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USDA Forest Service

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USDA United States Department of Agriculture

Forest Service

North Central Research Station

National Fire Plan Research and Development

2001 Business Summary

Cover photo by Dr. David V. Sandberg, Pacific Northwest Research Station

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The National Fire Plan
USDA Forest Service

Managing the Impacts of Wildfires on Communities and the Environment

Acknowledgments

We especially acknowledge the contributions of the Forest Service National Fire Plan Research Coordination Team, the Research Station Communication Directors, and their staffs. In particular, we gratefully acknowledge the contributions of Drs. David Shriner and Susan Barro for compiling this report, of Lucy Burde and Mary Jane Senter for editing it, and of Mary Peterson and Ralph Winn for designing it. We also thank Drs. David Cleaves, Enoch Bell, Linda Donoghue, and Sam Sandberg for their review and suggestions.

A report highlighting the accomplishments of Forest Service Research and Development under the National Fire Plan in FY 2001

Contents

Executive Summary

Wildland fire remains a serious concern to the people of our Nation. This concern has been turned into action in the form of the National Fire Plan (NFP), an accelerated interagency effort, begun after the disastrous 2000 fire season, to step up, coordinate, and concentrate activity on reducing fire risks.

Science plays a key role in the NFP. Scientific research and technological development are critical in increasing the capability of the Nation to manage, respond to, and recover from wildland fire. The solutions developed from the NFP are in many ways only as good as their scientific and technical foundations. Some of the most challenging and highest priority issues facing fire science include:

- Improving decisionmaking in fire suppression and fire use by better predicting fire behavior and providing tools for making better judgments;
- Increasing the effectiveness of postfire rehabilitation efforts;
- Developing integrated systems and guidelines for prescribed burning, thinning, postharvest processing, and marketing to reduce fire hazards and achieve ecological, social, and economic sustainability;
- Developing strategies for reducing the vulnerability of homes and communities where wildlands and urban areas meet.

The three main branches of the Forest Service—National Forest System, Research and Development, and State and Private Forestry—are teamed together under the National Fire Plan to address the serious problems the country faces in wildland fire occurrence, behavior, and management.

Addressing these complex issues requires the integration of physical, biological, and social sciences, to maximize the return on research investment. Research initiated in FY 2001 in response to NFP funding is strongly targeted at providing usable knowledge, in a timely manner, to key groups including firefighters, land managers, and homeowners living in communities potentially at risk from wildland fire. Information, technology, and tools developed through research will improve the ability to manage and cope with wildland fire by reducing fire risk and preparing agencies and communities to respond to and recover from fire events.

The NFP focuses USDA Forest Service (FS) and Department of the Interior (DOI) fire research and development dollars on the most pressing needs in managing wildfires

and keeping the public safe from them. The NFP is strengthening overall FS and DOI programs in fire research by:

- Doubling the dollars available for fire science and fire related research, allowing scientific advancement in areas that have never been adequately funded;
- Broadening the scope of fire research beyond traditional fire science and fire management topics;
- Focusing research on priority issues;
- Improving links among Federal and State land managers, fire managers, and research, by packaging research results in ways that can be easily used in the field;
- Building upon a foundation of FS Base Fire Science Programs (BFSP) and Joint Fire Science Program (JFSP) research,
- Fostering opportunities for interagency research collaboration; and
- Developing standards for improved accomplishment reporting and technology transfer.

The Forest Service is mobilizing its scientific resources to bring sound science into management actions

Forest Service Research and Development (R&D) received $26 million under the NFP. Guided by the strategic goals outlined in the plan, fire research was expanded in four areas in 2001:

- **Firefighting capacity**—improving firefighting decisions. *$9,737,000 awarded, 22 research teams funded, 69 new studies initiated in 39 States, and 52 new cooperative research partnerships established.*

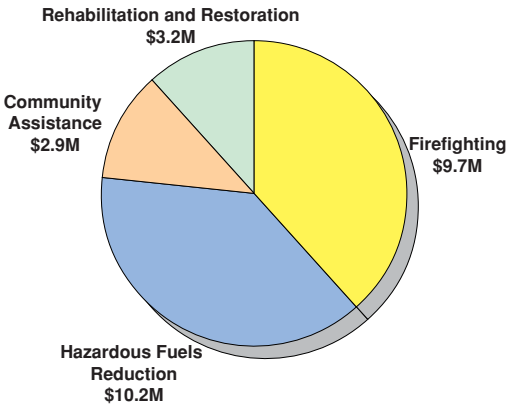
- **Rehabilitation and restoration**—restoring landscapes and rebuilding communities damaged by wildfire. *$3,175,000 awarded, 9 research teams funded, 40 new studies initiated in 11 States, and 27 new cooperative research partnerships established.*

- **Hazardous fuels reduction**—reducing fire risk through fuels (combustible forest materials) treatment. *$10,211,000 awarded, 24 research teams funded, 118 new studies initiated in 29 States, and 66 new cooperative research partnership established.*

- **Community assistance**—working with communities to reduce fire hazards and ensure adequate protection. *$2,877,000 awarded, 8 research teams funded, 25 new studies initiated in 17 States, and 22 new cooperative research partnerships established.*

Overall, with $26 million, FS R&D initiated 252 new NFP studies in 41 States, hired 49 new scientists (15 permanent) and 131 technicians (7 permanent), and established 167 new cooperative studies and contracts with universities and other research partners totaling $8.9 million. In the first 6 months after funding became available (in April 2001), research sponsored by the NFP has produced 35 new publications, 82 presentations at scientific conferences, 55 demonstrations and tours, and 45 short courses and workshops. In addition, there have been over 250 instances when scientists funded by the NFP have provided technical assistance and consultation to National Forest System regions, forests, and districts; to State, local, and tribal governments; and to community groups on fire related topics.

Resources by Issue



This document is a progress report on the first stages of FS R&D outputs from an evolving multiagency, interdisciplinary NFP effort. The primary goal is to strengthen national capability to assist those who must deal with the complex management and policy decisions involved in managing fire on the landscape. Most importantly, FS R&D will increase products and technical services that range from fundamental science to user-friendly tools and science syntheses that will help managers improve community safety and firefighting effectiveness on the ground. This will be accomplished by developing scientists, support staff, equipment, facilities, and other support needed and by building strong coalitions with other research organizations and users.

Introduction

The Fire Situation

On average, 67,000 fires burn about 2.7 million acres annually. This average has been increasing since 1980, interspersed with more frequent extreme fire years. The 10-year average for the period from 1991 to 2000 is 80,303 fires per year, burning an average of 3,666,705 acres. Fuel accumulation, suburban expansion, and weather extremes are causing increased fire hazard, values at risk, and risk of damages. At the same time, fire suppression efforts are becoming more complex. Consequently, wildfire costs and damages have been rising to more than $2 billion a year. Additional billions are spent by State and local agencies, and lost in property, resource, and economic impacts.

The severity of these extreme fires poses threats to ecosystem health as well as humans and human structures. Critical habitat for fish, wildlife, and plant species, including those at risk of extinction, can be degraded or destroyed. Such fires also emit millions of tons of gases and particulate matter into the air, with negative consequences for human health and global climate.

The extreme fire season of 2000 focused national attention on the destructiveness and the costs of wildland fire. More fires burned in 2000 than in any of the last 50 years—122,827 fires burned 8,422,237 acres. As a result, nearly 900 homes and other structures were destroyed. Communities in New Mexico, Colorado, Montana, and Idaho were besieged by fire and smoke, and valuable economic and social infrastructure was destroyed or threatened, including the Los Alamos National Laboratory.

Despite recent severe fire seasons, tens of millions of acres of American wildlands remain in poor health, in part because the natural fire cycles of these ecosystems have been interrupted. Restoring the nation's ecosystems will require an intensive and sustained use of fire as a positive ecological force. This year, Federal agencies will use prescribed fire on more than 50,000 projects to reduce fire hazard and restore ecosystems on 3 million acres. In addition, appropriate management responses to wildland fires are used to enhance resources on hundreds of thousands of acres per year. Fire use is heavily dependent on research to provide decision support in the form of physical, biological, and social science knowledge and prediction systems.

The National Fire Plan

In August 2000, President Clinton directed the Secretaries of Agriculture and the Interior to develop a plan to respond to severe wildland fires, reduce the impact of wildfires on rural communities, and ensure sufficient firefighting capacity in the future. Such a plan would call for actions that Federal agencies, in cooperation with States and local communities, could take to reduce immediate hazards in wildland-urban interface areas, and to ensure that sufficient resources would be available for extreme

fire conditions in the future. The Secretaries' report has since been developed into a multibillion dollar, multiagency National Fire Plan (NFP).

The NFP has five key points:

- **Firefighting**—Ensure adequate preparedness for coming fire seasons.
- **Rehabilitation and Restoration**—Restore landscapes and rebuild communities damaged by wildfire.
- **Hazardous Fuels Reduction**—Reduce fire risk through fuel treatment.
- **Community Assistance**—Work directly with communities to reduce fire risk and ensure adequate protection.
- **Accountability**—Be accountable and establish adequate oversight and monitoring of results.

For fiscal year 2001, Congress appropriated $2.89 billion for the NFP including $1.9 billion for the Forest Service and $977 million for the Department of Interior. Forest Service Research and Develoment (R&D) received less than 2 percent of the total amount appropriated.

Research will increase fire preparedness enabling more reliable forecasts of damaging fire events

The Role for Research

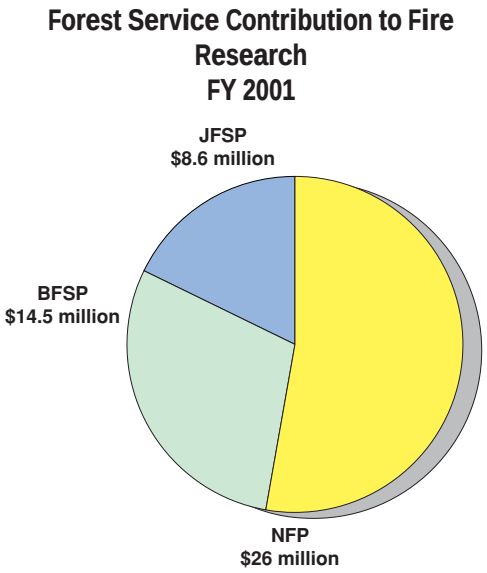
The long-term comprehensive strategy for the Forest Service relative to fire is guided by core principles including firefighting readiness, use of science, collaboration, biomass utilization, economic development, and accountability for results. The outcomes sought are healthier watersheds, healthier communities, and diminished risk and consequences of wildland fires. Achieving these outcomes in a timely manner will require a strong and coordinated program of research and development.

Forest Service R&D has sustained an active program of wildland fire research since the 1920s and remains the world's leader in wildland fire science. Forest Service R&D collaborates with universities and other research institutions and works closely with fire managers to identify research needs and ensure technology development.

Before the NFP, Forest Service R&D was investing about $14 million per year in fire science and fire-related research. There was an additional $4.6 million invested by the Forest Service in the Joint Fire Science Program (JFSP), 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 Survey in the Department of the Interior. The JFSP encourages collaborative research among agencies, universities, and other non-Federal cooperators, focused on fuels management.

National Fire Plan Research and Development

The National Fire Plan directed the Forest Service to increase the capability of its R&D program to support efforts to reduce the human and ecological losses from wildfires. Initial allocation of NFP funds in FY 2001 increased fire-related R&D in the Forest Service by $30.6 million (including $4.6 million for the JFSP). Further increases in the base funding are being requested as part of a progressive expansion of R&D capabilities for at least the next 5 years in the key areas of firefighting capacity, rehabilitation and restoration, hazardous fuel reduction, and community assistance.

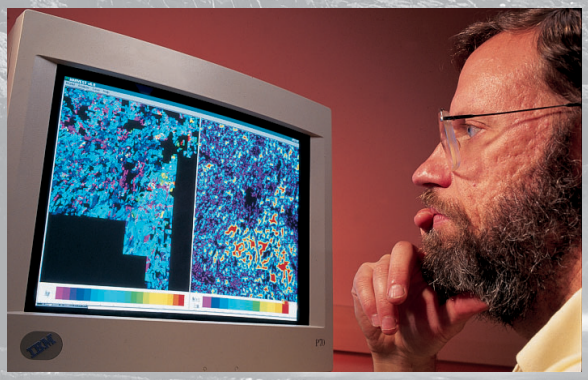


In response to the call for increased knowledge to implement the NFP, FS R&D funded 63 research teams in 2001 at a total of $26 million with NFP funds (Table 1).

Table 1 . Research project funding by key point

Key point	Funding level *($1,000s)*	Teams *(Number)*
Firefighting Capacity	9,737	22
Rehabilitation and Restoration	3,175	9
Hazardous Fuel Reduction	10,211	24
Community Assistance	2,877	8
TOTAL	26,000	63

The sources and levels of fire funding in 2001 for the seven Forest Service research stations are displayed in Table 3 of the Appendix. The table shows a fire program of base fire science, fire-related research, soft money, and JFSP money that was more than doubled upon receipt of NFP funds.



Accomplishments

Overall, with $26 million, FS R&D initiated 252 new NFP studies in 41 States, hired 49 new scientists (15 permanent) and 131 technicians (7 permanent), and established 167 new cooperative studies and contracts with universities and other research partners totaling $8.9 million. In the first 6 months since funding became available (in April 2001) research sponsored by the NFP has produced 35 new publications, 82 presentations at scientific conferences, 55 demonstrations and tours, and 45 short courses and workshops. In addition, there have been over 250 instances when scientists funded by the NFP have provided technical assistance and consultation to National Forest System regions, forests and districts; to State, local, and tribal governments; and to community groups on fire-related topics.

Building upon our past, vast store of scientific knowledge about wildfire and prescribed fire, we are bringing the study of wildland fire into the 21st Century to support wise management of forest and range lands.

Fire research conducted by FS R&D provides the scientific foundation necessary to help make better informed policy and fire management decisions and to better prepare citizens to live in fire-adapted ecosystems. This report summarizes the progress of FS R&D in fiscal year 2001 to support efforts to reduce wildfire losses. It represents the beginning of an ambitious effort to catch up with a growing problem. Research accomplishments in each NFP key area are summarized and early results representative of the work of new research teams are highlighted.

A Legacy of Research Results that Matter...

In the aftermath of the terrible tragedy of September 11, 2001, three Forest Service Incident Management Teams were deployed—one to "ground zero" near the World Trade Center Complex in New York City, one to New Jersey, and one to the Pentagon in Washington, DC, to assist in disaster management. These teams brought with them an Incident Command System (ICS) developed by Forest Service Research over 30 years ago. The ICS outlines procedures for organizing personnel, facilities, equipment, and communication at the scene of an emergency. The impetus for development of such a system was a series of devastating wildfires that hit southern California in the fall of 1970 burning over 600,000 acres and 772 structures in 13 days, and leading to 16 fatalities. In response to the disaster, Congress funded FIRESCOPE (Firefighting Resources of California Organized for Potential Emergencies) to analyze the problems in this emergency response. The ICS resulted and has subsequently been adopted by the Federal Emergency Management Agency for use in interagency coordination of disaster response across the United States and has been a model for emergency management agencies worldwide.

Accomplishments: Firefighting Capacity

Research Highlight

Southern Regional Models for Predicting Smoke Movement

Prescribed fire is used routinely in the South to reduce hazardous fuels, decrease the risk of catastrophic wildfires, improve forest health, and manage habitat for threatened and endangered species. Rapid growth of human populations in forested areas has limited the use of prescribed fire because of concerns about smoke impacts. Being able to predict smoke movement is critical for minimizing the smoke exposure of firefighters and nearby residents and for avoiding ground smoke at night, a hazard for roadway traffic. Scientists are developing and improving models for simulating and predicting smoke movement so that resource managers can develop and prescribe fuel reduction burns more safely and effectively.

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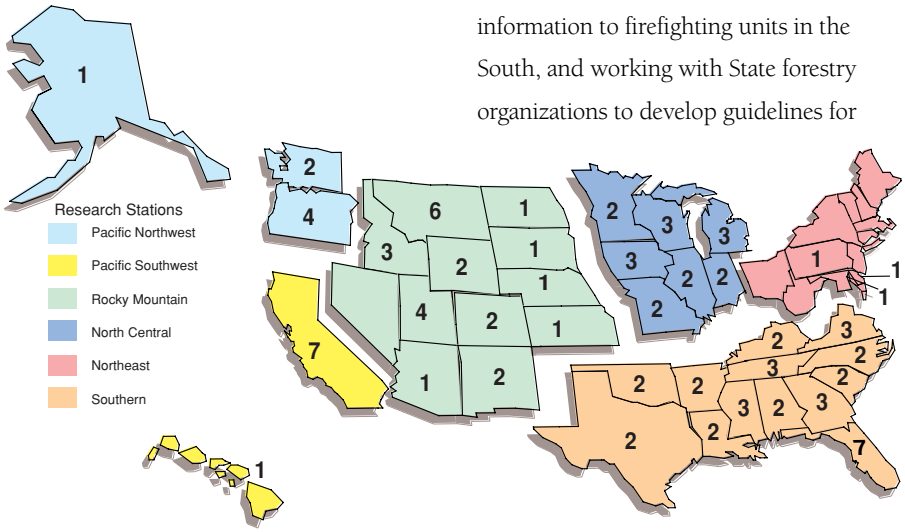
Firefighting organizations must make quick and effective decisions as they battle wildfires—all in the face of great uncertainty, complexity, and changing conditions. Research is needed to better predict local fire weather, more accurately predict fire behavior and smoke dispersal, and provide real-time information and decision tools to cost effectively and safely fight fires.

Synthesis of Accomplishments in Firefighting Research:
In 2001, 22 research teams, funded at $9,737,000, initiated 69 new studies in 39 States, hired 35 new scientists and technicians, and established 52 new cooperative agreements valued at $3.8 million with universities and other research partners (Appendix Table 2). Forest Service researchers and their cooperators are working on the following kinds of issues:

Fuel Conditions, Risk Assessment, and Fire Management

To prioritize fire suppression and fuel treatment activities, fire managers, firefighters, and communities at risk need information on the potential for catastrophic fire. New research initiated under the NFP is increasing our capability to assess areas most likely to burn and linking that information with where people live to create maps of areas that are most vulnerable to damages from wildfire.

The Southern Research Station established a new wildland-urban interface center in Gainesville, Florida, with the goals of providing fire prevention and suppression information to firefighting units in the South, and working with State forestry organizations to develop guidelines for



Number of NFP research projects listing studies in particular States. (Projects with national scope are not shown.)

small forest landowners, homeowners, and community leaders in reducing the risk of wildfires that destroy homes.

Under the NFP, researchers are developing a new initial attack simulation model for wildfires that includes new visualization software for air tanker base operations. The new model will help fire managers to explore initial attack options and evaluate the tradeoffs between investments in fuel treatments, prevention, and initial attack programs for different geographical areas.

Weather, Fire Behavior, and Smoke Dynamics

Accurate prediction of fire weather conditions is essential to forecasting fire risk, directing firefighting resources, ensuring firefighter safety, and preparing communities for fire protection measures.

Forest Service scientists are developing new models to more accurately predict fire potential and smoke dispersion and are working with partners from a broad range of Federal and State agencies in regional consortia for developing better regional forecasts of fire weather. These consortia represent a new approach to bring together specialists from multiple agencies to coordinate and distribute fire weather forecasts. Soon these consortia will be able to receive, decode, and archive real-time meteorological data (surface and upper air observations, satellite imagery, radar imagery, model output, and forecasts) and synthesize, repackage, and transmit this information in meaningful forms to fire managers.

These consortia have enabled remote sensing data, for the first time, to be successfully uplinked to an Internet site, allowing more immediate access by firefighters. During the 2001 fire season, the first aircraft-based, multi-spectral, thermal-infrared measurements were made of wildland fires in chaparral. Airborne measurements such as these will be used to provide extensive descriptions of ongoing wildfires to validate and improve models of fire behavior and fire effects.

At the national scale, FS researchers are working with the National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA) to receive near-real-time satellite data to monitor active fires, fire severity, and smoke concentrations and dispersion with as little as a 2- to 4-hour delay. This information will help fire managers develop fire attack strategies, allocate firefighting resources, and warn citizens of impending fire-related risks.

Research Highlight

Fire Consortia for Advanced Modeling of Meteorology and Smoke

Fire planners need better predictive models of fire weather and fire behavior to increase the efficiency, effectiveness, and safety of fire operations. Forest Service R&D has established four regional fire weather and smoke modeling centers (in Athens, GA; East Lansing, MI; Riverside, CA; and Seattle, WA) to provide fire weather and smoke modeling support to Federal, State, and local fire agencies.

These centers use weather forecasts and other data in high-resolution weather models coupled to fire behavior models to inform fire incident commanders, dispatchers, and those conducting prescribed burning operations to provide better forecasts of potential fire spread and intensity. Fuel management officers are using these forecasts to heighten firefighter and public awareness of potential conditions, and to allocate fire suppression resources more efficiently. All four centers have developed high-speed computing capabilities to support the delivery of a wide variety of research and development products and predictive services.

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Accomplishments: Rehabilitation and Restoration

Research Highlight

Testing the effectiveness of postfire emergency rehabilitation treatments in the West

The demand for postfire rehabilitation treatments and the costs of these treatments have increased dramatically in recent years as more lives and property are threatened by the aftereffects of fire. Little is known about the effectiveness of these costly treatments.

Good decisions about what methods to use in what situations require detailed knowledge about treatment effectiveness. Researchers are studying the impacts of these treatments on sediment movement, water quality, and water yield from burned watersheds. A team, consisting of ecologists, botanists, engineers, and hydrologists, has been equipped with a mobile lab enabling rapid installation of measuring devices on freshly burned areas. This team is ready for the next fire season and will be developing a rich database that can be used to formulate changes in rehabilitation strategies. Measurements of erosion, runoff, and vegetation responses are underway at four sites in Montana and California where fires have recently occurred.

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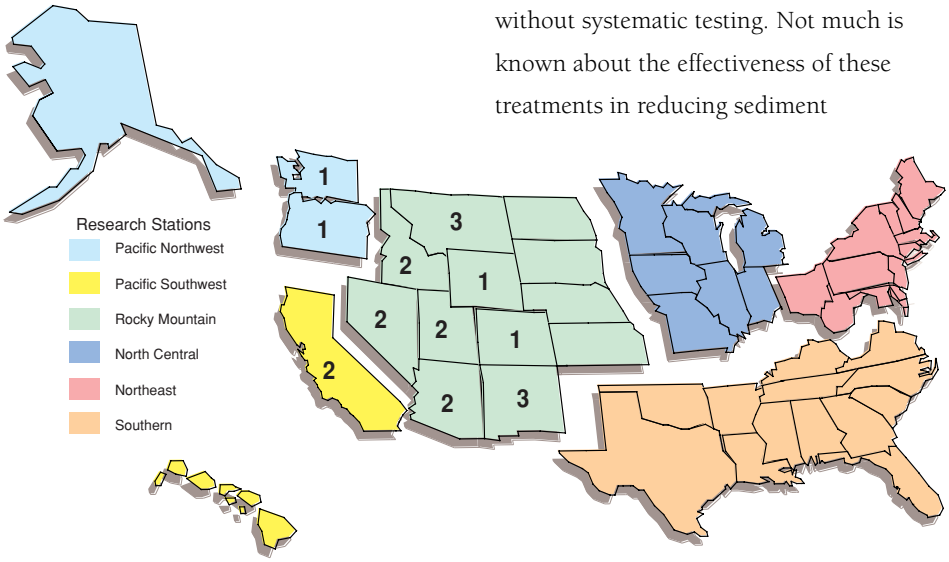
After wildfires, managers worry about maintaining water quality, minimizing impacts of accelerated erosion, bringing back native vegetation, and rebuilding communities. Minimizing erosion and flooding damage and optimizing conditions for recovery of native vegetation in burned areas are the topics actively being investigated. Tools, technologies, and knowledge anticipated from this research will assist land managers in applying and evaluating burned area emergency rehabilitation treatments, and developing procedures for monitoring restoration effectiveness.

Synthesis of Accomplishments in Rehabilitation and Restoration Research: In 2001, 9 research teams, funded at $3,175,000, initiated 40 different studies in 11 States in the West and Rocky Mountain regions, hired 6 new scientists and 20 technicians, and established 27 new cooperative agreements valued at over $1.1 million with universities and other research partners (Appendix Table 2). Forest Service researchers and their cooperators are working on the following kinds of issues:

Reducing Erosion and Flooding

Current rehabilitation treatments have been developed through prior experience with emergency responses without systematic testing. Not much is known about the effectiveness of these treatments in reducing sediment



Number of NFP research projects listing studies in particular States. (Projects with national scope are not shown.)

movement and water output from burned areas. Researchers have established plots in California and Montana to monitor sediment production and waterflow from burned areas receiving a variety of rehabilitation treatments. In Arizona and New Mexico, scientists are gathering information on how postfire erosion is impacted by waterflow patterns and site geology. This information will be used in predictive models that can assist managers in making rehabilitation and restoration decisions.

Minimizing Spread of Exotic Species and Pathogens

Researchers are investigating the dynamics of postfire weed invasions to help managers minimize the spread of weeds and pathogens after fires. They are exploring how prescribed burning can reduce the impacts and proliferation of various exotic species, such as Dalmatian toadflax and yellow star thistle and how biological controls can reduce tansy ragwort. Scientists are conducting training sessions for national forest crews on using handheld computers to inventory these noxious weeds and monitor their spread. Their work will allow managers to more quickly detect the introduction of exotic species and to apply corrective measures without using chemical or mechanical alternatives.

Research efforts are underway to identify and characterize the potential for the use of different native plants in burned area rehabilitation. Researchers are working to improve practices for seed production and seed storage. This will help ensure that native seed supplies are available to land management agencies when needed and are effective when deployed.

Research Highlight

Effects of Wildfire and Fuel Management Treatments on Exotic Weeds, Insects, and Pathogens

Severe wildfires can promote rapid invasion of exotic weeds and increase damage from forest insects and disease. When exotic weeds replace native plants, their shorter fire cycle can lead to declines in watershed health. Managers urgently need guidelines that will help them implement fuel management treatments and postfire rehabilitation treatments, and at the same time reduce the spread of weeds, forest insects, and pathogens that damage forest health.

Scientists have expanded two long-term studies in ponderosa pine forests in Arizona to better understand the response of understory vegetation (including exotic weeds) to insects and diseases following fuel management treatments. They helped train national forest field crews to sample and identify plants as they monitor treated areas. This knowledge will help managers make choices that favor native plants and minimize impacts from forest insects and diseases.

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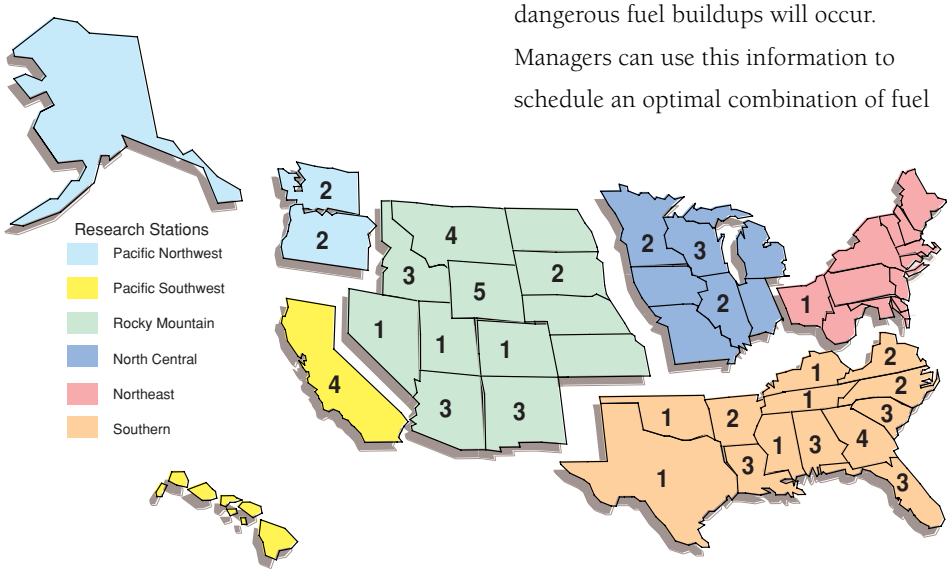
Accomplishments: Hazardous Fuels Reduction

One important way to reduce fire risk is by reducing the buildup of brush, small trees, and other fine fuels that may feed a fire. Research on hazardous fuels reduction will help managers set priorities and balance complex tradeoffs between benefits of an expanded fuel reduction program and possible consequences of mechanical and prescribed burning treatments. New investigations are underway to facilitate fire risk assessment, anticipate treatment impacts, and develop new uses and systems for harvesting forest undergrowth and small diameter trees.

Summary of Accomplishments on Hazardous Fuel Reduction Research: In 2001, 24 research teams, funded at $10,211,000, initiated 118 new studies in 29 States throughout the United States, hired 23 new scientists and 88 technicians, and established 66 cooperative agreements valued at $2.7 million with universities and other partners (Appendix Table 2). Forest Service researchers and their cooperators are working on the following kinds of issues:

Mapping and Modeling Fuels and Fire Hazards

Mapping and modeling efforts are underway to predict where the most dangerous fuel buildups will occur. Managers can use this information to schedule an optimal combination of fuel



Number of NFP research projects listing studies in particular States. (Projects with national scope are not shown.)

Research Highlight

Guidelines for Fuels Management in the Wildland-Urban Interface

Managers need socially acceptable fuel management treatments to reduce wildfire risks while simultaneously restoring forest health and productivity, providing desirable flows of clean water, and maintaining or improving wildlife habitat. Meeting these multiple goals, and sometimes conflicting objectives, requires comprehensive knowledge of treatment effectiveness and effects of scale from stand to landscape. Working with partners at Northern Arizona University and Stephen F. Austin State University and National Forests in Arizona (the Coconino, Kaibab, and Coronado) and in New Mexico (the Santa Fe and Lincoln), Forest Service researchers developed pilot guidelines for uneven-aged thinning. These guidelines are reaching managers of other Federal and State forest lands through demonstration tours, technical consultations, and scientific publications.

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treatments on the landscape. In Wisconsin, for example, scientists are modifying a sophisticated landscape change model, LANDIS, to study the interactions among human activities, natural disturbances, and wildfires and to better represent the fuel management challenges at the wildland-urban interface. These researchers have already delivered fire susceptibility maps to the Chequamegon National Forest in the Eastern Region of the Forest Service, and are investigating the applicability of the model to the entire Eastern Region.

Others are looking to the past to get insights into future fire scenarios. Researchers working in Montana and Idaho have taken a retrospective look at over 240 stands of trees to determine how stand structure has influenced burn severity in those stands. Early results have quantified how the density of stands alters burn severity and shown that homogeneous stands (e.g., plantations with interlocking crowns) have more tree mortality than variable density stands.

Researchers are using satellite images of South Dakota and Wyoming to look at impacts of insects and diseases on forest vegetation and their influence on the distribution of fire hazard and potential fire spread. Additional remote sensing of vegetation by researchers in the Southern States is improving existing fire behavior models. Ultimately the data will be incorporated into a Web page that will display wildland fuel and fire risk.

Fuel Reduction Options and Impacts

A variety of vegetation treatment options have been developed over the years to reduce levels of hazardous fuels—combinations of different applications of prescribed burning, herbicides, and mechanical methods.

Research Highlight

Ground-Based Support for Mapping Fuel and Fire Hazard

Assessing relative hazards posed by different fuel levels is a necessary step in deciding how and where to treat fuels. Currently the ability to precisely characterize and map fuels is too limited to make accurate fuel assessments. Lack of accurate fuel assessments hampers development of cost-effective treatment plans and may create the potential for undesirable treatment effects. Scientists are developing ways to monitor and assess fuels, map fuel characteristics, and validate fuels information with remote sensing. Managers will use these techniques to assess fire hazards and take actions to reduce them.

Researchers have completed an analysis from a large prescribed burn in Alaska's boreal forest where they compared information obtained from remote sensing with data on vegetation on the ground to validate the accuracy of fuels information from remote sensing. A series of photos is being developed to train land managers in better characterizing fuel types and using this information to predict fire potential and manage fuel levels.

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In many cases, these treatments are used in combination because stands are too dense to be burned safely without preliminary mechanical treatment. The relative effectiveness of alternative fuel treatments in reducing fire danger is a key question in policy debates about fuels management. For example, in some wildland-urban interface areas, prescribed burning is controversial due to air quality and other concerns, and mechanical manipulation is likewise being scrutinized for possible impacts on threatened and endangered (T&E) wildlife habitat and other resources. Researchers are examining the effects of these fuel reduction treatments on a range of resource values.

Scientists are investigating another key issue—how fuel reduction treatments impact sensitive riparian ecosystems, soils, and particular species of animals and plants. For example, researchers completed postfire sampling of fish communities on 21 streams in western Montana to determine if fire favors nonnative fish. In Washington, data from a study of the habitat requirements of northern spotted owls and woodpeckers will be integrated into a comprehensive landscape decision analysis program that managers can use to make choices about vegetation treatments.

Economic Uses for Hazardous Fuels

Researchers at the Forest Products Laboratory in Madison, WI, are developing new processing methods to better use vegetation that adds to the fuel hazard. They conducted an industrial processing trial in fall of 2001 to reduce small-diameter treetops to fibrous material. These same researchers are also developing marketable products from forest undergrowth and small-diameter trees to make their removal more cost effective. Future research in this area will evaluate the potential for energy production from these sources of biomass.

Research Highlight

Characterization of Fuels and Fire Behavior in Central Hardwood Forests

The vast oak-hickory forest that once dominated the Central United States is slowly shifting toward a moister forest. Fire exclusion due to development pressures is one reason for this shift. Implementing fuel management treatments such as thinning and prescribed burning can help restore these forests. However, managers have limited information on which to base the course of fuel management treatments (e.g., fire temperatures and fuel loading) to foster return of a pre-fire exclusion species mix. Scientists are building upon an existing study of the fire behavior and biological effects of prescribed fire and thinning to develop a photo series for rapid assessment of fuel conditions. In addition, they are analyzing how fire temperatures and fuel loadings impact certain insect populations, soil conditions, and wildlife habitat. By understanding the effects of fire and thinning on mixed-oak forests, managers will be better able to reduce fuel levels while maintaining a desirable species mix.

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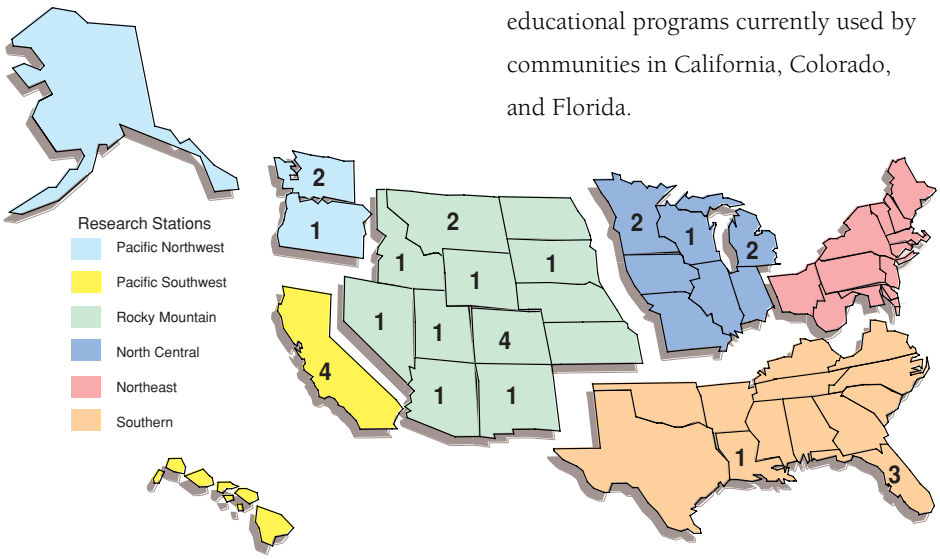
Accomplishments: Community Assistance

Fuel treatments on the landscape alone are not enough to ensure community safety from fire danger. These treatments must be integrated into an overall strategy that involves the community. Community residents and their leaders must be able to understand the rationale for fuel treatments and how community structures and plans can be modified to reduce overall fire risks. Research can help develop new ways to reduce community vulnerabilities and help people in communities coexist with fire-adapted ecosystems.

Summary of Accomplishments on Community Assistance Research:
In 2001, 8 research teams, funded at $2,877,000, initiated 25 new studies in 17 States, hired 3 new scientists and 5 technicians, and established 22 new cooperative agreements valued at almost $1.2 million with universities and other research partners (Appendix Table 2). Forest Service researchers and their co-operators are working on the following kinds of issues:

Community Effectiveness

To support managers in their efforts to keep communities safe, researchers are identifying what makes communities effective in preparing for fire. They are assessing the costs and effectiveness of regulatory, incentive-based, and educational programs currently used by communities in California, Colorado, and Florida.



Number of NFP research projects listing studies in particular States. (Projects with national scope are not shown.)

Research Highlight

Alternative Prescriptions for Residential Landscapes

A growing number of people are moving to the wildland-urban interface. The landscapes they create and care for influence local fuel loads and the risk of loss from fire. Fuel treatments in these built environments must be based on physical processes that govern fire spread and home ignition as well as expectations of residents for landscapes that provide beauty, privacy, views, shelter, and wildlife habitat.

Researchers are developing fuel treatment alternatives that more closely match the preferences of residents' and are thus more likely to be adopted by them in their home landscaping. They have gathered information on structures and vegetation of 102 residential properties in California, compiling costs and evaluating the effects of various landscape designs. A Web-based program enabling homeowners to view and compare alternatives is being developed.

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Researchers have selected a community adjacent to the Boundary Waters Canoe Area Wilderness in Minnesota to examine how community culture and level of coordination with nearby communities contribute to its fire preparedness.

Scientists in the Rocky Mountain Region have developed and nationally distributed a video "Protecting Your Home from Wildfires" that provides guidance for reducing the ignition potential of homes in the wildland-urban interface.

Public Perceptions

Researchers are looking at how people in Colorado, Florida, and Minnesota perceive different fuel management and restoration treatments and how informing the public about those treatments impacts their perceptions. In California and other Western States, scientists are talking with community residents about how they perceive fire impacts on recreation and how these impacts can be better managed. The results of these studies will be built into guidelines for fuels and fire managers and community leaders, and will guide public communication programs.

Research Highlight

Modeling People's Responses to Landscape Treatments

Fuel management treatments implemented in forests where people live can lessen the risk of fire losses. However, these treatments can alter the forest characteristics that drew people to these environments in the first place (e.g., scenic beauty, seclusion, naturalness).

Scientists are working with partners at seven universities across the country to evaluate public perceptions of fuel management treatments. Research cooperators have begun data collection in areas around the Boundary Waters Canoe Area Wilderness in Minnesota, and in Florida. Potential study areas in Michigan, Minnesota, and Wisconsin have been identified. This work will identify elements of fuel treatments that might be modified to make them more acceptable to community residents and will provide guidelines for communication with the public about fuel management treatments and restoration activities.

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Accountability

During the first year of the NFP, FS R&D has responded rapidly to strengthen agency fire suppression decisionmaking, enhance postfire restoration effectiveness, reduce the risks of hazardous fuels buildup, and improve assistance to communities at risk from wildland fire.

The foremost challenge of this first year has been in rebuilding and restructuring scientific capability. The ratio of R&D investment to Federal agency fire management cost is less than 2 percent. Just as fire operations today benefit from the wise investments in research of previous years, future effectiveness and efficiency will require commitment to continued, aggressive investment in R&D. Even with the FY 2001 funding increases through the NFP, FS R&D capability will be unable to keep up with the demands for new knowledge, products, and services created by the combination of fuels accumulation, climate variability, urban sprawl, and wildland development without an increased research investment of the kind summarized here.

Research is committed to delivering timely products and reporting outcomes

Forest Service R&D has a strong commitment to the fifth key point of the NFP: accountability. Accountability takes many forms, from emphasis on integration both within the agency and between agencies, to more effective Federal/State/private coordination, to follow-through in capacity development, to delivering timely products and reporting outcomes.

Coordination

Forest Service Research and Development works with public and private collaborators, including universities and industry, as well as other agencies, to both leverage research funding and incorporate multidisciplinary expertise to address current gaps in knowledge about fire behavior and management.

Forest Service R&D recognizes that it cannot do the job alone. Solving complex problems requires a well-orchestrated approach to access the full range of Federal, State, university, and private sector expertise. Forest Service R&D is moving aggressively to more effectively coordinate wildland fire science and technology development. A fire research coordinating group, composed of major providers of fire science information is being established to focus on the wise use of research funding, joint exploration of fire research problems, and priority setting around important science gaps and user needs. The result will be a Federal/State/private fire research and development program that operates with minimal duplication of effort and makes efficient use of taxpayer investments. Through the outreach already

demonstrated in 2001, scientists at over 100 universities and private sector partners have been engaged to address the key NFP issues with awards totaling approximately 35 percent of the total NFP amount awarded to Forest Service R&D.

Building Capability

To more effectively integrate research tasks and blend appropriate disciplines to attack complex problems, FS R&D needs to be able to make the most effective use of current intellectual resources, replace scientists who are retiring or leaving, and address new science problems or those that have been neglected. To that end, FS R&D will be striving to build integrated centers of excellence and virtual fire labs, consisting of local institutions, Forest Service and U.S. Geological Survey research units, land management units, and universities.

Accomplishment Reporting

The planning and prioritization process used by FS R&D has been refined and is being used to guide future research investments, assuring that our scientists address critical user needs, build logically on past investments and emerging knowledge, maximize coordination across different disciplines, and avoid unnecessary duplication. A systematic evaluation of user needs and science gaps was conducted in FY 2001 and built into the program's 2002 call for new NFP research proposals. The priorities developed for implementation in this strategic plan will direct the selection of projects for FY 2002 and beyond. Feedback from users and the research community will help to refine the plan and its priorities as the issues change or become clearer.

NFP research will deliver products that can be used by:

- land managers, fire managers, and other decisionmakers to more effectively manage fuels accumulation and increase fire preparedness, and
- communities to develop "fire safe" plans that reduce their risk in coexisting with wildland fire.

Accomplishment reporting provides information on research progress as well as on products that can contribute to the well-being of communities near forested areas. In order to emphasize accountability for the NFP, funding and reporting mechanisms have been developed to permit identification of performance problems and spotlight exceptional performance. This document, as well as the regular reporting and updating of research accomplishments on the NFP Web site under development, are additional examples of efforts to be accountable. The commitment of research stations to accountability facilitates rewarding units appropriately. The result is a strong portfolio of research investments that will return knowledge dividends long into the future.

Conclusions

Science plays a key role in the NFP. Scientific research and technological development are critical in increasing the capability of the Nation to manage, respond to, and recover from wildland fire. The solutions developed from the NFP are in many ways only as good as their scientific and technical foundations.

Addressing these complex issues requires the integration of physical, biological, and social sciences, to maximize the return on research investment. Research initiated in FY 2001 in response to NFP funding is strongly targeted at providing usable knowledge, in a timely manner, to key groups including firefighters, land managers, and homeowners living in communities potentially at risk from wildland fire. Information, technology, and tools developed through research will improve our ability to manage and cope with wildland fire by reducing fire risk and preparing agencies and communities to respond to and recover from fire events.

research will provide better tools to support management and policy decisions

Forest Service R&D in partnership with other Federal, State, university, and private sector partners will provide the information for difficult but pivotal policy questions. Researchers will describe the consequences of options without advocating an outcome or policy solution. This approach will help in identifying new ways to quantify variability and uncertainty in at-risk human systems.

The bottom line for research investment will be changes in firefighting safety and effectiveness, restoration of fire-scarred landscapes, reduction of fire risk through improved management of hazardous fuels, and better community preparedness to cope with wildfires. During 2001, FS R&D responded rapidly to the challenges raised in the NFP by mobilizing teams of scientists across the Nation, funding high-priority research, and reporting here on the early results of these efforts.

Appendix

Table 1. Research Projects[1] and Team Lead Scientists

KEY POINT A – FIREFIGHTING (22 teams of reseachers)

Project ID Number	Project Title	Team Lead Scientist	e-mail address
01.NCS.A.1	National and regional fire weather dynamics	Warren E. Heilman	wheilman@fs.fed.us
01.NCS.A.2	Assessing vulnerability of populations to wildfire in the North Central Region **(JFSP-1998-4)**	Robert G. Haight	rhaight@fs.fed.us
01.NCS.A.3	FIA pilot test of a fuel condition monitoring system	Dennis May	dmay@fs.fed.us
01.PNW.A.1	A smoke modeling framework for real-time predictions	Sue A. Ferguson	sferguson@fs.fed.us
01.PNW.A.2	Estimating haze from prescribed and wildland fires **(JFSP-1998-6)**	David V. Sandberg	dsandberg@fs.fed.us
01.PNW.A.3	Seasonal prediction of national fire risks and impacts	Ronald P. Neilson	rneilson@fs.fed.us
01.PNW.A.4	Fuel moisture mapping and combustion limits **(JFSP-1998-7)**	David V. Sandberg	dsandberg@fs.fed.us
01.PSW.A.1	Risks to fish and wildlife from wildfire and landscape treatments	Danny C. Lee	dclee@fs.fed.us
01.PSW.A.2	An initial attack model for fire management planning	Marc Wiitala	mrwiitala@fs.fed.us
01.PSW.A.3	Fire behavior in live fuels	David R. Weise	dweise@fs.fed.us
01.PSW.A.4	Real-time remote sensing of fire properties	Philip J. Riggan	priggan@fs.fed.us
01.PSW.A.5	Weather models for area coordination centers	Francis Fujioka	ffujioka@fs.fed.us
01.RMS.A.1	Improving decisions for fuel treatment options **(JFSP-1998-5)**	J. Greg Jones	jgjones@fs.fed.us
01.RMS.A.2	Real-time fire monitoring nationwide	Wei Min Hao	whao@fs.fed.us
01.RMS.A.3	New technology for monitoring smoke characteristics	Wei Min Hao	whao@fs.fed.us
01.RMS.A.4	Remote sensing, GIS and landscape assessment tools for fire management	Colin Hardy	chardy01@fs.fed.us
01.RMS.A.5	Fire management strategies for wilderness and other protected areas **(JFSP-1999-3)**	David Parsons	djparsons@fs.fed.us
01.SRS.A.1	Prediction of fire weather and smoke impacts in the Southeast	Gary L. Achtemeier	gachtemeier@fs.fed.us
01.SRS.A.2	Tradeoffs of alternative vegetation management strategies	Jeffrey P. Prestemon	jprestemon@fs.fed.us
01.SRS.A.3	Establishing a wildland-urban interface research and technology transfer unit for the South	Pete Roussopoulos	proussopoulos@fs.fed.us
01.SRS.A.4	Long-range forecasting of fire season severity	Dale Wade	rxfire@ix.netcom.com
01.SRS.A.5	Southern regional models for predicting smoke movement	Gary L. Achtemeier	gachtemeier@fs.fed.us

[1] Number in bold and parens following some titles indicates linkages to JFSP projects listed in Table 4.

Table 1. — Continued

KEY POINT B – REHABILITATION AND RESTORATION (9 teams of researchers)

Project ID Number	Project Title	Team Lead Scientist	e-mail address
01.PNW.B.1	Predicting spread of invasive species after fuel reduction treatments and postfire disturbance **(JFSP-1999-4)**	Edward J. DePuit	ejdepuit@fs.fed.us
01.PSW.B.1	Effectiveness of postfire emergency rehabilitation treatments in the West **(JFSP-1998-3)**	Jan Beyers	jbeyers@fs.fed.us
01.RMS.B.1	Effects of wildfire, vegetation treatments, hydrology and geomorphology on postfire erosion **(JFSP-1999-4)**	Daniel G. Neary	dneary@fs.fed.us
01.RMS.B.2	Native plant materials for restoration of sagebrush steppe and pinyon-juniper communities **(JFSP-2000-1-1)**	E. Durant McArthur	dmcarthur@fs.fed.us
01.RMS.B.3	Dynamics of weed invasions and fire in the northern Rockies	George Markin	gmarkin@fs.fed.us
01.RMS.B.4	Effects of wildfire and fire management options on invasive and exotic species and pathogens **(JFSP-1999-4)**	Karen Clancy	kclancy@fs.fed.us
01.RMS.B.5	Factors affecting Great Basin watersheds' susceptibility to invasive plants **(JFSP-2000-1-1)**	Jeanne C. Chambers	jchambers@fs.fed.us
01.RMS.B.6	Patterns of white pine regeneration after fire	Anna Schoettle	aschoettle@fs.fed.us
01.RMS.B.7	The role of grassland fire in managing exotic and woody plants	Deborah Finch	dfinch@fs.fed.us

Table 1. — Continued

KEY POINT C – HAZARDOUS FUELS REDUCTION (24 teams of researchers)

Project ID Number	Project Title	Team Lead Scientist	e-mail address
01.FPL.C.1	Harvesting underutilized trees and forest undergrowth	John F. Hunt	jfhunt@fs.fed.us
01.FPL.C.2	Using small diameter timber and cull for laminated building materials	John F. Hunt	jfhunt@fs.fed.us
01.NCS.C.1	Optimizing fuel reductions in time and space	Tom Crow	tcrow@fs.fed.us
01.NCS.C.2	Managing risk of fire on communities in the wildland-urban interface	Eric Gustafson	egustafson@fs.fed.us
01.NES.C.1	Fuels and fire behavior in the Central Hardwoods **(JFSP-1999-4)**	Daniel Yaussy	dyaussy@fs.fed.us
01.PNW.C.1	Ground-based support for mapping fuel and fire hazard **(JFSP-1998-1, JFSP-1998-2)**	David V. Sandberg	dsandberg@fs.fed.us
01.PNW.C.2	Fuel reduction and forest restoration strategies that sustain key habitats in the interior Northwest **(JFSP-1999-4)**	John F. Lehmkuhl	jlemkuhl@fs.fed.us
01.PSW.C.1	Effects of fuel reductions on stream ecosystems **(JFSP-2000-2-1)**	Carolyn T. Hunsaker	chunsaker@fs.fed.us
01.PSW.C.2	Alternatives to fire for fuel reduction in California shrublands within coniferous forest	Robert F. Powers	rpowers@c-zone.net
01.PSW.C.3	Fire-related erosive processes in southwestern ecosystems	Ken Hubbert	khubbert@fs.fed.us
01.PSW.C.4	Effects of wildfire and fuel treatments on California spotted owl	John J. Keane	jkeane@fs.fed.us
01.RMS.C.1	Impacts of exotic weeds on fuel loading and fire regimes **(JFSP-2000-1-1)**	Nancy L. Shaw	nshaw@fs.fed.us
01.RMS.C.2	Impact of fuel management treatments on fire behavior and forest vegetation **(JFSP-2000-2-2, JFSP-2000-2-3)**	Dennis E. Ferguson	deferguson@fs.fed.us
01.RMS.C.3	Impact of fuel management treatments on forest soil erosion and production **(JFSP-1998-3)**	William Elliot	welliot@fs.fed.us
01.RMS.C.4	Management alternatives for fire dependent ecosystems in Colorado and the Black Hills	Linda A. Joyce	ljoyce@fs.fed.us
01.RMS.C.5	Guidelines for fuel management in southwestern forests at the wildland-urban interface **(JFSP-1999-4)**	Carl Edminster	cedminster@fs.fed.us
01.RMS.C.6	Restoration techniques in lodgepole pine forests	Ward McCaughey	wmccaughey@fs.fed.us
01.RMS.C.7	Use of remote sensing to examine disturbance effects	John E. Lundquist	jlundquist@fs.fed.us
01.RMS.C.8	Riparian ecosystem dynamics in relation to fire in the Rocky Mountains.	Deborah Finch	dfinch@fs.fed.us
01.SRS.C.1	Wildfire risk in the Eastern U.S.	Steve McNulty	steve_mcnulty@ncsu.edu
01.SRS.C.2	Tradeoffs of fire and fuel management options: Herbicides **(JFSP-1999-4)**	Thomas A. Waldrop	twaldrop@fs.fed.us
01.SRS.C.3	Tradeoffs of fire and fuel management options: Mechanical methods	Kenneth W. Outcalt	koutcalt@fs.fed.us
01.SRS.C.4	A system for mechanized fuel reduction at the wildland-urban interface	John Stanturf	jstanturf@fs.fed.us
01.SRS.C.5	Fire and herbicide combinations to reduce fire intensity **(JFSP-2000-2-4)**	Dale Wade	rxfire@ix.netcom.com

Table 1. — Continued

KEY POINT D – COMMUNITY ASSISTANCE (8 teams of researchers)

Project ID Number	Project Title	Team Lead Scientist	e-mail address
01.NCS.D.1	Modeling people's responses to landscape treatments **(JFSP-1999-1, JFSP-1999-2)**	John F. Dwyer	jdwyer@fs.fed.us
01.NCS.D.2	Community partnerships	Pamela J. Jakes	pjakes@fs.fed.us
01.PSW.D.1	Recreation and fire in the wildland-urban interface	Deborah Chavez	dchavez@fs.fed.us
01.PSW.D.2	Firewise residential landscapes	Greg McPherson	egmcpherson@ucdavis.edu
01.RMS.D.1	Building consensus on fire management	Brian Kent	bkent@fs.fed.us
01.RMS.D.2	Preventing residential fire disasters at the wildland-urban interface	Jack D. Cohen	jcohen@fs.fed.us
01.SRS.D.1	Impact of wildfires on local economies	Jeffrey P. Prestemon	jprestemon@fs.fed.us
01.SRS.D.2	Fire protection in residential expansion areas	Terry Haines	thaines01@fs.fed.us

Table 2. Summary of Accomplishments

Accomplishment	Firefighting	Rehabilitation and Restoration	Hazardous Fuels Reduction	Community Assistance	TOTAL
Studies Initiated	69	40	118	25	252
Agreements/Contracts Established	52	27	66	22	167
$$ Value of Agreements (1000s)	3,771	1,170	2,748	1,182	8,871
Permanent Scientists/Professional hired	8	1	6	0	15
Term Scientists/Professionals Hired	9	5	17	3	34
Permanent Technicians Hired	2	0	4	1	7
Term/Temp. Technicians Hired	16	20	84	4	124
Refereed Publications	0	8	2	0	10
Non-Refereed Publications	9	6	10	0	25
Presentations at Scientific Conferences	18	12	44	8	82
User Bulletins, Leaflets Produced	1	0	6	1	8
Decision Support Tools, Models Developed	4	0	6	1	11
Demonstrations, Tours Hosted	8	6	29	12	55
Significant Consultations with:					
Regions, National Forests, Districts	20	34	61	9	124
States, State Foresters	14	4	28	4	50
Tribal Governments, Other Federal	2	3	5	0	10
County, Local Governments	0	4	10	13	27
Short Courses, Workshops, Training Offered	9	6	24	6	45
Communities Assisted	1	2	12	9	24
Fire Management Units Assisted	5	2	4	4	15

Table 3. FY 2001 Sources of Funding in Forest Service Fire-Related Research and Development[1]

Research Station	Core Fire Science $$ Appropriated (thousands)	Fire-related Research $$ Appropriated (thousands)	Joint Fire Science Funding[2] $$ (thousands)	Other Soft Funding $$ (thousands)	Fire Plan $$ Appropriated (thousands)	Total Fire Research $$ (thousands)
Forest Products Lab	0	0	0	0	750	750
North Central Research Station	103	345	276	306	2,806	3,836
Northeast Research Station	0	475	429	214	500	1,618
Pacific Northwest Station	897	152	1,511	315	3,500	6,375
Pacific Southwest Station	2,143	1,765	445	475	5,540	10,368
Rocky Mountain Research Station	4,607	2,367	3,349	3,577	8,409	22,309
Southern Research Station	787	867	171	312	4,337	6,474
TOTAL	8,537	5,971	6,181	5,199	25,842	51,730

[1] Dollar amounts represent estimates received from Research Stations in response to query in August 2001.
[2] Joint Fire Science funding amounts represent dollars received from the JFSP program following competitive review of submitted proposals.

Table 4. Joint Fire Science Program Projects with Linkages to National Fire Plan Projects

Year Funded	Project Title	Lead Scientist
1998-1	Photo series for major natural fuel types of the U.S.—phase II	Roger D. Ottmar
1998-2	Application of a fuel characterization systerm for major fuel types of the contiguous U.S. and AK	Roger D. Ottmar
1998-3	Risk assessment of fuel management practices on hillslope erosion processes	Peter Robichaud
1998-4	Characterizing historic and contemporary fire regimes in the Lake States	David T. Cleland
1998-5	A risk-based comparison of potential fuel treatment tradeoff models	David Weise
1998-6	Implementation of an improved emission production model	David Sandberg
1998-7	Modification and validation of fuel consumption models for shrub and forested lands in the SW, PNW, Rockies, Midwest, SE, and AK	Roger D. Ottmar
1999-1	Evaluating public responses to wildland fuels management: Factors that influence acceptance of practices and decision processes	Bruce Shindler
1999-2	Demographic and geographic approaches to predicting public acceptance of fuel management at the wildland-urban interface	Jeremy S. Fried
1999-3	Wildland fuels management: Evaluating and planning risks and benefits	Peter Landres
1999-4	Fire and fire surrogate study	Jim McIver
2000-1-1	Changing fire regimes, increased fuel loads, and invasive species: Effects on sagebrush steppe and pinyon-juniper ecosystems	Jeanne Chambers
2000-2-1	Kings River and Lake Tahoe Basin demonstration sites for fuel treatments	Carolyn Hunsaker
2000-2-2	Stand and fuel treatments for restoring old-growth ponderosa pine forests in the interior West (Boise Basin Experimental Forest)	Russell T. Graham
2000-2-3	Treatments that enhance the decomposition of forest fuels for use in partially harvested stands in the moist forests of the northern Rocky Mountains (Priest River Experimental Forest)	Russell T. Graham
2000-2-4	Maintaining longleaf pine woodlands: Is mechanical shearing a surrogate for prescribed burning?	Jeff Glitzenstein

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