

ACADIA NATIONAL PARK FIRE FUELS DATABASE

Final Technical Report

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May 2006

Cooperative Agreement 4560C0027
Task Agreement Number 006
(NCSU FAS Account 521162)

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May 5, 2006

Doug Wallner, Fuels/Fire Ecology Program Manager
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RE: Final technical report and deliverables for Acadia National Park fire fuels database
(Task Agreement No. 006 to Cooperative Agreement 4560C0027;
NCSU FAS Account 521162)

Dear Doug:

Enclosed is the final technical report for the Acadia National Park Fire Fuels Database and a CD containing the final data products and documents that comprise the Acadia set of deliverables for Task Agreement No. 006 to Cooperative Agreement 4560C0027.

Please let me know if you have any questions.

Sincerely,

Hugh A. Devine /e

Hugh A. Devine
Principal Investigator

enclosures

cc: K. Anderson
P. Head
D. Jones
J. Karish
✓B. Mitchell
N. Shaw

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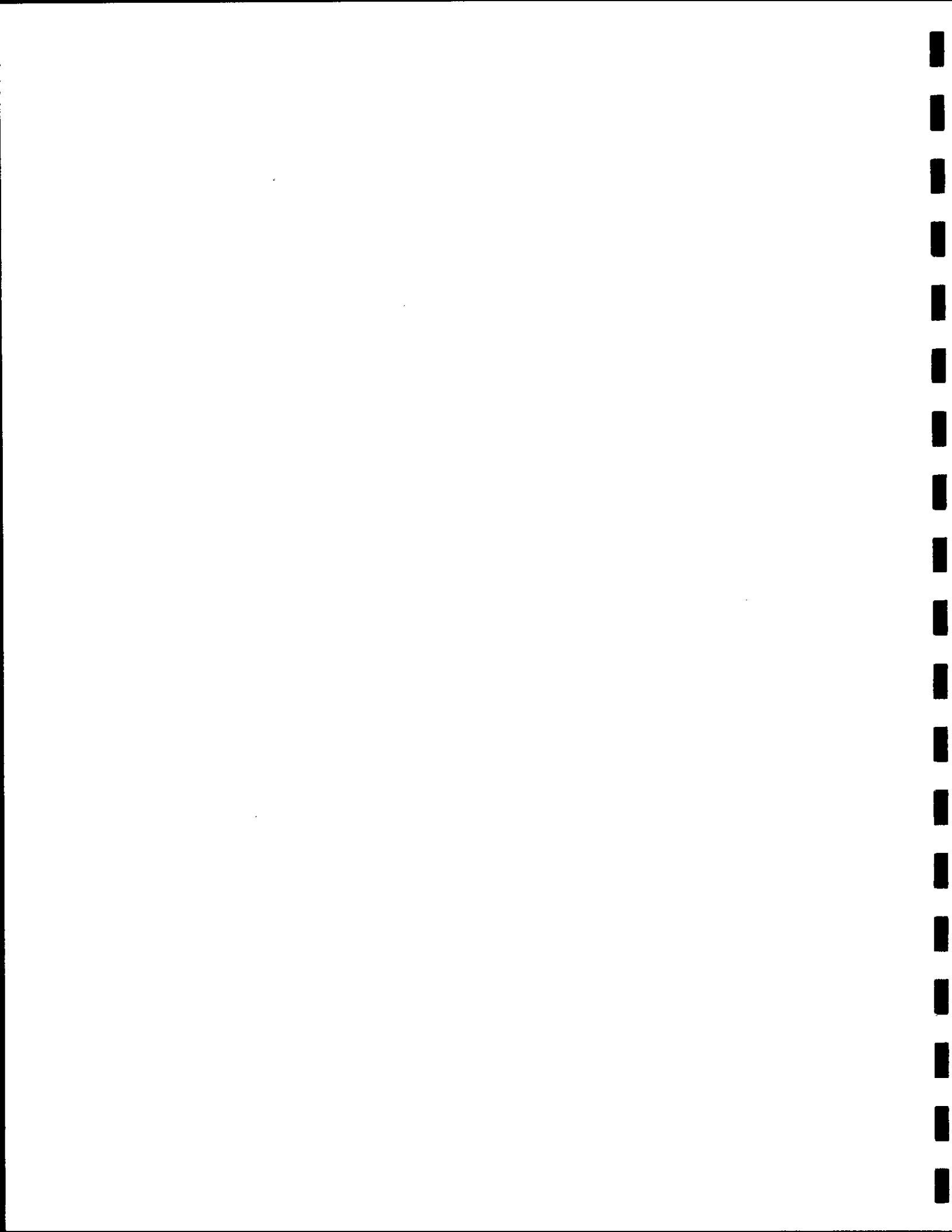
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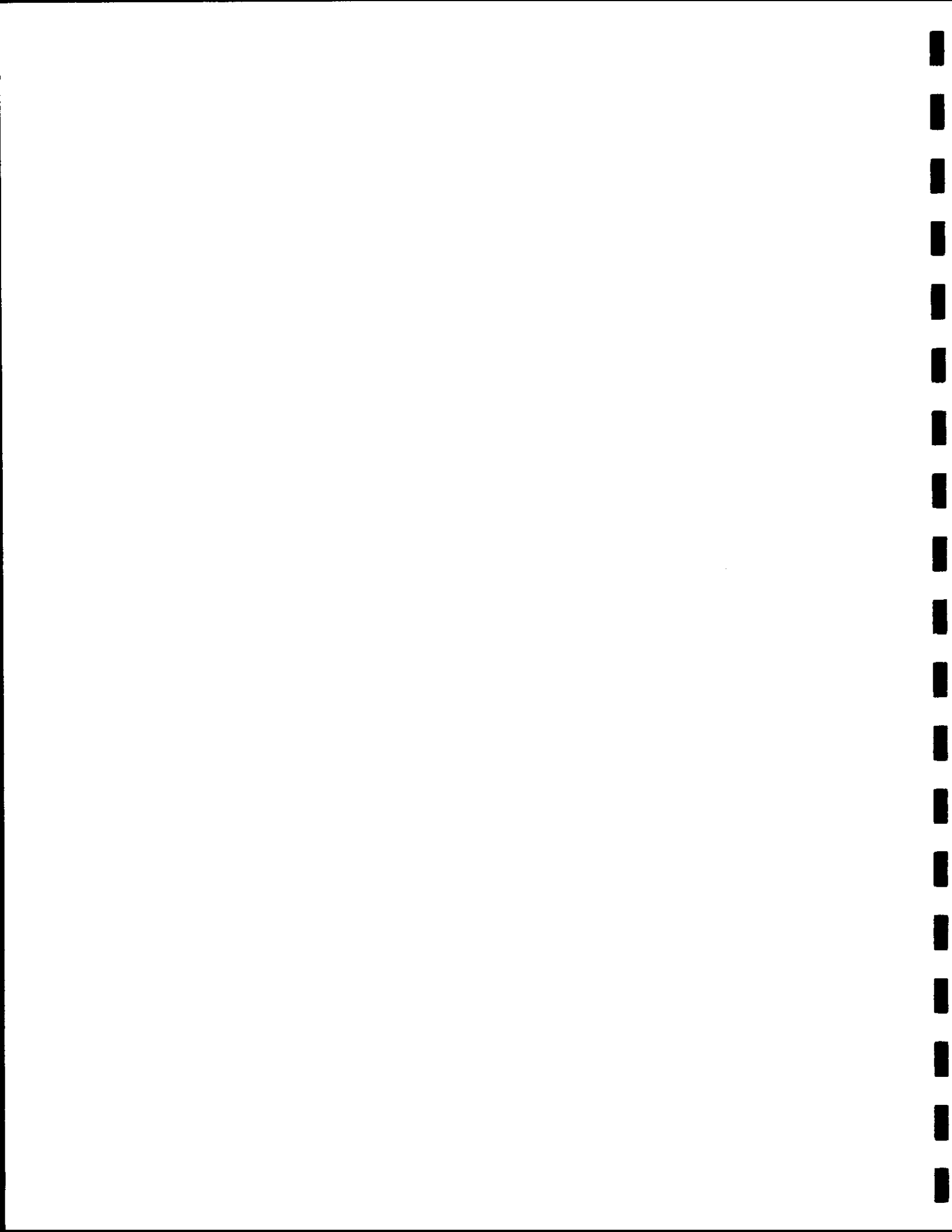
Summary

With the severity of recent fire seasons, increased national attention has been focused on better fire behavior models. Key to the performance of these models is the spatial arrangement of fire fuel loads. This research develops and deploys a protocol for establishing fire fuel GIS layers and other related vegetative fire modeling data directly from an existing digital vegetation map of Acadia National Park.

This protocol centered on developing a predictive relationship between National Fire Fuel Laboratory (NFFL) fuel models and formation level vegetation class from the National Vegetation Classification System. This relationship was established by collecting fire fuel load data from field plots in each major vegetation class and developing a crosswalk between the vegetation class and the fuel model. Fuel loads were measured on the plots using a modified Brown's transect procedure for inventorying dead and downed woody fuels (Brown 1974). Additionally, standard field techniques (Burgan and Rothermel 1984) were used to measure live fuels, stand height, canopy cover, canopy bulk density, and height to live crown.

The data products developed from this project include: 1) a GIS fire fuels database that contains estimated fire fuel loads for each formation vegetation class and both "complacent" (little vegetative seasonal drying or curing) and "available live fuel" (substantial vegetation drying or curing) fire fuel model values, 2) the corresponding "complacent" and "available live fuel" fire fuel model maps, 3) GIS layers representing stand height, canopy cover, canopy bulk density, and height to live crown base, and 4) a GIS data layer of field survey plots linked to an MS Access database containing all field measurements and north and east facing photographs of each plot. These layers constitute the required GIS vegetation data to run the FARSITE (2004) fire behavior model.

In general, as with previous eastern vegetation studies, we found that fuel loads were consistently lower than fuel loads reported by Anderson (1982). This is very likely due to Anderson's work being exclusively based on western United States vegetation. Fuel models were therefore assigned using Anderson's narrative descriptions and pictorial guide.



Introduction

This report documents data development procedures for creating a digital fire fuels database and associated spatial data for Acadia National Park. Managing wildfire has become increasingly important for the National Park Service and other land management agencies. This increased priority has led to greater interest in the development of more robust fire behavior models. Accurate depiction of spatial arrangement of fire fuel loads is key to the performance of these models. National Fire Fuel Laboratory (NFFL) fuel models are the current method of representing fuels in the behavior models. NFFL fuel models are derived from downed woody debris, vegetation type, and overall vegetation structure (Albini 1976). Field collection of these data can be very time consuming and our previous research has shown a strong one-to-one relationship between formation level National Vegetation Classification System vegetation class and NFFL fuel model (Devine, Millinor, and Smith 2003; Devine and Millinor 2005).

This protocol centered on developing a predictive relationship between NFFL fuel model values and formation level vegetation class from the National Vegetation Classification System. This relationship was established by collecting fire fuel load data from field plots in each major vegetation class and developing a crosswalk between the vegetation class and the fuel model. Fuel loads were measured on the plots using a modified Brown's transect procedure for inventorying dead and downed woody fuels (Brown 1974). Additionally, standard field techniques (Burgan and Rothermel 1984) were used to measure live fuels, stand height, canopy cover, canopy bulk density, and height to live crown.

The data products developed from this project include: 1) a GIS fire fuels database that contains estimated fire fuel loads for each formation vegetation class and both "complacent" (little vegetative seasonal drying or curing) and "available live fuel" (substantial vegetation drying or curing) fire fuel model values, 2) the corresponding "complacent" and "available live fuel" fire fuel model maps, 3) GIS layers representing stand height, canopy cover, canopy bulk density, and height to live crown base, and 4) a GIS data layer of field survey plots linked to an MS Access database containing all field measurements and photographs of each plot. These layers constitute the required GIS vegetation data to run the FARSITE (2004) fire growth simulation. Appendix A contains available and complacent fire fuel model maps of Acadia National Park. Appendix B is the vegetation to fire fuel model crosswalk developed from this and similar previous research. The CD included with this report contains the final data products and documents that comprise the deliverables for this project.

Methods

The Vegetation Spatial Database Coverage (vegetation map) for Acadia National Park produced by the U.S. Geological Survey Upper Midwest Environmental Sciences Center in October 2003 (USGS 2003) was used as the starting point for this project. The first step was to review the formation-level vegetation classification codes assigned to the vegetation polygons to ensure consistency with the most current National Vegetation Classification System classification scheme (FGDC 1997).

The vegetation map was then used to select a sample of 93 points located throughout the park for field data collection. The sample of data collection points was stratified based on vegetation type to ensure that data would be collected for vegetation types for which we had little or no previous fire fuel load data. At each point, a field crew measured downed woody debris using a modified Brown's transect technique (Brown 1974) and an ocular estimation procedure (Burgan and Rothermel 1984). Field data collection procedures, described in detail by Smith (2003), were reviewed and approved by the NPS Northeast Region Fuels/Fire Ecology Program Manager. A copy of the form that was used to record field data is included in Appendix C. On average, it took a two-man field crew two hours to take and record measurements at each field location. At each data collection point, the field crew took digital photographs to document ground conditions. We entered the fire fuel load data into an MS Access database that is linked to a corresponding map document (created with ESRI ArcMap version 9.0 software). One can view these data, including thumbnail photos of the field plot, by displaying the map document and clicking on the fire fuel data collection points with the hyperlink tool.¹ The MS Access database, plot photos, and map document are included on the CD that accompanies this report.²

The fire fuels database was created by assigning "complacent" and "available live fuel" fire fuel model numbers to each vegetation polygon based on its formation-level vegetation classification code and the field-collected fire fuel load data. Analysis of the fire fuel load data included comparing the field data to standard NFFL fuel model values. In general, we found that fuel loads were consistently lower than fuel loads reported by Anderson (1982). Undoubtedly, this is due to the fact that Anderson's work is based exclusively on data from the western United States where vegetation and forest characteristics are quite different from those in the eastern states. Therefore, we worked closely with NPS personnel to crosswalk vegetation to fire fuel models based on their experience, Anderson's narrative descriptions, and the field plot photographs.

The following raster data sets (in ESRI GRID format) for use in the FARSITE fire behavior model were created as part of this project. The cell size for each raster is 30 x 30 meters.

- **Available Live Fuel:** In this raster data set, cell values represent the NFFL fuel model number assigned to the corresponding vegetation polygon based on estimated amount of available live fuel. Estimates of available live fuel were based on a crosswalk of formation-level vegetation class to NFFL fuel model and field-collected fire fuel load data.
- **Complacent Fuel:** In this raster data set, cell values represent the NFFL fuel model number assigned to the corresponding vegetation polygon based on estimated amount of complacent fuel. Estimates of complacent fuel were based on a crosswalk of formation-level vegetation class to NFFL fuel model and field-collected fire fuel load data.

¹ If the user has Office XP (2002) this will work without any issues. If the user has Office 2003, the MS Access database will open with an error that can be fixed by reinstalling Microsoft Photo Viewer by following directions obtained at: <http://support.microsoft.com/?kbid=817095>. If you do not apply this fix, you can still view the field data form by clicking "end" and continuing in MS Access however, the plot photos will not display. This will not work with Office versions below XP (2002).

² If you copy the .mxd file to a different location (e.g. to a local hard drive) you must also copy all of the data referenced by the .mxd (e.g., geodatabase, MS Access database, and photos) to the same location and retain the same file structure as on the CD.

- **Stand Height:** In this raster data set, each cell value represents the average height, in meters, of the vegetation class (for woody terrestrial vegetation map classes only). Cell values were derived from attribute data in the original USGS/NPS-produced vegetation dataset, in which woody terrestrial vegetation map classes were assigned codes indicating the average height of the vegetation mapped. Cell values in this raster data set are: 25 (25 meters); 16 (16 meters); 8.5 (8.5 meters); 2.5 (2.5 meters); 0.25 (0.25 meters); and 0 (not applicable, e.g., non-woody vegetation, water, etc.)
- **Height to Live Crown Base:** In this raster data set, each cell value represents the average height to live crown base, in feet, of the vegetation class. Based on field data collected as part of this project, each vegetation class was assigned a value representing average height to live crown base in feet. Cell values in this raster data set range from 0 to 40.8.
- **Canopy Cover:** In this raster data set, each cell value represents the average percent canopy cover of the vegetation class. Cell values were derived from attribute data in the original USGS/NPS-produced vegetation dataset, in which vegetation map classes were assigned codes indicating general range of canopy cover density (closed/continuous canopy--60-100%; open/discontinuous canopy--25-60%; or dispersed/sparse canopy--10-25%). Cell values in this raster data set are: 80 (80%); 40 (40%); 17 (17%); and 0 (not applicable, e.g., roads, urban or built-up land, water, etc.)
- **Canopy bulk density:** In this raster data set, each cell value represents an estimate of the average number of kilograms of burnable fuel per cubic meter in coniferous forest³ canopy. According to guidance that the NPS Fire Geospatial Coordinator received from personnel at the Missoula Fire Sciences Lab (Stephen 2005), canopy bulk density in kilograms per cubic meter is approximately equal to 0.3 times the percent canopy cover. Cell values were derived from canopy cover density attribute data in the original USGS/NPS-produced vegetation dataset in which each polygon was assigned a code indicating general range of canopy cover density, as follows:
 - 1 = closed/continuous canopy, 60-100%;
 - 2 = open/discontinuous canopy, 25-60%;
 - 3 = dispersed/sparse canopy, 10-25%;
 Corresponding cell values in the raster data set are 0.24, 0.13, and 0.05, respectively. These values were computed by multiplying the midpoint of the canopy cover density range by the constant, 0.3. A cell value of 0 was assigned to all non-coniferous vegetation areas and to non-vegetated areas (e.g., roads, urban or built-up land, water, etc.)
- **Slope:** A digital elevation model was downloaded from the U.S. Geological Survey website (seamless.usgs.gov) and clipped to the extent of the Acadia fire fuel data layer. From this data set, a new raster data set in which each cell value represents percent slope of the ground was created using the surface analysis for slope function of the Spatial Analyst extension of ArcGIS 9.0 software.
- **Aspect:** A digital elevation model was downloaded from the U.S. Geological Survey website (seamless.usgs.gov) and clipped to the extent of the Acadia fire fuel data layer.

³ Cell values were computed for coniferous forest areas only because deciduous trees do not support canopy fires.

From this data set, a new raster data set in which each cell value represents direction of downward slope was created using the surface analysis for aspect function of the Spatial Analyst extension of ArcGIS 9.0 software. Slope aspect is represented in positive degree measurements from 0 to 360, measured clockwise from due north. Cells with no slope have a value of -1.

- **Elevation:** The 30-meter digital elevation model for Acadia National Park was downloaded from the USGS website (<http://seamless.usgs.gov>). The Spatial Analyst DEMGrid tool was used to convert the DEM to a grid. The grid was then reprojected to NAD83, UTM Zone 19N.

Results

In addition to this report, final deliverables for this project are included on the accompanying CD. Following is an overview of the contents and data structure of the CD:

Root folder:

Contains:

- Final fire and vegetation data layer in ESRI geodatabase and shapefile formats (acad_fire_and_veg.mdb and acad_final_veg_fire.shp, respectively)
- MS Access database of field-collected fire fuel load data (ACAD.mdb)
- ESRI shapefile of fire fuel load field data collection points (acad_all_points.shp)
- An ESRI map document containing the final fire and vegetation geodatabase linked to the MS Access database of field data so that users can view the field data by clicking on symbols representing fire fuel data collection points with the hyperlink tool (ACAD.mxd)
- A text file listing final data products created for the project (ReadMe.txt)

Folder: acad_ascii

Contains ASCII versions of each of the raster data sets created for use in the FARSITE fire behavior model:

- Aspect (acad_aspect.asc)
- Available live fuel (acad_avfuel.asc)
- Canopy bulk density (acad_blk_dn)
- Canopy cover (acad_canopy.asc)
- Complacent fuel (acad_cofuel.asc)
- Elevation (acad_elev.asc)
- Stand height (acad_ht.asc)
- Height to live crown base (acad_ht_crwn.asc)
- Slope (acad_slope.asc)

Folder: acad_grids

Contains the raster data sets created for use in the FARSITE fire behavior model (in ESRI GRID format):

- Aspect (acad_aspect)
- Available live fuel (acad_avfuel)

- Canopy bulk density (acad_blk_dn)
- Canopy cover (acad_canopy)
- Complacent fuel (acad_cofuel)
- Elevation (acad_elev)
- Stand height (acad_ht)
- Height to live crown base (acad_ht_crwn)
- Slope (acad_slope)
- A folder that contains additional required data files for the GRIDs (info)

Folder: metadata

Contains FGDC compliant metadata for each of the final data sets (in HTML, TXT, and XML formats):

- Metadata for the MS Access database of field-collected fire fuel load data (ACAD.xxx)
- Metadata for the shapefile of fire fuel load field data collection points (acad_all_points.xxx)
- Metadata for the “aspect” raster data set (acad_aspect.xxx)
- Metadata for the “available live fuel” raster data set (acad_avfuel.xxx)
- Metadata for the “canopy bulk density” raster data set (acad_blk_dn.xxx)
- Metadata for the “canopy cover” raster data set (acad_canopy.xxx)
- Metadata for the “complacent fuel” raster data set (acad_cofuel.xxx)
- Metadata for the “elevation” raster data set (acad_elev.xxx)
- Metadata for the final fire and vegetation shapefile (acad_final_veg_fire.xxx)
- Metadata for the final fire and vegetation geodatabase (acad_fire_and_veg.xxx)
- Metadata for the “stand height” raster data set (acad_ht.xxx)
- Metadata for the “height to live crown base” raster data set (acad_ht_crwn.xxx)
- Metadata for the “slope” raster data set (acad_slope.xxx)

Folder: pictures

Contains three digital photos of each field data collection plot (JPEG images) named with their respective field plot number and an abbreviation for bearing/view: N=north, E=east, and A=full plot.

Folder: technical_report

Contains a copy of this report.

Literature Cited

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- Devine, Hugh A. and William A. Millinor. 2005. Geospatial vegetation data development for selected national parks. Unpublished final technical report for Supplemental Agreement 10 to Cooperative Agreement 4000-7-9003. Raleigh, NC.
- FARSITE. 2004. Missoula, MT: Systems for Environmental Management. Retrieved from http://farsite.org/index.php?option=com_content&task=category§ionid=2&id=8&Itemid=25
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- Stephen, Douglas (NPS Fire Geospatial Coordinator). Re: Acadia NP fire data (e-mail communication). 9 Dec. 2005.

U.S. Geological Survey (USGS), Upper Midwest Environmental Sciences Center. 2003.
Vegetation spatial database coverage for the Acadia National Park vegetation mapping project.
Retrieved from <http://biology.usgs.gov/npsveg/acad/>

Appendix A
Available and Complacent Fire Fuel Model Maps

Acadia National Park Available Fire Fuel Models



Available Fire Fuel Models

- | | |
|--|--|
| 0 - Rock / Small Island | 6 - Shrub Group / Brush Higher than 2 Feet with Hardwood Slash |
| 1 - Grass Group / Short Grass | 9 - Timber Group / Hardwood Litter with Understory |
| 2 - Shrub Group / Timber Overstory | 98 - Non-burnable Water |
| 5 - Shrub Group / Brush Higher than 2 Feet | 99 - Non-burnable Urban |

Acadia National Park Complacent Fire Fuel Models



Complacent Fuel Models

0 - Rock / Small Island

1 - Grass Group / Short Grass

5 - Shrub Group / Brush Higher than 2 Feet

6 - Shrub Group / Brush Higher than 2 Feet
with Hardwood Slash

8 - Timber Group / Hardwood Litter
with Little Understory

9 - Timber Group / Hardwood Litter
with Understory

98 - Non-burnable Water

99 - Non-burnable Urban

Appendix B

Vegetation and Associated Fire Fuel Models

(Note: This crosswalk was developed using data from several national parks and, therefore, some of the codes included do not occur in Acadia National Park.)

Vegetation or Land Use/Land Cover	NFFL Fire Fuel Model	
	Complacent	Available Live
National Vegetation Classification System formation-level vegetation codes:		
I.A.4.N.a	8	9
I.A.8.C.x	8	9
I.A.8.N.b	8	9
I.A.8.N.c	8	9
I.B.2.N.a	9	9
I.B.2.N.d	9	9
I.B.2.N.e	9	9
I.B.2.N.g	9	9
I.C.3.N.a	8	9
I.C.3.N.b	8	9
I.C.3.N.d	8	9
II.A.4.N.a	8	9
II.A.4.N.b	8	9
II.A.4.N.f	8	9
II.B.2.N.a	9	9
II.B.2.N.f	9	9
III.A.2.N.a	5	6
III.A.2.N.f	5	5
III.A.2.N.g	5	5
III.B.2.N.a	5	6
III.B.2.N.d	5	5
III.B.2.N.e	6	6
III.B.2.N.f	5	5
III.B.2.N.g	6	6
III.B.2.N.h	1	1
IV.A.1.N.a	2	3
IV.A.1.N.b	5	5
IV.A.1.N.g	5	5
IV.B.2.N.a	5	5

Vegetation or Land Use/Land Cover	NFFL Fire Fuel Model	
	Complacent	Available Live
V.A.5.C.x	1	1
V.A.5.N.c	1	1
V.A.5.N.e	1	1
V.A.5.N.k	1	1
V.A.5.N.l	1	1
V.A.5.N.n	1	1
V.A.7.C.a	1	2
V.B.2.N.d	1	3
V.B.2.N.g	1	3
V.C.2.N.a	1	3
VI.B.1.N.c	1	1
VI.C.2.N.a	98	98
VII.A.2.N.a	1	1
VII.C.2.N.d	98	98
VII.C.4.N.d	98	98
User-defined land use/land cover classes:		
Agricultural	1	1
Beach	99	99
Boardwalk/Dock	blank	blank
Building	blank	blank
Land Use	blank	blank
Lawn_cut grass	1	1
Mosquito ditch	98	98
No Data	blank	blank
Residence/Building	blank	blank
Road	99	99
Rock Pile or Jetty	blank	blank
Sand Road/Path	blank	blank
Small Island with Vegetation	blank	blank
Sparsely Vegetated Sand	blank	blank
Water	98	98

Vegetation or Land Use/Land Cover	NFFL Fire Fuel Model	
	Complacent	Available Live
<u>Anderson (1976) land use/land cover codes:</u>		
11	blank	blank
12	blank	blank
13	blank	blank
14	99	99
15	blank	blank
16	blank	blank
17	1	1
51	98	98
52	98	98
53	98	98
54	1	1
<u>Mitchell (1995) codes:</u>		
1.1.1 Developed Deciduous	1	1
1.1.2 Developed Coniferous	3	3
1.1.3 Developed Mixed	9	9
1.2 Developed Open Land	1	1



Appendix C **Fire Fuel Load Field Data Collection Form**

NCSU Vegetation Map Fuel Inventory Data Sheet

No. District Date / /
 Photo No. Photo Numbers Total # Taken
 Transect Length (m): 0-0.25 0.25-1 1-3 3+
 UTM

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0-0.25 (1-5)	0.25-1 (6-10)	1-3 (101-105)	3+ (1001-105)	L	D	Non	L	D	Non
				1			25		
				5			30		
				10			35		
				15			40		
				20			45		

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0-0.25 (1-5)	0.25-1 (6-10)	1-3 (101-105)	3+ (1001-105)	L	D	Non	L	D	Non
				1			25		
				5			30		
				10			35		
				15			40		
				20			45		

Observation	
Can. Code	(9)
Species	9 Species

Canopy Codes: 1 = (100), 2 = 21-40, 3 = 51-60, and 4 = 61-100

Canopy	Bottom	Base	BL to Crown	Notes

Height (BL to Crown) - Bottom of the live crown + Base of the tree
(BL = Ref.) and 24m = 24m = Ref.

Canopy Distance	Top	Base	Height	Notes

Height = Top of the tree + Base of the tree * (distance is 100', 50', 60', or 30')

Formulation for the plot area _____



Figure 1

100' - 60' (divide by 2) = 30'
 60' - 30' (divide by 2) = 15'



Figure 2

Figure 1. Digitized Fuel Database (front)

Fuel Data Entry Form
Shenandoah National Park

Project: _____ Plot: _____
 Recorder: P Date: _____
 UTM: _____ E _____ N _____ 4km

Grass Model Type 1, Dynamic Grass Type 1, Fine -- colonial bent, poverty, oat grass
 2, Static 2, Medium -- fescue, orchard, Japanese bromegrass
 3, Coarse -- sedges and rushes
 4, Very Coarse -- sawgrass, tall oatgrass

Shrub Density Class (1-6) _____
 Total Grass Load (0-30 lbs/acre) _____ or Grass Depth (0-10 ft) _____
 Dynamic Models enter medium % that can be live (0-100%) _____
 Static Models enter current % live (0-100%) _____
 Percentage of area covered by grass (0-100%) _____

Shrub Type 1, Fine stem, thin leaves -- huckleberry, gooseberry
 2, Medium stem, thin leaves -- Chokeberry, yew, Spicebush
 3, Medium stem, thick leaves -- Ceanothus, Vaccinium
 4, Densely packed fine stems and leaves -- Spirea, Rubus
 5, Thick stems and leaves -- Lil. Laurel, Rhododendron

Shrub Density Class (1-6) _____
 Total Shrub Load (0-40 lbs/acre) _____ or Shrub Depth (0-10 ft) _____
 Dynamic Models enter medium % that can be live (0-100%) _____
 Static Models enter current % live (0-100%) _____
 Percentage of area covered by shrubs (0-100%) _____

Percentage of area covered by forbs (0-100%) _____
 Percentage of area covered by vines (0-100%) _____
 Percentage of area covered by epiphytes (0-100%) _____

Yes or No

Figure 10. Burgeis and Rothermel Dataset (back)

Plot	Date
Litter	Litter Source: 1. Conifers 2. Herbaceous 3. Both but at least 30% of lesser type
Needle length if conifers or both (1-2)	1. Medium/Long 2. Short
Litter Compactness	1. Loose (freshly fallen) 2. Normal 3. Compact (older compressed)
Total litter load (0-500 lbs/acre) or Litter Depth (0-40) (feet/100.48)	
Percentage of total litter load in each size class. Enter as whole % (must tot. 100%)	
1. 1-1/8" (0-1/4 inch)	
2. 10-1/8" (1/4-1 inch)	
3. 100-1/8" (1-3 inches)	
Percentage of area covered by litter (0-100%)	

NOTES

