TA Request for Joint Fire Science Program Software Development

FERA

Fire and Environmental Research Applications Team

USDA Forest Service
Pacific Northwest Research Station
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Strategic Technical Approval Request for

Fire Environmental Research Applications Team
USDA Forest Service, Pacific Northwest Research Station

Software and Database Development for

USDI/USDA Forest Service Joint Fire Science Program
Decision Support System

The **Fire and Environmental Research Applications** (**FERA**) of the USDA Forest Service Pacific Northwest Research Station is a significant partner in the **USDI/USDA Forest Service Joint Fire Science Program (JFSP).** The Program is an emergency response to problems associated with accumulating wildland fuels (combustible material, generally living and dead plant materials). In each of the next four years, FERA will develop decision tools for the JFSP. Combining funds from the JFSP ($2.13 million) with normal research appropriations to FERA ($2.67 million), this effort will devote $4.8 million ($1.2 million per year) to the project. We request Technical Approval to spend $2.15 million of that amount in the first 4 years for rapid improvement of FERA's capacity to procure new information technology including hardware, software, and professional services; and to produce new software and databases integral to the JFSP. In addition, we request a departmental waiver (not Technical Approval) for $9.85 million, which is the anticipated cost of implementing this program from years 5 through 10.

In order to meet the Congressionally mandated timelines, we must be able to procure approximately $438K in goods and services from outside the Forest Service during FY99 ($662K in FY00, $608K in FY01, $442K in FY02; $2.15 million total), and can only accomplish this with expedited technical approval. Products must be made available to a wide range of users including other federal agencies, states, and private interests outside the Forest Service. This demand for urgency and flexibility requires rapid technical approval, purchase, acquisition, and contracting for new hardware and software, software development, data acquisition, and networking.

Fifteen projects at other federal institutions and universities were funded by JFSP in FY98, and are outside the scope of this request. FERA will submit proposals for additional JFSP funding to augment this project, so we may or may not add to this plan in future years.

USDI/USDA Joint Fire Science Program. Responding to wildfire catastrophes and the resulting loss of life and property stemming from wildland fuel accumulations on lands administered by the USDA Forest Service and four bureaus in the Department of the Interior, Congress appropriated $184 million to federal agencies for fuel hazard reduction in the last two fiscal years (1998-1999). A five-fold increase in prescribed burning is part of the implementation of the mandated program, and all fire use must comply with the recent EPA Interim Air Quality Policy on Wildland and Prescribed Fires in order to protect air quality. Realizing that there is insufficient science and technology support for effective implementation of a hazard abatement strategy consistently across agency jurisdictions and fuel types, Congress also established and funded JFSP ($8 million per year) to provide accelerated development of decision tools for this emergency implementation.

The Joint Fire Science Program is a partnership of six Federal land management and research agencies (USDA Forest Service, and the Bureau of Indian Affairs, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Service of the Department of the Interior). The Program is managed by a diverse10-member Governing Board representing the six agencies, and a small Program office located at the National Interagency Fire Center in Boise, Idaho. The Program operates a competitive grants program with requests for proposals (RFP). All products developed for JFSP must have deliverables in each of the first two years, be implementable by end users during FY2001, and be consistent across all land management agencies and geographic areas.

The Joint Fire Science Program addresses four needs that must be addressed for the fuels management and fire use programs to be successful. These are:

1. The need to develop and implement consistent interagency fuels mapping and inventories with common classifications and resolution within ecosystems.

2. The need to evaluate and compare fuels treatment practices and techniques, including prescribed fire, thinning and other mechanical methods, increased utilization of biomass, and no treatment.

3. The need to develop treatment schedules, determine the frequency of subsequent treatments, and coordinate treatment schedules among agencies.

4. The need to establish compatible interagency processes and procedures for monitoring, evaluating, and reporting fuels treatments.

The **Fire and Environmental Research Applications Team** is an element of an integrated research and development program of the USDA Forest Service Pacific Northwest Research Station to manage natural disturbance processes. Our mission is "to protect terrestrial ecosystems and air quality by facilitating informed decisions by society about the role of fire in a changing environment." FERA will provide five decision support tools for JFSP. A sixth product requires no new information technology, and will not be mentioned again in this plan. The five FERA products (PHOTO, FCC, CONSUME, EPM, RISK) involve significant software development and information systems that require new information resource capability within FERA, and are the subject of this TA request.

As a group, these five FERA products:
- provide the means to inventory fuelbeds using an extended series of photographs
- characterize fuelbeds in relation to fire potential and wildlife habitat using a nationally consistent but locally flexible classification system
- predict fuel consumption by combustion stage for all fuel and fire types
- calculate emission rates for gases, particles and heat

- provide a national risk map derived from the climatology of atmospheric dispersion processes.

FERA products by themselves form an integrated decision support system to manage the effects of fire on air quality. FERA products are also a component of the larger evolving system to manage the ecosystem consequences and economic efficiency of fuel management. Fifteen projects by other federal laboratories and universities were funded in FY98, and several more will be funded this year. There is no overarching systems design for the decision support system yet for the entire Program, so technical approval is being sought individually by the funded projects. System design is evolving as collaboration develops between investigators and with the JFSP Board of Governors. Eventually, it may be useful to combine this TA request and Life Cycle Plan with other projects. Our current concern is only to make FERA products compatible with and able to share information with model systems being developed elsewhere.

The following FERA products are under development:

Photo Series for Major Natural Fuel Types of the United States--Phase III (PHOTO): The deliverable products include (1) a fuels-inventory database, and (2) a digital multimedia distribution kit, such as CD-ROM or DVD-ROM (or current standard digital medium), hardcopy, downloadable photo series documents, and online interactive photo series through the Internet. This project will involve extensive field experimentation, data analysis, remotely-sensed data acquisition, database development, and intensive digital imaging processing. Extensive consultation with users and beta testing of preliminary products will be required. Eventually, we want to develop the capability to produce an all-digital photoseries that will incorporate the newest digital technology tools into the fuel appraisal process.

Application of a Fuel Characterization System for Major Fuel Types of the Contiguous United States and Alaska (FCC): The deliverable product will be a fuel classification system with associated data assignments and photographs both on CD-ROM and on an interactive network-based reference data library. This project will involve extensive field experimentation, data analysis, remote data acquisition, data base development, model-building, real-time linkage to third party models and databases, and computer programming. This product will require intensive input from regional experts on vegetation, land, and fuels via regional workshops, and consultation and feedback capture from an interactive website as the FCC system progresses.

Modification and Validation of Fuel Consumption Models for Shrub and Forested Lands in the Southwest, Pacific Northwest, Rockies, Midwest, Southeast, and Alaska (CONSUME): Deliverable products include: (1) CONSUME v. 3.0 with users manual and training packet that will be distributed in a CD-ROM, in addition to providing users the capability to run CONSUME remotely/interactively from FERA's website, and

(2) a fuel consumption research manuscript. This project will involve extensive field experimentation, data analysis, database development, model-building, real-time linkage to third party software and databases, computer programming, and extensive users' beta testing.

Implementation of an Improved Emission Production Model (EPM): Deliverable products include: (1) EPM v. 2.1 with user's manual and training packet, (2) model linkage to a wide variety of third-party software and databases and (3) a network-based interactive data base and downloadable regional upgrades of program objects and versions. This project will involve some field experimentation, data analysis, remote data acquisition, and data base development; extensive model-building, real-time linkage to third party software and databases, and computer programming.

Assessing Values of Air Quality and Visibility at Risk from Wildland Fire (RISK): Deliverable products include mean monthly maps and daily frequency diagrams of mixing height, surface wind, and dispersion potential; and an assessment of spatial and temporal patterns. Prototype products will be presented to potential users from an interactive web site where user comments will be collected and reviewed. Final products will be available in an interactive GIS with zoom viewing and clickable maps that provide statistical detail of mapped information within each pixel. This project will involve remote data acquisition, data base development, real-time linkage to third party software and databases, and computer programming.

These tools are absolutely unique in their ability to predict and model the effects of fires on ecosystems and air quality. Their widespread use by fuel managers is critical for implementation of the Federal Wildland Fire Policy (U.S. Department of the Interior and U.S. Department of Agriculture 1996) and the federal strategy to use prescribed fire to protect life and property and to restore ecosystems. Each product is currently available only as a prototype or an early version. Each product is now technically outmoded, limited to a one or a few regions of the U.S., and lacking in linkage to other models and data systems. Recognizing the dire consequences to the six federal land management agencies of not being able to meet the either the EPA policy or the mandates of Congress, JFSP insists on substantial re-design of each of the products in FY99, beta test versions of the software products within one year, and phased implementation in FY2000 to 2002. This requirement puts us on an emergency schedule to develop and implement the software improvements for which we seek technical approval.

FERA, during the late 1980s and early 1990s, had one of the most capable and modern software development teams in the Forest Service. However, budget and personnel reductions in the mid-1990s and the loss of skilled personnel to private industry left us with virtually no internal capacity for software design and development. Now we are faced with the need to rapidly regain functionality. We are recruiting several new scientific and technical positions to collect and analyze data, and will need to equip them during FY99. We have recently relied on private consultants for advanced software development, and expect to use a mixture of in-house and contracted-out programming in the future. We have just begun to discuss our implementation and distribution strategy for software and database products, but expect to make most products available on CD-ROM (or other current standard digital hardcopy media) and provide access to interim upgrades and databases via the Internet, as well as the ability to run computer programs off FERA's website.

Fire Environmental Research Applications Team
USDA Forest Service, Pacific Northwest Research Station

USDI/USDA Forest Service Joint Fire Science Program
Decision Support System

Life Cycle Plan

I. Program Description

FERA requests Technical Approval to accomplish the following program of work:

A. Needs and Objectives:

Fuel managers and resource managers in six land management agencies (USDA Forest Service, and the Bureau of Indian Affairs, Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Service of the Department of the Interior) in every state require decision support and access to scientific knowledge in order to implement a mandated Congressional program to prevent catastrophic wildfires, ecosystem consequences, and air quality degradation resulting from the accumulation of wildland fuels. New decision processes must be in use by managers by 2001 in order to meet the expectations of Congress, and these decisions must be supported by new information systems that can be delivered by then.

Several thousand federal land managers, fire managers, and fuel managers require the consistent, accurate, and timely ability to plan, predict, and monitor fire behavior, fire severity, fire effects, and fire risk for more than 150 thousand prescribed fires and wildland fires per year. State, private, and non-governmental land managers have similar needs. Regulatory agencies and public groups need access to land management plans, risk assessments, and impact assessments at the individual fire and programmatic level.

Fire managers must also comply with new policies and regulations that protect air quality. Accurate and timely computation of biomass consumption and air pollutant emission rates from every prescribed burn (roughly 80,000 per year) must be done by local managers, regional coordinators, and land management planners, and conveyed to air resource managers. Easy access to real time and historic meteorological data and statistics by fire and air resource managers is necessary to analyze atmospheric dispersion characteristics and assess the risk of degrading air quality.

Part of the decision support system will entail the distributed, consistent ability by end users to appraise fuel hazards, classify fuelbed characteristics according to risk and hazard, predict and model the severity (i.e. fuel consumption) in prescribed fires and wildfires; and to assess air quality and visibility values at risk from fires based on atmospheric conditions. This ability depends on user access to scientific databases, computer simulation models, and interpreted output from models and databases that reside on the world-wide-web or are distributed to managers for use on personal computers and workstations.

These models and databases will be produced and distributed by the Fire Environmental Research Applications Team (FERA), a team in the Managing Natural Disturbances RD&A Program of the USDA Forest Service Pacific Northwest Station. These products are promised as deliverables to the USDI/USDA Forest Service Joint Fire Science Program (JFSP), a Congressionally mandated and funded program with tight fiscal and timeline requirements.

FERA products by themselves form an integrated decision support system to manage the effects of fire on air quality. We are guided by the *National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality* (Sandberg and others 1999). The schedule of deliverables, life cycle plan, and cost benefit analysis are based on the implementation of FERA products alone. Briefing papers for each of the FERA projects are available for viewing and comment on FERA's website, http://www.fs.fed.us/pnw/fera. The briefing papers offer more information of the content and schedule of deliverables and the linkages of FERA products with other components of the JFSP decision support system.

FERA products are also a component of the larger decision support system that is evolving to manage the ecosystem consequences and economic efficiency of fuel management. Fifteen projects by other federal laboratories and universities were funded in FY98, and several more will be funded this year. There is no overarching systems design for the decision support system quite yet, so technical approval is being sought individually by the funded projects. System design is evolving as collaboration develops between investigators and with the JFSP Board of Governors. Eventually, it may be useful to combine this TA request and Life Cycle Plan with other projects. Our current concern is only to make FERA products compatible with and able to share information with model systems being developed elsewhere. Of special relevance are the models and systems being developed by the Missoula Forestry Sciences Laboratory and their partners.

B. Project Overview:

Five FERA projects (PHOTO, FCC, CONSUME, EPM, RISK) are being developed in parallel that have models and data systems as deliverables. All five projects are based on models that FERA developed earlier and that are still used by innovative clients. However, the earlier versions are all limited in scope, have technological shortcomings, and are outmoded in their design and user interface. FERA has not previously had databases or web-based information available to users, and our linkage to other models and databases in use is non-existent. We expect to deliver the models and databases on CD-ROMs (or other current standard hardcopy digital media) for use by managers and scientists; and to make regional variants, model updates, with background information available to users by download from the Internet.

Web sites will be developed at the beginning of each project to share progress with clients (most of whom are outside of the FS Intranet). In addition, interactive capability will be required for all clients during two stages, depending on the project. The first stage is to acquire comments from users about prototype products. At this stage, users will review products on the web while completing a questionnaire. Their comments then will be synthesized and used to develop final products. The second stage will help build a national database. In this case, users will be able to upload pertinent data to a web site location, where it undergoes quality control, then is integrated with other data and fed back to all users via web or other media. Other interactive web capability may include downloading data and models, viewing of digital photos (PHOTO), on-line execution of models (CONSUME and EPM), and point-and-click options for viewing 4-dimensional data (FCC, RISK).

All of the projects have a field-study component where data will be collected and analyzed. Three of the field studies (CONSUME, EPM, and RISK) will require continuous data collection involving telemetry. All of the field data will be available to model end-users in their raw form, in statistical summaries, and in the form of updated coefficients and regional calibrations that refine the model outputs. All data will be geographically referenced using GPS coordinates and made available to users of Geographic Information Systems (GIS). FERA will not be developing GIS layers, but will be registering and formatting databases so they can be readily incorporated by others in GIS systems.

C. Schedule of Deliverables:

Currently, March 25, 1999, all five projects are underway. The strategy and proposal phases are completed, and the design phase of each project is nearing completion. We are engineering the technological improvements to earlier prototypes, assessing user needs, and planning our approach for data collection and software development, and building internal capacity.

Strategy phase:	January	1998 to June	1998
Proposal phase:	June	1998 to September	1998
Design phase:	October	1998 to April	1999

Following completion of the design phase, each project enters the production phase wherein several subordinate tasks are anticipated

1. **PHOTO:** the principal product is a CD-ROM-based database and stereo photography. PHOTO phase two is now being printed and distributed. Phase three is in design phase (80% completed), and will be the product of this new activity. If there are future (i.e. Phase four) revisions, they may incorporate new visualization technology. To attain extensive feedback from users on the development of the PHOTO project, partial Photo Series could be made available through an interactive web site by vegetation types and by region as they are completed. The final Photo Series product could be delivered on printed and digital media, and made available on FERA's website for downloading and viewing.

Production phase:			
Data Reduction Software	February	1998 to August	1999
User Interface:	October	1999 to August	2000
Output Report Writer:	October	1999 to April	2000
Reference Data Library:	October	1999 to March	2000
Annual Updates:	October	1999, 2000, 2001 2008	
User Review and Feedback:	August	1999 to October	2001
Revision:	June	2001 to October	2001
Distribution:	November	2001 to March	2002
Training, Implementation:	November	2001 to March	2002
Retirement			
(Assumed for benefit calculation)		September	2009
(Expected product utilization)		September	2025

2. **FCC,** the principal product is a database to characterize fuelbeds according to their properties, to be used as an input to other models. FCC version one has been published, and is in use for the Columbia Basin Assessment and in the Fire Effects Tradeoff Model, and some other local fire assessments in the Forest Service Region 6. Version two, the product of this new activity, has a planning draft that is being peer

reviewed. Continuous updates are planned for the life of the FCC project, and will be posted periodically on FERA's web page. FCC is in design phase (70% completed)

Database Design:	February	1999 to August	1999
Production phase:			
Analysis Engine:			
Prelim Database	July	1998 to December	1999
Synthetic Data	July	1999 to March	2000
Mature Database	December	1999 to August	2000
User Interface:	October	1999 to August	2000
Report Writer:	April	2000 to August	2000
Reference Data Library:	October	1999 to March	2000
Annual Updates:	October	1999, 2000, 2001 2008	
Beta Testing:	October	2000 to March 2001	
Model Linkages:	October	1999 to June	2001
Revision:	June	2001 to October	2001
Distribution:	November	2001 to March	2003
Training, Implementation:	November	2001 to March	2002
Support:			
Triennial Upgrades	August	2001, 2004, 2008, 2013	
Retirement			
(Assumed for benefit calculation)		September	2009
(Expected product utilization)		September	2045

3. **CONSUME** has just had a new version, v.2.0, developed through contract and is being beta tested. CONSUME v3.0 will be the product of this new activity.

Production phase:			
Analysis Engine:			
Tech Update 1	February	2000 to August	2000
Tech Update 2	February	2002 to August	2002
User Interface:	October	2000 to August	2001
Report Writer:	April	2001 to August	2001
Reference Data Library:	October	1999 to March	2000
Annual Updates:	October	1999, 2000, 2001 2008	
Beta Testing:	October	2001 to March	2002
Model Linkages:	October	2001 to June	2002
Revision:	June	2002 to October	2002
Distribution:	November	2002 to March	2003
Training, Implementation:	November	2002 to March	2003
Support:			
Triennial Upgrades	August	2005, 2008, 2013	
Retirement			
(Assumed for benefit calculation)		September	2009
(Expected product utilization)		September	2025

4. **EPM** has just had a task order written to produce a preliminary beta test version of the analysis engine only. The principal product is a model to predict air pollutant emission rates.

Production phase:			
Analysis Engine:			
Tech Update 1	February	1999 to August	1999
Tech Update 2	February	2000 to August	2000
User Interface:	October	1999 to August	2000
Report Writer:	April	2000 to August	2000
Reference Data Library:	October	1999 to March	2000
Annual Updates	October	1999, 2000, 2001 2008	
Beta Testing:	October	2000 to March	2001
Model Linkages:	October	2000 to June	2001
Revision:	June	2001 to October	2001
Distribution:	November	2001 to March	2002
Training, Implementation:	November	2001 to March	2002
Support:			
Triennial Upgrades:	August	2001, 2004, 2008	
Retirement			
(Assumed for benefit calculation)		September	2009
(Expected product utilization)		September	2015

5. **RISK,** the principal product is a library of model-processed climatological summary and a family of processing algorithms. A portion of RISK hardware has been purchased and installed. This project must simultaneously analyze very large databases over long time periods. Therefore, it needs very fast computer processing technology and inexpensive data storage systems to store input and output data files. For example, the size of a data containing final product information for the state of Oregon could be close to 10GB. Because products are being developed for every state in the country, the total inventory for input and output files can approach 100's of GBs or TBs. Prototype products are due 6/99 at which time a user evaluation is planned on an interactive web site. Final products will be available in a variety of formats, including interactive GIS sessions that allow users to view time series and detailed statistics at each pixel from a summary map.

Production phase:			
Analysis Engine:			
Tech Update 1	February	1999 to August	1999
User Evaluation	June	1999 to October	1999
Tech Update 2	February	2000 to August	2000
User Interface:	October	1999 to August	2000
Report Writer:	April	2000 to August	2000
Reference Data Library:	October	1999 to March	2000
Annual Updates:	October	1999, 2000, 2001 2008	
Beta Testing:	October	2000 to March	2001

Model Linkages:	October	2000 to June	2001
Revision:	June	2001 to October	2001
Distribution:	November	2001 to March	2002
Training, Implementation:	November	2001 to March	2002
Support:			
Triennial Upgrades	August	2002, 2005, 2008	
Retirement			
(Assumed for benefit calculation)		September	2009
(Expected product utilization)		September	2025

II. Business Need Information

A. Sponsor:

1. USDI/USDA Forest Service Joint Fire Science Program ($2.13 million, with possible future add-ons through the competitive RFP process)
2. Fire Environmental Research Applications Team, PNW ($2.67 million)

B. Scope of Business:

FERA has promised to develop and disseminate a series of software products and databases via issue of CD-ROMs (or other digital media) and interactive access via a network. This will require rapid and substantial upgrades of our internal capacity to access information resources, analyze and manage data, develop software and database products, perform alpha- and beta- tests, share databases and software outputs with a wide variety of users, communicate results; provide training materials, user instruction, and technical support.

FERA will disperse at least $1.2 million per year through FY02 for the development and distribution of new models and databases specifically in response to the Joint Fire Sciences Program. These include $2.67 million in PNW research appropriations and $2.13 million in contracted dollars from the JFSP. One -half of the $4.8 million total will be for Forest Service salaries, travel, and support. We anticipate dispersing the remaining $2.15 million through contracts for goods and services (including hardware and software purchases, professional services, production and distribution of products, etc). Of the $2.15 million, we plan to procure $438K in FY99; $662K in FY00; $608K in FY01; and $442K in FY02.

By the end of FY99 FERA will add approximately 16 new employees, mostly in term positions. One of the employees will primarily be administrative, but will have responsibility for Web design and maintenance. Six of the employees will have part-time data reduction duties. Ten of the employees will be scientists or analysts whose sole responsibility will be to collect, analyze, synthesize, model, and communicate data and research results. These ten employees must be all equipped to collect, analyze, manage, and communicate data by August 1999.

To the extent possible, the FERA team and new employees will utilize the Forest Service IBM contract hardware and software to provide IRM needs. Some of those products will be needed on an accelerated delivery schedule (30-45 days as acceptable) in order to meet deadlines. State-of-the-art computing equipment is needed to keep pace with the rapid technological developments that our clients use, such as, interactive networking, sophisticated visualization and GUI, and 4-dimensional statistical and numerical analysis programs. These include high-speed graphics abilities, full capacity laptops for visual demonstrations, employing multi-processing and cluster computing technologies to analyze large data files, and fast and secure networking for data sharing and web access. Most of our clients will not be using IBM hardware or software, nor will they have access to the Forest Service Intranet.

We also propose extensive use of external consulting contracts to supplement our internal capacity, and seek approval to contract services that are exclusively available or more efficiently obtainable from private consultants, and academic and research institutions. For example, extensive coding in C++ and other programming platforms, digital multimedia production, and model architecture using up-to-date methods and equipment is best obtained through contracting out.

A national contract provides outsourcing access to monitoring and modeling expertise not available within the Forest Service. Five approved vendors have issue knowledge and prior experience with many of the products we develop and with the information resources that we link to. Where these advantages are important, we will use the National Air Quality Contract to obtain professional services.

We plan to do the short turn-around time projects such as data reduction and engineering updates with our internal staff, but to build complete model interfaces, analysis engines, major upgrades, and system documentation through outside contracts. We are still analyzing options for providing support for implementation, training, and continuing product use.

C. Resources:

1. Dollars by stage: $4.8 million will be expended in the development of information products in the four-year period FY's 1999-2002.

a. Strategy	$ 400 K
b. Design	300
c. Analysis	1,000
d. Production	1,400
e. Testing and revision	500
f. Implementation and training	1,200
g. Support and updating	200K/year after FY 2002

2. Dollars by year:	Acquisition(external)	Operating (internal)
a. FY99	$438K	$762K
b. FY00	$662K	$538K
c. FY01	$608K	$692K
d. FY02	$442K	$758K

3. FTE's by stage:

12.4 FTE's will be committed, roughly three FTE's/year for four years

a. Strategy	0.4 FTE
b. Design	1.3
c. Analysis	3.7
d. Production	2.0
e. Testing and revision	3.0

f. Implementation and training 2.0
g. Support and updating 0.8/year after FY 2002

D. Benefits and Beneficiaries:

The principal beneficiaries of these information products are fuel managers and land use planners in federal agencies who administer a $200 million/year program including $100 million/year special appropriation by Congress.

The products will reduce errors in prioritization, scheduling, and executing fuel treatment projects; and will improve the effectiveness of fire use. Errors in prioritization mean that the most cost-effective competing fuel treatment projects are not selected, resulting in a 25% inefficiency in the investments. Perfect information would effectively add $50 million per year to the investment in treatments. Conservatively, we assume that this investment would result in $50 million in benefits. Errors in scheduling result in repeated attempts at treatment, estimated to increase treatment costs by 50%. Avoiding these scheduling errors entirely would save $70 million per year. Mistakes resulting in damage to air quality, escaped fire damage, and air quality intrusions exceed $20 million/year, or 10% of the treatment cost.

Current methods of appraising fuel hazard, fire severity, air pollutant emissions, and air quality-related risks are accurate to less than a factor of one-in-three, meaning that the total sum of the errors of commission and errors of omission due to the lack of information is in the range $75 million to $125 million per year. Perfect information is conservatively estimated at $75 million per year. This estimate is also conservative in that it assumes that the cost benefit of fuel treatment is 1:1, and that the only benefits accrue to the principal users.

FERA products are designed to reduce the mean uncertainty in estimating fire hazard, fire severity, and emission production to +/- 15%, and the error in assessing risk from 50% to 25%. This three-fourths reduction in uncertainty would, at full product implementation, result in an annual benefit of $37,500,000.

We assume for this analysis that the product life is ten years, although our expectation is that they will be utilized for 15 to 35 years. Estimates of benefits are based only on those that accrue to the management of air quality goals, in order to limit the analysis to the stand-alone use of FERA products. The benefits will be much larger when FERA products are integrated way with other JFSP decision tools to manage cost effectiveness and the ecological consequences of fuel treatment.

E. Cost/Benefit:

We assume that 50% implementation of FERA products is accomplished within the 10-year planning horizon, beginning slowly in year three and gradually ramping up to 50% in year ten. Annual benefits will ramp up from $6 million in the third year to $29 million in year 10.

We assume that the user community will absorb the cost of implementation and system maintenance after the fourth year. As the $1.2 million cost of development diminishes, implementation costs will rise at an equal rate. In other words, we added $7.2 million to the cost estimate over and above the $4.8 million that we will actually spend for development.

The cost benefit over the first decade is estimated at about 19:1, with residual benefits of $225 million in the 15-year life of product utilization after investment has ended.

F. Application Risks:

Several factors could reduce product through inherent errors in the information products, misapplication by users, and dissatisfaction by users resulting in lack of use. These risks will be guarded against by using a vigorous QA/QC program including alpha- and beta-testing, user needs assessments and surveys, documentation, and training. Some of the risks include:

- Slow delivery of information products would result in ineffective implementation.
- Access to products limited to specific computer platforms or limited access to databases and upgrades.
- Incomplete geographic or situation coverage.
- Incompatibility with other model systems, data storage, or decision processes.
- Lack of success by users to run model without crashes and errors
- Unrealistic, meaningless, or inconsistent model outputs and data categorization.
- Cumbersome, inefficient, or confusing model instructions.
- Information system use that requires too much user knowledge or skill.
- Lack of success by users to rapidly and easily obtain updates of models, coefficients, and databases.
- Inability of all users (federal and non-federal; land managers and air regulators) to access the same models and data systems.
- Failure of other component models in the JFSP to deliver.

G. Performance Measures:

These products are designed to improve fuel hazard appraisal, fuelbed classification, prediction of fire effects, and air quality management. The measures of importance are:

- Substantial attainment of the four principal needs identified in the Joint Fire Science Program (see page 2).

- Effective implementation of the National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality (Sandberg and others 1999)
- Universality of product use by the principal beneficiaries
- Appropriateness and accuracy of use by principal beneficiaries
- Improved performance and cost efficiency of fuel treatment decisions
- Improved integration of fuel treatment decisions and land-use planning

H. Monitoring Performance

Four mechanisms will be used to monitor performance:

- The governing board and Program Manager of the Joint Fire Science Program will monitor fiscal responsibility, product delivery, implementation, and benefits of the decision support tools developed by FERA.
- The National Wildland Fire Coordinating Group will monitor implementation of recommendations in the National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality (Sandberg and others 1999) including the information products developed by FERA for the JFSP.
- The Program Manager of the PNW Research Station Managing Natural Disturbances RD&A Program will monitor and evaluate the development, implementation, and impact of FERA products.
- Peer review and formal user review panels will evaluate the quality, implementation, and impact of decision support tools for fuels management and air quality management.

III. Functional Capabilities Needed by FERA

In order to meet FERA's deliverables to JFSP for each of the five projects, we must build the capability to perform the following functions. FERA requests technical approval to acquire (estimated acquisition cost: $2.15 million; excluding Forest Service salaries, operating costs, travel, and administration that add $2.65 million):

A. **Internal Knowledge Engineering,** i.e. internal (to FERA) data collection, reduction, processing, analysis; internal scientific hypothesis testing and engineering; and internal model design and prototype development. (Estimated acquisition cost: $200K, excluding Forest Service salaries, travel, and administration.) (All this is required during of the 1999 field season April to October.)

1) **Telecommunications:** FERA needs to have a telecommunications system to communicate in the field with cooperators from other federal land management agencies and other institutions that use different radio technology than the Forest Service; for example, digital radios and aircraft-compatible radios. The field work also is carried out in remote areas with no access to regular radios and telephones, requiring communications equipment that will allow field

crews to communicate to FERA headquarters regardless of the working location or lack of access to regular radios and telephones.

Example Hardware/Software Acquisition Needs:

- *Dual narrow- and wide-band radios, digital radios, aircraft-compatible radios, vehicle radios, handheld radios*
- *Cellular phones*
- *Satellite phones*

2) **Data Acquisition and QA/QC:** FERA needs to maintain high standards of data quality assurance, control and security during all the phases of the five projects. To maintain a rigid QA/QC of field data acquisition for the five projects we require real time access to data collected by the field crews or equipment. To ensure immediate access to data by scientists and staff working in data reduction and analysis, FERA requires portable equipment to collect data in a digital form, and services that allow remote link from the field to headquarters in Seattle.

Example Hardware/Software Acquisition Needs:

- *Weather stations, Small, portable, with RH, temperatures, wind, precipitation, CO/PM sensors*
- *Smoke emissions sampling equipment, CO, nephelometer, particulate samplers; sample analysis*
- *Data recorders/laptops*
- *Digital video cameras*
- *High speed modems*
- *Data telemetry hardware*
- *Computer webserver*
- *Software to link dataloggers to PCs*
- *Photographic equipment and accessories*
- *1 TB of data storage*

3) **Geo-referencing:** It is a requirement that our field data is truly geographically referenced, and also be able to relocate semi and permanent plots, thus we need access on real time to unscrambled GPS signals. We need to purchase equipment that the satellite signal can be corrected by the Department of Defense for federal agencies.

Example Hardware/Software Acquisition Needs:

- *GPS PLGR*

4) **Data Reduction and Analysis:** FERA needs to develop and improve current data reduction and analysis tools, as well as increase the statistical analysis and modeling capability. Prototypes will be developed by FERA's staff; minor version releases will also be made in-house. Data reduction for repeated

(annual) data collection will require a professionally-engineered data reduction program.

Example Hardware/Software Acquisition Needs:

- *Programming compilers (FORTRAN, C++)*
- *Database managers*
- *Statistical modeling, data visualization, flowcharting*
- *Color and black and white laserjet printers*

Example Professional Services Contract Acquisition Needs:

- *Data reduction program (contract)*
- *Data reduction and analysis (contract)*

B. External Data Acquisition, i.e. acquisition of climate data, remote sensing data, terrain data, digital vegetation cover data, aerial photography, etc. The functionality that FERA will achieve through external data acquisition is to obtain geographically referenced data sets that will create input variables for the models and databases that will be developed. This geo-referenced external data will also allow us to create a link that will enable users to integrate our products into mapping tools, such as GIS, derived from remote sensing, aerial photography and other field data. External data acquisition will allow us to gain access to the state of the art in technology and science currently available. It will also allow us to satisfy current federal data standards. (estimated acquisition cost: $300K)

Example Hardware/Software Acquisition Needs:

- *Software to access, process Climate data files*
- *Telephone access to network for x-terminal demonstrations of preliminary products*
- *Hi-speed, simultaneous processing with more that 4 processors to help analyze data files covering large domains and long time periods.*
- *Inexpensive data storage facilities to archive several TBs of data and make available in real-time close over 100 GB of data.*

Example Professional Services Contract Acquisition Needs:

- *Aerial photo flights*
- *Database software*
- *Remote sensing data*
  Digital satellite images (Landsat and AVHRR)
- *Synthetic data (e.g. model runs of FVS-FFE, FARSITE)*
- *Literature searches*

C. Database and Software Development and Production, i.e. creation of CONSUMEv3.0, EPMv2.0 models; PHOTO, FCC, RISK models and databases; and Reference Data Library model variants and upgrades, databases, and heuristics. This is our largest and most central category of need, i.e. the production of our deliverable products. (estimated acquisition cost: $1.100 million).

Acquisition of products and services under this TA for the production phase will enable FERA to maintain high standards of data security, QA, and QC and deliver the products under the contract with the JFSP in a timely fashion. To achieve this goal we need a fast and high capacity data communications system to oversee the development of products by contractors and interact with cooperators in different parts of the country, to release BETA testing products to users and to encourage extensive participation of users in BETA testing, and to capture their feedback in an optimum manner. We will need compatibility during the development, production, release and maintenance phases with different computing platforms used by all the land management agencies that integrate the JFSP.

Example Hardware/Software Acquisition Needs:

- *Network*
- *Remote connectivity software*
- *Office suites*
- *SQL (or similar tool) to query the database*
- *Development of a modular program to link existing and new tools, and development of a GUI*
- *UNIX workstations*
- *UNIX server*

Example Professional Services Contract Acquisition Needs:

- *Contracts for software engineering to build an overall simulation modeling framework for EPM and CONSUME. (2 separate tasks envisioned under the National Air Quality Contract (NAQC))*
- *Contracts for database design for FCC's, PHOTO databases, and RISK (14 separate tasks envisioned under the NAQC, and 6 separate contracts to vendors not under the NAQC)*
- *Contracts for software engineering that incorporate new science results and theory into simulation model DLL's for EPM and CONSUME upgrades. (9 separate tasks envisioned under the NAQC)*
- *Contracts for software engineering to develop a graphical user interface for each of the five FERA products (simulation models CONSUME and EPM; FCC, PHOTO, and RISK hard-copy databases) (8 separate tasks envisioned under the NAQC, and 2 separate contracts to vendors not under the NAQC)*
- *Contracts for software engineering to develop a report writer to generate digital output files from each of the five FERA products (simulation models CONSUME and EPM; hard-copy databases for FCC, PHOTO, and RISK) that can be used to link with other models (7 separate contracts to vendors not under the NAQC)*

- *Contracts for users' manuals for each FERA product for each class of user, i.e. fuel manager, scientist, air quality manager. (contract the development in 14 separate contracts)*

D. **Production and Distribution of Hardcopy and Digital Products**, i.e. Printed Photo Series, digital multimedia, CD-ROM's, User Manuals. Products will be delivered in traditional printed format. However, we want to deliver our products in an economical, efficient, and more modern digital fashion without sacrificing the quality and usefulness of the products. To achieve this goal, we need to have an in-house digital multimedia production capability to create digital prototypes. We also want to have the capacity to deliver the finished products through FERA's website. The products we will deliver under the JFSP should be compatible across all federal agencies involved in it. (estimated acquisition cost: $200K)

Example Hardware/Software Acquisition Needs:

- *Digital media writer*
- *Digital media writer software*
- *Copying of digital medium*
- *R/W CD-ROMs*

Example Professional Services Contract Acquisition Needs:

- *Contracts for alpha- and beta-testing of each phase of FERA product distribution. (16 separate tasks envisioned under the National Air Quality Contract (NAQC), and 8 contracts to vendors not included in NAQC)*
- *Contracts for pressing and distributing the suite of hard copy products for the five FERA deliverables (simulation models CONSUME and EPM; hard-copy databases for FCC, PHOTO, and RISK) at each triennial upgrade (8 separate tasks envisioned under the National Air Quality Contract, and 2 separate contracts to vendors not under the NAQC)*
- *Contracts for authoring, printing, and distributing users' manuals (8 separate tasks envisioned under the National Air Quality Contract, and 2 separate contracts to vendors not under the NAQC)*

E. **Creating and Maintaining a Website** for user support, user access to models and products, databases, and Reference Data Library, interactive access to products (Photo Series), and remote execution of products (CONSUME). FERA needs to be able to deliver its products in a timely manner and reach an wider group of users across federal land management agencies supporting the JFSP. Additionally, we need to respond quickly to user needs and suggestions to improve the quality of our deliverables. Those improved products have to be made available quickly back to the users. We want to be able to maintain a constant two-way interaction with our main user group across agencies nationwide in a timely manner. We also want to have the ability to maintain high standards of QA/QC and data security in our web server, making use of a bastion between . To achieve these goals we need a high capacity web server with the most current hardware and software technology to rapidly develop and update web sites. Additionally, we require a web multimedia production capacity that will be compatible with current technological standards that also will allow us to maintain compatibility with our cooperators and users.

During several stages of projects we will need to provide unrestricted network access to users and cooperators from several federal agencies and academic institutions, as well as FERA scientists, following Forest Service network security standards. The IT resources acquired under this item will allow us to set up a bastion at FERA's network to protect data security. (estimated acquisition cost: $50K)

Example Hardware/Software Acquisition Needs:

- *Secure firewall*
- *Real-time access to over 10 GB of data*
- *Real-time update and quality control of a national database*
- *Reasonable down-load time for data files several to hundreds of MB in size*
- *Interactive exchange of information and data*
- *Twice daily update of telemetered data from several field locations.*
- *Laptops*
- *Personal computer (large)*
- *Increased network capability and Internet access*
- *Web server*
- *Scanners*
    - *Flatbed, slide, other*
- *Web authoring/ webmaster software*
- *Operating system to run server*
- *Image processing software*
- *URL submission service*

Example Professional Services Contract Acquisition Needs:

- *Internet Service Provider or other service agreement*

F. Training and User Support, including a beta test program, QA/QC monitoring of implementation. FERA has been successful as an R&D group because of the wide base of cooperators and product users within land and fire managers in the DOI and FS. We want to keep and enhance that capability. We need to have fast communication channels with users groups by traditional communication media such as telephone, publications, public presentations, but also we want to be able to reach a wider base of users in several a federal agencies through a mass media such as the Internet. We have the compromise to train users by means of multimedia training kits or by more traditional ways such as training sessions, workshops, seminars, symposiums, etc, and also through FERA's website. We want to be able to periodically monitor the success of the products. The following are examples of IT resources that we need to achieve those goals:

Example Hardware/Software Acquisition Needs:

- *Modems*
- *Video/slideshow development (contract)*
- *Personal computers*
- *LCD projector*
- *Digital camera*
- *Office suite*
- *Image processing software*
- *Remote connectivity software*
- *PDF creation software*
- *Workshop presentations*

Example Professional Services Contract Acquisition Needs:

- *Contracts for training and implementation support for each product (16 separate tasks envisioned under the National Air Quality Contract, (NAQC), and 8 contracts to vendors not included in NAQC)*
- *Contracts for user support (15 separate tasks envisioned under the National Air Quality Contract, written as tri-annual support contracts)*
- *Users' manuals (contract the development)*

IV. Alternatives and Proposed Solution

A. General Solution: We plan to do the short turn-around time projects such as data reduction, scientific analysis, prototype development, database management, and engineering updates with our internal staff (45% of total effort). We intend to build complete model interfaces, analysis engines, major upgrades, software engineering, programming, beta testing, and system documentation through outside contracts (55% of total effort). We are analyzing the options (i.e. whether internal or external) for providing support for implementation, training, and continuing product use.

1. Hardware and Software: We anticipate new hardware and software acquisition at $750 K to equip new employees; keep current with necessary upgrades; improve our capacity for database management, numerical and statistical analysis, flowcharting, engineering, image processing, digital multimedia production, and GIS; maintain a Website; telemetery data; and communicate in the field.

a. IBM Contract: (estimated acquisition cost: $400K)

To the extent possible, the FERA team and new employees will utilize the Forest Service IBM contract hardware and software to provide IRM needs. The majority of those products will be needed on an accelerated delivery schedule in order to meet our computer processing power needs; compatibility and networking requirements with clients and contractors; and website integrity. Network tools need improving to ensure efficient and reliable communications with clients outside of the Forest Service Intranet.

b. **Items that we are uncertain they are available on IBM contract:** (estimated acquisition cost: $350K)

Much of our work entails complex analysis of large datasets and sharing data files and results with our clients. This requires state-of-the-art computing, networking, data storage, and display capabilities; including, but not limited to, large anonymous-ftp and web servers, simultaneous computing on multiple processors, large disk arrays, tape and CD libraries, web design tools, client-compatible word processing and graphics programs, portable display devices, and tools for numerical and statistical analysis, flowcharting, engineering, and image processing.

Other technology not on the IBM contract include products that facilitate voice and data communications in the field. These include upgrading radios to match our client's functionality (digital and narrowband analogue), and using satellite and cellular systems, programmable data loggers, and remotely-sited data sensors.

2. **Professional Services:** (estimated acquisition cost: $1.4 million). We propose to the extensive use of external consulting contracts to supplement our internal capacity, and seek approval to contract services that are exclusively available or more efficiently obtainable from private consultants, and academic and research institutions. For example, extensive coding in C++ , Internet programming tools, or web technology, and model architecture using up-to-date methods is best obtained through contracting out. We will also fund collaborating science and modeling teams to build model linkages and to produce synthetic data sets..

a. **National Air Quality Contract:** (estimated acquisition cost: $780 K): A national contract is available to outsource access to monitoring and modeling expertise not available within the Forest Service. Five approved vendors have issue knowledge and prior experience with many of the products we develop and with the information resources that we link to. Where these advantages are important and we are within the scope of the National Contract, we will use it to obtain professional services through task orders. We expect that three-fourths of CONSUME, all of EPM, one-fifth of FCC, and one-third of RISK can be handled through this national contract.

b. **Other Professional Services:** (estimated acquisition cost: $640 K) Some tasks will not be covered by the National Contract because they are outside the scope of that agreement or can be more efficiently obtained through other vendors through advertised competition. For example, linkages to other fire behavior, fire effects, biogeography, vegetation, and management models can be better built by the authors of those models. Also, purchase of climate, remote sensing, and biogeography databases will be obtained from other vendors.

B. **Alternative Solutions:**

1. **Internal Knowledge Engineering**:
   a. **Internal science production:** The preferred alternative is based on the assumption that the responsibility and intellectual capacity to create the science and basic engineering design resides in permanent FERA scientists. There is no reasonable alternative to that assumption, given that we are the accountable parties. There is neither the time available nor the longevity of the input resources in the framework of the JFSP) to warrant the hire of new scientists or the replacement of current scientists.
   b. **Internal data reduction/analysis:** The preferred alternative is based on the assumption that short-term data reduction and analysis and prototype development is most efficiently performed in-house by post-doctoral and term employees now being recruited. Part of our assumption is that we want to retain direct day-to-day oversight of those processes, and that we want to ensure data security, quality assurance, or quality control.
   (1). One alternative is for the permanent scientific staff to assume this role. However, we are already overcommitted and are less technically capable in this mode that the candidates available.
   (2). Another alternative is to contract out these tasks competitively. However, we are reluctant to lose the immediate oversight, data QA/QC, and data security interest that this option would compromise.

2. **External Data Acquisition:** The preferred solution assumes that the proprietary or the authoring entities are the most efficient and most ethical source of external data. This includes synthetic data that are generated from proprietary or other scientists' models. Implementation of the preferred solution will imply that we will acquire data that follows stringent QA/QC procedures by data providers.

   a. One alternative is to recruit and develop new employees who would compete or duplicate the currently existent capabilities to supply these data. We estimate that this option would consume eight times the resources (i.e. $2.4 million) and take six time as long (i.e. nine years) to acquire.
   b. Another alternative would be to not obtain the external data. This would violate the intent of Congress and the JFSP to create a nationally consistent decision support system. It would make FERA products incompatible with other vendor products.

3. **Production (mostly obtained from external contact sources)** The preferred solution assumes that the modern programming skills and

robust internal capacity needed is most efficiently found primarily in the private, academic, and research sectors. This assumption is bolstered by our experience in the past three years in obtaining services through the five approved vendors on the National Air Quality contract.

a. One alternative is to recruit and develop new employees who would compete or duplicate the currently existent capabilities within private consultants/contractors to perform these tasks. This option may be partially feasible, but there is no way of knowing until our current recruitment of 16 term/post-doctoral employees is completed. When those employees are on board and have been evaluated, we may want to shift some of our planned production to an in-house responsibility. Currently, we have no expectation of realizing that level of internal capacity. There are no resources or time available within FERA or JFSP constraints to recruit additional (to the 16) positions or intensively train FERA's personnel. Keeping up with the fast development pace of information technology necessary to fulfill the JFSP commitment would make it extremely expensive to develop an inhouse capacity.
b. Another alternative would be to seek collaboration elsewhere within the Forest Service or Interior Agencies research community. This alternative may be partially obtainable although, as well as FERA is networked with the community of scientists and developers within the federal agencies, we would be very surprised to discover such internal capacity.

4. **Creating and Maintaining a Website:** The preferred solution assumes the current situation, which we realize is an assailable assumption given the rapid pace of development in this technology. We require that all users have unconstrained access to our reference data library; and that FERA personnel have immediate and unconstrained ability to revise web pages and downloadable files. Given the current (1999) situation, the Forest Service capacity to support a website fails on both accounts. Fortunately, we have about one year (February 2000) to inextricably select an alternative.

    a. One alternative is a change in Forest Service internal capacity and policy to provide a more efficient and technologically capable service. If that happens, then our preferred alternative will shift toward the Forest Service as the provider of Internet services.
    b. Another alternative is to utilize other federal agencies as the provider. The National Interagency Fire Center (NIFC) service is an obvious alternative worth considering. NIFC supports JFSP in many other ways, and provides a Web service to the fire/fuels community now that is robust and capable.

c. A third alternative is to engage a private ISP to provide Web access, and support an internal Web server at our Seattle laboratory. This is our fall-back position, if nothing else pans out.

5. **Training and User Support:** The preferred solution assumes that we will mix, on a 30%/70% ratio, the responsibility for training and user support with private or external agency collaborators in the period 2002 to 2025. That is a ratio we have found to be effective in the last 25 years, but that we realize is subject to change as the technology and infrastructure of technical support evolves. We intend to remain flexible as this capacity evolves.
   a. The alternatives to the preferred solution depend on the evolving capacity of internal, other federal, and private vendors to provide training and user support relative to FERA's internal capacity. Fortunately, we have no irreversible decisions to make until FY2002.

V. Possible Future Augmentation:

The JFSP is an ongoing program with a series of proposal requests expected over the next 2 to 3 years. Although it is difficult to anticipate the context of each proposal, FERA is likely to respond to some of the requests. Potential future proposals may include:

Scientific assessment of consumption and emission models for application to land management. This will be a joint project between FERA and scientists at the Rocky Mountain Fire Lab in Missoula. It will generate a quality-controlled data base of consumption and emission measurements, evaluate model function in a variety of vegetation types, provide guidelines for using each model, develop case studies, and create a strategic plan for future research. Expected IT requirements will include workstations for 2 new employees (at Missoula and Seattle labs), analytical software, contract services to reprogram models for ease of comparison or reformat measurement data if needed, high-speed network communications, and interactive web access by a variety of clients. Total cost of expected IT for the PNW Research Station is about $100,000 (not included in this TA request).

Modular linkage between FERA products to create a GIS-based risk assessment for the use of prescribed fire as a fuels management tool. This project will take all of the elements of FERA's products, modify them for large, landscape applications, and link them into a risk evaluation system. It will require high speed processing capability, interactive access to large databases, inexpensive data storage media, multi-processing computer capability, and interactive web access to prototype and final products. Expected IT requirements will include updates to the IBM server and disk storage components, workstations for 2 new employees at the Seattle lab, high-speed network communications, interactive web access by a variety of clients, and state-of-the-art GIS, database software, analytic, and visualization software. Total cost of expected IT is about $300,000 (not included in this TA request).

Modular linkage of FERA products to products developed elsewhere. This will be a joint project between FERA and several other research institutes throughout the country. It will take elements of FERA's products, modify them for linkage to database management tools, remote sensing databases, object-oriented modular modeling systems, and air quality models and habitat models. In addition, FERA's GIS data layers will be adapted to benefit spatial analysis of many systems; including, but not limited to, habitat conditions, gap and corridor analyses, and disturbance by fire, insect, and disease. Expected IT requirements will include updates to the IBM server and disk storage components, workstations for 1 new employee at each collaborating laboratory, high-speed network communications, interactive web access by a variety of clients, and state-of-the-art GIS, database software, analytic, and visualization software. Total cost of expected IT for the PNW Research Station is about $500,000 (not included in this TA request).

VII. Summary or TA Request:

FERA is engaged in information systems development in response to a national priority and emergency program (JFSP) to develop an information system that serves as decision support for policy and management on the subject of fuels management, prevention of economically and ecologically catastrophic wildland fires, and degradation of air quality. We have committed to the accelerated development of key information products in that decision support system. We must provide deliverable products beginning in August 1999 to serve this national priority. We appreciate the active support of expedited technical approval for this development from the Managing Natural Disturbances RD&A Program; the PNW Station Director's Office; and R6/PNW Information Resource Management in achieving this first step toward accomplishment. To proceed, we need and request:

A. Technical Approval to provide the information products (PHOTO, FCC, CONSUME, EPM, RISK) that we have been funded for and are already accountable to the JFSP to deliver.

B. Technical Approval to acquire $2.15 million, over a four-year period to acquire internal capacity (hardware and software, up to $750K) and competitively-bidded professional services (up to $1.4 million) necessary to provide those deliverables.

C. Departmental waiver (not Technical Approval) for $9.85 million, which is the anticipated cost of implementing this program from years 5 through 10.

D. Continued advice and support from IRM to adjust and improve our product development and acquisition strategy.

VII. References

Sandberg, David V.; Hardy, Colin C.; Ottmar, Roger D. [and others]. 1999. National strategic plan: modeling and data systems for wildland fire and air quality. Gen. Tech. Rep. PNW-GTR-450. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 60 p.

U.S. Department of the Interior and U.S. Department of Agriculture. 1995. Federal wildland fire management policy and program review. Boise, ID. Bureau of Land Management; final report. 45 p

	EXAMPLE PURCHASES			
CAPABILITY	Hardware	Software	Services	
Internal Knowledge Engineering	GPS Telemetry PCs Data recorders Cell phones Radios Weather stations Smoke Samplers Laptops Modems Printers	Compiler for --FORTRAN --C++ Database --modeling --visualization --flowcharting --statistics Software to link dataloggers to PCs	Data reduction program-ming Data reduction analysis	200K
External Data Acquisition	Parallel processors*	Database software	Remote sensing data Synthetic data (model runs) Literature searches Climate files Aerial photos	300K
Database and Software Development and Production	Network Parallel processors* 1 TB of storage	Office suite Remote connectivity software Query softare Development of modular linking program	User's manuals	1,100K
Production and Distribution of Hardcopy Products	Digital media writer Personal computer R/W CD-ROMS	Writer software	Copying of digital medium	200K
Creating and Maintaining a Website	PC (large) Increased netowrk capabil-ity and Internet access Server Scanners Laptops	Web authoring and webmaster software OS to run server PDF creation software Image processing software	ISP or other ser-vice agree-ment URL sub-mission service	50K
Training and User Support	PCs LCD projector Digital camera	Office suite PDF creation software Image processing software Remote connectivity software	Workshop presenta-tions	300K
TOTAL	300K	350K	1.5 mil	2.15 mil

FERA/JFSP Decision Support System: Proposed Solution

**** COST ITEMS ***					(Values in $1,000)					
NON-RECURRING COSTS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Totals
--ACQUISITION COST ITEMS	------	------	------	------	------	------	------	------	------	------	------
Equipment/Related Items	92.0	90.0	48.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	270.0
ADP/OA Equip. Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Equipment Maintenance	5.0	5.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
Software Packages	51.0	92.0	125.0	82.0	0.0	0.0	0.0	0.0	0.0	0.0	350.0
ADP/OA Support Servic (1)	290.0	475.0	425.0	310.0	0.0	0.0	0.0	0.0	0.0	0.0	1,500.0
In-house S/W Dev-Mtce (FTE)	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0
--SYSTEM LIFE COST ITEMS											
Site Preparation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Agency Costs	307.0	183.0	180.0	240.0	0.0	0.0	0.0	0.0	0.0	0.0	910.0
Training Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overhead Expenses	180.0	180.0	180.0	180.0	0.0	0.0	0.0	0.0	0.0	0.0	720.0
Space/Environ/Utility	235.0	135.0	192.0	298.0	0.0	0.0	0.0	0.0	0.0	0.0	860.0
Supplies	40.0	40.0	40.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	160.0
Subtotals	1,200.0	1,200.0	1,200.0	1,200.0	0.0	0.0	0.0	0.0	0.0	0.0	4,800.0
RECURRING COSTS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Totals
--ACQUISITION COST ITEMS	------	------	------	------	------	------	------	------	------	------	------
Equipment/Related Items	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ADP/OA Equip. Service	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Equipment Maintenance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Software Packages	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ADP/OA Support Service	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In-house S/W Dev-Mtce (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
--SYSTEM LIFE COST ITEMS											
Direct Agency Costs	0.0	0.0	0.0	0.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	7200.0
Training Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overhead Expenses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Space/Environ/Utility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supplies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotals	0.0	0.0	0.0	0.0	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0	7,200.0
TOTAL COSTS											
Acquisition & System Life	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0	0.0	0.0	0.0	0.0	0.0	12,000.0
Acquisition only	438.0	662.0	608.0	442.0	0.0	0.0	0.0	0.0	0.0	0.0	2,150.0

**** QUANTIFIABLE BENEFIT ITEMS **** (Include Boundary Estimates for Non-Quantifiable Benifits)

NON-RECURRING BENEFITS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Totals
	------	------	------	------	------	------	------	------	------	------	------
Cost Reduction Items	0.0		500.0	1,000.0	2,000.0	2,200.0	2,400.0	2,500.0	2,600.0	2,600.0	15,800.0
Value Enhancement Items	0.0	0.0	750.0	1,500.0	3,000.0	3,300.0	3,600.0	3,900.0	4,100.0	4,100.0	24,250.0
Cost Avoidance Items	0.0	0.0	1,000.0	2,000.0	4,000.0	4,400.0	4,800.0	5,100.0	5,500.0	5,500.0	32,300.0
Benefit to Public Items	0.0	0.0	4,000.0	8,000.0	10,000.0	12,000.0	14,000.0	16,000.0	17,000.0	17,000.0	98,000.0

Other Benefits		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotals		0.0	0.0	6,250.0	12,500.0	19,000.0	21,900.0	24,800.0	27,500.0	29,200.0	29,200.0	170,350.0
RECURRING BENEFITS		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Totals
		------	------	------	------	------	------	------	------	------	------	------
Cost Reduction Items		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Value Enhancement Items		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost Avoidance Items		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benefit to Public Items		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Benefits		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotals		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL BENEFITS		0.0	0.0	6,250.0	12,500.0	19,000.0	21,900.0	24,800.0	27,500.0	29,200.0	29,200.0	170,350.0
BENEFITS - COSTS		(1,200.0)	(1,200.0)	5,050.0	11,300.0	17,800.0	21,900.0	24,800.0	27,500.0	29,200.0	29,200.0	158,350.0
PAYBACK		(1,200.0)	(2,400.0)	2,650.0	13,950.0	31,750.0	53,650.0	78,450.0	105,950.0	135,150.0	164,350.0	
C/B ANALYSIS SUMMARY VALUES						THRESHOLD ANALYSIS						

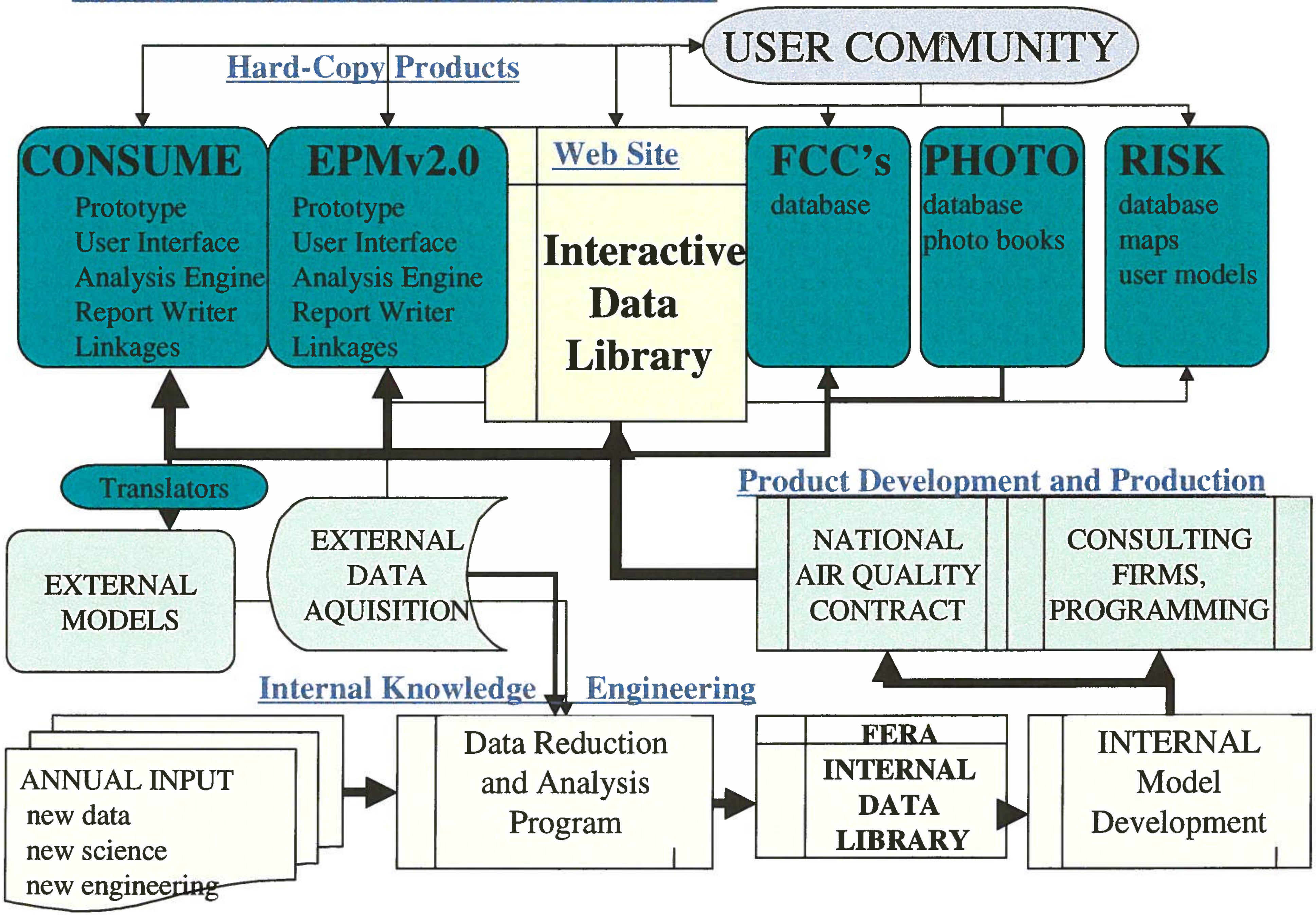
				------------	------------	------------	------------	------------	------------			
				Threshold		Acqis'n	FS		Over			
System Life, Years	5			Category		Cost	Threshold		Threshold?			
				------------		------------	------------		------------			

Acquisition Cost	2,150.0		Equip. Items	270.0	100.0		TRUE		
(over System Life									
			Equip. Service	0.0	100.0		FALSE		
System Life Cost	12,000.0								
			Equip. Maint.	30.0	50.0		FALSE		
Present Value Cost	5,002.8								
			Software	350.0	50.0		TRUE		
Residual Value	54.0								
			Support Service						
Discounted Residual									
Value	30.5		Contract Items	1,500.0	250.0		TRUE		
Adjusted Cost	4,972.3		In-House Soft.	12.0	6.0		TRUE		
			Dev & Maint						
System Life Benefits	170,350.0								
							0 = No		
Present Value Bene.	95,238.8						1 = Yes		
Net Present Value	90,266.5								
Benefit/Cost Ratio	19.2								
Payback Period	3	Years							

Valid Spreadsheet?		85900										
0 = Yes, Non-Zero = No												
	1	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	
	1	NA	166750	161700	150400	132600	110700	85900	58400	29200	0	

(1) includes acquisition of professional (consulting) services and external data acquisition.

FERA/JFSP Information Products



Joint Fire Science Program — Department of the Interior and USDA Forest Service

Introduction

There is increasing concern that fuel loadings are reaching hazardous levels that can lead to widespread catastrophic fires in ecosystems where frequent fire has been excluded. This situation was addressed in the 1995 Federal Wildland Fire Management Policy Review and Report that contributed to the development of a new Federal fire policy. That policy directs agencies to achieve a balance between suppression capability and the use of fire to regulate fuels and sustain healthy ecosystems.

The need to understand both the role of wildland fire as an ecosystem process and the appropriate use of fire as a management tool has been recognized for years. Historically fire has played an important role in many ecosystems by removing fuel accumulations, decreasing the impacts of insects and diseases, stimulating regeneration, cycling critical nutrients, and providing a diversity of habitats for plant species and wildlife. As land management agencies have become more successful at suppressing wildland fires, and other human actions have reduced the spread of fires, fire frequencies have been reduced substantially in many ecosystems. However, there has been a growing recognition that disturbances by fire can have both positive and negative effects on human and environmental values. As a result, there has been a growing desire to understand the long-term consequences of altering fire regimes on the structure and health of plant communities, wildland fuels, fire severity, and air and water quality.

In the 1998 appropriation, Congress, with the support of the Administration, provided a more flexible funding authority to support the aggressive use of fire and mechanical fuels treatments, with the goals of reducing the occurrence of uncharacteristically severe wildland fires and improving ecosystem health. This change will help implement the new fire policy. In granting this new funding authority, Congress expressed a concern that "both the Forest Service and the Department of the Interior lack consistent and credible information about the fuels management situation and workload, including information about fuel loads, conditions, risk, flammability potential, fire regimes, locations, effects on other resources, and priorities for treatment in the context of the values to be protected." Congress directed the Department of Interior (including the Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), National Park Service (NPS), Fish and Wildlife Service (FWS), U.S. Geological Survey (USGS)), and the Forest Service (FS) to establish a Joint Fire Science Program to supplement existing fire research capabilities.

The new Joint Fire Science Program, described in this document, will be designed to provide a scientific basis and rationale for implementing fuels management activities, with a focus on activities that will lead to development and application of tools for managers.

This plan will address four issues critical to the success of the fuels management and fire use program. These issues are:

The need to develop and implement consistent interagency fuels mapping and inventories with common classifications and resolution within ecosystems. This information will help managers identify the location of hazardous fuels, determine where fuels have accumulated beyond the historic range of variability, determine potential impact of current fuel conditions on fire regimes and ecosystem processes, determine where fire damages and costs are increasing, recognize the most at-risk fuel/fire regime components, set priorities for treatments, and determine the appropriate type and frequency of treatment.

The need to evaluate and compare fuels treatment practices and techniques, including prescribed fire, thinning and other mechanical methods, increased utilization of biomass, and no treatment. The evaluations will assess cost effectiveness, social impacts, air quality and watershed impacts, ecological consequences, and potential effects on wildland fire size, severity, and cost.

The need to develop treatment schedules, determine the frequency of subsequent treatments, and coordinate treatment schedules among agencies. In developing treatment priorities and schedules, managers will need to consider the potential effects on other resources such as air and water quality, wildlife habitat, threatened and endangered species, and cultural values; on management activities, such as timber harvest, grazing, recreation, control of invasive, nonnative plants; and on costs, benefits, and risks associated with treatment and no treatment.

The need to establish compatible interagency processes and procedures for monitoring, evaluating, and reporting fuels treatments. This will allow managers to determine whether the fuels management program is meeting its goals and objectives, by regularly updating fuels maps and inventories, and allowing synthesis of information across geographic and agency boundaries.

The Joint Fire Science Program will establish the process and program oversight structure to identify and meet fire information and technological support needs for a national interagency fuels management program. Procedures will be developed to ensure financial accountability and proper business management practices. These include a competitive process for awarding contracts or other forms of agreements, contract administration that ensures deliverables are timely and meet specifications, and annual reporting requirements. The Joint Fire Science Program will be fully reviewed, and appropriate adjustments made, by the end of the year 2001.

Background

Fire and resource managers have learned about the interrelationships among current levels of wildland fuels, fire effects, and ecosystem functions both through personal experience and from results of a limited number of scientific studies. This has led to concerns over the contribution of fuel accumulations to severe wildland fires and the relationship between such fires and ecosystem health problems. These concerns are substantiated by fire ecology studies and by data that show increasing fire severity. For

Contact: Dr. Bob Clark
Interim Project Manager
(208)387-5349 or blclark@nifc.blm.gov

August 18, 1998

Roger D. Ottmar
Robert E. Vihnanek
USDA Forest Service
Pacific Northwest Research Station
4043 Roosevelt Way N.E.
Seattle, WA 98105

Dear Roger and Robert,

The Governing Board of the Joint Fire Science Program recently met to evaluate peer review comments, review proposals, and select science project proposals for funding. The proposal you submitted ("Photo Series for major natural Fuel types of the Unites States -- Phase II") was selected and approved for funding in the amount of $292,043. As indicated in your proposal, the work should begin on October 1, 1998.

Please provide a complete, itemized budget (including identification of capitalized equipment) and firm timeline. In particular, the Governing Board expects annual progress reports in the timeline. We will attempt to get the funding (total amount of $292,043) transferred prior to September 30, 1998; however, the funds are currently in two accounts in different agencies and as you know, fiscal matters may not be straightforward. Therefore, please provide us with the name and phone number of the appropriate PNW accountant. Finally, if there is anything the Program can do to help you, please call me at the number on the letterhead.

We appreciate your interest in the Joint Fire Science Program and the wildland fuels issue, and thank you for the time and effort you committed to preparing the proposal. We look forward to working with you as you complete this project.

Sincerely,

Bob Clark
Interim Program Manager

Briefing Paper: PHOTO SERIES

Photo Series for Major Natural Fuel Types of the United States--Phase II

Executive Summary: The photo series is an important land management tool that can be used to ecologically assess landscapes through the appraisal of living and dead woody material and vegetation, and stand characteristics. The purpose of this study is to continue the development of a natural fuels photo series and include important fuels types previously not attempted because of funding and time limitations. This study is composed of 4 tasks including: (1) a needs assessment to determine the fuel types and fuel elements for inclusion into the phase II photo series; (2) field data collection; (3) data reduction and analysis; and (4) preparation of camera ready manuscript and CD-ROM. This study addresses issue 1 (fuel mapping and inventory) and issue 4 (establish compatible interagency processes for monitoring fuels treatment) of the Joint Fire Science Program, and task 1 (information available for fuels inventory) and task 4 (synthesize available information on current wildland fuels situation).

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Introduction

Knowing the fuel properties across a landscape is one of the most important pieces of information required by the land managers to operate fuel and fire management decision support systems. Most managers have little available fuels data to the extent, detail, or resolution needed for fire behavior and fire effects prediction. A sequence of photos called a photo series provides a quick, easy means for quantifying and describing existing fuel properties for selected sites across a landscape. Although there are over 20 officially published photo series in existence today (Maxwell and Ward 1980, Fischer 1981, Blonski and Schramel 1981, Ottmar and others 1990) they are limited in scope, contain single photographs, and generally do not contain sufficient fuels property data for the operation of fire effects and fire behavior models. Available photo series also lack the detail needed for linking to remote sensing signatures, development of fuel condition classes, and are often restricted to activity fuels in forested biomes. With the increase in prescribed burning proposed for natural fuel areas and non-forested biomes, a study was commissioned by the Department of the Interior in January 1995 to develop a natural fuels photo series that would improve the photo series coverage of several major fuel types common to federally managed lands in the United States. Although this project is nearly complete (Ottmar 1997, Ottmar and others 1998), several critical fuel types were not covered within the scope of this project because of funding and time limitations. Several important fuel types not included in phase I of the photo series development include hardwood and tundra types in Alaska, cedar salt brush in the Southwest, old growth Douglas-fir/western hemlock (late successional reserves) along the west coast, mixed conifer/pine/shrub types in northern California and southwest Oregon, exotic and native grass and shrub types in Hawaii and mixed hardwood types in the Southeast. Opportunities to link this study with other efforts and to acquire matching dollars from other agencies such as USDA Forest Service, Bureau of Land Management, EPA, and NASA are good, and will be pursued.

The process of compiling a photo series provides the added benefit of creating a substantial data base of fuelbed descriptions in cover types where data is now scarce. These data are essential for the formation of Fuel Condition Classes, for providing default fuel descriptions as fire behavior and effects model inputs, and for validating remote sensing or other techniques that infer fuelbed conditions from other data.

Objective

The primary objective of this project is:

To continue the development of the natural fuels photo series to include a maximum of 10 additional fuel types not covered by previous projects

The goals of this objective are to: (1) complete an assessment of the literature and the needs of the land manager to define the fuel types and fuel elements for continual development of the natural fuels photo series; (2) locate and photograph a maximum of 20 sites within a fuel type that cover a range of fuel loading or vegetation density, field inventory; and (3) reduce data format into camera-ready manuscript and CD-ROM, and assist with printing process.

Methods

The photo series project will be accomplished in three major phases, each closely linked and occurring, in many cases, simultaneously. During the coordination phase, a simple needs assessment will be implemented, existing photo series reviewed, and literature scanned to determine inventory and data reduction protocols, and work plan finalized. The research phase will determine fuel types, locate photo sites, finalize sampling protocols, collect field data, photograph, and reduce and summarize data. The implementation phase will synthesize results and complete camera ready volume or volumes for printing and distribution. This phase will also scan photos and documents onto a CD-ROM for distribution according to procedures developed by Weise (1998).

Coordination Phase

This phase reviews all available photo series, assesses needs from managers and scientists, and synthesizes input variables required to remotely map fuels and operate new fire effects and fire behavior models. This review will be used to determine the fuel type, fuel elements, and layout design for the natural fuels photo series, phase II project. In addition, inventory protocols will be developed by consulting with regional scientists such as Elaine Kennedy Sutherland, Dale Wade, Jon Regelbrugge, Larry Vanderlinden, and Mike Hilbruner for specific fuel types. Study plan will be completed during this phase. Roger Ottmar will lead this needs assessment with assistance from Dr. David Sandberg, Bob Vihnanek, Colin Hardy, and David Weise.

Research Phase

Roger Ottmar and Bob Vihnanek will lead an aggressive field effort to gather data. Land managers and scientists will be contacted to locate units followed by a photographic crew and field technicians for data collection. In addition, crew assistance from Jon Reggelbruggee, Dale Wade, and Elaine Kennedy Sutherland may be employed to assist in sampling and data analysis. Stereo-pair photographs will be included in this photo guide along with two larger views (wide-angle and standard views). The needs assessment and discussions with the Department of the Interior, and U.S. Forest Service will determine the type of data to be collected. We surmise the variables to be measured will include but not limited to: (1) GPS location and magnetic locator; (2) SAF cover type; (3) brief history of site; (4) soil type; (5) woody loading by size class and rot class; (6) litter depth, duff depth, and moss depth; (7) mineral soil exposure; (8) fuel depth; (9) grass, herb and shrub species, (10) herb and shrub loading; (11) tree species; (12) tree diameter and height, (13) live and dead stems per acre by diameter class; (14) seedling density; (15) percent canopy closure; (16) number of canopy layers; (17) height to live crown; (18) ladder fuel height; and (19) live crown height. If a companion proposal to develop Fuel Characteristic Classes (FCC) (Ottmar and Sandberg 1998) receives support, FCC's will be assigned to each photo series.

Implementation Phase

After the active field research is completed, the photo series volumes will be prepared and submitted to the Publication Management System in Boise for printing and distribution. In addition, both the natural photo series phase I and II will be placed on CD-ROM for eventual distribution.

Briefing Paper: FUEL CHARACTERISTIC CLASSES

Fuel Types of the Contiguous United States and Alaska

Executive Summary: The purpose of this study is to design a national fuels characterization system, based on the rapidly expanding use of Fuel Characteristic Classes for hazard appraisal and mapping that will (1) provide a range and distribution of realistic values based on field data for each fuel property and fuel element; (2) provide the precision commensurate with fuels management decisions; and (3) enable the modeling of transitions over time from one class to another. This study is composed of 4 major tasks completed over 4 years that include: (1) a coordination phase to design a preliminary fuels characteristic key; (2) design a final set of fuel characteristic classes; (3) field sampling of fuel elements for groups of fuel characteristic classes; and (4) distribution of fuel characteristic classes with associated data assignments and training package. This study addresses issue 1 (fuels mapping and inventories), and task 1 (inventory information), task 2 (survey of ongoing fuels mapping projects),and task 4 (values at risk) of the Joint Fire Science Program.

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Investigators:
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Colin C. Hardy and Dr. Robert E. Keane, USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory, Missoula, MT
Steve Sackett, Jon Regelbrugge, Sally Haase, USDA Forest Service, Pacific Southwest Research Station, Riverside, CA
Dr. Elaine Kennedy Sutherland, USDA Forest Service, Northeastern Forest Experiment Station, Delaware, OH
Dale Wade, USDA Forest Service, Southern Research Station, Athens, GA

Introduction

Background--The use of Fuel Characteristic Classes as a method to appraise and map fuel hazard potential fire effects is growing rapidly in all parts of the United States, but no nationally consistent design or coordination now exists. The development and use of a comprehensive set of fuel characteristic classes that enables the assignment of fuel fire effects prediction systems; (2) development of a national fuel map; and (3) providing the basic fuels building blocks to complete fuels related landscape assessments. These FCCs will be used by our collaborators to assess fuel conditions and fuel treatment options.

What is a Fuel Characteristic Class?

A Fuel Characteristic Class is a stylized description of a fuelbed of interest, including a characteristic value for all of the physical properties of each fuelbed component The FCC may be identified by ecological description (for example, the cover type, stand structure, age, and density), by remotely-sensed data (for example, TM data cluster, NDVI and location), by vegetation model output (for example Leaf Area Index or biomass by structural class), or even by using actual measured data (for example from a photo-series inventory). FCC's may be nested such that a broad class, such as "mature ponderosa pine" for example could include several specific classes such as "Front Range, Open Grown, Mature, Thinned, Recently Burned, Ponderosa Pine".

The values for each physical property of an FCC is assigned such that the best information available indicates that the value is characteristic of the described fuelbed. The source of the data may be existing published or unpublished data, inventory data collected specifically to characterize the type, or the best estimate by a panel of experts. The values assigned may vary in quality from a set of values simply thought to be realistic, to a set that is known from actual data to be realistic, to a set that is known to approximate the mean value of all of sites represented by the class, to a set of probability distributions that represent the frequency of observed values across all sites represented by the FCC.

How will this Project Proceed?

This fuel characteristic class project will be accomplished in three major phases, each closely linked and occurring simultaneously. In the coordination phase, fuel and fire management specialists, fire scientists, and fire ecologists assemble, where FCC's are not yet identified, to define the divisions appropriate to the regional ecology, fire hazard potential, and fuel management choices. The model for this activity is our experience in the Pacific Northwest. The design phase will use existing field data, photo series data, biophysical models (where available) and expert knowledge to assign values to fuel properties associated with a particular FCC. The research phase of this project will include the field sampling of fuel elements within a group of fuel characteristic classes to obtain a distribution and range of values. The implementation phase synthesizes results from the first three phases into a set of classes for use by scientists or land managers for fire behavior and fire effects prediction and for mapping fuels onto the landscape

Coordination Phase

Implementation Phase

The implementation phase of this project will include the distribution of the fuel characteristic classes with associated data assignments and corresponding photographs either in a printed format, on CD-ROM, or in a computer software format. A panel of experts composed of fuel specialists, ecologists, and product developers will be convened to design the final deliverable. The product will be designed so that land managers and researchers can use the fuel characteristics to apply to the landscape and generate new, useful products. In addition, a training packet will be prepared and distributed.

Briefing Paper: CONSUME

Modification and Validation of Fuel Consumption Models for Shrub and Forested Lands in the Southwest, Pacific Northwest, Rockies, Midwest, Southeast, and Alaska

Executive Summary: The purpose of this study is to modify and improve existing fuel consumption models for implementation into a software program Consume 3.0 to better predict total and smoldering fuel consumption during wildland fires for National application. This study is composed of 6 major tasks that include: (1) a needs assessment; (2) synthesis of existing fuel consumption data for study plan development and model development; (3) field data collection, data analysis and validation; (4) implementation of new and modified models into the user software product Consume 3.0; (5) completion of a user manual and training package; and (6) scientific documentation. This study addresses issue 2 (evaluate and compare fuels treatment practices and techniques) and task 9 (modeling smoke from wildland fires) of the Joint Fire Science Program.

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Steve Sackett, Jon Reggelbrugge and Sally Haase, USDA Forest Service, Pacific Southwest Research Station, Riverside, CA
Dr. Elaine Kennedy Sutherland, USDA Forest Service, Northeastern Forest Experiment Station, Delaware, OH
Dale Wade, USDA Forest Service, Southern Research Station, Athens, GA

Introduction

Background--Fire is recognized as an essential natural process in many ecosystems and managers are increasingly expected to use fire as a landscape-level fuel treatment mechanism to improve ecosystem health and reduce the likely hood of catastrophic fires. Also, an environmentally aware public has required managers to improve their decision making processes and use tradeoff models and various regulatory requirements to better assess land use decisions. Fuel consumption is the key variable in the modeling of fire effects; consequently, is the most critical attribute for understanding when and how fire should be applied to meet site and

The primary goals of this objective are to: (1) provide improved operation of fire behavior, fire effects prediction systems, wildland fire tradeoff models, and emission production models; (2) provide improved wildland fire emission tracking ability; and (3) provide the basic fuel consumption algorithms for large landscape and global assessments.

Methods

This fuel consumption project will be accomplished in three major phases, each closely linked and occurring, in many cases, simultaneously. During the **coordination phase**, a literature review, needs assessment, and consultation with managers and consumption experts, will provide fuel types and fuel properties to be studied, with a detailed study plan as the major project resulting from this phase. The **research phase** will collect field data and assess previously collected fuel consumption data for the empirical and theoretical development of fuel consumption models, and validation of current models. The **implementation phase** provides a software development product and user manual for use by managers and scientific documentation of the science behind the models. Opportunities to link this study with other efforts and to acquire matching dollars from other agencies such as EPA and NASA are good, and will be pursued.

Coordination Phase

Roger D. Ottmar and Dr. David Sandberg will lead the coordination effort. The coordinating phase will involve a needs assessment, extensive synthesis of the literature, and consultations with land managers including Jim Roessler, Jim Russell, and Mike Hilbruner, and expert theoretical and empirical modelers including Elizabeth Reinhardt, Steve Sackett, and Dr. Frank Albini, to design and prepare a detailed study plan that will include fuel types and fuel elements to be studied. Fuels data from previous studies in the Southwest, Southeast, Midwest, and Pacific Northwest will also be sought from Sally Haase and Steve Sackett, Dale Wade, and Dr. Elaine Kennedy Sutherland, and assessed for usefulness in future modeling. This assessment will determine the number of burns required to obtain enough data for adequate modeling of fuel consumption for selected fuel types.

Research Phase

An extensive synthesis of the literature and consultations with experts and land managers will be used to design and prepare a detailed study plan that will include fuel types and fuel elements to be studied. Research scientists Steve Sackett, Dr. Elaine Kennedy Sutherland, and Dale Wade will advise and assist in locating areas for burning and developing measurement procedures. Following the study protocols, a minimum of 6 units in each selected fuel type will be inventoried for biomass consumption. We surmise that the fuel types selected for consumption modeling will include chaparral, sagebrush, pinyon/juniper, mixed conifer, ponderosa pine, black determining the output format. In addition, a training packet and users manual will be prepared with assistance from Jim Roessler, Mike Hilbruner, and Jim Russell, and distributed upon the release of the software.

Location

This research will be performed by the **Fire and Environmental Research Applications (FERA)** team headquartered in Seattle Washington, who is an extremely mobile field-oriented fire research team. Our field laboratory is defined by our Forest Service, USDI, and State collaborators to provide the broadest possible range of environmental conditions and issue relevance within a fuel type of interest. In this project, we will perform field studies and user workshops in interior Alaska, in the Pacific Southwest, in Florida and elsewhere in the Southeast, and in the Midwest.

Briefing Paper: EMISSION PRODUCTION MODEL (EPM)

Implementation of an Improved Emission Production Model

Executive Summary: The purpose of this project is to improve the usability, accuracy, and applicability of an Emission Production Model (EPM)(Sandberg and Peterson 1984) to predict air pollutant emissions source strength, heat release rate, and plume buoyancy consistently for all fire environments and all fuel types. We will improve a flexible and friendly user interface, correct technical problems relating to long-smoldering fires and non-buoyant plumes, and link EPM to other model systems and data sources. A team of collaborating users will implement the model to better evaluate fuel treatment options and protect air quality.

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Introduction

Project Justification-- The Federal Wildland Fire Policy (USDA and USDI 1996) identifies smoke as a factor that may affect land managers ability to use larger and more frequent fire for the restoration and maintenance of fire-dependent ecosystems. The Joint Fire Science Plan proposes to develop a nationally consistent system of models for fuel consumption, emission production, and smoke dispersal that can assess cumulative effects. Identical wording is found as a recommendation from the national fire directors annual meeting in 1997. The National Strategic Plan and Workshop Report, Wildland Fire and Air Quality Modeling and Data Systems concludes that, Current models to predict emissions from fires are inadequate in coverage and incomplete in scope. Emission production models should be improved to include all fire and fuel types and to model multiple sources. Emission models should be linked to models of fire behavior, air quality, and dispersion in a geographically resolved system, and will provide aggregation or scaling to all spatial scales (Air Quality EXPRESS Team 1998). The need for emission models is also identified to improve the assessment of fires' contributions to the global atmosphere. (Forest Service Global Change Research Program 1992)

Predicting the source strength of air pollutant emissions from fires is a necessary basis for managing fires because (1) prescribed fires in most states are permitted only when they can be shown to have an acceptable impact on air quality; and (2) because deciding the

Outdated User Interface--The current version of EPM, written in-house in the 1980s, is antiquated and amateurish. It was designed primarily to serve managers of prescribed fires in Pacific Northwest activity fuels. Although the underlying model is more robust than that, it gives the appearance of being limited in scope. User queries are based on Pacific Northwest fuels and activities. Users in other regions are less comfortable using EPM, and no QA/QC data checks are built into EPM for them. EPM is not easily modified by the user to accept locally specific fuel or fire behavior adjustments.

Technical Limitations--EPM works fine for the initial burning period, including the flaming and initial smoldering stages (see figure 1). But it fails to account the late residual smoldering that takes place in deep duff or moss layers, stumps, and rotten logs. It also neglects fires burning in tree crowns. Another problem is that while EPM predicts heat-release rate, it cannot be used to predict plume rise unless the whole fire can be considered a single buoyancy source. Landscape-scale burning can result in several independent plumes that must be considered individually in order to accurately predict non-convective "drift" smoke. Still another problem is the limited spatial representation of fire spread and ignition patterns. Those assumptions work fine for burning a unit in strips or multiple ignition points, but are inadequate for free-spreading fires or extremely complex ignition patterns.

Outdated Model and Data Linkages: Ongoing photo series, FCC, and FARSITE data layer development, make it desirable to design EPM for easy linkage to these growing data sources. Fire models in general are in a rapid period of development, with new products due out of Missoula, Riverside, and Seattle in the next couple of years. These developments argue for a more flexible interface design for EPM to facilitate linkage with these other processors. EPM is not currently linked to FARSITE. EPM is linked specifically to the Consume model, although it would be desirable to use FOFEM or BURNUP to broaden the range of available consumption predictions. Default fuel loadings and other characteristics are limited to a few cases where Fuel Characteristic Classes (FCCs) or regional inventories have been accomplished. EPM is linked to several dispersion models, including VSMOKE, TSARS and NFSPuff. However, specific programming has been required to make those linkages because EPM is not currently object-oriented.

Limited Validation: An extensive set of aircraft and ground-based plume sampling was accomplished in the 1980s specifically to test and validate EPM. However, the tests were limited to plumes from broadcast burning in the Pacific Northwest. The validations confirm the overall performance of Consume, Emission Factor selection, and EPM in the one setting where all of those inputs were available. EPM has been used widely in other regions with very different fire environments, but no attempt has been made to validate its predictions. Where validation has been done, it has been only during the first few hours after ignition; not during a residual smoldering stage.

documentation. including a draft users manual. data dictionary, input source description, technical reference, and training messages for the beta version.

In year 2 (FY 2000) EPM v. 2.1 will be released and distributed. If possible, we will contract with a private firm to maintain, document, distribute, and provide user support for the product. The fall-back solution will be to accomplish this in-house. Training materials will be developed and distributed. The principal investigators, collaborating scientists, and software engineering teams will develop linkages to other models and provide modules to incorporate into other model systems. The Principal Investigators and collaborating users teams will begin to work with state air regulators and smoke management offices to systematize the communication of EPM output for project screening and NEPA documentation.

In year 3 (FY2001), we will work to improve the accessibility and integration of EPM into smoke management systems. We will use the Internet and possibly other networks to allow real-time EPM runs linked to mesoscale meteorology models and dispersion programs to form a complete screening system. We will collaborate with users to include EPM into FASTRAC and other decision-support systems.

Technical Improvements--The general approach will be to develop generalized interim solutions for the technical limitations during the first year and incorporate those hypothesized solutions into EPM v. 2.0. These are not simple problems, because solutions do not exist elsewhere and must be conceived for EPM. The problems of crowning, smoldering, consumption, spread in deep organic layers, and initial plume dynamics have not been solved anywhere, so the best that could be done now is to postulate what those solutions will be for immediate inclusion in EPM.

Subsequent annual upgrades will replace the interim solutions with more rigorous solutions as they become available. Also, a rigorous validation and QA/QC process will be implemented to insure that reasonable output is being obtained over a wide variety of fuel and fire characteristics. The validation effort may include in-the-field monitoring of pollutant flux from selected fires. Specifically, the following technical upgrades are envisioned.

Long Residual Smoldering: The interim solution will be to add a hypothesized fire behavior and consumption algorithm for smoldering piles, moss, and independent duff consumption based on preliminary work at RMRS and PNW; and for smoldering bark and litter concentrations from work underway at PSW. The form of the solution will be a multiple-day exponential-decay function with a diurnal forcing function to account for wind and humidity changes. A similar approach will be used to add the contribution of rotten logs and stumps, although it will be more speculative because no data are available beyond expert judgment.

The longer-range (i.e. two to three year) solution will be to conduct additional field studies (with other funding to companion studies) to improve Consume and possibly be made about spread rates, spatial pattern, and fire duration; and characteristic dimensions of the heat source will be calculated based on these assumptions. The output will be similar to the second approach, but will allow quick calculations where the more complex solution is warranted. This simple approach will also be useful for gaming hypothetical fire situations.

Plume Buoyancy: The dynamics of the convection column depend on the spatial pattern of heat generated as well as the temporal pattern. The majority of large burns in natural fuels produce many less-buoyant plumes and a much larger proportion of non-buoyant drift smoke. We will incorporate the improvements made in Calpuff to account for temporal plume development stages. Then, we will propose new derivations of the original Briggs'(1975) equations to provide an equation for plume buoyancy based on the spatial pattern of heat generated by a fire, and from this, calculate the proportion of convective versus non-convective emissions source strength. The engineering solution will be accomplished in year 1, and incorporated into EPM in year 2 and 3.

Improved Model and Data Linkages--Our approach will to provide a flexible architecture in the first-year revision of EPM that allows users or developers to easily add input data sets and to obtain output data sets that can be used to drive other models. EPM will include a full set of default values, fire behavior processors, and fuel consumption algorithms; but will allow the substitution of other models and data sets.

Default Fuels: The first task is to access Fuel Condition Classes (FCC), as they become available, to serve as a default set of fuel properties. FCC development is the subject of a separate proposal by Ottmar and others, and will generate a default data set of characteristic fuels for all of the United States. If that study is not funded, we will simply provide a default set based on currently available literature and the expert judgment of the collaborating scientists and collaborating users. This task will be completed in the first year, but be upgraded in subsequent years.

Consumption: FOFEM (Reinhardt and others 1997) is scheduled for an update in the next year or so. EPM will be designed to accept and pre-process (see flaming versus smoldering, above) predicted consumption from FOFEM. This task will likely be done in the second year.

Fire Models: PNW, RMRS, and PSW have been working together to arrive a common vision and overall design for fire model development. We are committed to providing users with a coherent and consistent system of fire behavior and effects models. That means that user interfaces will have increasingly similar appearance, produce output that is more consistent between models, and that the models will easily share input files and pass output between them. We intend that most of EPM will eventually be embedded into the successor to BEHAVE being designed by Pat Andrews. We will work with the collaborating scientists over the life of this project to realize this vision.

incorporate this mechanical tool into decision processes used by land managers and air resource managers. This integration does not need to be funded by the Joint Fire Science Program. but we will provide a final report of implementation success at the conclusion of this project. Training materials will be included as one of the deliverables in the second year of this project.

Briefing Paper: ASSESSING RISK to AIR QUALITY

Assessing Values of Air Quality and Visibility at Risk from Wildland Fire

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Introduction

Air quality and visibility are two values whose impairment has prohibited the extensive use of prescribed fire in many parts of the country. Also, they often are ignored when assessing risks from wildfire. Rigorous assessment, however, has been hampered by the use of inaccurate or inadequate smoke dispersion models. So far, these types of models have been too cumbersome for many managers to employ regularly or too simple to employ over a range of landscapes, burning styles, and fuel types. Therefore, they are used only for select case studies or site plans. Also, to assess relative risk from a broad category of management units requires running a model for each unit under a variety of meteorological conditions. This is a significant effort that has prevented detailed assessments of risk to air quality and visibility from wildland fire in the United States. Despite difficulties in using physical models for regional assessments, they have been partly successful. For example, an assessment in the Columbia River basin showed that surface concentrations from prescribed burning do not exceed ambient air quality standards, whereas wildfire emissions frequently exceed standards (Scire and Tino 1996). Studies like these are criticized, however, because the coarse spatial resolution of the model terrain allow smoke to disperse in unrealistic directions and often the meteorological scenarios used are unlike actual burning conditions. Also, the coarse spatial resolution and short-duration emission rates in modeling studies prevent the assessment of risk to air quality and visibility from residual smoldering, which is common both in prescribed fire and wildfire.

Materials and Methods

In places exposed to the effects of wildland fire, risks to air quality and visibility are dependent on the dispersion potential of smoke emissions. Dispersion is controlled by the mixing height of the atmosphere and local winds. We propose to generate a series of regional maps and frequency diagrams showing mean monthly patterns and daily variability statistics of mixing height, surface winds, and dispersion potential. Data will be generated separately for day and night. This is to account for nighttime drainage winds that cause local temperature inversions, which play havoc with non-convective smoke associated with smoldering fires.

The daytime mixing height data will be derived from available radiosonde data and maximum daily temperature. The data will be interpolated to 2.5 minute latitude-longitude (about 5 km) spatial resolution using a multiquadric interpolation scheme[1] (Nuss and others 1994) where mixing heights rise above topography. Interpolation will be restricted by topography where mixing heights are below surrounding elevations. The maps will be interactive in a way that mouse-activated clicks on a radiosonde observation site will show the frequency of mixing height for that station and that month. Figure 1 shows an example of how maps of mixing height may appear in a GIS layer. The variability in daytime mixing heights can be seen through frequency plots like those in figure 2.

Because nighttime mixing heights are strongly dependent on local topography, these data will be generated from a 30 second latitude-longitude (about 1 km) digital elevation model (DEM). At this resolution, national coverage is readily available. Although ground cover and ambient air conditions affect the magnitude and rate of formation, in determining dispersion potential for relatively cool, non-convective smoke, it is not necessary to know absolute temperature differences. Also, variations in the rate that local inversions form caused by different land-cover characteristics may be negligible, making equations that relate topographic features to mixing height depth (e.g., Gustavsson and others 1998; Kondo and Okusa 1990) relatively straightforward. The widths of valley tops and bottoms, drainage area (size of area sloping toward the valley), pool area (the highest elevation that occurs on both sides of the valley) and valley depth can be used to define potential mixing heights due to radiational cooling of nighttime temperatures; accounting for both in situ cooling and advection from down-slope drainage winds. All of these topographic parameters can be derived automatically from DEMs using geographic information system (GIS) software like ArcInfo. Results from previous experiments and theoretical investigations of nighttime cooling events will be synthesized to determine the best fit to topographic elements that provide the most accurate estimate of local mixing height. Additional field experiments will be conducted to help verify the nighttime inversion algorithms under actual burning conditions.

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[1] Multiquadratic interpolation (MQD) is an objective scheme that is well suited for handling data of different observation densities, like radiosonnde data.

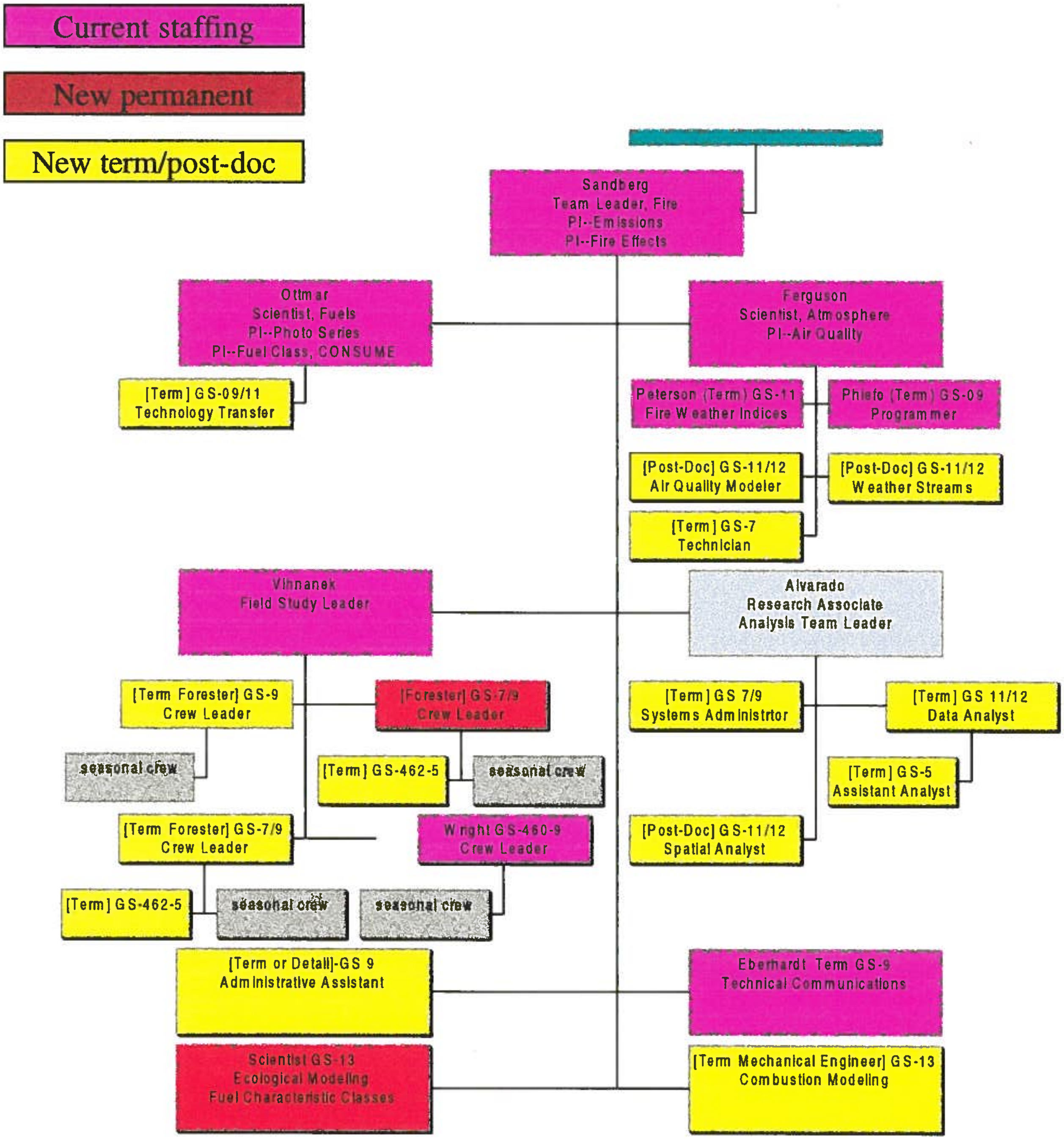
more variable wind speeds in regions of complex terrain. Maps of dispersion index will be generated at 2.5' spatial resolution (to match the resolution of wind data) for each month. Like maps of mixing height and wind, users will be able to zoom to view details of local regions. Also, dispersion potential maps will be linked to mixing height and wind data so that users can view details of each parameter from each grid cell.

Each map and data layer will be geo-referenced with each other and with other related maps and products (e.g. the National Fire Risk Map). All will use common projections. This will ensure compatibility between products and improve usability.

The maps and day/night statistics of mixing height, wind, and dispersion potential will be used to assess the local, regional, and national risks to air quality and visibility. Because places with low dispersion potential will be at greatest risk for impairment of air quality and visibility from fires, the map products can show relative risks between management units and between regions. This, along with fire start data, fire risk predictions, or prescribed burn plans, can be used by managers and policy makers to evaluate management treatment alternatives and assign budget priorities. Also, the maps can be used to help communicate with regulators and local communities about the expected risks from wildland fires in the area. Because fires occurring upwind of areas with low dispersion potential also can threaten air quality and visibility values, the accompanying surface wind maps and day/night wind statistics will help show potential impact from neighboring fires as well. As maps and data are completed for each region, they will be analyzed both spatially and temporally. A summary of results will describe the risk to air quality and visibility from wildland fire in that region. At the completion of the project, summaries of all regions will be collated into a national report.

Dr. Sue Ferguson will coordinate scientific functions and the development of products. Dr. David Sandberg will coordinate linkages with other data layers and models, including proposing and facilitating a linkage framework. Mr. Rich Fisher will coordinate a user group to 1) help design the display format of maps and data layers, 2) help verification with local knowledge of dispersion patterns, and 3) evaluate the usability of resulting products.

FERA -- Joint Fire Science Plan
Emergency Staffing Proposal



Briefing Paper: FUEL CHARACTERISTIC CLASSES

Fuel Types of the Contiguous United States and Alaska

Executive Summary: The purpose of this study is to design a national fuels characterization system, based on the rapidly expanding use of Fuel Characteristic Classes for hazard appraisal and mapping that will (1) provide a range and distribution of realistic values based on field data for each fuel property and fuel element; (2) provide the precision commensurate with fuels management decisions; and (3) enable the modeling of transitions over time from one class to another. This study is composed of 4 major tasks completed over 4 years that include: (1) a coordination phase to design a preliminary fuels characteristic key; (2) design a final set of fuel characteristic classes; (3) field sampling of fuel elements for groups of fuel characteristic classes; and (4) distribution of fuel characteristic classes with associated data assignments and training package. This study addresses issue 1 (fuels mapping and inventories), and task 1 (inventory information), task 2 (survey of ongoing fuels mapping projects),and task 4 (values at risk) of the Joint Fire Science Program.

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Introduction

Background--The use of Fuel Characteristic Classes as a method to appraise and map fuel hazard potential fire effects is growing rapidly in all parts of the United States, but no nationally consistent design or coordination now exists. The development and use of a comprehensive set of fuel characteristic classes that enables the assignment of fuel properties on landscapes for major vegetation types across the United States and Alaska is critical to modern fire management activities. These classes will allow the development of a National fuels map, provide stylized (i.e. fuel model) inputs to drive first order fire effects models (e.g. FOFEM (Reinhardt and others 1997), Consume (Ottmar and others 1993), and EPM (Sandberg and Peterson 1984)), fire behavior models (e.g. FARSITE, Behave, and NEXUS), fire danger rating systems (NFDRS), dynamic vegetation simulation models (e.g. CRBSUM, MAPSS), and provide the basic fuel building blocks to complete fuels related landscape assessments such as the ICRB (Quigley 1997) and Fire Emissions Trade Model (FETM, TOM). Fuel mapping, hazard assessment, evaluation of fuel treatment options and sequences, and monitoring effects all require a consistent and scientifically applied fuel classification system.

Problem--The development of spatial fuel property layers is one of the most important tasks required to operate fuel and fire management decision support systems and vegetation dynamics models. Currently, fire behavior and NFDR fuel models are the most commonly used mechanism for applying fuel characteristics to a landscape. However, the fire behavior and fire danger models generalize the smaller diameter fuel properties into 13 or 20 stylized models. Each stylized model was then adjusted to predict expected fire behavior or fire danger indices. This means the models rarely match actual loadings (Anderson 1982), and do not account for the main fuel classes that determine fire effects and crown fire potential such as large woody fuels, forest floor, and crown mass. Consequently, a new national fuels characterization system needs to be developed that will provide a range of realistic values based on field based data for each fuel property, to provide the precision commensurate with fuels management decisions, and to enable the modeling of transitions over time from one class to another.

Fuel Characteristic Classes (FCC) have already been used successfully as inputs for fuels assessments such as the Interior Columbia Basin Project in order to detect changes in fire risk over time. They have also been used for inputs to the Fire Emissions Tradeoff Model (FETM) in order to assess the benefit of fuel treatments in the Pacific Northwest. The approach has quickly gained acceptance in both the management and science community, across the United States and by all agencies.

Objective

The primary objective of the fuel characterization project is:

> *To develop and apply a set of comprehensive fuel characteristic classes (FCCs) representing a range of fuel properties and attributes for major vegetation type of the United States and Alaska.*

The primary goal of this objective is to provide a common set of fuel characteristic classes that describe a range of fuel properties enabling: (1) operation of fire behavior and fire effects prediction systems; (2) development of a national fuel map; and (3) providing the basic fuels building blocks to complete fuels related landscape assessments. These FCCs will be used by our collaborators to assess fuel conditions and fuel treatment options.

What is a Fuel Characteristic Class?

A Fuel Characteristic Class is a stylized description of a fuelbed of interest, including a characteristic value for all of the physical properties of each fuelbed component The FCC may be identified by ecological description (for example, the cover type, stand structure, age, and density), by remotely-sensed data (for example, TM data cluster, NDVI and location), by vegetation model output (for example Leaf Area Index or biomass by structural class), or even by using actual measured data (for example from a photo-series inventory). FCC's may be nested such that a broad class, such as "mature ponderosa pine" for example could include several specific classes such as "Front Range, Open Grown, Mature, Thinned, Recently Burned, Ponderosa Pine".

The values for each physical property of an FCC is assigned such that the best information available indicates that the value is characteristic of the described fuelbed. The source of the data may be existing published or unpublished data, inventory data collected specifically to characterize the type, or the best estimate by a panel of experts. The values assigned may vary in quality from a set of values simply thought to be realistic, to a set that is known from actual data to be realistic, to a set that is known to approximate the mean value of all of sites represented by the class, to a set of probability distributions that represent the frequency of observed values across all sites represented by the FCC.

How will this Project Proceed?

This fuel characteristic class project will be accomplished in three major phases, each closely linked and occurring simultaneously. In the coordination phase, fuel and fire management specialists, fire scientists, and fire ecologists assemble, where FCC's are not yet identified, to define the divisions appropriate to the regional ecology, fire hazard potential, and fuel management choices. The model for this activity is our experience in the Pacific Northwest. The design phase will use existing field data, photo series data, biophysical models (where available) and expert knowledge to assign values to fuel properties associated with a particular FCC. The research phase of this project will include the field sampling of fuel elements within a group of fuel characteristic classes to obtain a distribution and range of values. The implementation phase synthesizes results from the first three phases into a set of classes for use by scientists or land managers for fire behavior and fire effects prediction and for mapping fuels onto the landscape

Coordination Phase

The coordination phase will involve the preparation of a study plan and an extensive synthesis of the literature and actual inventory data available. A national team of fuels experts and fire ecologists representing Alaska, the Pacific Northwest, Southwest, Rockies, Midwest, Southeast, and the Northeast will be convened to design a preliminary fuel characteristic class key. Roger Ottmar and Dr. David V. Sandberg will take the lead in organizing this series of workshops with ecologists such as Jon Regelbrugge, and fuels specialists such as Colin Hardy and Dale Wade leading smaller groups to represent various regions throughout the United States.

Design Phase

A final set of fuel characteristic classes will be designed that will include a fuels key, the fuel characteristic classes, and the fuel properties represented within each class. The extensive data synthesis from the coordinating phase will be used to begin assigning range and variation values to each fuel property within a class and to determine where field sampling will be required to fill in data gaps. Several sub-teams lead by regional representatives representing the 7 regions will be convened to review final fuel characteristic classes. This will help retain ownership throughout the country. Data synthesis, field sampling, and product development will be coordinated with other related studies and accepted Joint Fire Science Program proposals to make efficient use of time, dollars and resources.

Research Phase

The research phase of this project will include the field sampling of fuel elements within a group of fuel characteristic classes to obtain a distribution and range of values. Discussions with scientists and land managers such as Paul Tine, Jim Russell, Jim Roessler, Dale Wade, Colin Hardy, Dr. Elaine Kennedy Sutherland, and Jon Regelbrugge will assist in location of inventory sites to acquire the range and variability within a particular group of fuel characteristic classes. A scientist and a 3-person crew will survey the site and collect data. Several crews may be operating at the same time, although each crew will be trained by a single supervisor to keep a high level of quality control over the data collected. The inventory technique will vary depending on the type of fuel. Woody fuel and forest floor biomass will be measured along transect lines. Grasses and smaller shrubs will be clipped and oven dried. Larger shrubs will be clipped, or diameter and crown heights/widths will be measured. Overstory and understory trees will be measured in circular plots approximately 0.005 acres each located systematically throughout a 5 acre sample area. Some of the variables to be measured will include: (1) GPS location; (2) SAF cover type; (3) brief history of site; (4) soil type; (5) woody loading by size class and rot class; (6) litter depth and duff depth; (7) mineral soil exposure; (8) fuel depth; (9) grass, herb and shrub species, (10) herb and shrub loading and height; (11) tree species; (12) tree diameter and height, (13) live and dead stems per acre by diameter class; (14) seedling density; (15) percent canopy closure; (16) number of canopy layers; (17) height to live crown; (18) ladder fuel height; and (19) live crown height.

Implementation Phase

The implementation phase of this project will include the distribution of the fuel characteristic classes with associated data assignments and corresponding photographs either in a printed format, on CD-ROM, or in a computer software format. A panel of experts composed of fuel specialists, ecologists, and product developers will be convened to design the final deliverable. The product will be designed so that land managers and researchers can use the fuel characteristics to apply to the landscape and generate new, useful products. In addition, a training packet will be prepared and distributed.

Briefing Paper: CONSUME

Modification and Validation of Fuel Consumption Models for Shrub and Forested Lands in the Southwest, Pacific Northwest, Rockies, Midwest, Southeast, and Alaska

Executive Summary: The purpose of this study is to modify and improve existing fuel consumption models for implementation into a software program Consume 3.0 to better predict total and smoldering fuel consumption during wildland fires for National application. This study is composed of 6 major tasks that include: (1) a needs assessment; (2) synthesis of existing fuel consumption data for study plan development and model development; (3) field data collection, data analysis and validation; (4) implementation of new and modified models into the user software product Consume 3.0; (5) completion of a user manual and training package; and (6) scientific documentation. This study addresses issue 2 (evaluate and compare fuels treatment practices and techniques) and task 9 (modeling smoke from wildland fires) of the Joint Fire Science Program.

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Introduction

Background--Fire is recognized as an essential natural process in many ecosystems and managers are increasingly expected to use fire as a landscape-level fuel treatment mechanism to improve ecosystem health and reduce the likely hood of catastrophic fires. Also, an environmentally aware public has required managers to improve their decision making processes and use tradeoff models and various regulatory requirements to better assess land use decisions. Fuel consumption is the key variable in the modeling of fire effects; consequently, is the most critical attribute for understanding when and how fire should be applied to meet site and landscape objectives, and assessing wildland fire consequences.

The Pacific Northwest Research Station (Sandberg 1980, Sandberg and Ottmar 1983, Ottmar and others 1993), Missoula Fire Lab (Brown and others 1991, Reinhardt and others 1997, Albini and Reinhardt 1997), and the Pacific Southwest Station have been leaders in the development of both theoretical and empirical fuel consumption models. Through that effort, we have a wealth of fuel consumption predictive algorithms for various fuel bed components and combustion phases for prescribed burning in Douglas-fir/western hemlock, west coast hardwoods, and associated species logging slash. These efforts have lead to several software programs currently being implemented by managers including Consume 2.0 (Ottmar 1993, 1998); FOFEM 4.0 (Reinhardt and others 1997), and a modified theoretical/empirical model called Burnout (Albini and Reinhardt 1997). In addition, ongoing fuel consumption research by the Pacific Northwest Research Station has been directed toward natural fuel prescribed burning in the spruce types in Alaska, ponderosa pine types of the Southwest, and mixed conifer regions of eastern Washington and Oregon, although residual stage smoldering combustion was not emphasized. Finally, funding by the Department of Interior through the Air Chemistry Project of the Missoula Fire Laboratory has brought to bear additional data from tall grass prairie and oak burning in Midwest and long leaf pine and marsh grass burning in the southeast for new development and modification of current fuel consumption models.

Problem--Although a tremendous amount of research has been accomplished thus far in the development of fuel consumption models, little effort has been directed toward the shrub fuel types such as chaparral, sage, and palmetto/galberry types in the West and South, pinyon juniper in the Southwest, Alaska boreal forest types, and hardwood types in the East and South. In addition, relatively little work has been accomplished to characterize long duration fuel consumption from the burning of large, rotten logs, stumps, or deep concentration of organic material such as duff or moss, often prevalent in forested areas where natural fire has been eliminated for the past 80 to 100 years. Fire is becoming an important landscape-level fuel treatment tool in these fuel types. In order for managers to develop improved wildland fire plans that will meet specific land management objectives, research will be required to better characterize both the fuel loading and fuel consumed during wildland fires in these fuel types.

Objective

The primary objective of the project to develop and apply CONSUME, is:

> ***Improve existing models to better predict fuel consumption during the smoldering phase of wildland fires; develop new fuel consumption models for shrubland, hardwood, and boreal forest fuel types; implement modified and new consumption equations into Consume 3.0; and validate current consumption equations in Consume 2.0, Burnup, and FOFEM.***

The primary goals of this objective are to: (1) provide improved operation of fire behavior, fire effects prediction systems, wildland fire tradeoff models, and emission production models; (2) provide improved wildland fire emission tracking ability; and (3) provide the basic fuel consumption algorithms for large landscape and global assessments.

Methods

This fuel consumption project will be accomplished in three major phases, each closely linked and occurring, in many cases, simultaneously. During the **coordination phase**, a literature review, needs assessment, and consultation with managers and consumption experts, will provide fuel types and fuel properties to be studied, with a detailed study plan as the major project resulting from this phase. The **research phase** will collect field data and assess previously collected fuel consumption data for the empirical and theoretical development of fuel consumption models, and validation of current models. The **implementation phase** provides a software development product and user manual for use by managers and scientific documentation of the science behind the models. Opportunities to link this study with other efforts and to acquire matching dollars from other agencies such as EPA and NASA are good, and will be pursued.

Coordination Phase

Roger D. Ottmar and Dr. David Sandberg will lead the coordination effort. The coordinating phase will involve a needs assessment, extensive synthesis of the literature, and consultations with land managers including Jim Roessler, Jim Russell, and Mike Hilbruner, and expert theoretical and empirical modelers including Elizabeth Reinhardt, Steve Sackett, and Dr. Frank Albini, to design and prepare a detailed study plan that will include fuel types and fuel elements to be studied. Fuels data from previous studies in the Southwest, Southeast, Midwest, and Pacific Northwest will also be sought from Sally Haase and Steve Sackett, Dale Wade, and Dr. Elaine Kennedy Sutherland, and assessed for usefulness in future modeling. This assessment will determine the number of burns required to obtain enough data for adequate modeling of fuel consumption for selected fuel types.

Research Phase

An extensive synthesis of the literature and consultations with experts and land managers will be used to design and prepare a detailed study plan that will include fuel types and fuel elements to be studied. Research scientists Steve Sackett, Dr. Elaine Kennedy Sutherland, and Dale Wade will advise and assist in locating areas for burning and developing measurement procedures. Following the study protocols, a minimum of 6 units in each selected fuel type will be inventoried for biomass consumption. We surmise that the fuel types selected for consumption modeling will include chaparral, sagebrush, pinyon/juniper, mixed conifer, ponderosa pine, black and white spruce, pine with a palmetto/galberry understory, and eastern hardwood. Six units that are scheduled for burning will be selected for each fuel type from BLM, Forest Service, BIA , and State lands in the Southwest, Pacific Northwest, Southeast, Midwest, and Alaska. Each unit must be relatively homogenous in fuel concentrations and must have reasonable access for the inventory crew. Lighting technique and pattern will be at the discretion of the land manager.

A 4-person crew from the Pacific Northwest Research Station will be individually inventorying each unit or assisting local crews from other scientific projects. One to four areas in each unit will be inventoried for fuels before and after burning using standard protocols with modifications as needed depending on the fuel type. A minimum of one sample area will be positioned within each fuel type if the unit contains multiple fuel types. Herbaceous and grass fuels will be inventoried before and after the burn using a semi-random plot design, clipping and weighing. Preburn and postburn shrub biomass will be estimated using either a semi-random plot design, clipping and weighing, or measuring stems and height and using biomass equations. Loadings of the woody material for each unit will be estimated from a planar intersect inventory (Brown 1974). Consumption of the of the large woody material will be measured as diameter reduction using wires tied around logs with periodic ocular estimates of percent consumption over time. The smaller woody fuel consumption will be determined from pre and post burn planer intersect measurements. Forest floor consumption will be measured as depth reduction using metal rods inserted into the forest floor prior to the burn. Approximately 300 points will be measured for the forest floor reduction on each unit. Bulk density samples will be collected to convert forest floor depth to loading. On sites covered with trees, tree densities, crown bulk densities, and percent consumption will be measured using ocular estimates and photographic interpretation.

The data will be used to (1) correlate fuel consumption with emission production; (2) generate coefficients for theoretical and empirical fuel consumption model design for implementation into a national consumption software product (Ottmar 1998); and (3) validate current fuel consumption models such as Consume 2.0 (Ottmar and others 1993), FOFEM (Reinhardt and others 1997), and Burnout (Albini and Reinhardt 1997). **Data synthesis, field sampling, and product development will be coordinated with other related studies to make efficient use of time, dollars and resources.**

Implementation Phase

The implementation phase of this project will include the development and distribution of a fuel consumption software product called Consume 3.0 designed for National use and with the users" needs in mind. The product will be engineered so that land managers and researchers can use the fuel characteristics, lighting patterns, fuel conditions, and meteorological attributes to output fuel consumption by combustion phase. The output will be formatted to feed various models including the Emission Production Models (EPM)(Ferguson and Sandberg 1997) and Emissions Tradeoff Model (FETM, TOM) (Ottmar and Schaaf 1996); fill in data base models like FASTRAC, and provide usable outputs for burn plan preparation and smoke management requirements. Colin Hardy, Mike Hilbruner, Jim Roessler, and Dr. David Sandberg will assist in determining the output format. In addition, a training packet and users manual will be prepared with assistance from Jim Roessler, Mike Hilbruner, and Jim Russell, and distributed upon the release of the software.

Location

This research will be performed by the **Fire and Environmental Research Applications (FERA)** team headquartered in Seattle Washington, who is an extremely mobile field-oriented fire research team. Our field laboratory is defined by our Forest Service, USDI, and State collaborators to provide the broadest possible range of environmental conditions and issue relevance within a fuel type of interest. In this project, we will perform field studies and user workshops in interior Alaska, in the Pacific Southwest, in Florida and elsewhere in the Southeast, and in the Midwest.

Briefing Paper: EMISSION PRODUCTION MODEL (EPM)

Implementation of an Improved Emission Production Model

Executive Summary: The purpose of this project is to improve the usability, accuracy, and applicability of an Emission Production Model (EPM)(Sandberg and Peterson 1984) to predict air pollutant emissions source strength, heat release rate, and plume buoyancy consistently for all fire environments and all fuel types. We will improve a flexible and friendly user interface, correct technical problems relating to long-smoldering fires and non-buoyant plumes, and link EPM to other model systems and data sources. A team of collaborating users will implement the model to better evaluate fuel treatment options and protect air quality.

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Introduction

Project Justification-- The Federal Wildland Fire Policy (USDA and USDI 1996) identifies smoke as a factor that may affect land managers ability to use larger and more frequent fire for the restoration and maintenance of fire-dependent ecosystems. The Joint Fire Science Plan proposes to develop a nationally consistent system of models for fuel consumption, emission production, and smoke dispersal that can assess cumulative effects. Identical wording is found as a recommendation from the national fire directors annual meeting in 1997. The National Strategic Plan and Workshop Report, Wildland Fire and Air Quality Modeling and Data Systems concludes that, Current models to predict emissions from fires are inadequate in coverage and incomplete in scope. Emission production models should be improved to include all fire and fuel types and to model multiple sources. Emission models should be linked to models of fire behavior, air quality, and dispersion in a geographically resolved system, and will provide aggregation or scaling to all spatial scales (Air Quality EXPRESS Team 1998). The need for emission models is also identified to improve the assessment of fires' contributions to the global atmosphere. (Forest Service Global Change Research Program 1992)

Predicting the source strength of air pollutant emissions from fires is a necessary basis for managing fires because (1) prescribed fires in most states are permitted only when they can be shown to have an acceptable impact on air quality; and (2) because deciding the appropriate action on wildland fires is based in part on anticipated air quality impacts. Air quality is often the constraining variable to continuing or expanding a burn program on federal lands. Many states already require the use of an emission production model as part of an application to burn, and some states use an emission production model to compile emission inventories from fires.

Objective

The primary objective of the Emission Production Model project is:

To improve the usability, accuracy, and applicability of an Emission Production Model to predict air pollutant source strength, heat release rate, and plume buoyancy from all fire environments and all fuel types. We will correct technical limitations, provide a flexible user interface that is friendly and nationally consistent; and link EPM to improved data sources and other fire models as they come on line. Meeting all of these objectives will require a three-year program, but the most significant product, a redesigned and user-friendly modeling package, will be delivered in one year.

Background

The Emission Production Model, EPM (Sandberg and Peterson 1985), is the only emission source strength model for fires in widespread use. EPM requires an estimate of flaming and smoldering consumption and a stylized description of ignition pattern as inputs. EPM adds the dimensions of time and space to point estimates of fuel consumption by internally computing consumption rate and fire spread between ignition points. EPM calculates timed emission rates for gases, particles and heat. Source strength (i.e. emission rate) predictions from EPM have been verified during the active convective stage through aircraft measurement of pollutant flux.

EPM has been used satisfactorily as input to models of long and short range plume dispersion, and by fire managers to predict air quality impacts and to communicate those estimates to state air quality regulators. EPM has been used with some success to characterize air quality impacts from prescribed fires across the United States. It has also been used to estimate emissions from large wildfires such as the Silver complex (Hardy 1990), and the effect of land-use practices on global emissions (Ferguson 1997). Training in the use of EPM is incorporated in standard fire management and air quality management courses offered by federal agencies.

Extensive use of EPM has uncovered several inadequacies in today's environment of increased fire use, increase in natural fuels burned, and concern over emissions from wildfires. Some of these are technical limitations in the model itself, some are due to the outdated and limited user interface, and some are due to the unavailability of input data. This proposal addresses all three problems and the need for additional validation:

Outdated User Interface--The current version of EPM, written in-house in the 1980s, is antiquated and amateurish. It was designed primarily to serve managers of prescribed fires in Pacific Northwest activity fuels. Although the underlying model is more robust than that, it gives the appearance of being limited in scope. User queries are based on Pacific Northwest fuels and activities. Users in other regions are less comfortable using EPM, and no QA/QC data checks are built into EPM for them. EPM is not easily modified by the user to accept locally specific fuel or fire behavior adjustments.

Technical Limitations--EPM works fine for the initial burning period, including the flaming and initial smoldering stages (see figure 1). But it fails to account the late residual smoldering that takes place in deep duff or moss layers, stumps, and rotten logs. It also neglects fires burning in tree crowns. Another problem is that while EPM predicts heat-release rate, it cannot be used to predict plume rise unless the whole fire can be considered a single buoyancy source. Landscape-scale burning can result in several independent plumes that must be considered individually in order to accurately predict non-convective "drift" smoke. Still another problem is the limited spatial representation of fire spread and ignition patterns. Those assumptions work fine for burning a unit in strips or multiple ignition points, but are inadequate for free-spreading fires or extremely complex ignition patterns.

Outdated Model and Data Linkages: Ongoing photo series, FCC, and FARSITE data layer development, make it desirable to design EPM for easy linkage to these growing data sources. Fire models in general are in a rapid period of development, with new products due out of Missoula, Riverside, and Seattle in the next couple of years. These developments argue for a more flexible interface design for EPM to facilitate linkage with these other processors. EPM is not currently linked to FARSITE. EPM is linked specifically to the Consume model, although it would be desirable to use FOFEM or BURNUP to broaden the range of available consumption predictions. Default fuel loadings and other characteristics are limited to a few cases where Fuel Characteristic Classes (FCCs) or regional inventories have been accomplished. EPM is linked to several dispersion models, including VSMOKE, TSARS and NFSPuff. However, specific programming has been required to make those linkages because EPM is not currently object-oriented.

Limited Validation: An extensive set of aircraft and ground-based plume sampling was accomplished in the 1980s specifically to test and validate EPM. However, the tests were limited to plumes from broadcast burning in the Pacific Northwest. The validations confirm the overall performance of Consume, Emission Factor selection, and EPM in the one setting where all of those inputs were available. EPM has been used widely in other regions with very different fire environments, but no attempt has been made to validate its predictions. Where validation has been done, it has been only during the first few hours after ignition; not during a residual smoldering stage.

Methods and Deliverables

This project will produce a modern version of EPM in the first year, complete with prototype solutions to all of the current technical shortcomings. Linkage to data sources will be improved. Validation and QA/QC programs will be initiated. Full implementation will take place in the second year with full distribution, documentation, and training programs. During the second and third year of the project, linkage to fire behavior and effects models, dispersion models, and meteorological models will be developed; and technical progress from parallel fire effects research will be incorporated. During the third year, we will concentrate on integrating EPM into fuels management and smoke management decision processes.

Four teams will work together to complete this project:

Principal Investigators, who are responsible for design, innovation, and deliverables, and validation;
Collaborating Users, who will be responsible for specifying the output and user-interface requirements and for beta testing, training, and distribution.
Collaborating Scientists, who will be responsible with the principal investigators for creating linkages and common design elements with other models and data sources; and
Software Engineering Team, who will be responsible for the programming and documenting the software package.

Four subprojects will be carried out, each corresponding to the issues described in the background section: Improved User Interface, Technical Improvements, Improved Model and Data Linkages, and Validation.

Improved User Interface--We will convene a team of trainers, users, researchers, and programmers in fall of 1998 to specify the information content, data quality standards, and output format of an improved EPM that will be locally useful and nationally consistent. The collaborating user team will also begin to design implementation strategies.

The Software Engineering Team will be charged with providing two products in the first year (FY 1999) of contract: (1) A object-oriented beta test model version of EPM v 2.0 that satisfies the needs of fire managers, State-level air resource mangers, and scientists in several fields (air quality science, fire science, global environmental science). The interface will be flexible enough to accept local modifications, allow easy substitution of input models such as fuel characteristic classes and consumption algorithms; facilitate linkage to fire behavior, fire-effects, and ecological response models; be neutral with respect to geographic region or land stewardship; link sensibly to alternative climate scenarios and other probability distributions representing climate risk; and fully reveal the quality, level of certainty, and derivation of predicted values. (2) Preliminary documentation, including a draft users manual, data dictionary, input source description, technical reference, and training messages for the beta version.

In year 2 (FY 2000) EPM v. 2.1 will be released and distributed. If possible, we will contract with a private firm to maintain, document, distribute, and provide user support for the product. The fall-back solution will be to accomplish this in-house. Training materials will be developed and distributed. The principal investigators, collaborating scientists, and software engineering teams will develop linkages to other models and provide modules to incorporate into other model systems. The Principal Investigators and collaborating users teams will begin to work with state air regulators and smoke management offices to systematize the communication of EPM output for project screening and NEPA documentation.

In year 3 (FY2001), we will work to improve the accessibility and integration of EPM into smoke management systems. We will use the Internet and possibly other networks to allow real-time EPM runs linked to mesoscale meteorology models and dispersion programs to form a complete screening system. We will collaborate with users to include EPM into FASTRAC and other decision-support systems.

Technical Improvements--The general approach will be to develop generalized interim solutions for the technical limitations during the first year and incorporate those hypothesized solutions into EPM v. 2.0. These are not simple problems, because solutions do not exist elsewhere and must be conceived for EPM. The problems of crowning, smoldering, consumption, spread in deep organic layers, and initial plume dynamics have not been solved anywhere, so the best that could be done now is to postulate what those solutions will be for immediate inclusion in EPM.

Subsequent annual upgrades will replace the interim solutions with more rigorous solutions as they become available. Also, a rigorous validation and QA/QC process will be implemented to insure that reasonable output is being obtained over a wide variety of fuel and fire characteristics. The validation effort may include in-the-field monitoring of pollutant flux from selected fires. Specifically, the following technical upgrades are envisioned.

Long Residual Smoldering: The interim solution will be to add a hypothesized fire behavior and consumption algorithm for smoldering piles, moss, and independent duff consumption based on preliminary work at RMRS and PNW; and for smoldering bark and litter concentrations from work underway at PSW. The form of the solution will be a multiple-day exponential-decay function with a diurnal forcing function to account for wind and humidity changes. A similar approach will be used to add the contribution of rotten logs and stumps, although it will be more speculative because no data are available beyond expert judgment.

The longer-range (i.e. two to three year) solution will be to conduct additional field studies (with other funding to companion studies) to improve Consume and possibly

BURNUP. and to capitalize on the laboratory studies of smoldering already underway at RM, and the proposed Joint Fire Science Program study by Darold Ward and others.

Flaming versus Smoldering: It is important to separate out these two initial burning stages when predicting fuel consumption, because the two stages have such different emission factors. Unfortunately, only Consume has that ability at present; FOFEM and BURNUP do not. The interim solution will be to add an intermediate processor based on experimental data. Our intent will be to let the user decide what consumption model or data to use as an input to EPM. The interim processor will always be an approximation that introduces another source of error, but that will be the users' choice.

The longer range solution is to develop a national version of Consume (proposed separately by Ottmar and others) that predicts flaming and smoldering consumption in all fuel types. When using other consumption models or estimates, the long-range solution will be the same as the interim solution, because there are no plans to add this capability to other modeling systems.

Crowning and Torching: The interim solution is to use a rule-based approach to crowning potential material in the crowns in consumed; all in the flaming stage. The long range solution is to incorporate improved crowning models as they become available from ongoing research in Canada, Australia, and at RM.

Landscape Spatial Representation: Three approaches will be taken to model the extent of fires over time, in order to improve the prediction of emission source strength and plume rise. All three approaches will begin in year 1 by the principal investigators and collaborating scientists, but not will be fully incorporated into EPM until year 2 and 3.

The brute-force solution to this problem will be integration of EPM and FARSITE, but simpler solutions are also needed where such integration is unfeasible. Merging EPM and FARSITE will provide much more information than is needed for any plume rise or source strength estimation, but has the advantage of leading to fully integrated model systems. We will probably merge the two programs by structuring EPM as a post-processor to FARSITE, accessing the spatial pattern of heat generated in each polygon at each timestep. FARSITE is currently being revised to allow this possibility.

The second approach will be to build a routine that allows the user to draw or adjust existing drawings of fuel and topographic patterns on a screen. A processor will calculate spread rates and fire duration in a manner consistent with FARSITE and BEHAVE and calculate the characteristic spatial dimensions of the heat source over time. This approach will be much less data intensive than using FARSITE and will yield much less spatially explicit output, but will satisfy the need to predict emissions source strength and convective lift.

The third approach will be a simple characterization of topography , fuels, and ignition patterns based on a series of questions asked of the user. Some simple assumptions will be made about spread rates. spatial pattern. and fire duration; and characteristic dimensions of the heat source will be calculated based on these assumptions. The output will be similar to the second approach. but will allow quick calculations where the more complex solution is warranted. This simple approach will also be useful for gaming hypothetical fire situations.

Plume Buoyancy: The dynamics of the convection column depend on the spatial pattern of heat generated as well as the temporal pattern. The majority of large burns in natural fuels produce many less-buoyant plumes and a much larger proportion of non-buoyant drift smoke. We will incorporate the improvements made in Calpuff to account for temporal plume development stages. Then, we will propose new derivations of the original Briggs'(1975) equations to provide an equation for plume buoyancy based on the spatial pattern of heat generated by a fire, and from this, calculate the proportion of convective versus non-convective emissions source strength. The engineering solution will be accomplished in year 1, and incorporated into EPM in year 2 and 3.

Improved Model and Data Linkages--Our approach will to provide a flexible architecture in the first-year revision of EPM that allows users or developers to easily add input data sets and to obtain output data sets that can be used to drive other models. EPM will include a full set of default values, fire behavior processors, and fuel consumption algorithms; but will allow the substitution of other models and data sets.

Default Fuels: The first task is to access Fuel Condition Classes (FCC), as they become available, to serve as a default set of fuel properties. FCC development is the subject of a separate proposal by Ottmar and others, and will generate a default data set of characteristic fuels for all of the United States. If that study is not funded, we will simply provide a default set based on currently available literature and the expert judgment of the collaborating scientists and collaborating users. This task will be completed in the first year, but be upgraded in subsequent years.

Consumption: FOFEM (Reinhardt and others 1997) is scheduled for an update in the next year or so. EPM will be designed to accept and pre-process (see flaming versus smoldering, above) predicted consumption from FOFEM. This task will likely be done in the second year.

Fire Models: PNW, RMRS, and PSW have been working together to arrive a common vision and overall design for fire model development. We are committed to providing users with a coherent and consistent system of fire behavior and effects models. That means that user interfaces will have increasingly similar appearance, produce output that is more consistent between models, and that the models will easily share input files and pass output between them. We intend that most of EPM will eventually be embedded into the successor to BEHAVE being designed by Pat Andrews. We will work with the collaborating scientists over the life of this project to realize this vision.

Dispersion Models: EPM's primary purpose is to provide input into plume dispersion models such as VSMOKE, TSARS+, CalPuff and NFSPuff. Additional dispersion model development is underway with EPA oversight. There is less clarity with regard to how dispersion of non-buoyant plumes will be modeled in the future. In the near term, EPM will simply generate an output file for post-processing by any of these dispersion models. We will also provide, in years 2 and 3, program modules that can easily be incorporated in dispersion models, much as exists now in NFSPuff.

Validation

Validation will take two forms, trial runs and field measurements of smoke plumes whose characteristics have been predicted by EPM. Validation will begin in the first year, but we will wait until the third year to issue a validation report. Validation results in the initial years will be used by the Principal Investigators to improve the beta-test version of the model.

Trial Runs: The collaborating users, beta testers, and principal investigators will conduct several hundred trial runs using data available from the USDI Photo Series and other sources of real fuels data. As a team, we will assess the reasonableness of the model output for forest and range vegetation from Alaska (spruce), the Pacific Northwest (mixed conifer), the Great Basin (sage/grass), California (chaparral), Southeast (pocosin), and Lake states (hardwood litter). We will also do trial runs of EPM linked to NFSPuff, VSMOKE, VSMOKE-GIS, and TSARS+.

Field Measurements: Two companion proposals to the Joint Fire Science Program by Ottmar and others (Consume), by Ward and others ("Smoke Produces from Residual Combustion"), will measure fuel consumption and smoldering emissions on a series of approximately fifteen fires in Alaska, the Northwest, Southwest, and Southeast. EPM will be used to predict emissions source strength and plume behavior for each of these burns. If those efforts are funded, they will represent 90% of what is needed to validate EPM.

We will complement the field measurements by Ward and Ottmar by making observations of plume geometry and duration. Time-lapse, triangulated photogrammetry will be used to describe the convection column on selected units. Additional balloon cross-sections and lidar soundings of the drift smoke plume will also be added to the validation effort.

Implementation

The intent of this project is not to just to develop a model, but to use the model to make more effective decisions about fuel treatment options and to protect air quality. The Principle investigators and collaborating users will continually explore ways to incorporate this mechanical tool into decision processes used by land managers and air resource managers. This integration does not need to be funded by the Joint Fire Science Program. but we will provide a final report of implementation success at the conclusion of this project. Training materials will be included as one of the deliverables in the second year of this project.

Briefing Paper: ASSESSING RISK to AIR QUALITY

Assessing Values of Air Quality and Visibility at Risk from Wildland Fire

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Introduction

Air quality and visibility are two values whose impairment has prohibited the extensive use of prescribed fire in many parts of the country. Also, they often are ignored when assessing risks from wildfire. Rigorous assessment, however, has been hampered by the use of inaccurate or inadequate smoke dispersion models. So far, these types of models have been too cumbersome for many managers to employ regularly or too simple to employ over a range of landscapes, burning styles, and fuel types. Therefore, they are used only for select case studies or site plans. Also, to assess relative risk from a broad category of management units requires running a model for each unit under a variety of meteorological conditions. This is a significant effort that has prevented detailed assessments of risk to air quality and visibility from wildland fire in the United States. Despite difficulties in using physical models for regional assessments, they have been partly successful. For example, an assessment in the Columbia River basin showed that surface concentrations from prescribed burning do not exceed ambient air quality standards, whereas wildfire emissions frequently exceed standards (Scire and Tino 1996). Studies like these are criticized, however, because the coarse spatial resolution of the model terrain allow smoke to disperse in unrealistic directions and often the meteorological scenarios used are unlike actual burning conditions. Also, the coarse spatial resolution and short-duration emission rates in modeling studies prevent the assessment of risk to air quality and visibility from residual smoldering, which is common both in prescribed fire and wildfire.

Although there continues to be a lack of useful risk assessments, air quality and visibility remain critically at risk from wildland fires, especially with the increased use of prescribed fire, the increased threat of wildfire, and the encroaching urban interface. Many managers are postponing fuel treatment or choosing more expensive non-burn alternatives because of unknown or perceived risk to air quality and visibility.

In addition to assessment of risk from individual units or events, cumulative or relative risk also is important. The deterministic output products from modeling exercises are useful in evaluating certain scenarios but do not provide any statistics that suggest probabilities of risk or relative risk between different management units or from one region to another. Therefore, it is difficult to make decisions about whether to burn or not, especially on a 5 to 10 year planning horizon.

In this work, we propose to define a new way of assessing risk to air quality and visibility that relies on readily available data, can be applied spatially, provides probability statistics for objective analysis of relative risk, and can be overlain with other products for more complete descriptions of risk from wildland fire. We propose to define risk to air quality and visibility on the basis of dispersion potential alone. This avoids the cumbersome task of estimating gas and particle concentrations and their relation to air quality and visibility, which can be full of inaccuracies because of the disparate spatial and temporal scales between available input data and equation requirements for air quality and visibility calculations. Also, we will be deriving a methodology to define dispersion potential at fine spatial scales during the night, a task for which mesoscale models have great difficulty. Therefore, the information not only can be used on its own for risk assessments but can enhance model assessments by providing greater detail where needed. Maps of dispersion potential can be used by local managers to determine the risk potential of individual units, by regional managers to estimate relative risk over the landscape, and by policy makers to help understand the overall risks to air quality and visibility from increased burning. The dispersion potential data can be overlain with other risk assessments and fuels data, and integrated with fire, smoke, and air quality models, to help provide a more complete understanding of risk and more objective means of determining priorities for alternative management treatments.

Objective

The primary objective of this work is to **assess the local, regional, and national risks to air quality and visibility from wildland fire.** This will be done by generating and analyzing statistics of daily and nightly variability of surface wind, mixing height, and dispersion potential and by creating and analyzing mapped mean values of all variables on local, regional, and national scales (1km to 5km spatial resolution).

A secondary objective is to make available maps and data layers to all users so they can assess potential dispersion as it relates more specifically to their management concerns and so the data can be linked with other data layers or models for more complete views of associated risks from wildland fire.

Materials and Methods

In places exposed to the effects of wildland fire. risks to air quality and visibility are dependent on the dispersion potential of smoke emissions. Dispersion is controlled by the mixing height of the atmosphere and local winds. We propose to generate a series of regional maps and frequency diagrams showing mean monthly patterns and daily variability statistics of mixing height, surface winds, and dispersion potential. Data will be generated separately for day and night. This is to account for nighttime drainage winds that cause local temperature inversions, which play havoc with non-convective smoke associated with smoldering fires.

The daytime mixing height data will be derived from available radiosonde data and maximum daily temperature. The data will be interpolated to 2.5 minute latitude-longitude (about 5 km) spatial resolution using a multiquadric interpolation scheme[1] (Nuss and others 1994) where mixing heights rise above topography. Interpolation will be restricted by topography where mixing heights are below surrounding elevations. The maps will be interactive in a way that mouse-activated clicks on a radiosonde observation site will show the frequency of mixing height for that station and that month. Figure 1 shows an example of how maps of mixing height may appear in a GIS layer. The variability in daytime mixing heights can be seen through frequency plots like those in figure 2.

Because nighttime mixing heights are strongly dependent on local topography, these data will be generated from a 30 second latitude-longitude (about 1 km) digital elevation model (DEM). At this resolution, national coverage is readily available. Although ground cover and ambient air conditions affect the magnitude and rate of formation, in determining dispersion potential for relatively cool, non-convective smoke, it is not necessary to know absolute temperature differences. Also, variations in the rate that local inversions form caused by different land-cover characteristics may be negligible, making equations that relate topographic features to mixing height depth (e.g., Gustavsson and others 1998; Kondo and Okusa 1990) relatively straightforward. The widths of valley tops and bottoms, drainage area (size of area sloping toward the valley), pool area (the highest elevation that occurs on both sides of the valley) and valley depth can be used to define potential mixing heights due to radiational cooling of nighttime temperatures; accounting for both in situ cooling and advection from down-slope drainage winds. All of these topographic parameters can be derived automatically from DEMs using geographic information system (GIS) software like ArcInfo. Results from previous experiments and theoretical investigations of nighttime cooling events will be synthesized to determine the best fit to topographic elements that provide the most accurate estimate of local mixing height. Additional field experiments will be conducted to help verify the nighttime inversion algorithms under actual burning conditions.

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[1] Multiquadratic interpolation (MQD) is an objective scheme that is well suited for handling data of different observation densities, like radiosonnde data.

Mixing height alone cannot fully explain dispersion potential. Wind also plays a vital role. Wind at night can completely disrupt nighttime inversions and improve dispersion. On the other hand, lack of wind can enhance risks to air quality and visibility. Because surface winds are strongly controlled by topography, observations from a single location cannot represent wind patterns over broad areas of landscape. We propose to use a simple, one-level hydrostatic meteorological model (Danard 1977; Ferguson and others 1998) to reconstruct the spatial and temporal variability of wind for two times each day (0000 and 1200 Greenwich Mean Time [GMT]) when historical initialization data are available. Cooling and heating algorithms in the model allow us to estimate winds at times of minimum temperature (e.g., shortly after sun rise) and maximum temperature (e.g., a couple of hours after noon) that correspond to daytime and nighttime mixing heights, respectively. Figure 3 shows mean July winds in the Pacific Northwest that were derived from the proposed model. In this case day and night conditions are averaged together, even so areas of stagnation and potential scouring are visible. The advantage of using a simple physical model as opposed to a fully 3-dimensional mesoscale model like MM5 (Grell and others 1994) or RAMS (Tripoli and Cotton 1982) is that it is computationally efficient and can be run twice each day for 30 years at 2.5' spatial resolution[2] over the contiguous U.S. with modest computing power. In this way, the frequency of wind speed for each of 16 cardinal wind directions can be determined for both day and night. Maps of monthly mean winds will be developed. Also, each grid cell will be linked to frequency plots of nighttime inversions and to a wind rose (figure 4) that shows the daytime and nighttime variations in wind speed and direction for that time, that location, and that month.

Finally, an index of dispersion potential will be developed that combines the mixing height data with wind speeds. This type of product now is used by air quality forecasters and linked to output from some real-time mesoscale model forecasts. For example, the Holzworth Pollution Index (Holzworth 1972) varies according to the following table:

Wind Speed (meters/second)	Mixing Height (meters above ground level)			
	500	1000	1500	2000
2	1	2	3	4
4	2	4	5	6
6	3	4	7	8

The lower the index the higher the potential for risk to air quality and visibility. A modification of this index may be necessary to account for the smaller areas of nighttime inversions and the

[2] The hydrostatic assumption in the proposed wind model prevents finer resolutions. In the future, however, these data can be used to initialize a kinematic wind model that can generate winds at 30m horizontal resolution. Kinematic models cannot be used initially because they are strongly dependent on observation data, which are scarce in most wildland areas, especially regions of complex terrain.

more variable wind speeds in regions of complex terrain. Maps of dispersion index will be generated at 2.5' spatial resolution (to match the resolution of wind data) for each month. Like maps of mixing height and wind, users will be able to zoom to view details of local regions. Also, dispersion potential maps will be linked to mixing height and wind data so that users can view details of each parameter from each grid cell.

Each map and data layer will be geo-referenced with each other and with other related maps and products (e.g. the National Fire Risk Map). All will use common projections. This will ensure compatibility between products and improve usability.

The maps and day/night statistics of mixing height, wind, and dispersion potential will be used to assess the local, regional, and national risks to air quality and visibility. Because places with low dispersion potential will be at greatest risk for impairment of air quality and visibility from fires, the map products can show relative risks between management units and between regions. This, along with fire start data, fire risk predictions, or prescribed burn plans, can be used by managers and policy makers to evaluate management treatment alternatives and assign budget priorities. Also, the maps can be used to help communicate with regulators and local communities about the expected risks from wildland fires in the area. Because fires occurring upwind of areas with low dispersion potential also can threaten air quality and visibility values, the accompanying surface wind maps and day/night wind statistics will help show potential impact from neighboring fires as well. As maps and data are completed for each region, they will be analyzed both spatially and temporally. A summary of results will describe the risk to air quality and visibility from wildland fire in that region. At the completion of the project, summaries of all regions will be collated into a national report.

Dr. Sue Ferguson will coordinate scientific functions and the development of products. Dr. David Sandberg will coordinate linkages with other data layers and models, including proposing and facilitating a linkage framework. Mr. Rich Fisher will coordinate a user group to 1) help design the display format of maps and data layers, 2) help verification with local knowledge of dispersion patterns, and 3) evaluate the usability of resulting products.

Technology Transfer

During each phase of this project. feedback from professionals with local knowledge of each region (e.g., fire weather forecasters. smoke managers. and fire managers) will be sought through informal discussions and beta testing of products. Every effort will be made to ensure that products are understood by forecasters and managers and that they are applicable to forecast and planning problems. Upon completion of each region. the data and user's guide will be made available on the World Wide Web (WWW) and a package CDs will be created. In addition, an hour-long training session will be designed to introduce users to the products, help them understand the limitations and benefits of such an approach, and help them interpret the products to evaluate relative risks to air quality and visibility in their areas of concern. Regional representatives will be trained through national courses or specially arranged sessions. Coordination with scientists at FERA, the Missoula and Riverside Fire Labs, and other institutions will be on-going to ensure compatibility with other types of risk assessments, fire and smoke models, and fuels data.

FERA -- Joint Fire Science Plan
Emergency Staffing Proposal