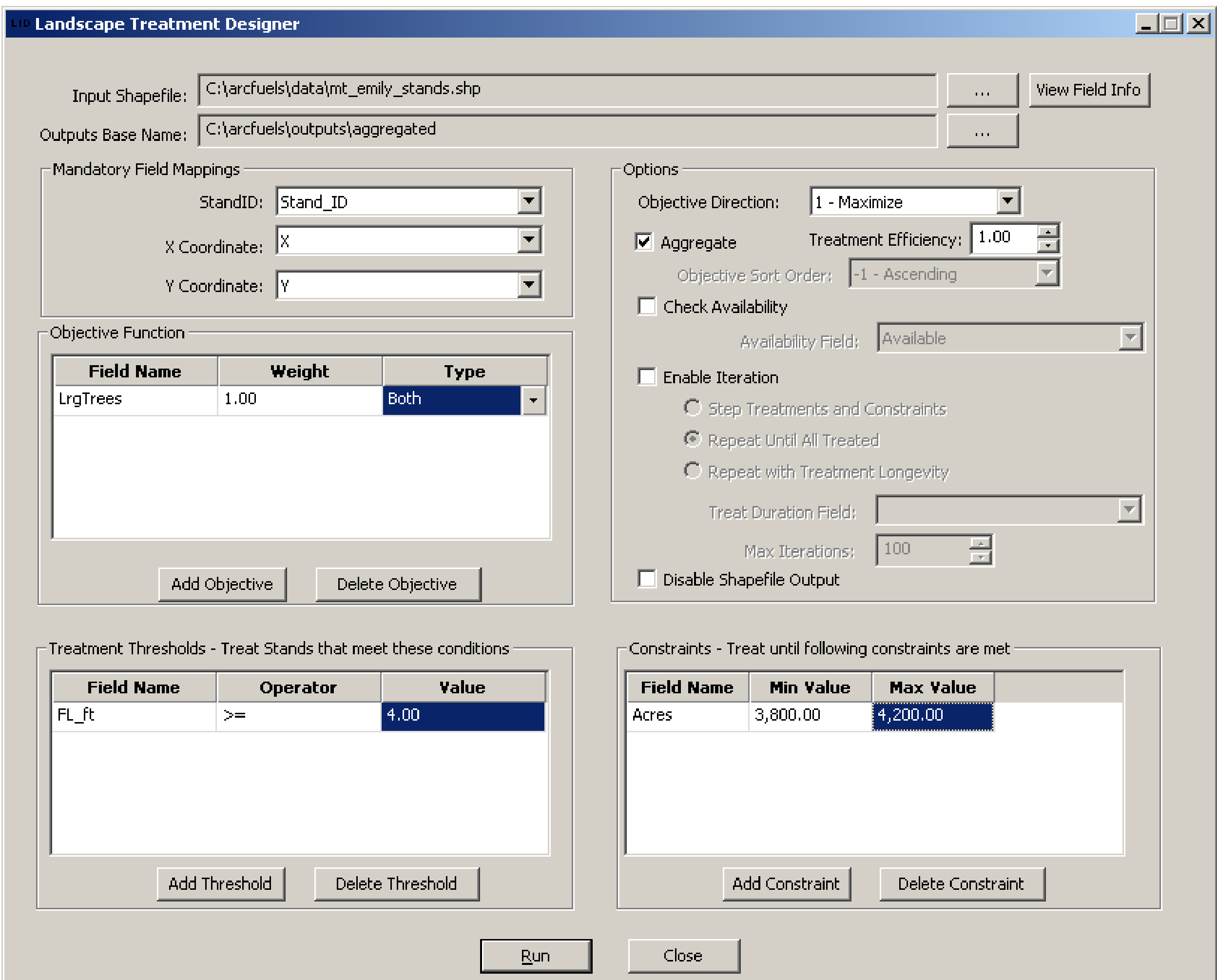


Figure 5-5—LTD setup to create an aggregated treatment plan maximizing large trees.

a) *Input Shapefile*: navigate to and open mt_emily_stands.shp from the data folder in the ArcFuels directory.

b) Click **View Field Info** (fig. 5-6) to see statistics about all the attributes in the shapefile.

Field Information for C:\arcfuels\data\mt_emily_stands.shp
Number of Records: 1082

Field Name	Type	Width	Decimals	Min	Max	Avg
Acres	N	9	0	1	926	37
ForestType	C	50	0	0	0	0
X	F	19	11	408568.187237	418218.632615	413270.771287
Y	F	19	11	5026472.589150	5050387.288770	5036582.712560
homedens	N	16	6	0.000000	6.000000	0.362292
LrgTrees	N	16	6	0.000000	9874.000000	132.596118
Available	N	16	6	0.000000	1.000000	0.498152
Duration	N	16	6	0.000000	20.000000	11.400185
LrgTree_Tr	N	9	0	0	9380	126
LrgTree_NT	N	9	0	0	3979	38
FireType	N	4	0	0	3	2
FL_ft	N	4	0	0	130	28
Slope_per	N	4	0	4	92	34
Stand_ID	N	4	0	2	1262	616
fml	N	4	0	91	188	154
cc	F	19	11	0.000000	71.000000	35.328096
ch	F	19	11	0.000000	375.000000	218.327172
cbh	F	19	11	0.000000	33.000000	5.192237
cbd	F	19	11	0.000000	33.000000	5.192237

Figure 5-6—Field Information.

c) *Outputs Base Name*: navigate to the outputs folder in the ArcFuels directory and name the base files "aggregated" (fig. 5-7).

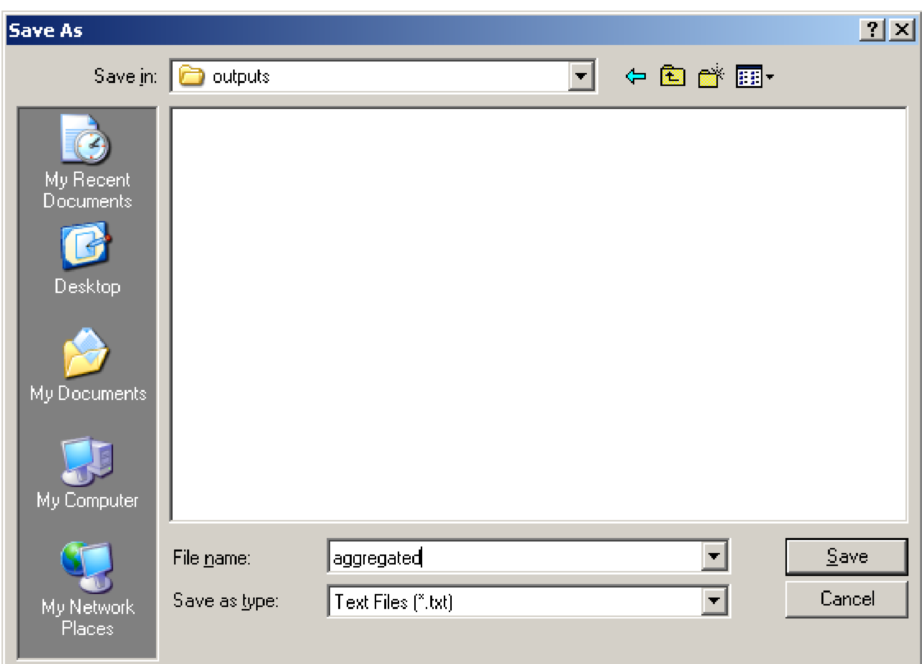


Figure 5-7—Saving the base outputs name.

d) Set the *Mandatory Field Mappings*

   i) *StandID*: select Stand_ID from the drop-down list.

   ii) *X Coordinate*: select X from the drop-down list.

   iii) *Y Coordinate*: select Y from the drop-down list.

e) Set the *Options*

   i) *Objective Direction*: select 1 – Maximize from the drop-down list.

   ii) Select the *Aggregate* option.

   iii) *Treatment Efficiency*: use the arrow buttons to set it to 1.0.

   iv) Do not select the *Check Availability*, *Enable Iteration*, or *Disable Shapefile Output* options.

f) Set the *Objective Function*

   i) *Field Name*: select LrgTrees from the drop-down list. LrgTrees is the number of trees greater than 53.3cm dbh in each stand.

   ii) *Weight*: type "1.00" in the text box. To change the *Weight*, click on the cell; once highlighted, type in the new value.

   iii) *Type*: select Both from the drop-down list. Both is selected because this field contains information about the current conditions of the stand.

g) Set the *Treatment Thresholds*

   i) *Field Name*: select FL_ft from the drop-down list. FL_ft is the flame length of each stand in feet.

   ii) *Operator*: select >= (greater than or equal to) from the drop-down list.

   iii) *Value*: type "4.00" in the text box. To change the *Value*, click on the cell; once highlighted, type in the new value.

h) Set the *Constraints*

   i) *Field Name*: select Acres from the drop-down list. Acres is the area of each stand in acres.

   ii) *Min Value*: type "3,800.00" in the text box.

   iii) *Max Value*: type "4,200.00" in the text box.

i) Click **Run** to run LTD. Once completed, the **LTD Progress...** window will open telling you it has finished. Click **OK** to close the window (fig. 5-8).

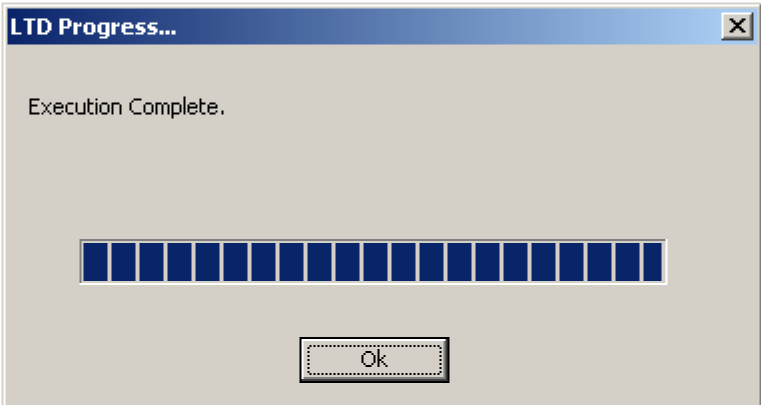


Figure 5-8—LTD Progress window.

j) Next, the **LTD Complete** window will open (fig. 5-9). This window lists the outputs with their name and path shown, and allows you to open select outputs without having to navigate to the folder where they are saved.

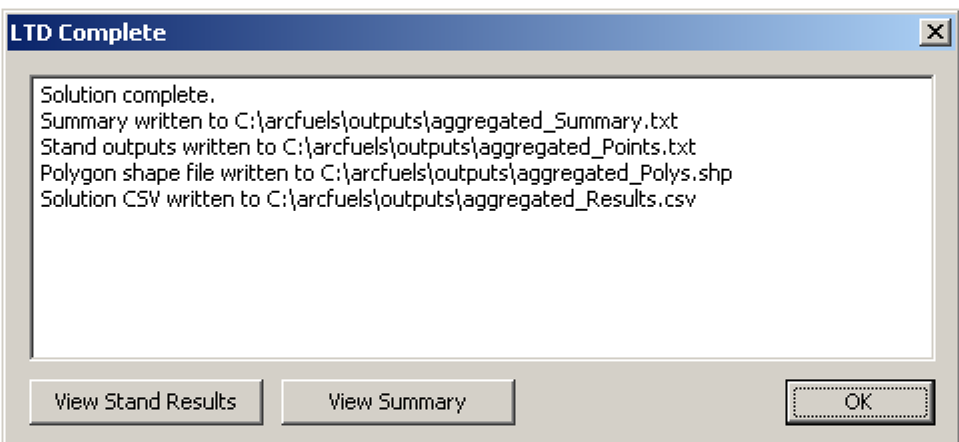


Figure 5-9—LTD Complete window.

k) Open the Agg_simple_Points.txt file by clicking the **View Stand Results** button on the **LTD Complete** window. The aggregated_Points.txt file maintains information for every stand within the loaded shapefile. By default the StandID, X-Y coordinates, and availability fields are always written to this file (fig. 20). The original data for the *Objective Function(s)*, *Treatment Threshold(s)* and *Constraint(s)* used in the run are also appended. The last three columns are always *"InPatch"*, *"DoTreat"*, and *"Combo." InPatch* indicates that a stand is selected to be within the larger patch area (and does not always need to be treated). *DoTreat* indicates the stand meets the *Treatment Threshold(s)* and *Constraint(s)* and should be treated. *Combo* is the sum of *InPatch* and *DoTreat*: 0 indicates it is neither in the patch or needing treatment, 1 indicates it is in the patch but does not need treatment, and 2 indicates it is both in the patch and requires treatment.

This is the same information that is in the attributes table of the aggregated_Polys.shp file.

```
"Stand_ID","X","Y","available","Acres","LrgTrees","FL_ft","InPatch","DoTreat","Combo"
2,411579.468750,5050085.500000,1,28.000000,0.000000,24.000000,0,0,0
3,411732.718750,5050211.000000,1,34.000000,0.000000,40.000000,0,0,0
4,411877.000000,5050331.500000,1,5.000000,0.000000,16.000000,0,0,0
5,412257.531250,5049736.500000,1,138.000000,0.000000,23.000000,0,0,0
6,412166.343750,5050387.500000,1,3.000000,0.000000,14.000000,0,0,0
7,412974.500000,5049556.500000,1,125.000000,0.000000,11.000000,0,0,0
```

Figure 5-10—Aggregate_Points.txt file.

2) Open the aggregated_Summary.txt file by clicking the View Summary button on the **LTD Complete** window. The Agg_simple_Summary.txt file summarizes the run completed (fig. 5-11). The *Objective Function(s)* and *Weight(s)*, *Treatment Threshold(s)* and *Value(s)*, and *Constraint(s)* are listed along with the *Options* specified. In addition, the results and the run time are shown. The results include the *Max Objective Value*, which is the sum of the values of the *Objective Function(s)* in the stands flagged for treatment (*DoTreat*=1); this is the total number of large trees in the patch for this run. The *Constraint Max* is the sum of the *InPatch* area, and the *Constrain Max Treat* is the sum of the *DoTreat* area.

```
LTD run generated: Thursday, September 20, 2012
Objectives: (1)
  LrgTrees  1.000000

Thresholds: (1)
  FL_ft  >=  4.000000

Constraints: (1)
  Acres  3800.000000 - 4200.000000

obj_dir 1
check_avail 0
write_debug_file  0
sort_output_file  -1
results_headers 0
aggregate_soln  1


Results
Max Objective Value: 75174.000000
```

Figure 5-11—Aggregated_Summary.txt file.

3) Click **OK** to close the **LTD Complete** window.

4) Open the aggregate_Results.csv file (fig. 5-12) from the outputs folder of the ArcFuels directory. The aggregate_Results.csv file contains information about the run set up and results, similar to the output summary file (Agg_simple Summary.txt).

ShapeFileName	Acres_Min	Acres_Max	FL_ft(>=)	LrgTrees	max_value	Total_Acres	Treat_Acres
C:\arcfuels\data\mt_emily_stands.shp	3800	4200	4	1	75174	4138	4138

Figure 5-12—Aggregated_Results.csv file.

5) LTD does not include a visual display of the output data. Open ArcMap, and add the aggregated_Polys.shp shapefile to the map. The spatial reference is undefined for the shapefile (fig. 5-13).

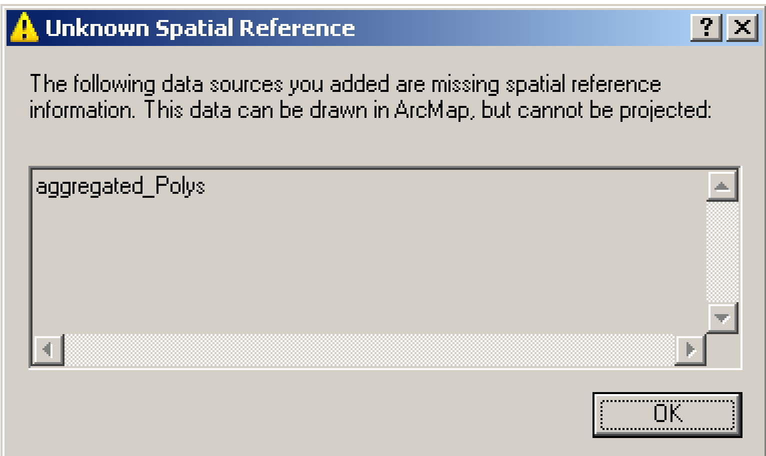


Figure 5-13—Unknown Spatial Reference window from ArcMap.

6) Define the spatial reference (**ArcToolbox→Data Management Tools→Projections and Transformations→Define Projection**, fig. 5-14).

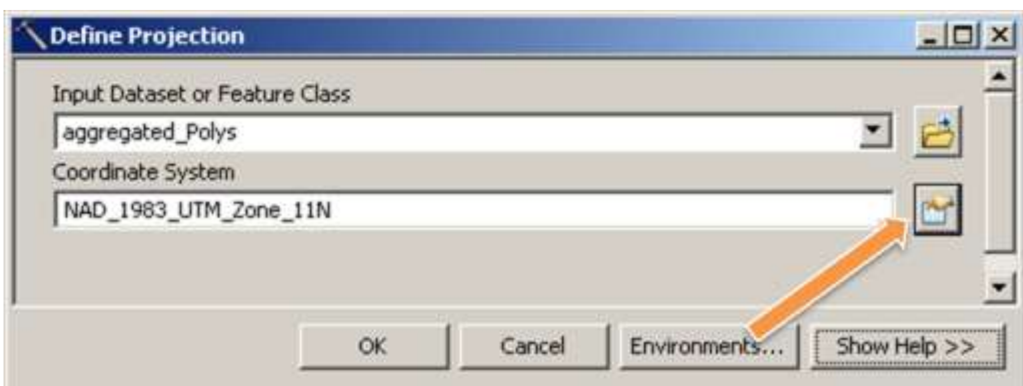


Figure 5-14—Define Projection form.

a) Click the hand pointing to the paper button (see fig. 5-14) to open the **Spatial Reference Properties** form (fig. 5-15).

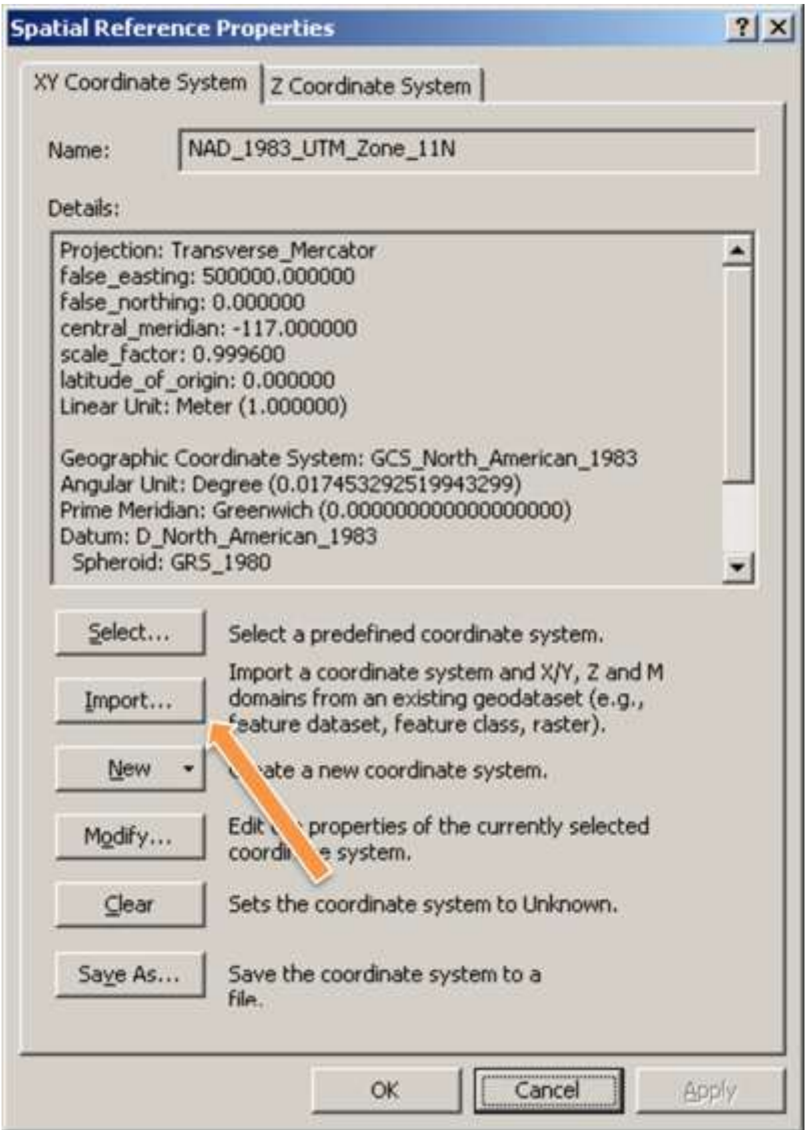


Figure 5-15—Spatial Reference Properties form.

b) Click the **Import...** button, and navigate to and add one of the layers in the data folder of the ArcFuels directory.

c) Click **OK** to close the **Spatial Reference Properties** form.

d) Click **OK** to define the projection.

7) Change the Symbology to show the COMBO field (**right-click on the layer →Properties**, fig. 5-16). COMBO is the sum of InPatch and DoTreat: when it's 0 it is neither in the patch or needing treatment, when it's 1 it is in the patch but does not need treatment, when it's 2 it is both in the patch and requires treatment.

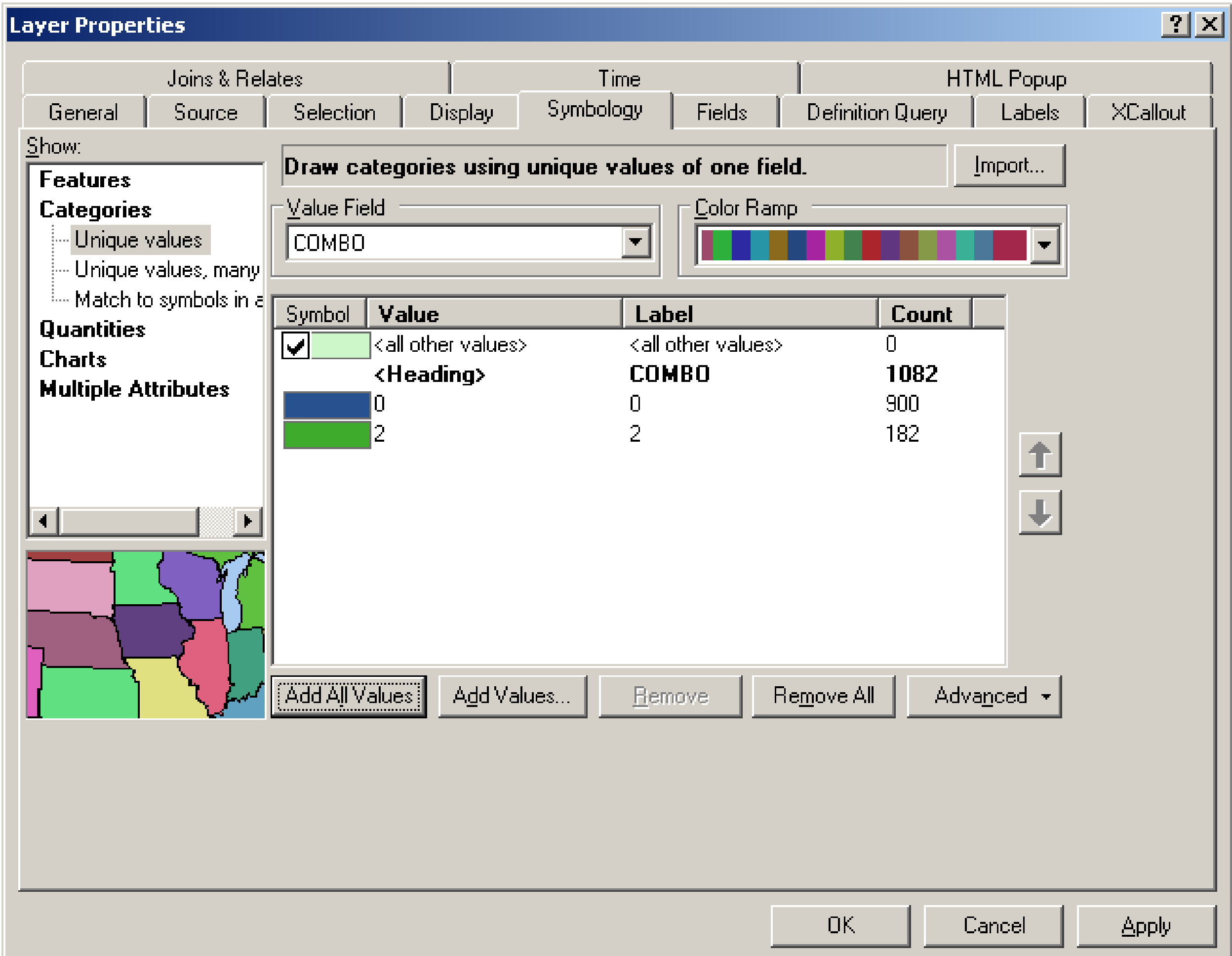


Figure 5-16—Changing the symbology to show the values for the COMBO attribute.

a) Select the **Symbology** tab.

b) *Show*: select **Categories** and then select **Unique values**.

c) *Value Field*: select <u>COMBO</u> from the drop-down list.

d) Click **Add All Values**.

e) Click **OK** to apply the changes (fig. 5-17).

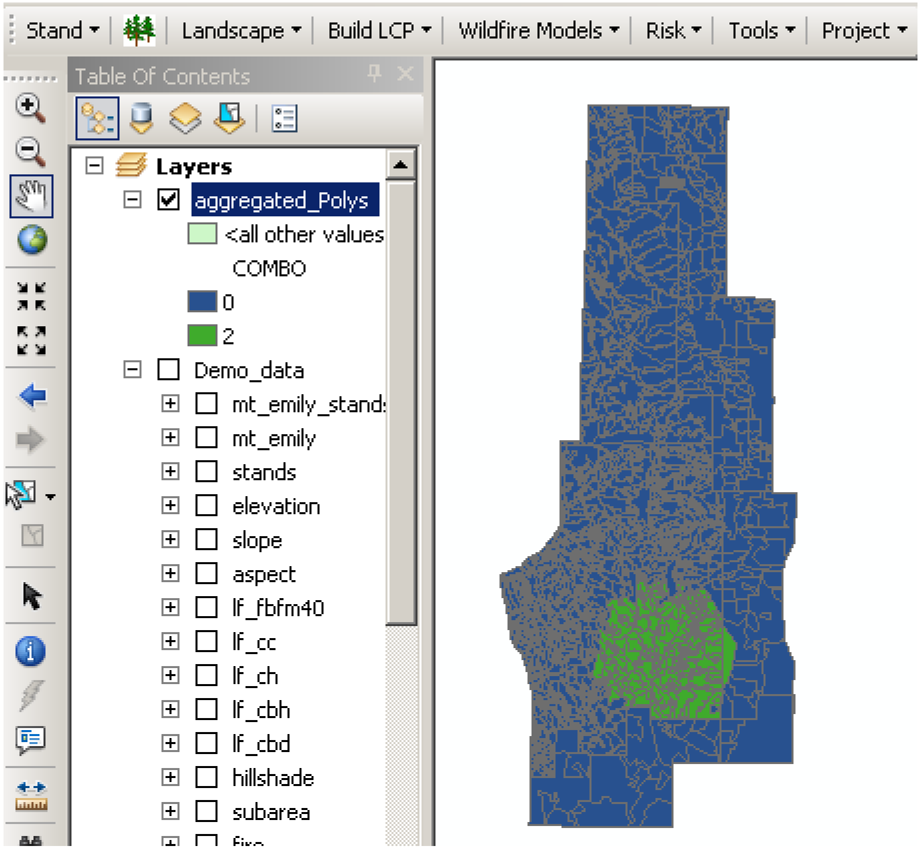


Figure 5-17—The spatial solution for the aggregated run.

Simple dispersed treatment plan—

This second example uses the same conditions as the first, but this time the *Aggregate* box will be unchecked to see the difference between the two types of runs. This example creates a non-spatially explicit prioritized treatment plan. It prioritizes the selection of stands based on the *Objective Function(s)* indicated regardless of spatial location.

For a dispersed run, the *Objective Sort Order* dictates the priority of stand selection for treatment. In this example, we are setting the *Objective Sort Order* to 1 – Descending, because we want to again maximize the number of large trees within our treatment run. By sorting in the descending order, stands with the greatest number of large trees are listed first; these stands are therefore selected first for treatment if they also meet the *Treatment Threshold(s)* and *Constraint(s)*. If the sort was set to -1 – Ascending, the solution would prioritize stands with the fewest number of large trees. If the sort was based on 0 – StandID, the prioritization would only be based on the StandID, regardless of the *Objective Function(s)*.

1) Return to the LTD form (fig. 5-18).

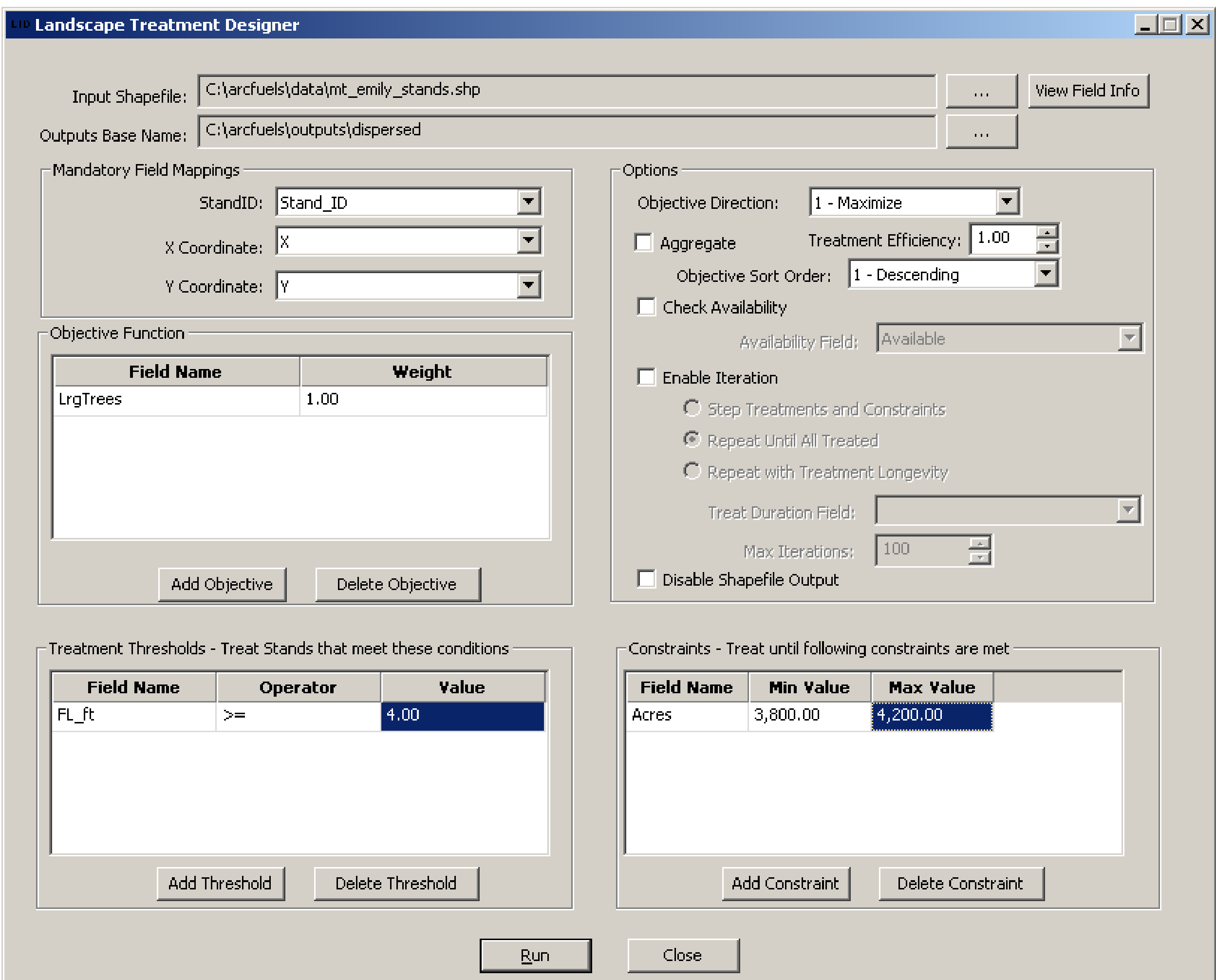


Figure 5-18—LTD setup to create a dispersed treatment plan maximizing large trees.

a) Enter the *Outputs Base Name* “dispersed” by using the navigation button, and save it in the LTD folder. This will create a standard prefix for the output files.

b) Set the *Mandatory Field Mappings*

   i) *StandID*: select Stand_ID from the drop-down list.

   ii) *X Coordinate*: select X from the drop-down list.

   iii) *Y Coordinate*: select Y from the drop-down list.

c) Set the *Options*

   i) *Objective Direction* select 1 – Maximize from the drop-down list.

   ii) Uncheck the *Aggregate* check box.

   iii) *Treatment Efficiency:* use the arrow buttons to set it to 1.0.

   iv) *Objective Sort Order:* select 1 – Descending from the drop-down list.

   v) Verify *Check Availability*, *Enable Iteration*, *Conditional Objective*, and *Disable Shapefile Output* are unchecked.

d) Set the *Objective Function*

   i) *Field Name:* select LrgTrees from the drop-down list

   ii) *Weight:* type “1.00” in the text box.

e) Set the *Treatment Threshold*

   i) *Field Name:* select FL_m from the drop-down list.

   ii) *Operator:* select >= (greater than or equal to) from the drop-down list.

   iii) *Value:* type “4” in the text box.

f) Set the *Constraints*

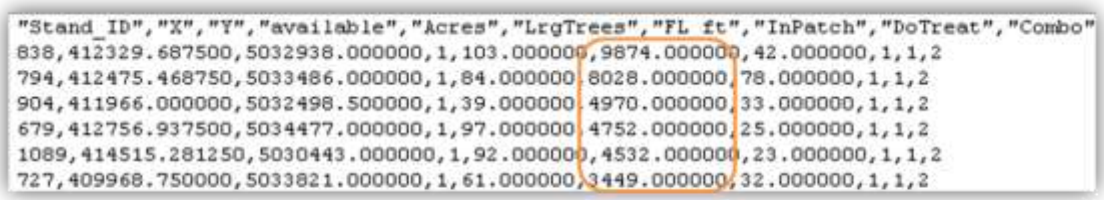
   i) *Field Name:* select Area_ha from the drop-down list.

   ii) *Min Value:* type “3,800.00” in the text box.

   iii) *Max Value:* type “4,200.00” in the text box.

g) Click **Run** to run LTD.

2) Open the dispersed_Points.txt file by clicking the **View Stand Results** button on the **LTD Complete** window. Notice because the *Objective Sort Order* was set to 1-Descending, the stands with the highest number of *LrgTrees* (large trees) are at the top of the list, and therefore chosen first for the treatment solution (fig. 5-19).



```
"Stand_ID","X","Y","available","Acres","LrgTrees","FL_ft","InPatch","DoTreat","Combo"
838,412329.687500,5032938.000000,1,103.000000,9874.000000,42.000000,1,1,2
794,412475.468750,5033486.000000,1,84.000000,8028.000000,78.000000,1,1,2
904,411966.000000,5032498.500000,1,39.000000,4970.000000,33.000000,1,1,2
679,412756.937500,5034477.000000,1,97.000000,4752.000000,25.000000,1,1,2
1089,414515.281250,5030443.000000,1,92.000000,4532.000000,23.000000,1,1,2
727,409968.750000,5033821.000000,1,61.000000,3449.000000,32.000000,1,1,2
```

Figure 5-19—Dispersed_point.txt file, showing how the sort order affects the solution.

3) Map the solution (fig. 5-20). Note that this time the solutions possible are 0 and 2. Where 0 denotes not in the patch and do not treat and 2 indicates *InPatch* and *DoTreat*. Because the *Aggregate* box was unchecked, there will only be these two options no matter how complex the run, because the process is not trying to create a contiguous patch; rather, it disperses treatments across the landscape.

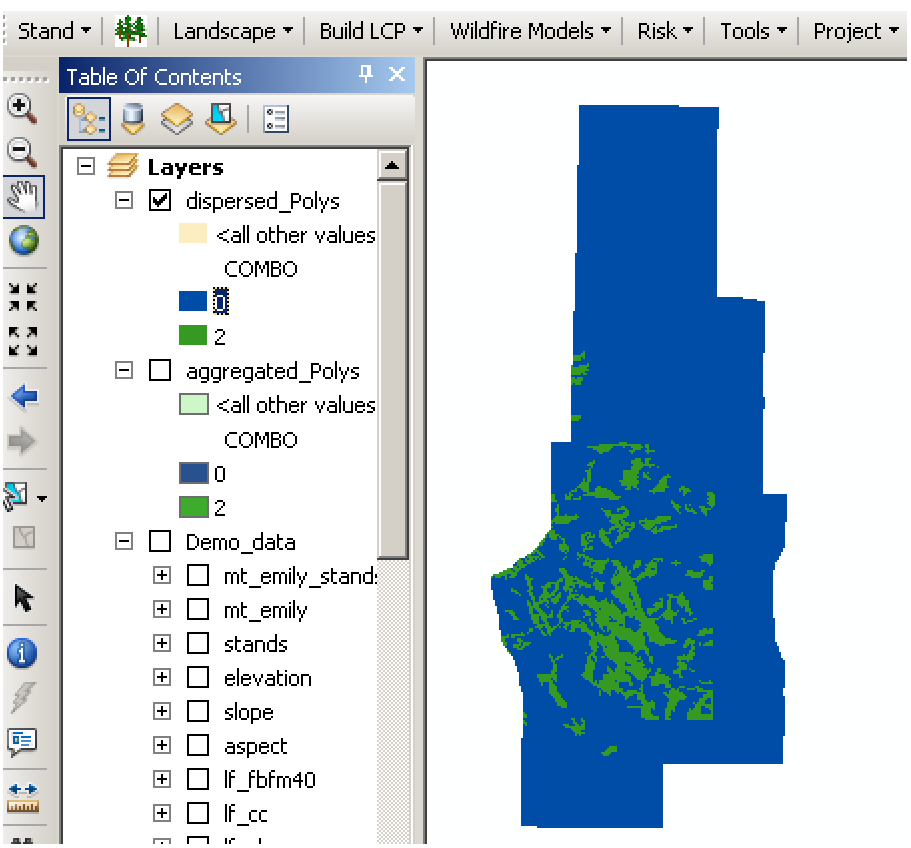


Figure 5-20—Treatment solution where green areas indicate a need for treatment.

Notice the differences between the two solutions in figures 5-17 and 5-20. The general treatment area is the same because that is where the concentration of large trees is. The aggregated solution creates one large contiguous treatment patch where the solution suggests treatments for 4,138 ac and contains 75,174 large trees. The large trees contained in the aggregated solution include all trees in the patch regardless of treatment preference. On the other hand, the dispersed solution suggests treatments for 4,200 ac and contains 129,178 large trees because it is able to disperse the treatments to include all the stands with the highest density of large trees.

A warning window will open if you forget to rename the file base name, or choose to re-run a run with the same base name. You can either overwrite or append to the existing outputs (fig. 5-21)

Figure 5-21*—Output Files Already Exists window.*

If you forgot to re-name your output files, and still have the Results CSV File open, you will get the following error window (fig. 5-22). Click ***OK*** *and the LTD run will terminate. Close the CSV file and try again.*

Figure 5-22*—LTD error window if you have your Results CSV file open.*

Aggregated treatment with multiple objectives and thresholds—

The third treatment example is a more complex scenario than the first example. The goal is to create a single treatment patch which treats about 10% of the landscape. In addition, the goal is to maximize treatments in stands with large trees and high home density in available stands where slopes are accessible and fire type is undesirable (crown fire type).

1) Return to the LTD form (fig. 5-23).

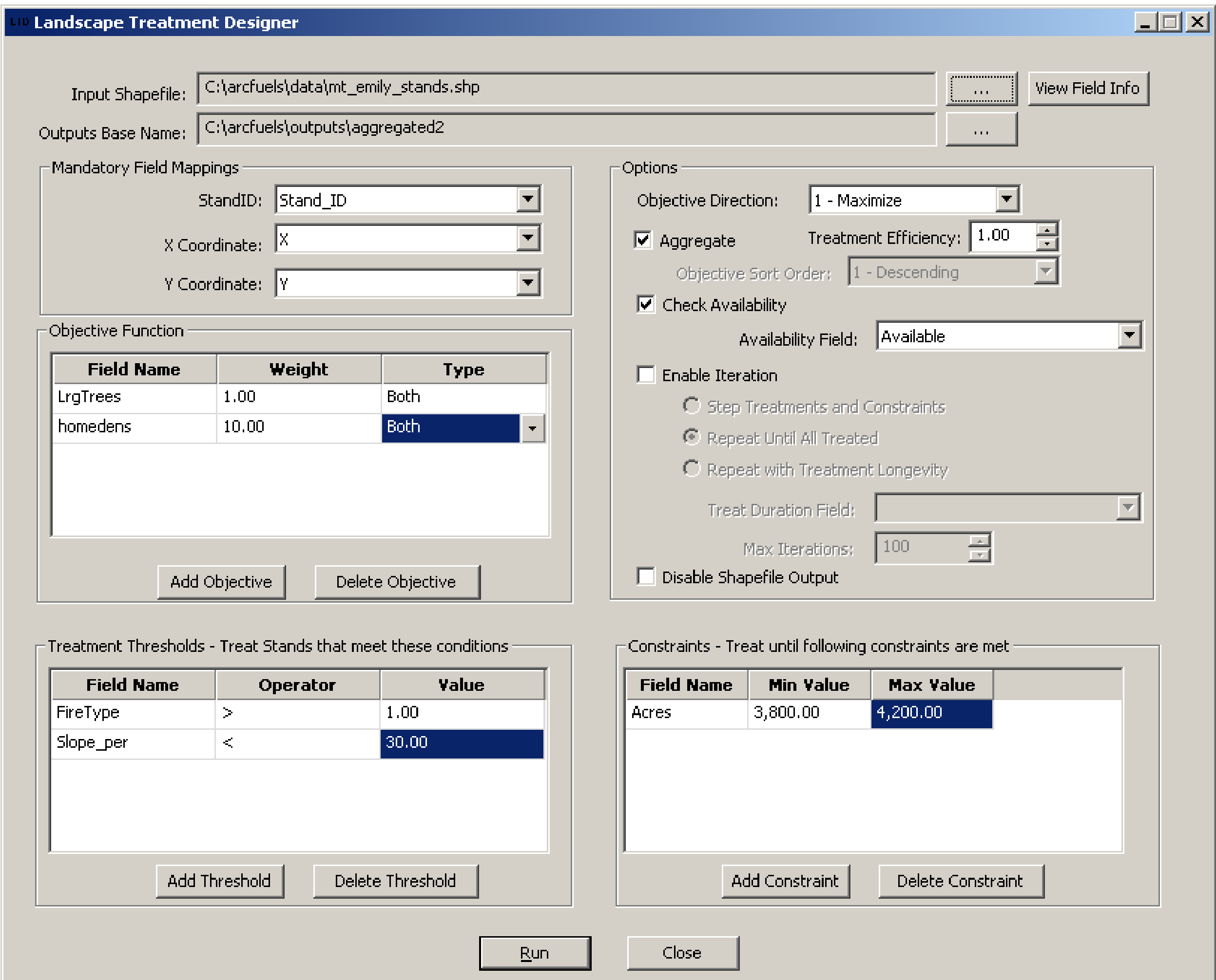


Figure 5-23—LTD setup to create an aggregated treatment plan maximizing treatments where large trees and homes are present.

a) Enter the *Outputs Base Name* “aggregated2” by using the navigation button, and save it in the LTD folder. This will create a standard prefix for the output files.

b) Set the *Mandatory Field Mappings*

i) *StandID*: select Stand_ID from the drop-down list.

ii) *X Coordinate*: select X from the drop-down list.

iii) *Y Coordinate*: select Y from the drop-down list.

c) Set the *Options*

i) *Objective Direction*: select 1 – Maximize from the drop-down list.

ii) Select the *Aggregate* option.

iii) *Treatment Efficiency*: use the arrow buttons to set it to 1.0.

iv) Select the *Check Availability* option.

v) *Availability field*: select Available from the drop-down list. The *Check Availability* box is another type of constraint; however, it is pre-determined within the *Input Shapefile*. The *Availability Field* must be binary, containing only integers of 0 (not available for treatment), and 1 (available for treatment). Only stands available for treatment will be part of the *DoTreat* solution (*DoTreat* = 1). For the *Aggregate* example, because stands are not available for treatment, it does not preclude them from being a part of the patch (*InPatch* = 1).

vi) Do not select the *Enable Iteration* and *Disable Shapefile Output* options.

d) Set the *Objective Functions*

i) *Field Name*: select LrgTrees from the drop-down list.

ii) *Weight*: type "1.00" in the text box.

iii) *Type* select: Both from the drop-down list.

iv) *Field Name*: select homedens from the drop-down list. homedens is the number of homes in each stand. To add additional *Objective Functions* click the **Add Objective** button, and select the *Field Name* from the pull-down menu. If you change your mind and want to remove an objective, simply click on either the *Field Name* or the *Weight* for the object you would like to remove (it will be highlighted), then click the **Delete Objective** button.

v) *Weight*: type "10.00" in the text box.

vi) *Type*: select Both from the drop-down list.

e) Set the *Treatment Thresholds*

i) *Field Name*: select FireType from the drop-down list. FireType is the crown fire activity code from a fire behavior run completed in FlamMap, where 0 is no fire, 1 is surface fire, 2 is passive crown fire, and 3 is active crown fire.

ii) *Operator*: select ≥ (greater than) from the drop-down list.

iii) *Value*: type “1.00” in the text box.

iv) *Field Name*: select Slope_deg from the drop-down list. Slope_deg is the average slope of the stand in degrees.

v) *Operator*: select ≤ (less than) from the drop-down list.

vi) *Value*: type “30.00” in the text box.

f) Set the *Constraints*

i) *Field Name*: select Area_ha from the drop-down list. Area_ha is the area of each stand in hectares.

ii) *Min Value*: type “5,000.00” in the text box.

iii) *Max Value*: type “10,000.00” in the text box.

g) Click **Run** to run LTD.

2) Open the aggregated2_Summary.txt file by clicking the **View Summary** button on the **LTD Complete** window (fig. 5-24). Notice the multiple *Objectives* and *Thresholds* are now listed with their weights. The *Max Objective Value* is the sum of LrgTrees*1 + homedens*10 for all stands within the patch.

```
LTD run generated: Friday, September 21, 2012 at 08:42:44
Objectives: (2)
  LrgTrees  1.000000
  homedens  10.000000

Thresholds: (2)
  FireType  >  1.000000
  Slope_per  <  30.000000

Constraints: (1)
  Acres  3800.000000 - 4200.000000

obj_dir 1
check_avail 1
write_debug_file  0
sort_output_file  1
results_headers 0
aggregate_soln  1


Results
Max Objective Value: 146139.000000
                                Constraint Max      Constraint Max Treat
                    Acres         22531.000000          4193.000000

0.34 seconds runtime
```

Figure 5-24—Summary file for a run with multiple Objectives and Thresholds.

3) Map the solution (fig. 5-25).

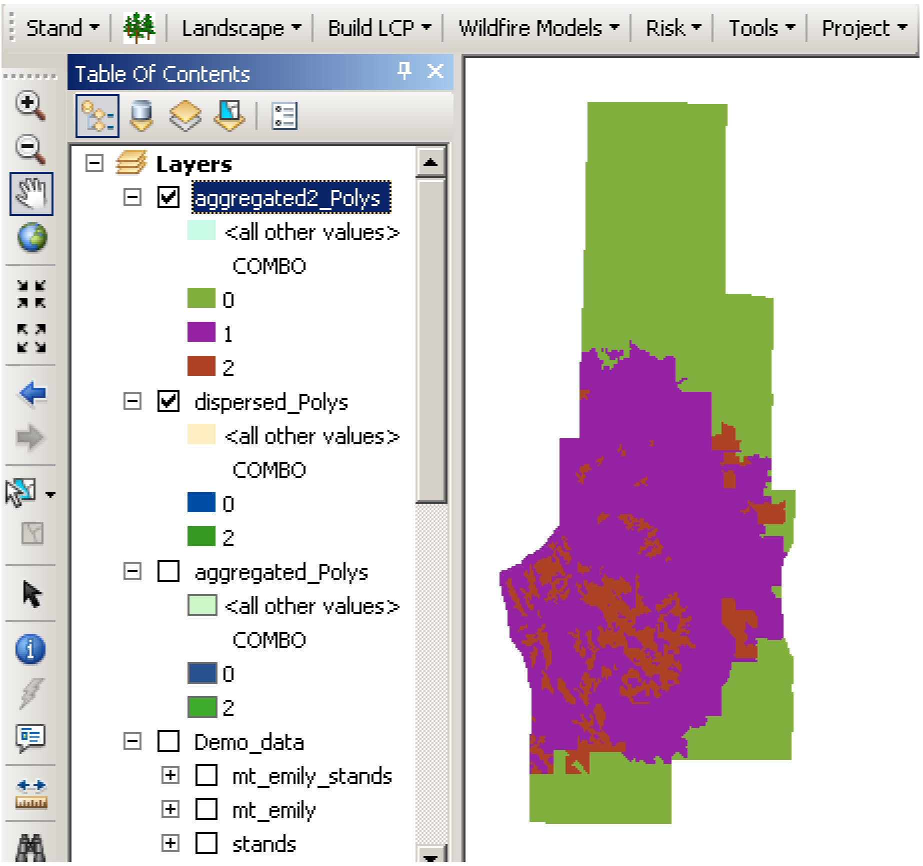


Figure 5-25—Aggregate2 solution with multiple objectives and constraints.

4) Open the attributes table (right-click on the layer in the ArcMap table of contents→select *Open Attributes Table* from the menu) (fig. 5-26). Notice that the OBJ_VAL values represent the weighted values (i.e. LrgTrees*1 + homedens*10) rather than the raw sum.

aggregated2_Polys

FID	Shape	Stand_ID	X	Y	Available	LrgTrees	homedens	FireType	Slope_per	Acres	OBJ_VAL	IN_PATCH	DO_TREAT	COMBO
915	Polygon	1058	415616.875	5031086.5	1	274	1	2	54	9	284	1	0	1
305	Polygon	497	414621.15625	5036967.5	1	225	1	2	53	13	235	1	0	1
431	Polygon	518	414875.40625	5036820	1	173	1	2	65	14	183	1	0	1
407	Polygon	457	414496	5037575	1	132	1	2	64	9	142	1	0	1
301	Polygon	490	414801.09375	5037082.5	0	126	1	2	56	9	136	1	0	1
459	Polygon	553	414891.78125	5036387	1	93	1	2	59	10	103	1	0	1
354	Polygon	377	414690.28125	5038226	0	48	1	2	40	16	58	1	0	1
1081	Polygon	285	414819.5625	5038950	1	37	1	2	50	5	47	1	0	1

Figure 5-26—Attributes table for the aggregate2 run.

Dispersed iterative treatment with multiple thresholds—

This example enables iteration, and will build treatment plans to reduce fire hazard (defined by the FireType data). Each iteration will include stands totaling up to about 10% of the landscape (4,000 ac), where flame length is greater than or equal to 8 ft, and non-surface fire triggers the need for treatment. Iterations will be completed until all stands in the landscape that meet the treatment threshold are included. Because fire hazard is the *Objective Function*, this will be a fuel treatment prioritization plan.

1) Return to the LTD form (fig. 5-27).

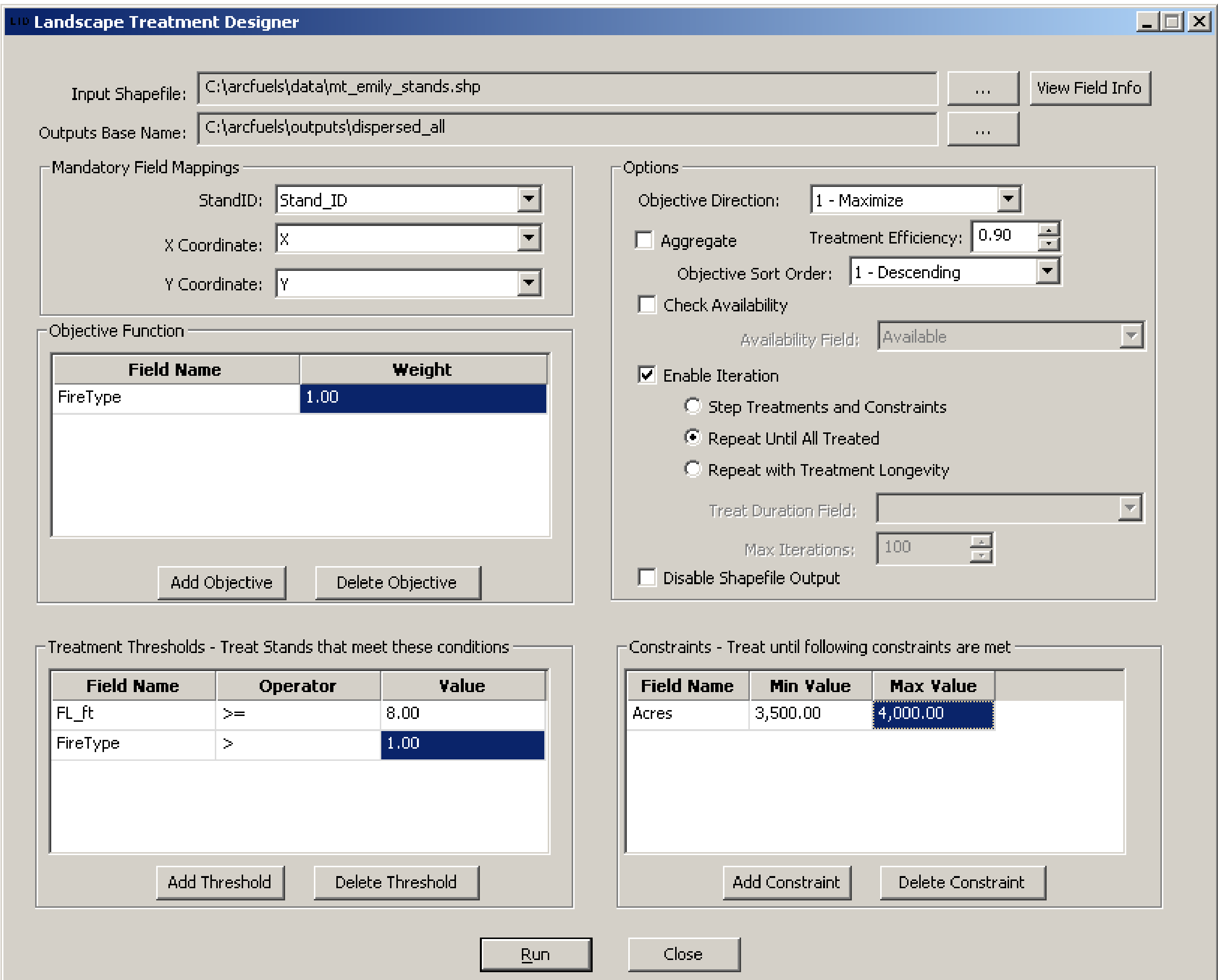


Figure 5-27—LTD setup to create a multi entry treatment prioritization plan.

a) Enter the *Outputs Base Name* "dispersed_all" by using the navigation button, and save it in the LTD folder. This will create a standard prefix for the output files.

b) Set the *Mandatory Field Mappings*

i) *StandID*: select Stand_ID from the drop-down list.

ii) *X Coordinate*: select X from the drop-down list.

iii) *Y Coordinate*: select Y from the drop-down list.

c) Set the *Options*

i) *Objective Direction*: select 1 – Maximize from the drop-down list.

ii) Do not select the *Aggregate* option.

iii) *Treatment Efficiency*: use the arrow buttons to set it to 0.9.

iv) Do not select the *Check Availability* option.

v) Select the *Enable Iteration* option.

vi) Do not select the *Disable Shapefile Output* option.

d) Set the *Objective Functions*

i) *Field Name*: select FireType from the drop-down list.

ii) *Weight*: type “1.00” in the text box.

e) Set the *Treatment Thresholds*

i) *Field Name*: select FL_ft from the drop-down list.

ii) *Operator*: select ≥ (greater than or equal to) from the drop-down list.

iii) *Value*: type “1.00” in the text box.

f) Set the *Constraints*

i) *Field Name*: select Area_ha from the drop-down list. Area_ha is the area of each stand in hectares.

ii) *Min Value*: type “1,500.00” in the text box.

iii) *Max Value*: type “2,000.00” in the text box.

g) Click **Run** to run LTD.

5) Open the dispersed_all_Results.csv file within the outputs folder of the ArcFuels directory (fig. 5-28). The results file lists all the iterations as separate line items with the inputs, and the final value max_value. Solutions with the highest max_value values are a higher priority for treatment. Notice the last three solutions are not able to treat the 4,000 ac target.

Acres_Min	Acres_Max	FL_ft(>=)	FireType(>)	FireType	max_value	Total_Acre	Treat_Acres
3500	4000	8	1	1	199	40383	4000
3500	4000	8	1	1	96	36383	4000
3500	4000	8	1	1	116	32383	4000
3500	4000	8	1	1	284	28383	4000
3500	4000	8	1	1	284	24383	4000
3500	4000	8	1	1	276	20383	4000
3500	4000	8	1	1	316	16383	4000
3500	4000	8	1	1	116	12383	1165
3500	4000	8	1	1	14	11218	147
3500	4000	8	1	1	0	11071	0

Figure 5-28—Results file, showing the different treatment solutions. Those with a higher max_value values are a higher priority for treatment.

6) Map the solution (fig. 5-29). There are nine treatment solutions, the COMBO field is the sum of DoTreat and the iteration, so it starts as two. When COMBO is zero this means the stand did not meet the treatment thresholds.

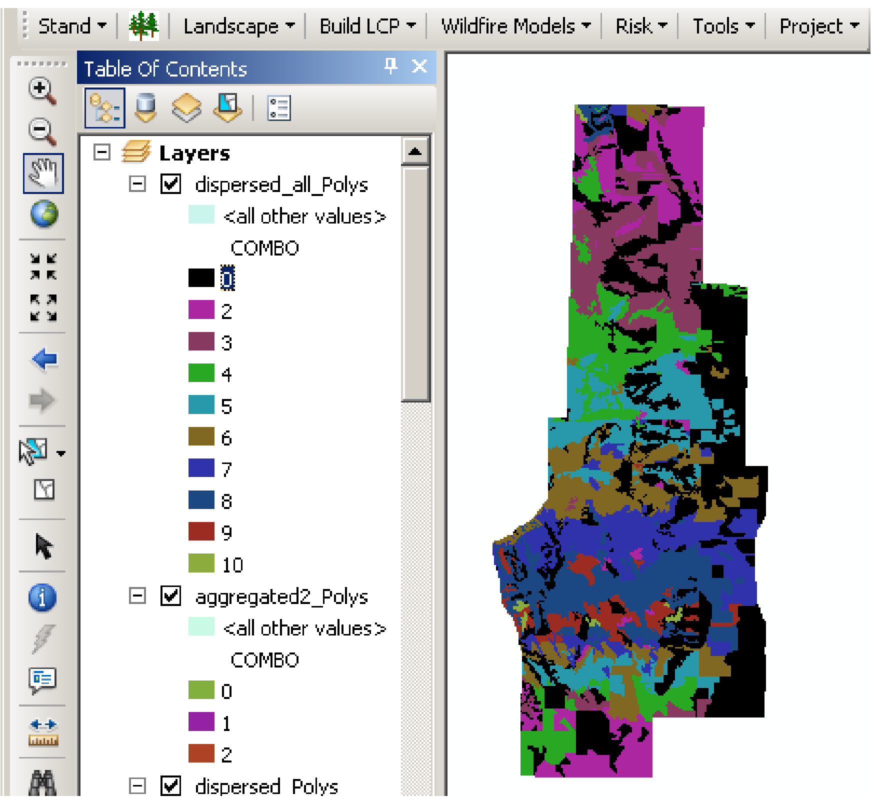


Figure 5-29—Dispersed solution, with multiple objectives and constraints.

7) Close LTD. You are done with the tutorial. Congrats!

6. ArcGIS – ArcMap10

This section is meant to be a very brief introduction to file types and processes in ArcMap. ArcMap can be considered one of those lifelong learning process tools. This section is by no means all inclusive, and only presents one way of completing tasks in the program. There are many ways to accomplish the same task; if you are more familiar with another method, by all means do what you know!

Program Overview

ArcMap is the main component of ESRIs ArcGIS collection of geospatial processing programs. Other ArcGIS programs include ArcCatalog, ArcGlobe, and ArcScene. ArcMap is used primarily to view, edit, create, and analyze geospatial data and create maps. ArcCatalog would be the second most used component and is used primarily for file organization.

ArcMap Fundamentals

Feature classes (shapefile)—

A shapefile (*.shp) is a format for storing the location and attribute information of geographic features. A shapefile can be represented by points, lines, or polygons (fig. 6-1). Typically features such as roads and streams are line files, plot or structure locations are often represented by points, and any area feature such as forest stand, vegetation unit, or wildlife habitat are shown with polygons.

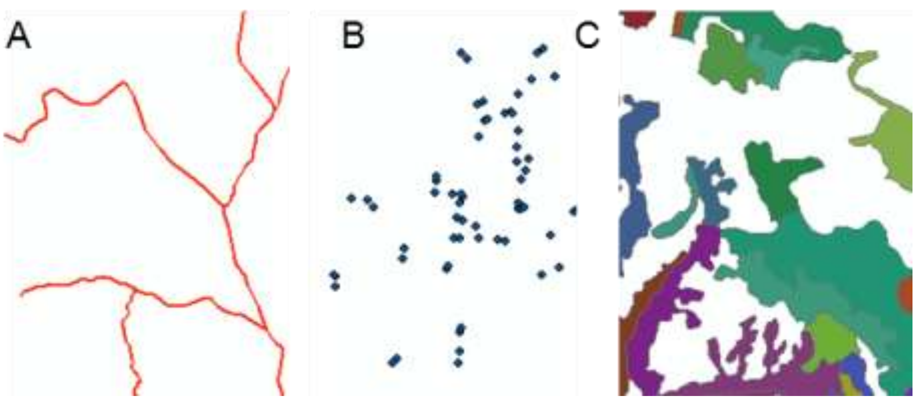
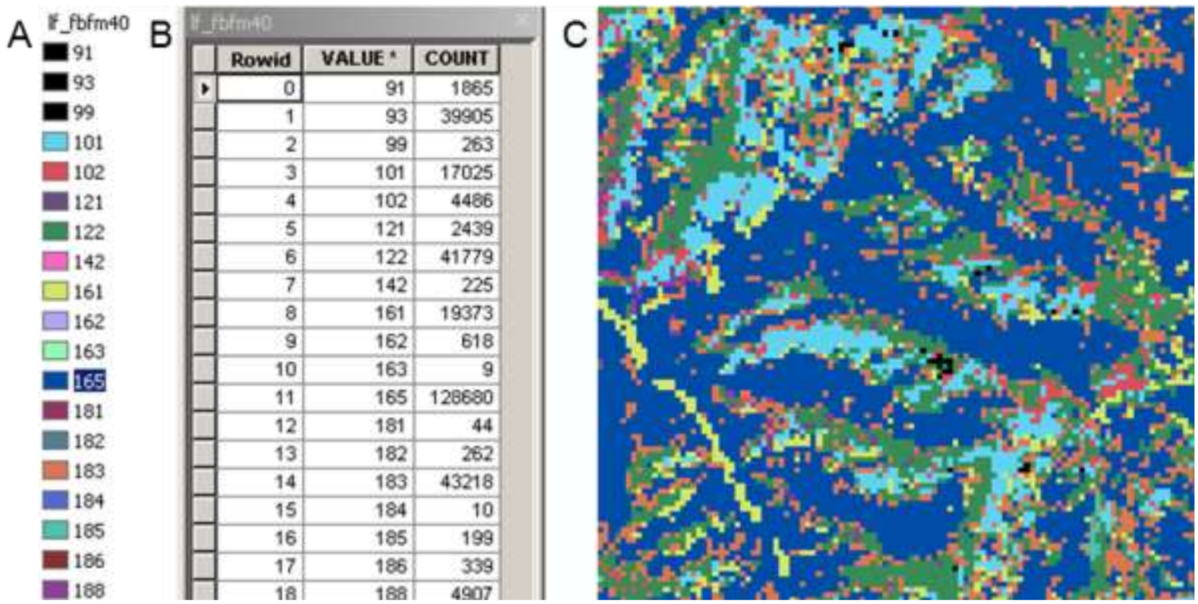


Figure 6-1—Example shapefile types: (A) line file of roads, (B) (C)

When looking in Windows Explorer a shapefile is comprised of 7 parts (*.dbf, *.prj, *.sbn, *.sbx, *.shp, *.shp.xml, and *.shx). All parts are required to map the shapefile. If you are transferring files between folders or computers it is recommended to use ArcCatalog rather than just copying and pasting files to move them in Windows Explorer.

Rasters—

A raster, also known as a grid, consists of a matrix of cells (or pixels) organized into rows and columns, where each cell contains a value representing information, such as fuel model, elevation, etc. (fig. 6-2). Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps. Rasters contain either discrete (e.g., fuel model) or continuous information (e.g., elevation) or are simply pictures (ESRI 2009).



Rowid	VALUE *	COUNT
0	91	1865
1	93	39905
2	99	263
3	101	17025
4	102	4486
5	121	2439
6	122	41779
7	142	225
8	161	19373
9	162	618
10	163	9
11	165	128680
12	181	44
13	182	262
14	183	43218
15	184	10
16	185	199
17	186	339
18	188	4907

Figure 6-2—Example of fuel model raster display legend (A), attributes (B), and raster (C).

When adding raster data to your ArcMap table of contents, you may be prompted to build pyramids. It is not critical to choose either *Yes* or *No*; however, selecting *Yes* will speed up viewing the data at varying scales.

Multiple raster file types exist:

ASCII Raster– file extension *.asc (e.g., fuel_mdl.asc). ASCII file types are exported from fire behavior programs such as FlamMap and FARSITE and need to be converted to ESRI rasters before they can be viewed. ASCII raster names do not have a character limit, but it is good practice to keep names under 13 characters, as they will need to be shortened when converted to an ESRI raster.

ERDAS Imagine – file extension *.img (e.g., fuel_model.img). Imagine file types can be produced using the program ERDAS imagine (burn severity data is often manipulated with this program). Fuels planners will likely not need to work with .img rasters. However, since it is the default output file type for many geoprocessing tools within ArcToolbox, it is important to be aware of this file type so that you erase the *.img before naming your ESRI raster files.

ESRI Raster– no file extension (e.g., fuel_mdl). ESRI girds are the typical file format used, native to ArcMap. ESRI rasters have a 13 character file name limit. There are two types of ESRI rasters, Integer and Float.

Integer- Discrete attributes for an integer raster are stored in an attribute table. Integer rasters can store only whole numbers; therefore all data to the right of the decimal point is lost when converted to an Integer. Summarizing data for NEPA, for example, can be achieved by exporting the attribute table of an integer raster to Excel.

Float- The cells in this type of raster do not fall neatly into discrete categories and therefore do not have an attribute table, the data are continuous. Float rasters can store numbers with decimal points. Burn probability is inherently a float raster because it is expressed as a fraction of 1, and therefore requires storage of decimal points. But float values can be converted to an integer for easy analysis, by multiplying the raster by 1000 (using the **Raster Calculator**), or reclassifying the raster into new categories.

Layers—

A layer file (*.lyr) can be used to group shapefiles and rasters. This can be very handy when adding the same data layers to multiple maps (fig. 6-3).

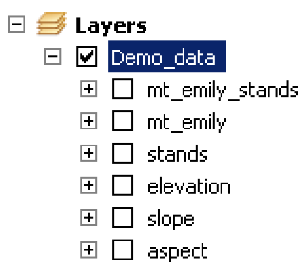


Figure 6-3—The demonstration data for ArcFuels10 is a layer file (“Demo_data”) comprised of many shapefiles and rasters.

Turning on and off Toolbars—

ArcMap comes with many pre-loaded toolbars. These can be turned on and off by opening the toolbar list (**ArcMap main menu→Customize→Toolbars**, fig. 6-4). Toolbars that are turned on have a check mark to the left.

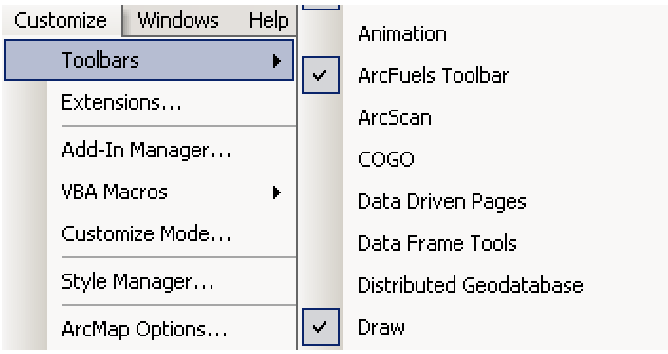


Figure 6-4—Turning on and off toolbars available in ArcMap. In this figure, the ArcFuels toolbar and Draw toolbar are turned on; the other toolbars are turned off.

Turning on and off Extensions—

As with toolbars, extensions can be turned on and off by opening the toolbar list (**ArcMap main menu→Customize→Extensions**, fig. 6-5). Extensions that are turned on have a check mark to the left. If an extension is not available, "(License not available)" will be to the right of the extension name. This means the extension was not loaded when ArcGIS was installed.

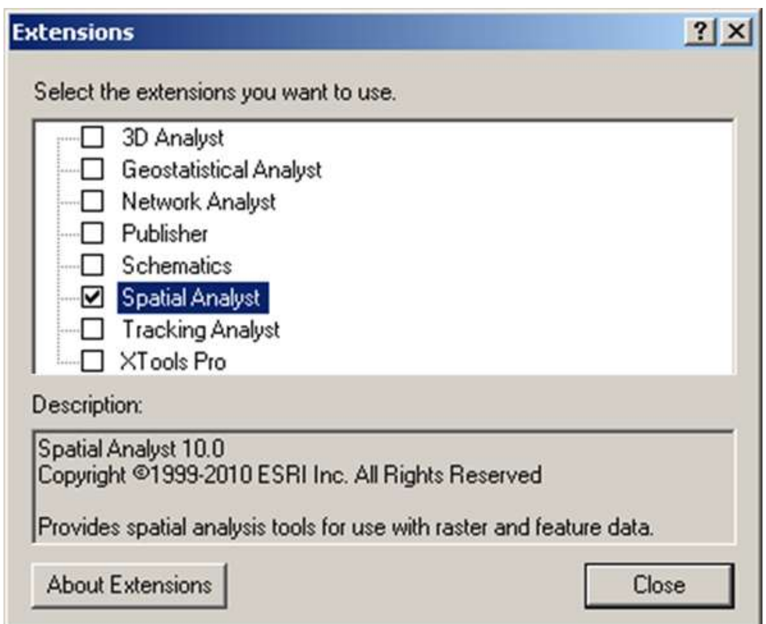


Figure 6-5—The Extensions window in ArcMap, showing the Spatial Analyst extension is available and turned on (box checked).

Opening and Docking ArcToolbox—

The ArcToolbox window is the central place where you find, manage, and execute geoprocessing tools. ArcToolbox contains forms for all the processing you will need for the ArcFuels tutorial exercises. ArcToolbox can be opened via the icon on the **Standard** ArcMap menu bar (fig. 6-6a), or from **ArcMap main menu→Geoprocessing→ArcToolbox**. The tools within the ArcToolbox all have hammers to the left (fig. 6-6a). Throughout this document, the location of tools will be shared via the path; for example the path to the **Create Feature Class** tool in Figure 6-6b is: **ArcToolbox→Data Management Tools→Feature Class→Create Feature Class**.

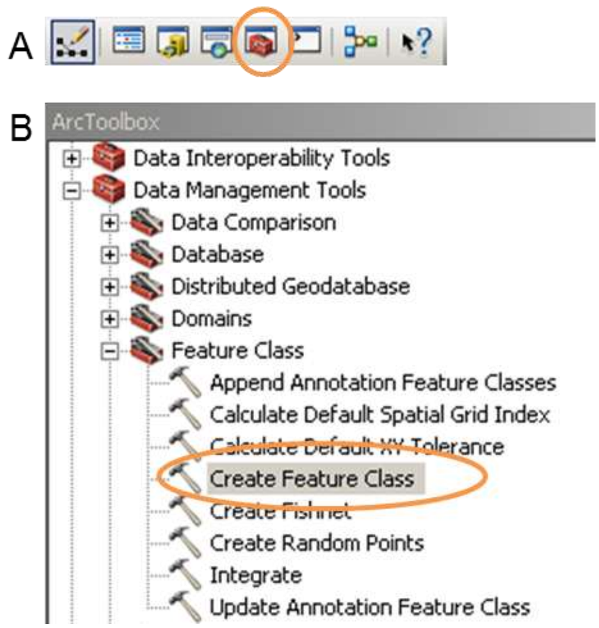


Figure 6-6—Opening ArcToolbox (A) and navigating to the Create Feature Class tool (B).

Docking the ArcToolbox can be a little tricky. With ArcToolbox open, click on the box to move it. Drag it to one of the blue arrows until that section of ArcMap turns blue then let go (fig. 6-7).

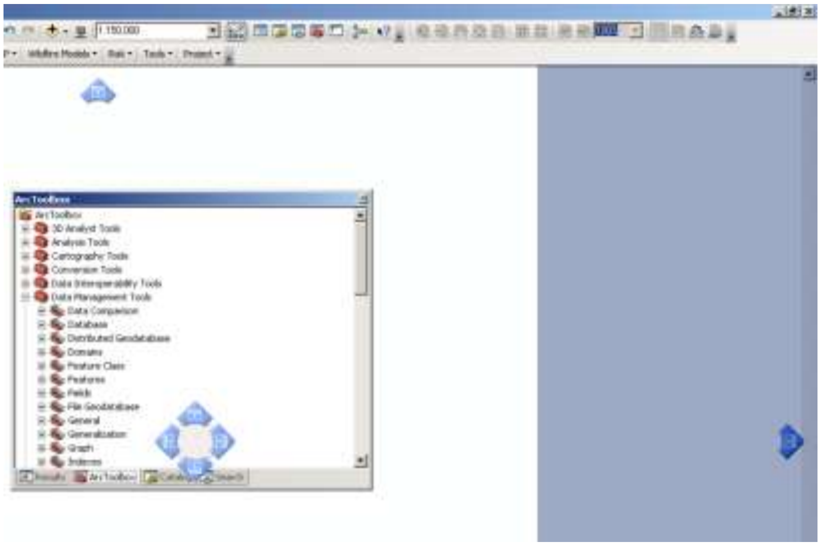


Figure 6-7—Docking the ArcToolbox.

Adding data to ArcMap—

The simplest way to add shapefiles and rasters to ArcMap is by using the **Add Data** button, which is part of the **Standard** toolbar (fig. 6-8a). When adding other types of data, such as base map data or XY coordinate data, you must use the main menu toolbar (**ArcMap main menu→File→Add Data**, fig. 6-8b).

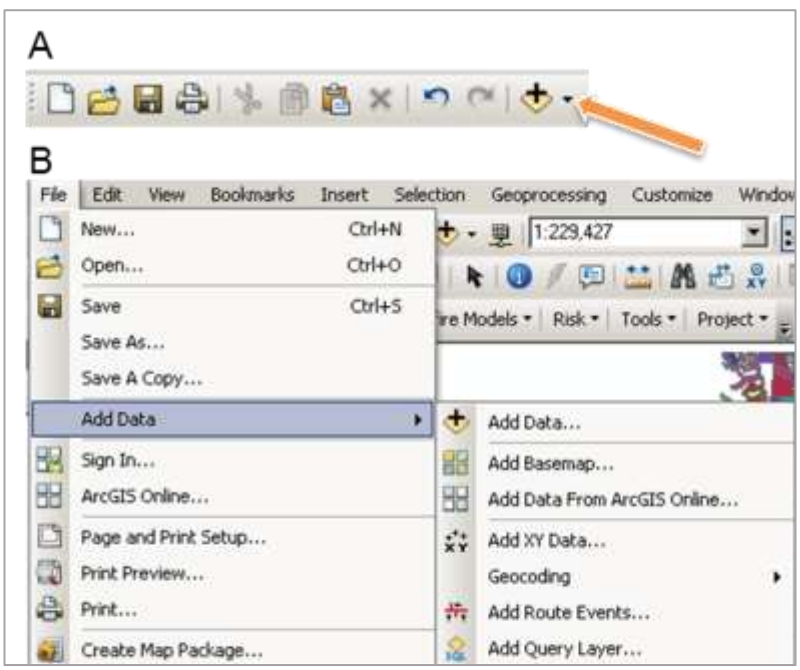


Figure 6-8—Adding data to ArcMap via the Add Data button (A), and via the add Add Data menu options (B).

When adding data, each file type is characterized by a different icon (fig. 6-9).

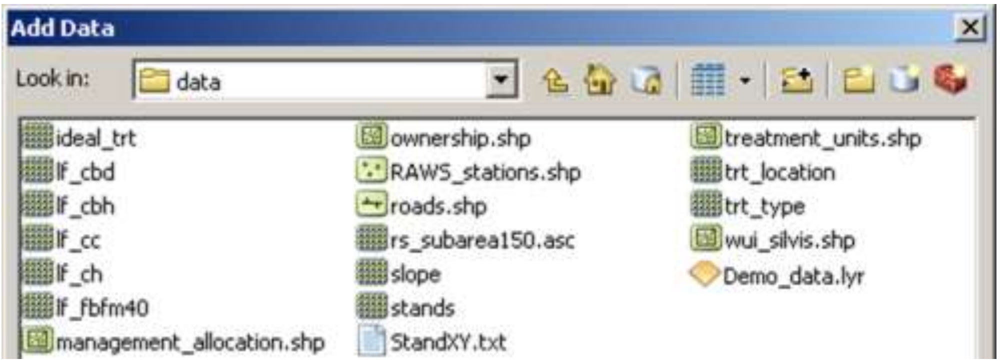


Figure 6-9—Data type icons where “ideal_trt” is a raster (raters with the *.asc extension are ASCII raster files and need to be converted to rasters for mapping in ArcMap), “ownership” is a polygon shapefile, “RAWS_staions” is a point shapefile, “roads” is a line shapefile, and “Demo_data.lyr” is a layer file.

Projection (a.k.a spatial reference, or coordinate system)—

After you add your data and before beginning a project, it is important to ensure that all of your data and data frame are in the same coordinate system (a.k.a spatial reference, or projection). Some processes may function properly with varying projections, but others will not; so it is best to eliminate a projection issue as a potential source of error later in your analysis. The projection of your data frame is established when the first file is added to the table of contents, but can be changed at any time via the **Data Frame Properties** window (**ArcMap main menu→View→Data Frame Properties...→Coordinate System**, fig. 6-10).

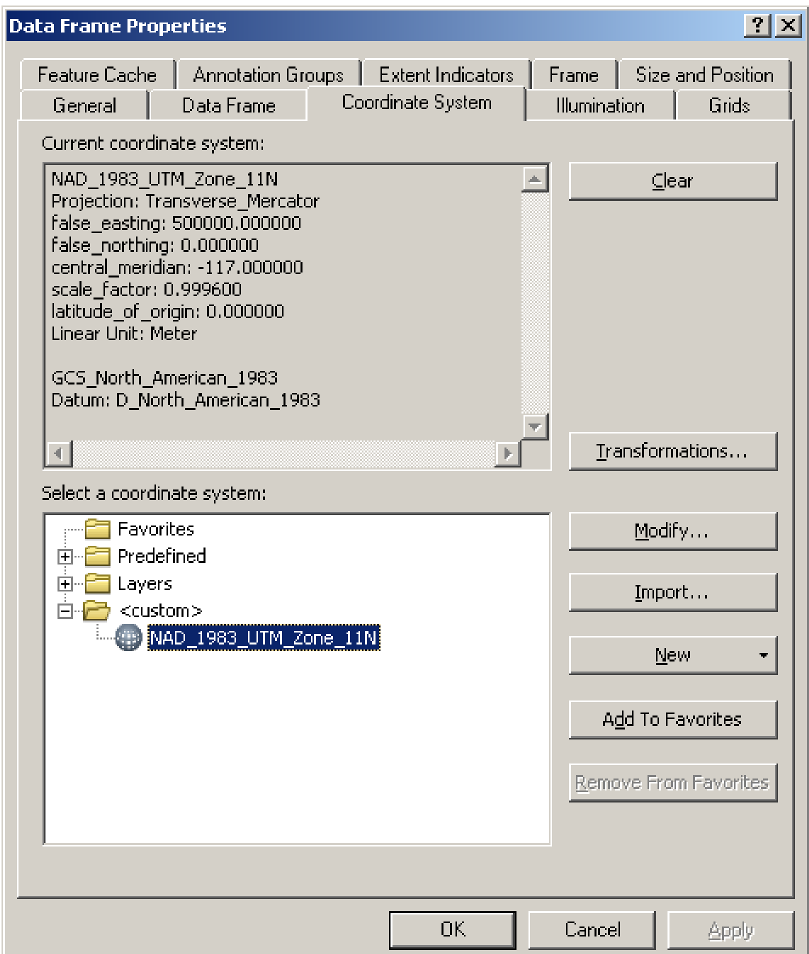


Figure 6-10—Data Frame Properties window showing the current map coordinate system.

If you have data loaded in ArcMap with multiple projections, they will be listed in the box like the “NAD_1983_UTM_Zone_11N” in figure 6-8. If more than one exists, you should re-project your data as a single projection. To apply a single projection, highlight it and click **OK**.

The **Data Frame Properties** form (**ArcMap main menu→View→Data Frame Properties...→Coordinate System**, fig. 6-11) can be used to check the projection for the layers r (shapefile or raster) in your map. Under the *Select a coordinate system* box, expand the **Layers** selection, and then expand each of your data layers.

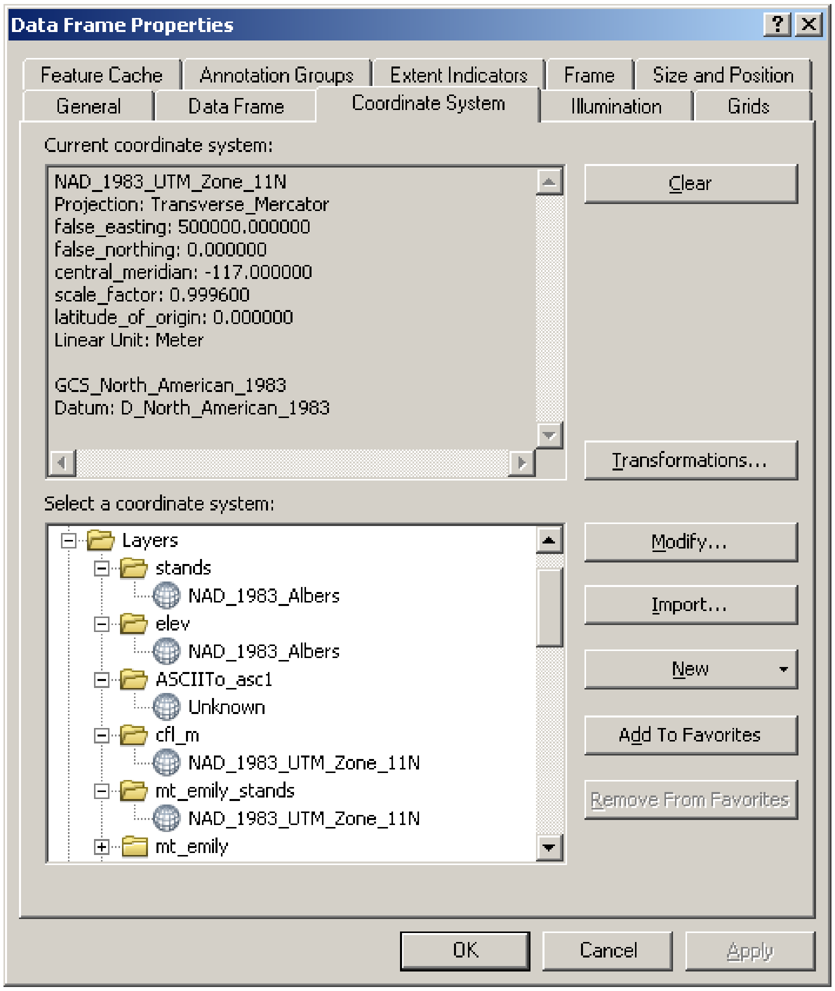


Figure 6-11—Identifying the projection for all the layers in your ArcMap. Notice the data layers are in three different projections. When starting a project, decide on a single projection, define unknown files, and re-project those in a different projection so they are all the same.

When the projection is unknown, the **Define Projection** tool (**ArcToolbox→Data Management Tools→Projection and Transformations→Define Projection**) is used to define the projection (fig. 6-12). There are two options for selecting the appropriate projection: **Select...** and **Import...** (fig. 6-12). **Select...** allows you to choose from pre-defined geographic and projected coordinate systems. **Import...** allows you to select the projection from another layer.

When defining the projection for a file, you must know what the projection should be. If not, the data will not be mapped correctly.

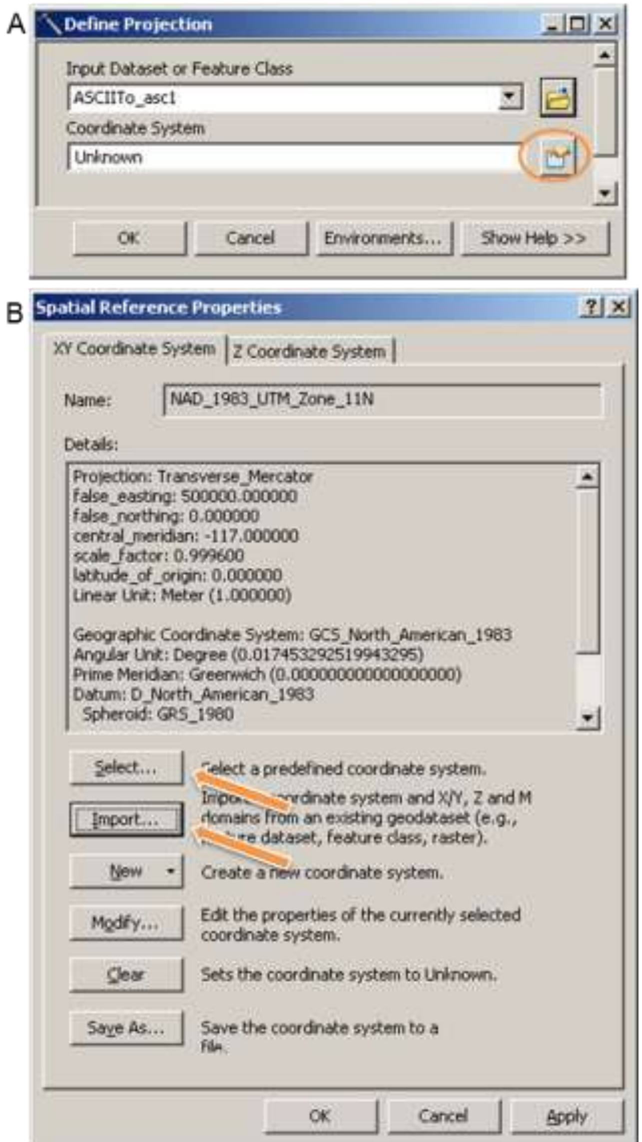


Figure 6-12—Defining the projection for a raster. When the button to the right of the Coordinate System box is pressed, the Spatial Reference Properties form opens, allowing you to Select... or Import... the correct projection.

If your data is already projected, but is not in the correct projection, the **Project** tool (**ArcToolbox→Data Management Tools→Projection and Transformations→Feature→ Project**, fig. 6-13a) needs to be used for shapefiles; and the **Project Raster** tool (**ArcToolbox→Data Management Tools→Projection and Transformations→Raster→Project Raster**, fig. 6-13b) needs to be used for rasters.

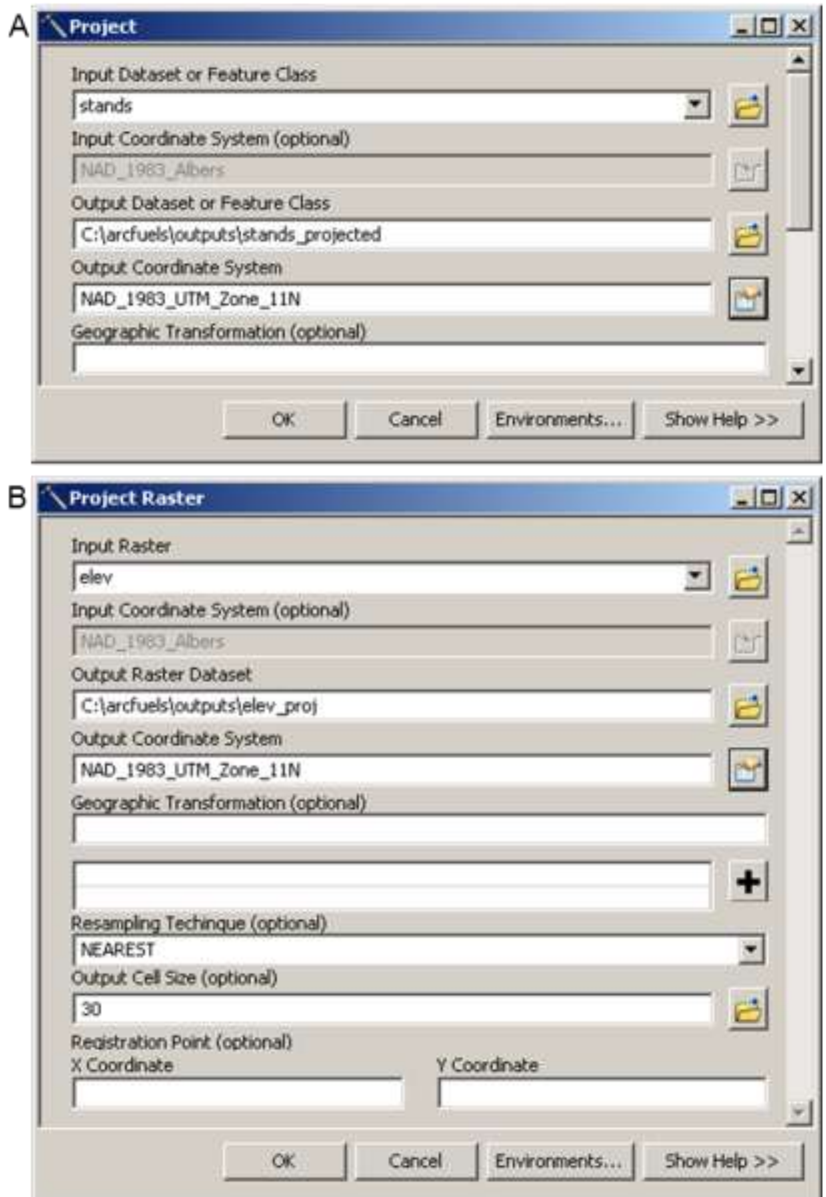


Figure 6-13—Forms used to re-project shapefiles (A), and rasters (B) in the correct projection for the Mt. Emily demonstration data.

Sometimes when you re-project raster data, the output cell size changes. Check the output cell size in the form, and change it if necessary to maintain the original size.

Working with Shapefiles

Changing the display of a shapefile—

To change the display of a shapefile, right-click on the layer in the ArcMap table of contents and select **Properties** from the menu. Next, select the **Symbology** tab (fig. 6-14). Data can be displayed by *Features*, *Categories*, *Quantities*, *Charts or Multiple Attributes* (fig. 6-15). Features is used to apply one style to all entries. Categories is used to assign different symbology based on unique values in the attribute value field (in fig. 6-14a this would be forest type). Quantities can be used to ramp (display from high to low), or classify continuous data into categories for display. Charts.... Multiple Attributes can be used to display up to three data fields at once.

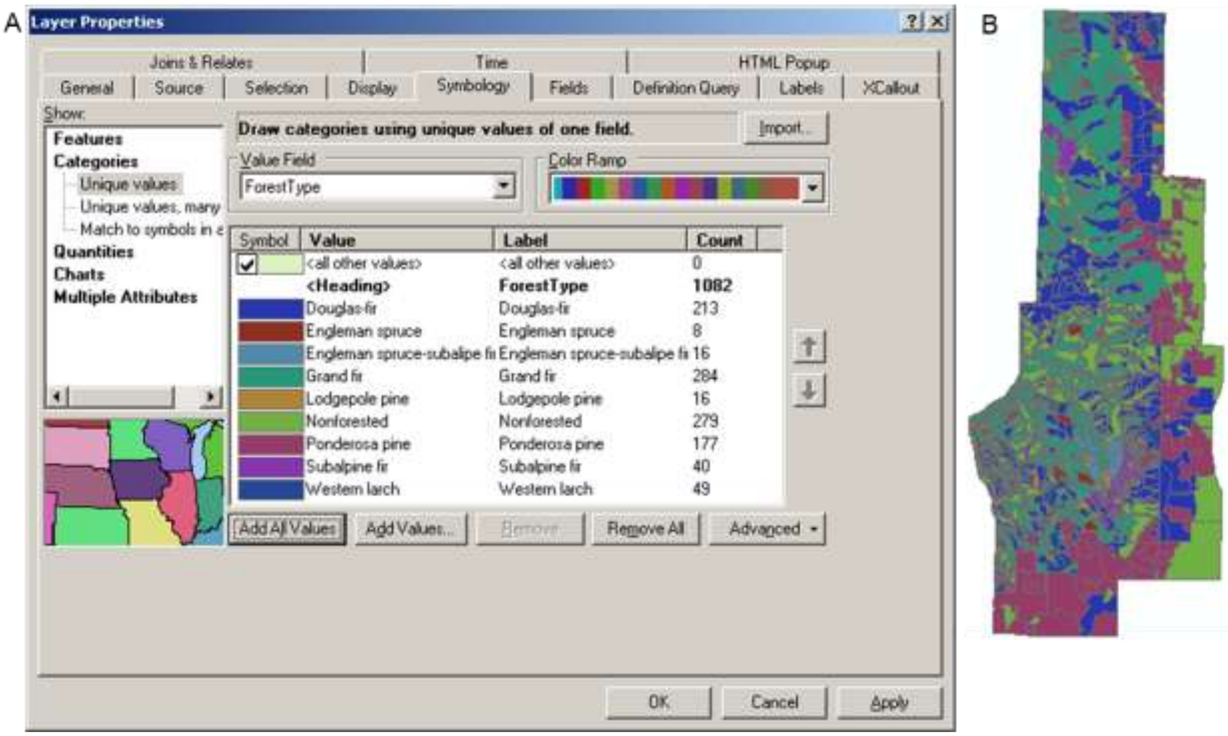


Figure 6-14—Changing the symbology of the stand shapefile to map forest type (A) and the resulting map (B).

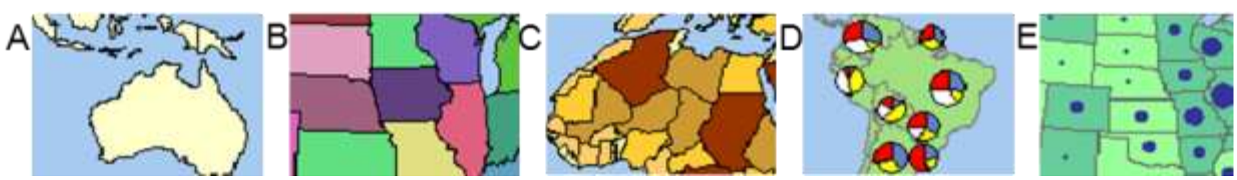


Figure 6-15—Example displays for Features (A), Categories (B), Quantities (C), Charts (D), and Multiple Attributes (E).

Shapefile attributes – Adding an attribute field—

Open the attribute table for the mt_emily_stands layer by right-clicking on the layer name in the ArcMap table of contents and then select the **Open Attributes Table** from the menu that opens. With the attributes table open, click on the **Table Options** button (fig. 6-16), and select **Add Field...** from the menu.

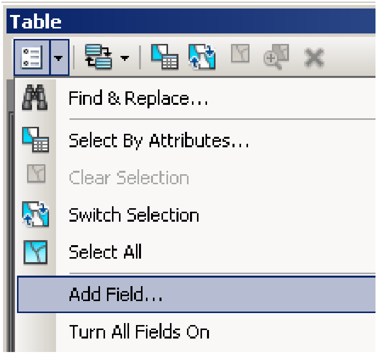


Figure 6-16—Adding a field to the attribute table.

Next, select the type of field you would like: short integer, long integer, double, float, text, or date (fig. 6-17). Integer fields are whole numbers, like 2 or 182; a short integer is any number between -32,768 and 32,767, and a long integer is a number between -2,147,483,648 to 2,147,483,647. Floats can only handle positive numbers with decimal places. Double can handle negative and positive numbers.

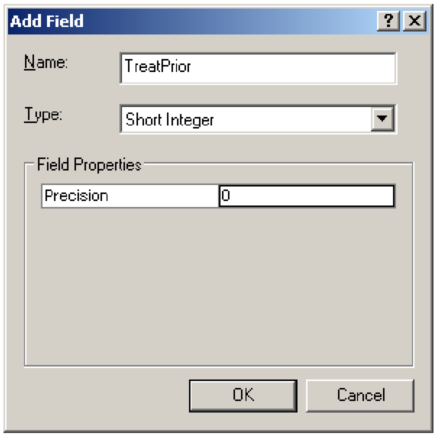


Figure 6-17—Adding a short integer field to assign treatment priorities to the stand shapefile.

Attribute field names can only be 10 characters long.

Shapefile attributes – Adding information in an editing session—

To start editing, right-click on the shapefile name in the ArcMap table of contents, and select **Edit Feature→Start Editing**. After you open the attributes table, you can simply start typing in the attributes table (fig. 6-18).

Ownership	TreatPrior
Wallowa-Whit	1
Wallowa-Whit	2
Wallowa-Whit	3
Wallowa-Whit	4
Wallowa-Whit	0
Wallowa-Whit	0
Wallowa-Whit	0

Figure 6-18—Typing in priority values in the attributes table while editing is turned on.

Shapefile attributes – Adding information outside of an editing session—

To update values in an attributes table outside of an editing session, the **Field Calculator** form is used. To open the form, right-click on the attribute field of interest, and select **Field Calculator...** from the menu (fig. 6-19a). This will open the **Field Calculator** form where the desired value can be typed (6-19b).

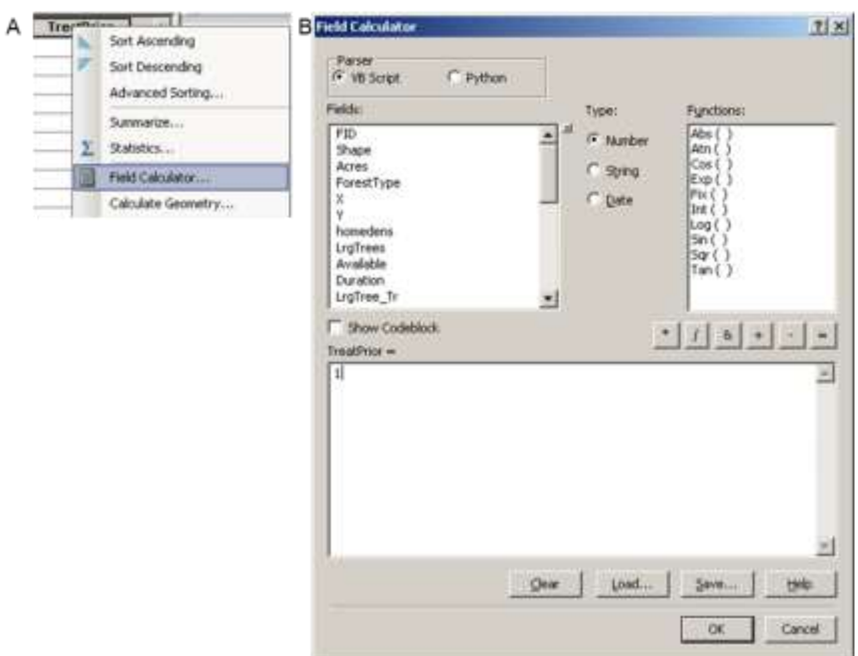
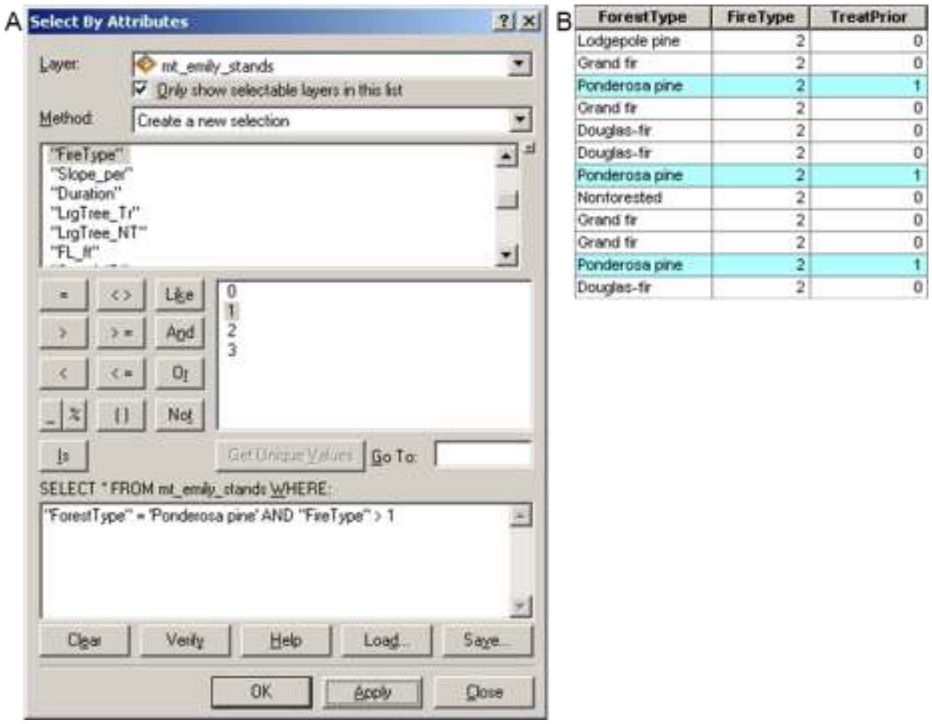


Figure 6-19—The field calculator location (A), and form (B).

When using the Field Calculator to update text fields, the text needs to be within single quotations, 'high'.

This option of updating values is most useful when combined with selecting multiple fields at once to assign values. For example, if the highest priority treatments are to occur in ponderosa pine stands with passive or active crown fire, a selection can be made to only apply a priority value of "1." The **Select By Attributes** form (**ArcMap main menu→Selection→ Select By Attributes**) is used to complete this selection (see fig. 6-20 for the selection criteria).



ForestType	FireType	TreatPrior
Lodgepole pine	2	0
Grand fir	2	0
Ponderosa pine	2	1
Grand fir	2	0
Douglas-fir	2	0
Douglas-fir	2	0
Ponderosa pine	2	1
Nonforested	2	0
Grand fir	2	0
Grand fir	2	0
Ponderosa pine	2	1
Douglas-fir	2	0

Figure 6-20—Selecting polygons by their attributes to create a priority ranking for all stands in Mt. Emily (A), and the selected fields priority (B).

Shapefile attributes – Calculating the geometric area—

If you want to determine the area of the individual polygons in a shapefile, you can calculate the area using the **Calculate Geometry** form. To do this, add an attribute field to the attributes table. You have four choices: short integer, long integer, double, or float. If you want the precise area, select double or float. If you are not concerned about the information to the right of the decimal point, select short integer or long integer, depending on the size of your individual polygons and your area units; most often a short integer is fine, but selecting long integer is also an option. To open the **Calculate Geometry** form (fig. 6-21), right-click on the attribute field you want to calculate the area to; then, select **Calculate Geometry** from the menu. Finally, select the *Units* you would like for the calculation.

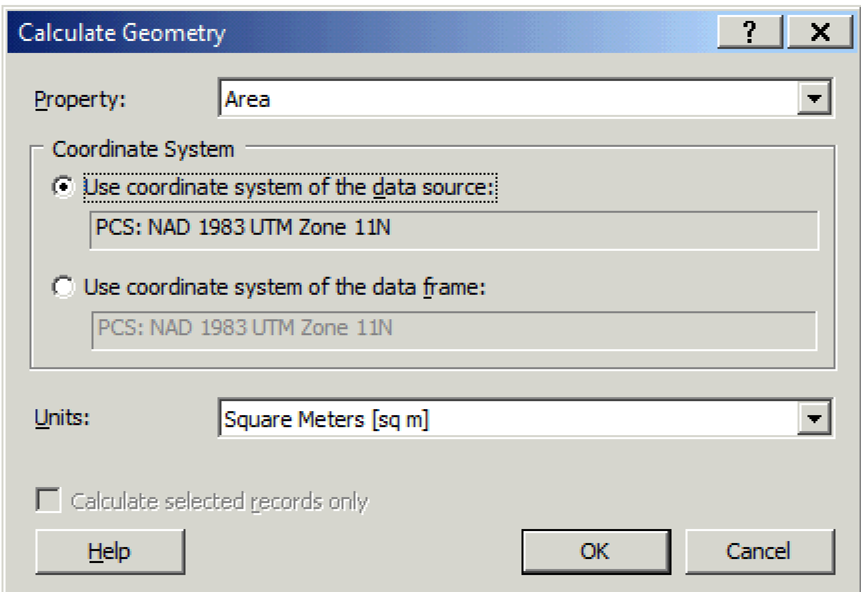


Figure 6-21—Calculating the area for all polygons in acres.

Shapefile attributes – Calculating the X and Y coordinates—

If you want to determine the X and Y coordinates for individual polygons in a shapefile, you can calculate them using the **Calculate Geometry** form. The centroid is the geometric center of the polygon. To do this, first add a double or float attribute field to the attributes table. To open the **Calculate Geometry** form (fig. 6-22), right-click on the attribute field you want to calculate the centroid coordinate for; then, select **Calculate Geometry** from the menu. Select <u>X Coordinate of Centroid</u> as the *Property* type from the drop-down list. Then choose your *Units*

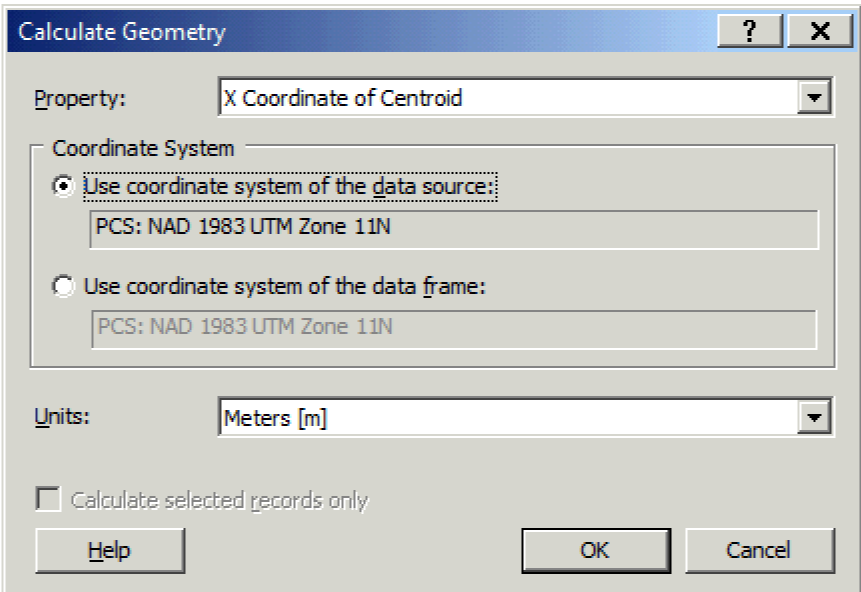


Figure 6-22—Calculating the X-centroid coordinate in meters for a shapefile.

This form can also be used to calculate the X-Y coordinates for points.

Creating a new shapefile—

You can create new shapefiles in ArcCatalog, or with the **Create Feature Class** tool (**ArcToolbox→Data Management Tools→Feature Class→Create Feature Class**, fig. 6-23). With the **Create Feature Class** tool, you define the name, location, type (point, line, or polygon), and projection. The tool will create the new shapefile, and add it to your map. At this point, there will be nothing to see until you edit the shapefile (see editor information below).

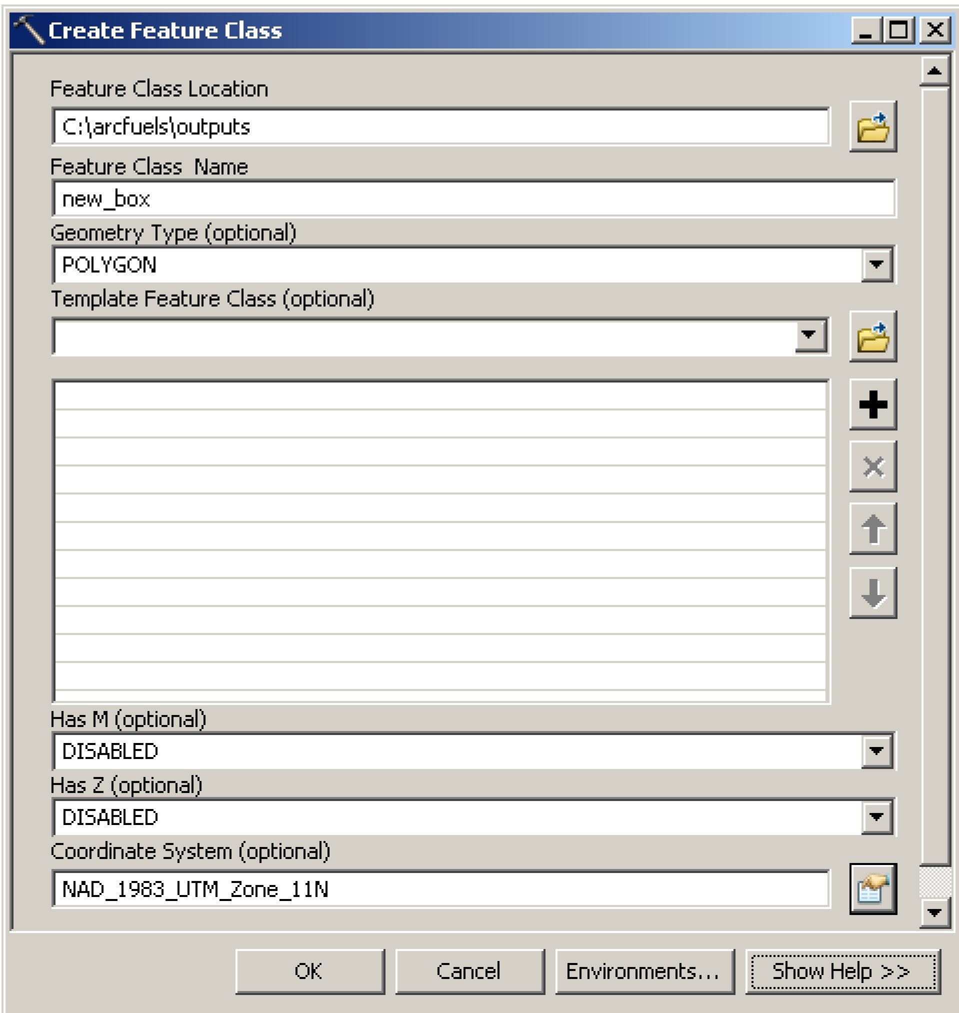


Figure 6-23—Creating a new polygon shapefile.

Editing shapefiles – Create a rectangular polygons in a shapefile—

There are many components to editing. Please read the **Editor** documentation in ArcGIS Desktop Help for more information about all the editing options that are available. The next few steps will focus on creating a simple rectangular shapefile that can be used to define the fire behavior modeling extent of a project.

Go to the **Editor** toolbar **Editor→Start Editing**; then, select the new_box layer and click **OK** (fig. 6-24).

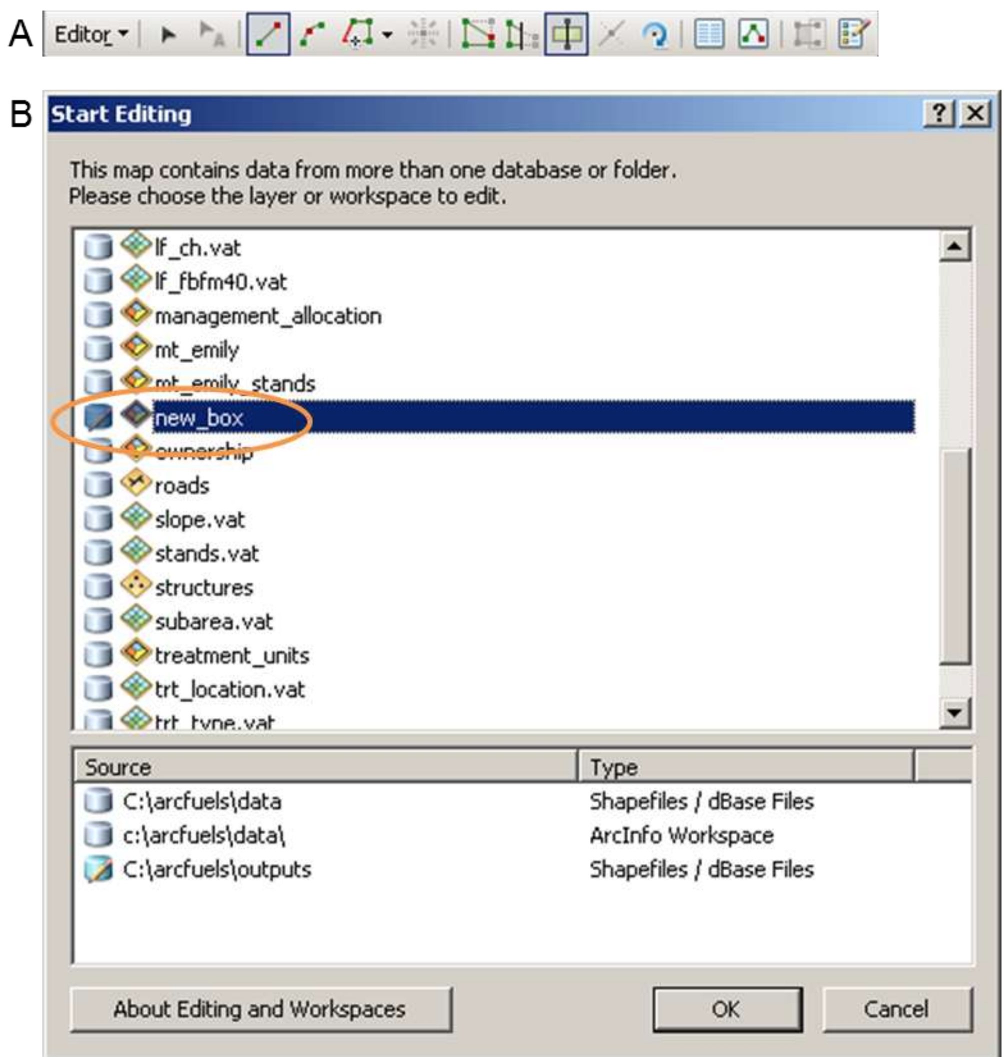


Figure 6-24—Starting editing for a specific shapefile.

This will open a new editing window (fig. 6-25). Select the the new_box shapefile, then select Rectangle under the *Construction Tools* heading (fig. 6-25).

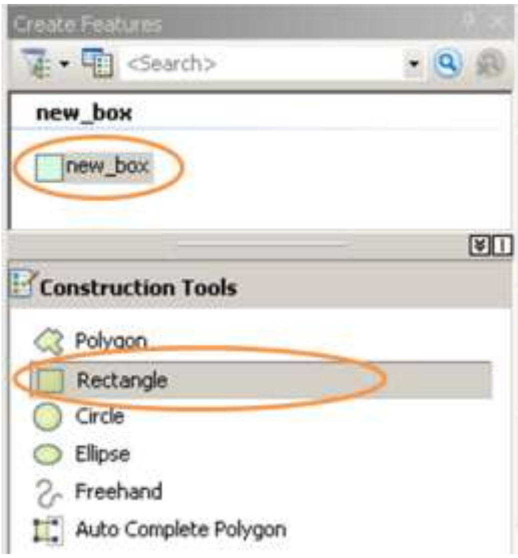


Figure 6-25—Editing the new shapefile to make a rectangle.

Using the crosshairs, create the rectangle (fig. 6-26a). To create straight lines, you can right-click then select **Direction,** Then, type in the direction you want the line to go while creating your rectangle (fig. 6-26b).

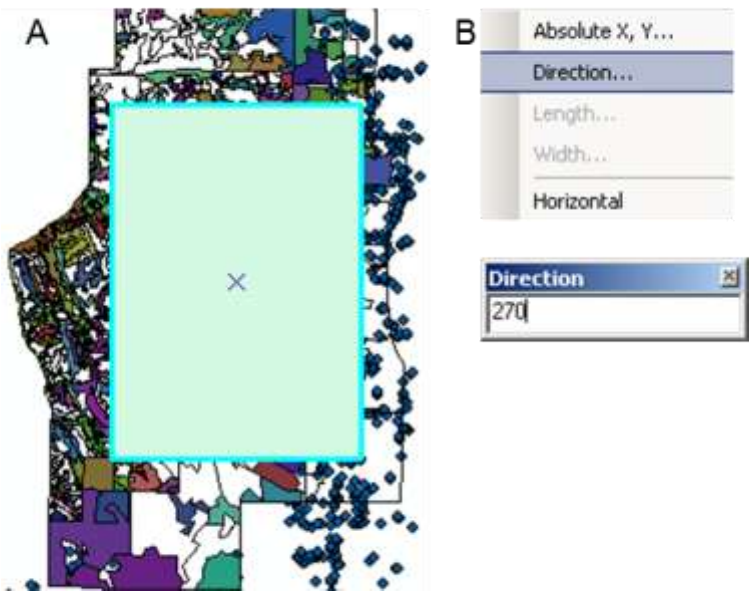


Figure 6-26—Creating a rectangular polygon while editing.

To save the new polygon, save your edits (**Editor→Save Edits**). When you have finished editing, stop the editing session (**Editor→Stop Editing**).

If you do not like the shape you made, select it and hit delete. You can also make multiple shapes of the same or different types in a single polygon.

Editing shapefiles – Modifying polygon shapes—

Only a couple editing options will be shown below, but is not all inclusive. There are many components to editing. Please read the **Editor** documentation in ArcGIS Desktop Help for more information about all editing options that are available.

Start an editing session for the new_box shapefile polygon. Select the polygon by clicking on it with the **Edit Tool** .

To divide the polygon into parts, select the **Cut Polygons** tool . Then draw a line that starts and ends outside of the polygon to cut it where you want (fig. 6-27). This tool can be used to divide the polygon in half (A), or into many parts (B). Once your "cutting" line(s) are complete, double click to cut the polygon (B).

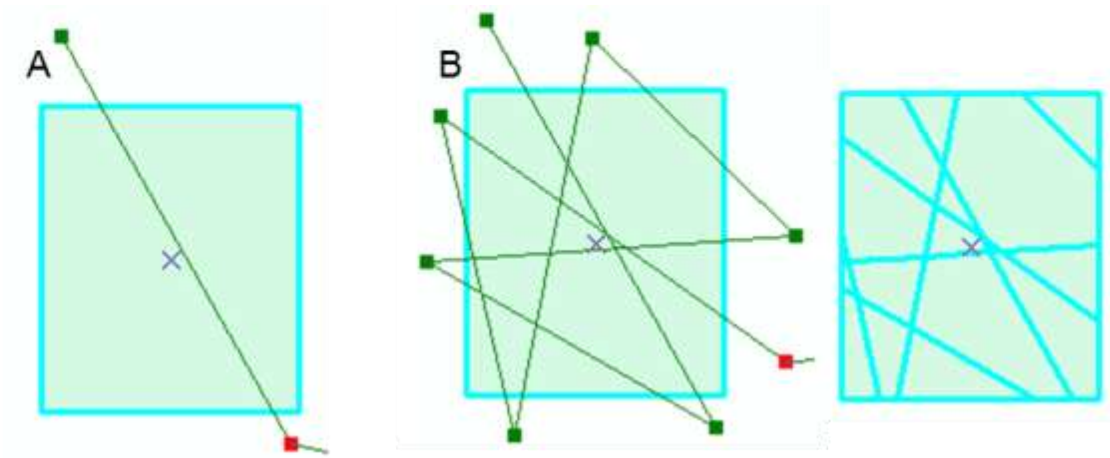
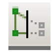


Figure 6-27—The Cut Polygons tool can be used to cut a polygon in half (A), or multiple pieces (B).

To reshape a polygon, the **Reshape Feature Tool**  is used. For this operation only one of the parts of the polygon can be selected. To add area outside of the polygon, draw the shape starting within and extending out (fig. 6-28a). To cut out part of the polygon, do the opposite (fig. 6-28b).

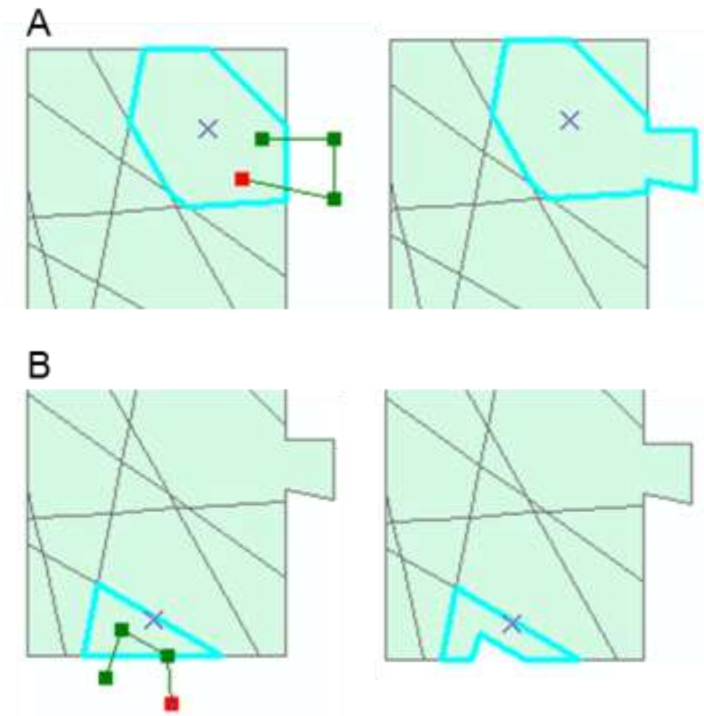


Figure 6-28—The Reshape Feature Tool can be used to extend the area of a polygon (A), or to clip out part of a polygon (A).

When you are done, remember to save your edits and stop editing.

Converting a shapefile to a raster—

Some of the functions in ArcFuels require a non-zero raster, rather than a shapefile, to define the area of analysis (i.e. Build LCP). A non-zero raster is one where the value of the pixel is not zero. The simplest way to achieve this is to add a short integer field, and calculate the value to be "1" before converting the file. The **Polygon to Raster** form (**ArcToolbox→Conversion Tools→To Raster→Polygon to Raster**) is used to complete this operation (fig. 6-29a). For all the raster data to work together, it must be lined up or "snapped" (fig 6-30), which is set in the **Processing Extent** portion of the **Environments** form (fig. 6-29b). And, it is best when the cell sizes are all the same.

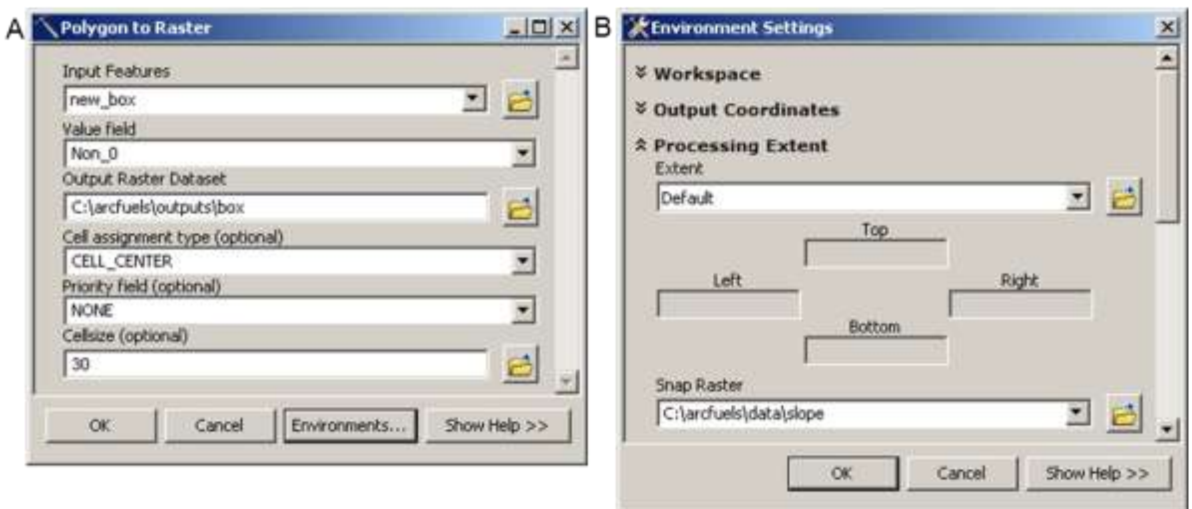


Figure 6-29—Converting a polygon to a raster (A), and setting the Environments to snap the new raster to an existing one (B).

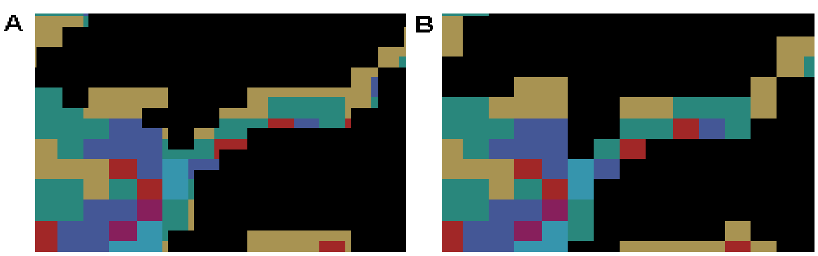


Figure 6-30—Examples of rasters that are not snapped (A), and are snapped (B).

*Be aware that even when the Environments are set correctly, the new raster is often **not** snapped! This is a GIS quirk that we cannot explain. Be sure to check the raster before proceeding, or it will likely create an ArcFuels error.*

In experimenting, the highest success rate is when you choose to snap to the original raster rather than one within a layer group file.

Working with Rasters

Cell size—

If you are unsure of the cell size of a raster, right-click on the name in the ArcMap table of contents, and select **Properties**. Go to the **Source** tab and find the *Cellsize (X,Y)* information (fig. 6-31).

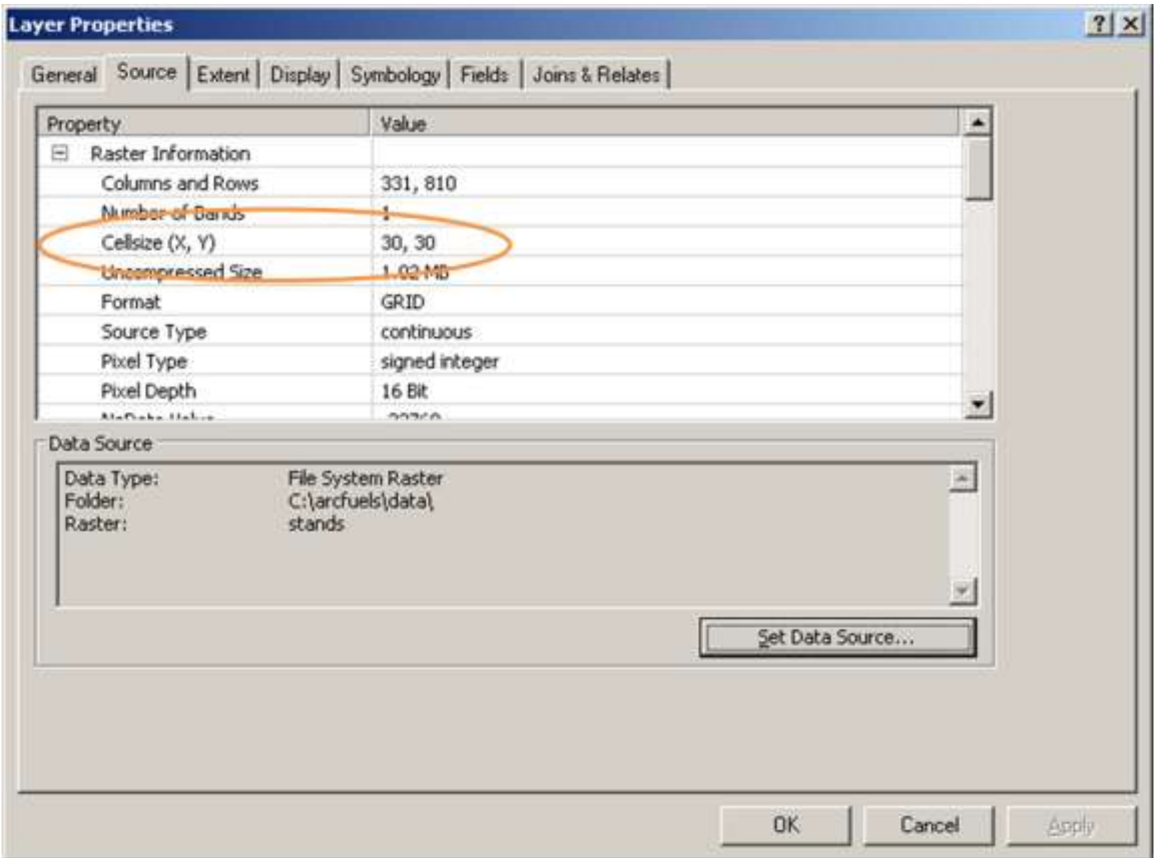


Figure 6-31—Checking the cell size for a raster.

Resample cell size—

If the cell size is not what you desire, or is different than the rest of the raster layers, you can resample the raster using the **Resample** form (**ArcToolbox→Data Management Tools→Raster→Raster Processing→Resample**, fig. 6-32). This will most likely be the case with fire modeled outputs from MTT runs in FlamMap. Realize when you are going from a larger cell size to a smaller one you are not gaining any more detail, but rather breaking the larger cells into smaller ones.

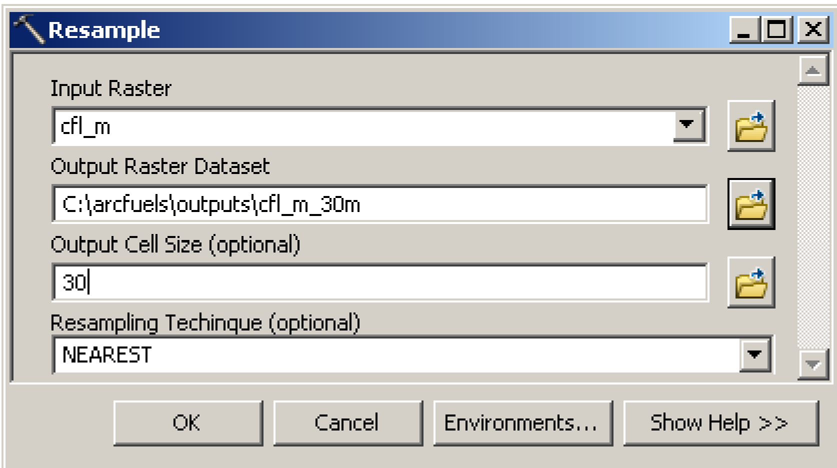


Figure 6-32—Resample form set up to resample the conditional flame length raster to 30 m cell size from 90 m.

Extract by mask—

The **Extract by Mask** form (**ArcToolbox→Spatial Analyst→Extraction→Extract By Mask**) allows you to clip a raster using another layer (shapefile or raster, fig. 6-33).

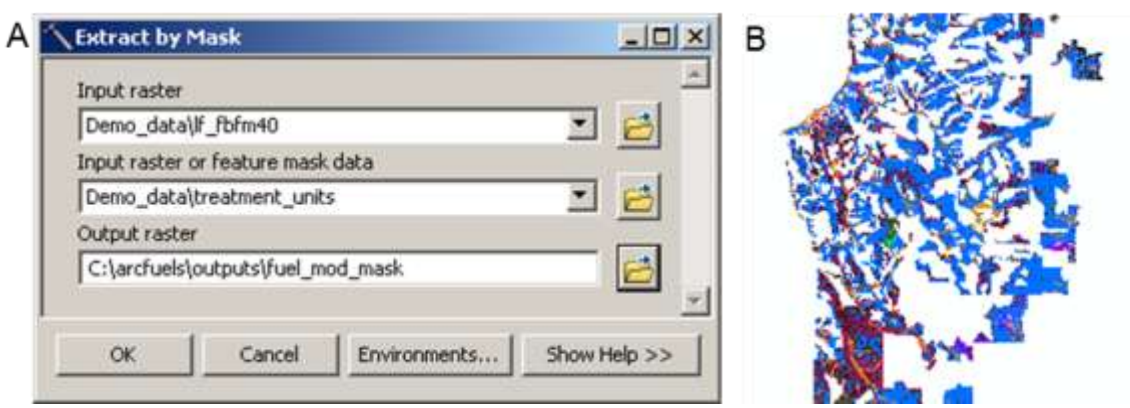


Figure 6-33—Extract by mask form, set up to extract the fuel model raster by treatment units (A), and the resulting raster (B).

Reclassify—

Changing the display of a layer is not the same as reclassifying the data. The display properties are only graphical representations of the data. To be able to further use the data, it needs to be reclassified. One common transformation is to reclassify flame length data into the hauling chart categories that correspond to suppression actions. The **Reclassify** form (**ArcToolbox→Spatial Analyst→Reclass→Reclassify**) is used to complete the reclassification (fig. 6-34). The classes are set in the Classification form which is opened via the **Classify...** button.

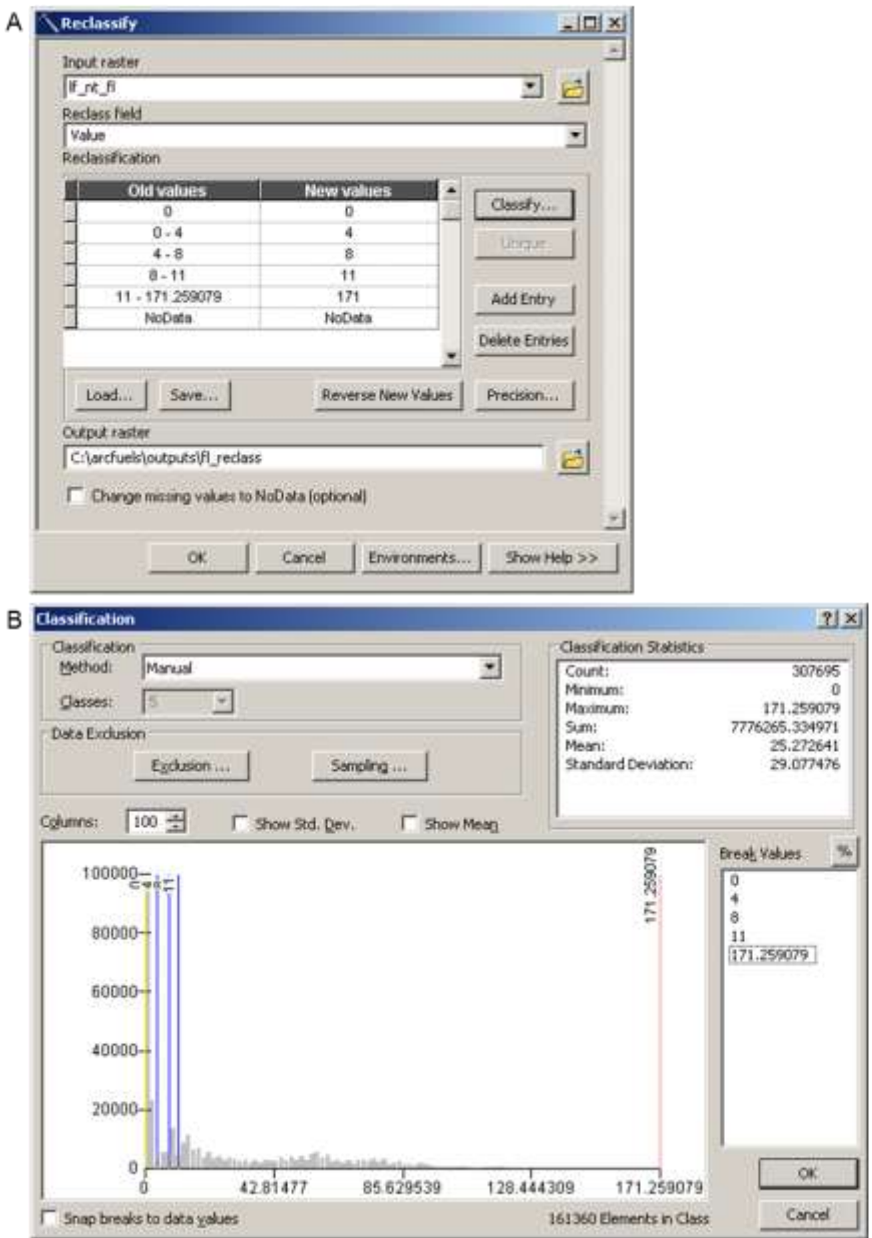
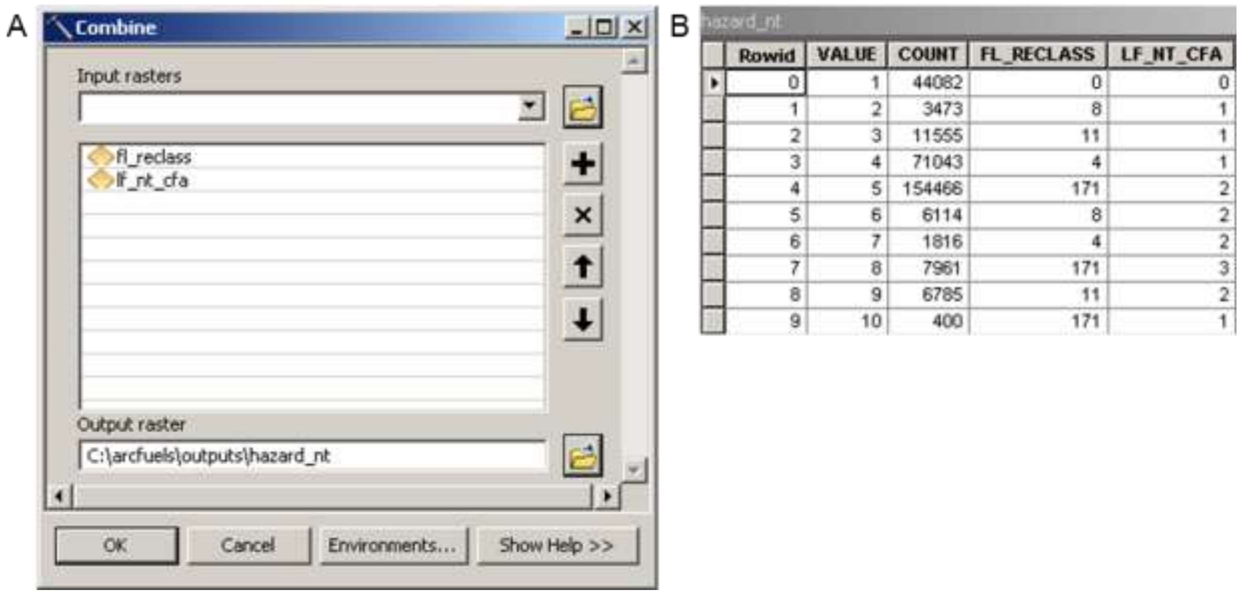


Figure 6-34—The Reclassify form (A), and Classification forms (B) are used to create a newly reclassified flame length raster.

Combine—

The ability to combine multiple rasters into a single raster makes summarizing data over multiple rasters easier. This is the case when trying to assign hazard values based on flame length and fire type. The **Combine** form (**ArcToolbox→Spatial Analyst→Local→Combine**) is used to combine the rasters (fig. 6-35).



Rowid	VALUE	COUNT	FL_RECLASS	LF_NT_CFA
0	1	44082	0	0
1	2	3473	8	1
2	3	11555	11	1
3	4	71043	4	1
4	5	154466	171	2
5	6	6114	8	2
6	7	1816	4	2
7	8	7961	171	3
8	9	6785	11	2
9	10	400	171	1

Figure 6-35—The Combine form set up to combine the flame length and fire type rasters (A), and the attributes table from the combined raster showing the values of both input rasters (B).

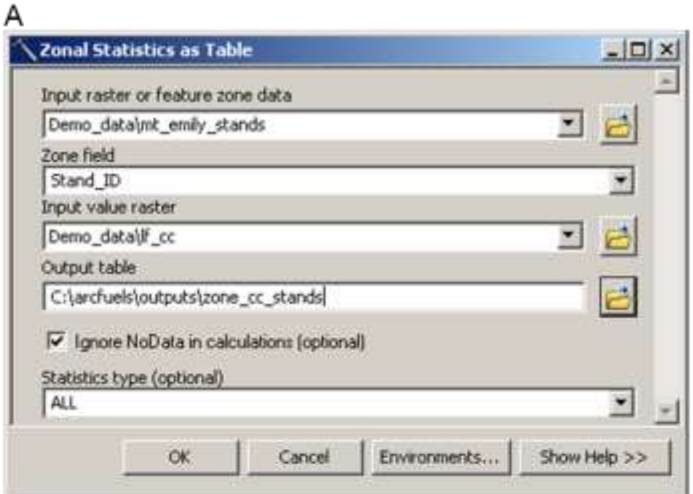
The default cell size output is that of the largest resolution. You can change this in the Environments form.

Zonal Statistics—

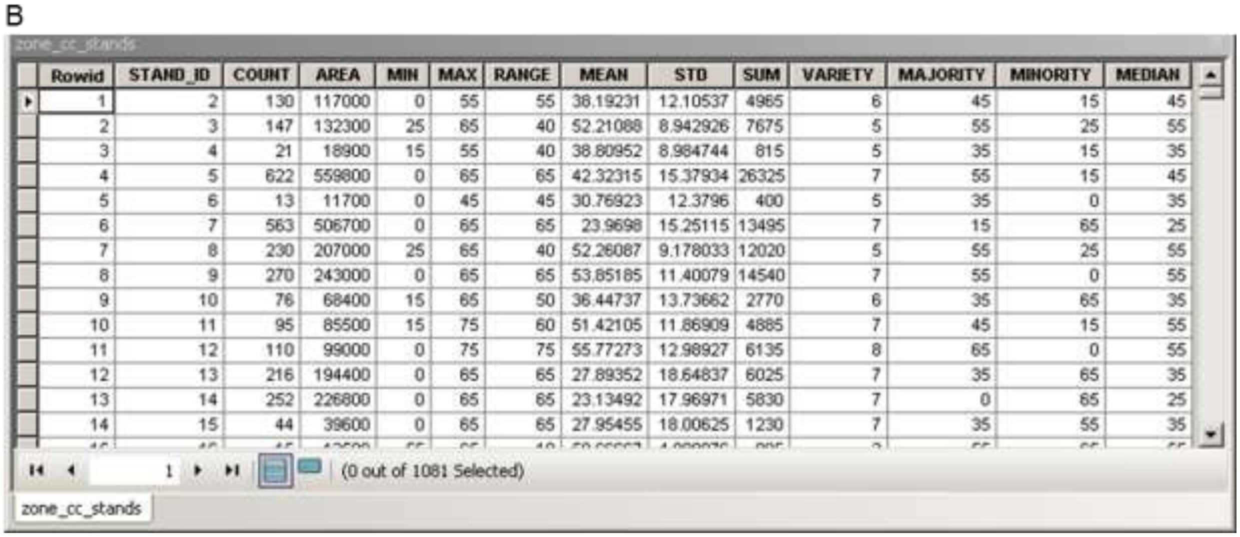
Zonal Statistics are used to summarize your data based on “zone” data. The zone can be defined with a shapefile, or another raster. The output can be a table, or a new raster. Zone data are any areas within which you would like to summarize your data. In other words, if you want to summarize the flame length within your treatment units (zones), use zonal statistics. Zonal Statistics can also be used to pick the value within a zone which represents the majority.

The **Zonal Statistics as Table** form (**ArcToolbox→Spatial Analyst→Zonal→Zonal Statistics as Table**) will output summary statistics for a raster using another raster or shapefile to define the zones (fig. 6-36). To see the table created, you need to change the ArcMap table of contents view to **List by Source** .

A



B



zone_cc_stands

Rowid	STAND_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN
1	2	130	117000	0	55	55	38.19231	12.10537	4965	6	45	15	45
2	3	147	132300	25	65	40	52.21088	8.942926	7675	5	55	25	55
3	4	21	18900	15	55	40	38.80952	8.984744	815	5	35	15	35
4	5	622	559800	0	65	65	42.32315	15.37934	26325	7	55	15	45
5	6	13	11700	0	45	45	30.76923	12.3796	400	5	35	0	35
6	7	563	506700	0	65	65	23.9698	15.25115	13495	7	15	65	25
7	8	230	207000	25	65	40	52.26087	9.178033	12020	5	55	25	55
8	9	270	243000	0	65	65	53.85185	11.40079	14540	7	55	0	55
9	10	76	68400	15	65	50	36.44737	13.73662	2770	6	35	65	35
10	11	95	85500	15	75	60	51.42105	11.86909	4885	7	45	15	55
11	12	110	99000	0	75	75	55.77273	12.98927	6135	8	65	0	55
12	13	216	194400	0	65	65	27.89352	18.64837	6025	7	35	65	35
13	14	252	226800	0	65	65	23.13492	17.96971	5830	7	0	65	25
14	15	44	39600	0	65	65	27.95455	18.00625	1230	7	35	55	35

1 (0 out of 1081 Selected)

zone_cc_stands

Figure 6-36—The Zonal Statistics as Table form, set up to summarize canopy cover by Stand_ID (A), and the zonal statistics table (B).

The **Zonal Statistics** form (**ArcToolbox→Spatial Analyst→Zonal→Zonal Statistics**) outputs a new raster for a single summary statistic (i.e. mean, standard deviation, majority), using another raster or shapefile to define the zones (fig. 6-36). The majority (most frequent occurrence) option is useful when trying to assign a single fuel model to a stand.

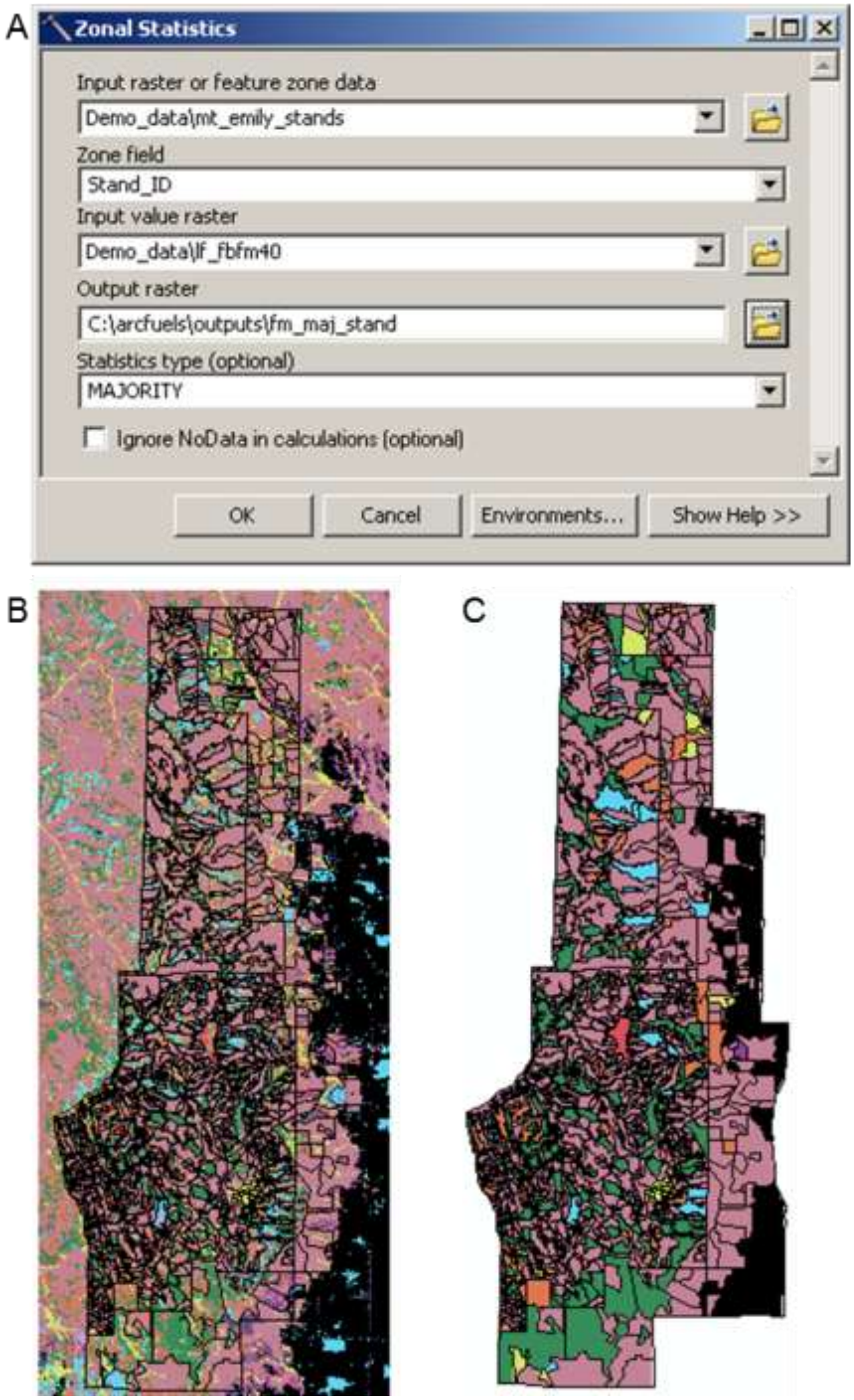


Figure 6-37—The Zonal Statistics form, set up to create a new raster of the majority fuel model within each stand (A), the fuel model raster before the zonal statistics (B), and after (C).

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