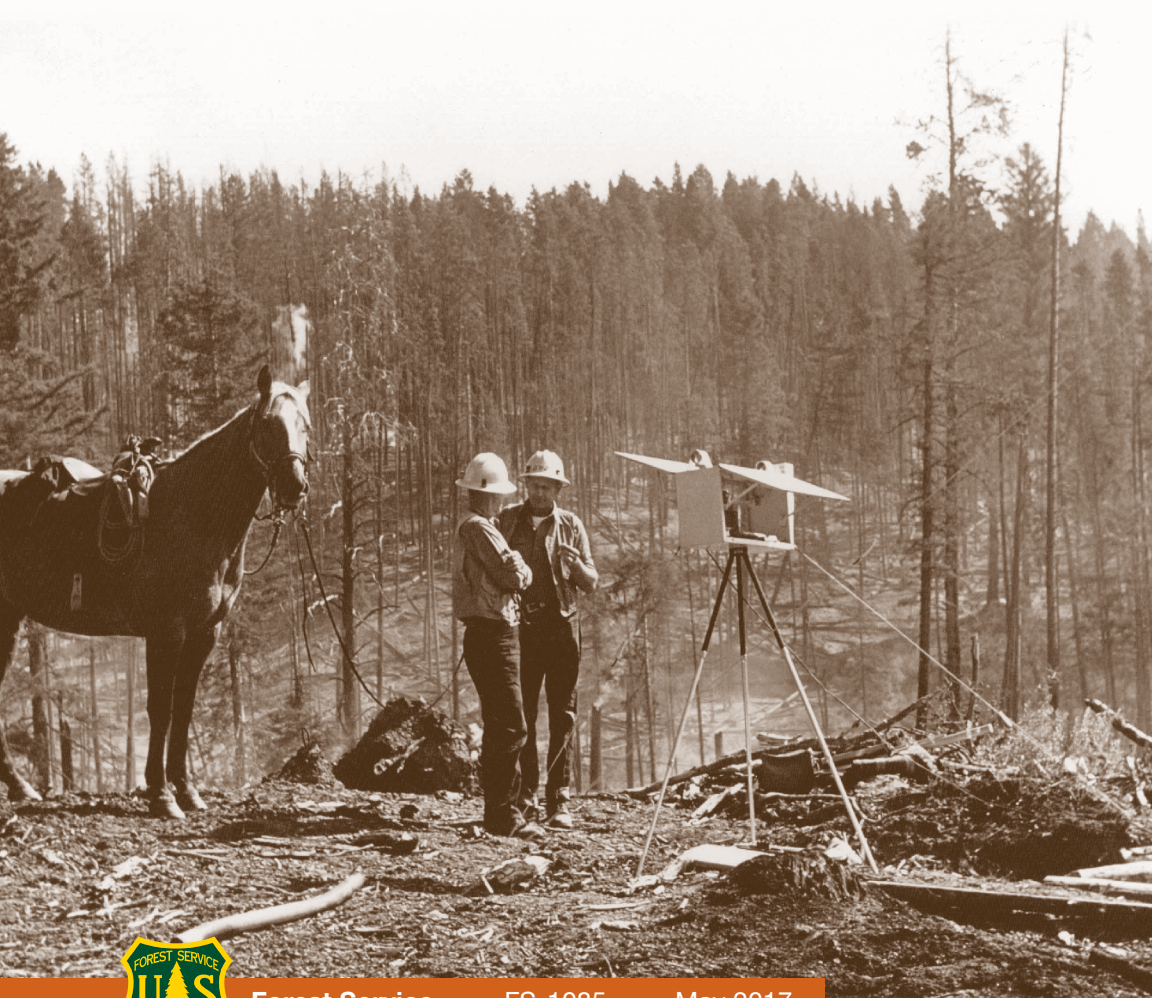
USDA

United States Department of Agriculture

Sustainability and Wildland Fire

The Origins of Forest Service Wildland Fire Research



Forest Service FS-1085 May 2017

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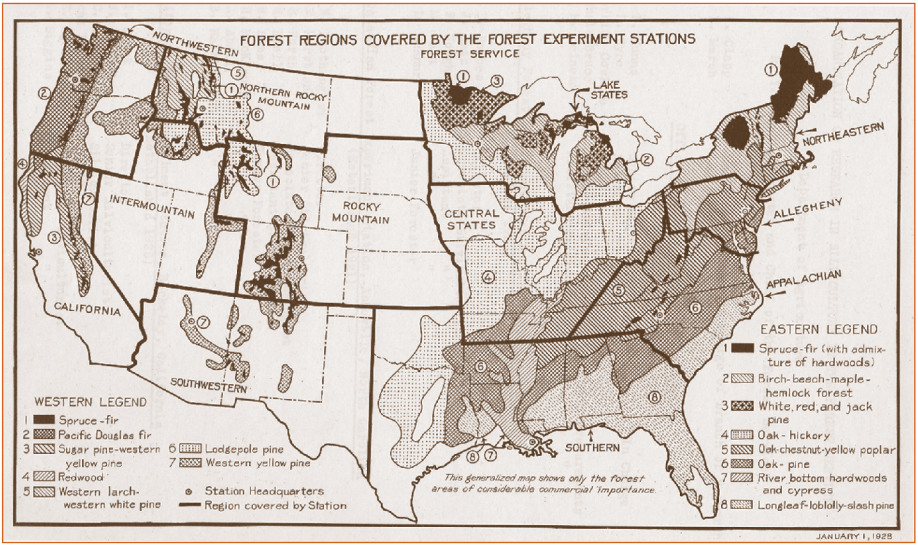


▲ Forest regions and forest experiment stations, where the Forest Service conducted most of its early fire research. Forest Service illustration from 1928.

Diane M. Smith
Missoula Fire Sciences Laboratory
Rocky Mountain Research Station

Forest Service FS-1085 May 2017

Acknowledgments

On June 1, 1915, Henry S. Graves established the Branch of Research in the Forest Service. To commemorate that event, Deputy Chief for Research and Development Carlos Rodriguez-Franco commissioned me to write a history of wildland fire research in the Forest Service.

As a postdoctoral research historian at the Missoula Fire Sciences Laboratory, I could not have wished for a better or more interesting assignment. It required that I go back to the beginnings of the Forest Service and learn alongside researchers as they tested new ideas, explored new approaches, and developed new technologies in their quest, in the words of Gifford Pinchot, to "replace with carefully gathered facts the vague general notions that now exist about forest fires."

I sincerely want to thank Dr. Rodriguez-Franco and Colin Hardy, Program Manager of the Rocky Mountain Research Station Fire, Fuel, and Smoke Science Program, for their support of this project.

I also want to thank Scott Stephens, who facilitated my research at the University of California, Berkeley, and Pat Andrews, Steve Arno, Mark Finney, Faith Ann Heinsch, Jane Kapler-Smith, Chuck McHugh, and Richard Rothermel, who provided invaluable suggestions and encouragement as I worked through the thousands of documents. Thanks, too, to Sonja Beavers, the National Publications Editor, who worked hard to get this into print. The Forest Service refers to itself as a family; even though I am not a permanent employee, I still felt a part of that family as I worked on this book.

Diane M. Smith
Missoula Fire Sciences Laboratory
Missoula, MT

Contents

Introduction

We are not doing research for research's sake. We have a definite, decidedly practical goal, and it is still the basic, over-all goal that Graves stated in 1910: "The first measure necessary for the successful practice of forestry is protection from forest fires." Fire research is therefore intended to serve as directly as possible the fire-control men who must first be successful before any of the other arts or artists of forestry can function with safety.

—Harry T. Gisborne, 1942

On June 1, 2015, the Forest Service, an agency of the U.S. Department of Agriculture (USDA), celebrated the 100th anniversary of the Branch of Research. Established in 1915 to centralize and elevate the pursuit of research throughout the agency, the Branch of Research focused on everything from silvicultural investigations conducted by the experiment stations to industrial studies and wood product improvement at the Madison, WI, Forest Products Laboratory. From its beginning, the branch oversaw ongoing research designed to develop insights, methods, and technologies to help foresters and land managers better understand, prevent, and suppress wildland fire.

Naturalists and explorers asked questions about fire and the sustainability of the Nation's forested lands long before the founding of the Forest Service in 1905, and these early concerns clearly influenced the agency's mission regarding wildland fire. For example, George Perkins Marsh published *Man and Nature* in 1864, warning of the dangers of deforestation worldwide (Marsh 1864), and Charles S. Sargent compiled his report on American forests, including fire, on behalf of the

▲ Surface fire in the Black Hills of South Dakota, 1896. Photo by Henry S. Graves, courtesy of the Forest History Society, Durham, NC.

1880 census (Sargent 1884). Detailed U.S. Geological Survey reports on the forest reserves in the American West, produced before 1905, often documented and mapped evidence of widespread fire in areas such as the northern Sierras and the Tahoe and Stanislaus Forest Reserves in California and the Bitterroot and the Lewis and Clark Forest Reserves in Montana (Ayers 1900; Leiberg 1899, 1902; Sudworth 1900). Reflecting on his travels through what he referred to as "the arid regions" of the Rocky Mountain West, John Wesley Powell reduced the question of forest sustainability to one single question: "Can these forests be saved from fire?" (Powell 1879: 17).

From its earliest days, the Forest Service pursued a single-minded goal regarding fire: minimize the size and number of wildland fires, if not eliminate them all together. This mission often came into direct conflict with the very nature of forests themselves, not to mention long-held beliefs about fire sustained by residents living in environments as diverse as the Southeast and the west coast. Local resistance to the agency's goal of complete fire suppression, however, only made Forest Service personnel more committed than ever to try to ensure the sustainability of the Nation's forested lands by investing in research designed to protect them from all wildland fire.

That is not to suggest that during the past 100 years the Forest Service and its employees followed a straightforward and logical research path defined solely by improving fire prevention and suppression techniques nationwide. Much like research in other areas of forestry, early investigators pursued projects of local or national concern, with some investigations and results more significant or successful than others. Scientists' personal interests, beliefs, and career goals also helped shape early research choices, as did the availability of innovative technologies that made asking new questions about fire and its effects possible.

The Forest Service grew out of this desire to protect and sustain America's forests for the greatest good for the greatest number in the long run. With this primary goal of sustainability, the new agency hired a generation of American-trained foresters, who brought their commitment to scientific forestry and what Samuel P. Hays has referred to as a "deep sense of hope" that motivated all those "at the turn of the century for whom science and technology were revealing visions of an abundant future" (Hays 1975: 2-3). These scientists based their optimism on the successful practice of forestry. They believed that for forestry to succeed in the United States—indeed for the science of forestry to be practiced at all—wildland fire must be eliminated.

Yet, as Gifford Pinchot noted when he became chief of the Division of Forestry in 1898, little was known about forest fires and their effect on the composition and reproduction of forests. To address this need, that same year, Pinchot initiated an indepth study of historical forest fires nationwide and on-the-ground investigations of recent fires. Although these investigations may not qualify as fundamental research by current standards, they laid the foundation for the fire research and management policies that followed. Pinchot's goal was "to reduce the loss from forest fires, the reported amount of which reaches a yearly average of not less than $20,000,000" (Pinchot 1898: 171).

Today, foresters have a more complete understanding of the contributions made by fire to the long-term health and sustainability of many forests, so it is easy to find fault with the choices researchers and managers made during these early years. These professionals, however, used their scientific training and what they believed at the time to be the best science-based information. Even when a small number of foresters deliberately undermined their own research to get the results they wanted, they did so out of a desire to protect the Nation's forested lands from what they considered to be the devastating consequences of fire.

After the uncontrollable fires of 1910, during which more than 3 million acres burned and at least 85 people died, most of them firefighters, foresters were more determined than ever to fight fire wherever they found it. It was, as the first Forest Service Manual (or "Use Book") reminded them, something only the Federal Government could do and was the basic foundation required before

they could practice the science of forestry (USDA Forest Service 1905). This overarching goal of controlling fire nationwide drove research in the Forest Service from the very beginning.

About This Book

This book, written for a general audience, but hopefully useful for researchers and land managers as well, presents the history of Forest Service fire research up through the early 1970s. It is organized thematically around the three areas Forest Service researchers believed would improve the long-term sustainability of forested lands—(1) fire control, (2) fire behavior, and (3) fire effects—and follows each of those research areas over time. The first chapters introduce these three research areas, starting in the mid-1800s with the early concerns expressed by Franklin B. Hough and others before World War II (chapters 1 through 4). It then picks up with the militarization of firefighting that sought to capitalize on available technologies, techniques, and trained personnel after the war (chapter 5) and introduces the three national fire research laboratories and their initial contributions (chapter 6).

The ultimate goal of this book is to help researchers, managers, and the public better understand the origins of wildland fire research, as well as the management and firefighting decisions based on that research. Understanding of the decisions that researchers and managers make today and the choices they will be called on to make in the future is improved by appreciating wildland fire research in its historical context.

A note about sources and terminology: Although many have contributed to the study of wildland fire research from its earliest years, including scientists in the U.S. Department of the Interior, researchers at universities, and even private landowners, this book focuses on the early history of fire research in the Forest Service. It relies on literally thousands of primary documents and reports drawn from the National Archives and the Library of Congress; collections at the University of California at Berkeley, the University of Montana at Missoula, and the National Forest Service Library; and decades of data and reports at the Missoula Fire Sciences Laboratory. Although some documents could not be accessed or found (e.g., when the Southern Forest Fire Laboratory closed in the mid-1980s, much of its original documentation appears to have been lost), formative documents and reports from research meetings, the forest experiment stations, and fire laboratories have been used whenever possible.

In addition, over the years, terminology used to describe fire and the Nation's wildlands has changed. For example, Forest Service researchers used terms such as *investigations* (as opposed to *research*) and the words *forest fires* and *wildfires* interchangeably. Today, the Forest Service manages a variety of "wild" lands, from grasslands and prairies to forested lands and wilderness; thus, the

preferred term now is *wildland fires*. Likewise, the term *fire effects* or *fire damage* initially referred to quantifying financial losses and the damage done to forested lands by fire, not to any potential benefits that fire might bring, as the term is often used now.

Terms such as *light burning*, *burning the woods*, *prescribed fires*, and *controlled burns* also have malleable meanings depending on the time and place of their use, but generally users are referring to deliberately using fire as a management tool or preventative measure. It also helps to know that researchers often refer to *fuels*, meaning any vegetation, live or dead, that can burn in a wildland fire, from grasses to trees. *Duff* is the decaying material on the ground or part of the forest floor, but it does not include needles, leaves, and twigs on the forest floor, which is referred to as *litter*. *Slash*, on the other hand, refers to the tree limbs and any other debris left behind after logging or other forestry activities.

The Forest Service also has changed how it refers to its management units, changing from *districts* to *regions* in 1930. Moreover, many of the original forest experiment stations have changed names and/or merged; changes are noted in the text, as appropriate. To avoid confusion, the names and terminology used at the time will be employed in their historical context, with more contemporary language used as appropriate in broader historical overviews.

▼ Pine forest in California in 1900. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

One last note: Although every attempt has been made to accurately reflect the intent and relevance of the research documented here, this book does not address the accuracy or completeness of any of the investigations discussed. Nor does it cover all fire-related research at all Forest Service locations around the country. Instead of a thorough listing of research projects, this book attempts to identify the origins of fire-related research, highlights the kinds of questions researchers asked during the formative years of the Forest Service and the Branch of Research, and features examples of some of the research and other projects conducted to answer those questions. It is the historical context for current wildland fire research that the study intends to highlight as opposed to the results of the actual research itself.

Chapter 1

Sustainability of the Nation's Forested Lands

With forester Gifford Pinchot as its first chief, the U.S. Forest Service was given the charge of managing the national forests to provide "the greatest good for the greatest number in the long run." Sustainability in a broad sense—ecological, economic, and social—had been established as the fundamental concept underlying forest policy in the U.S.

—V. Alaric Sample, 2004

When looking for the origins of wildland fire research in the Forest Service, an agency of the U.S. Department of Agriculture (USDA), historians have identified a variety of "firsts." Forester C.E. (Mike) Hardy, an early fire researcher, made the case for 1922, when Harry Gisborne became the first full-time fire researcher in the Forest Service (Hardy 1983). Stephen Pyne, a leading fire historian, argued that fire research originated after the 1910 fires under the leadership of Coert DuBois in California. Pyne pointed to DuBois' oversight of the first fire case study in 1911, the first use of statistical methods in analyzing fire reports in 1914, and the first fire behavior and fire effects research in 1915 (Pyne 1982; 1997). An unpublished Bureau of Forestry memo from approximately 1904, probably written by Gifford Pinchot himself, regards Pinchot's 1899 investigations as the point when the first "study of forest fires was begun" (USDA n.d. [ca. 1904]: 1).

Long before Gisborne, DuBois, and even Pinchot investigated the causes and effects of wildland fires and the methods to prevent and suppress them—indeed, before a Forest Service even existed within the

USDA—a physician and naturalist by the name of Franklin B. Hough expressed concern about fire and the sustainability of America's forests. Although trained as a physician, Hough was a prolific writer with wide interests. For example, Hough researched and published a series of local New York histories, prepared an analysis of the New York State Constitution, and even compiled a bibliography of publications related to the death of George Washington.

▲ Franklin B. Hough, ca. 1880 to 1885. Photo courtesy of the Library of Congress.

It was Hough's work on the New York State census (and no doubt the influence of the work of George Perkins Marsh), however, that ignited his commitment to sustainable forestry. While comparing the production of lumber as shown in the censuses of 1855 and 1865, Hough noticed a stark decline in some regions and new production opening up in others. "It did not take much reasoning," he later wrote, "to reach the inquiry: 'How long will the supplies last—and what then?'" (American Forestry 1922: 431).

Hough became convinced that the future of the Nation was tied to the health of America's forests, so he became a vocal advocate for the protection of forested lands. At the time, conserving large tracts of land for the public good was a relatively new idea, but not a unique one. Indeed, as Hough no doubt was aware, the New York State legislature had enacted an early precedent when, in 1853, it set aside 750 acres to establish what would become Central Park in New York City. In 1864, President Abraham Lincoln granted the Yosemite Valley and the Mariposa Big Tree Grove to the State of California, to be protected for public use and recreation for all time. The establishment of Yosemite was followed in 1872 by President Ulysses S. Grant's signing of an act creating Yellowstone National Park as a "public park or pleasuring-ground for the benefit and enjoyment of the people"; this "Act to set apart a certain Tract of Land lying near the Head-waters of the Yellowstone River as a public Park" also called for protecting the park's natural resources, including its timber. Three weeks later, on March 25, 1872, citizens presented a petition to the New York State Senate asking that a similar public park be set aside to preserve the forests and game of northern New York, in the area in and around the Adirondacks. In response, the State created a committee to investigate the request and appointed Hough as one of the group's members.

By the next spring, Hough, on behalf of the commission, submitted a report in which he argued in part that the State's forested lands should be safeguarded not only for social and moral reasons, but also because they protected New York's water resources and provided a source of wealth for the State. Even deforested lands, which the State routinely sold for next to nothing (i.e., 5 cents an acre), should be kept as a potential source of wealth, he wrote in the May 1873 report.

Hough had found his calling. In August of that same year, he made a similar argument in a paper he presented at the annual meeting of the American Association for the Advancement of Science (AAAS). In his address, "On the Duty of Governments in the Preservation of Forests," Hough warned that deforestation threatened the Nation's future growth. He called on the association to petition Congress and State legislatures, much as citizens had petitioned the State of New York, for the protection, cultivation, and regulation of forested lands nationwide (Hough 1873).

Hough made a compelling case and convinced AAAS members to pass a resolution in support of his recommendations. Government needed to do more to preserve the Nation's forests, AAAS members agreed, and they recommended legislation to promote this goal. They, too, formed a committee and appointed Hough and Boston educator George B. Emerson to take charge of promoting their resolution in Washington, DC. Yet, in spite of President Ulysses S. Grant's support for the proposed legislation, Congress did not at first act. Hough complained to a colleague, "'…it is evident that the preservation and reproduction of our forests is the great question of the future, and the time is near at hand when we must begin to study its practical relations with earnestness. But because the danger is not immediately pressing … too many of our public men look upon the exhaustion of our timber supplies as a calamity that may not come in their day and therefore it is to them of little account'" (Jacobsen 1934: 320).

The idea of protecting the Nation's forests did not die, however. Minnesota Congressman Mark Dunnell presented a forestry bill in 1876 and, in spite of what Hough considered Congress's indifference, a portion of the bill called for $2,000 to create a new office of "Special Agent" in the USDA. It passed as an amendment to the general appropriations. Edna Jacobsen of the New York State Library would later call this 1876 appropriation "the first concrete result of Hough's 1873 address before the Association for the Advancement of Science" (Jacobsen 1934: 321).

Again, leaders turned to Hough to take the lead, with USDA Commissioner Frederick Watts appointing him to the newly funded agent position that same month (Steen 1976; 2004). This small office with one agent, charged with investigating (i.e., researching) the condition of the Nation's forested lands, would become the foundation for the Division of Forestry in 1881, the Bureau of Forestry in 1901, and eventually the Forest Service in 1905. Although many historians and the agency itself point to 1876 and support for a special agent within the USDA as the origins of the Forest Service (e.g., see USDA Forest Service n.d.), the best places to find the origin of Forest Service research are Hough's protests on behalf of the sustainability of American wildlands and the subsequent AAAS memorial to Congress.

Origins of Fire Research

Franklin B. Hough also appears to be the inspiration for, if not the actual source of, America's earliest wildland fire research. In his new position as USDA forestry agent, Hough conducted extensive reviews of the Nation's forested lands and, as instructed, reported back to Congress on everything from the best means for the preservation and renewal of forests, to the influence of forests on climate. From his earliest investigations as forestry agent, Hough also expressed concern about the effect fire had on the sustainability of the Nation's forested lands.

Hough's first report, completed in 1878, compiled a history of recent wildfires in parts of the Northeast and also those in Western States and territories. Hough summed up the impact fire had on timbered lands by quoting from an 1871 report from Quebec in which the Canadian commissioner of lands reported that "'[t]he most formidable agent in the destruction of our forests is, certainly, fire. All the most active operations in lumbering which have taken place since the settlement of the country, and all those which are likely to take place for the next twenty years, have not caused and will not cause to our forests so much devastation as this one destroying element has effected to the present time'" (Hough 1878: 158).

After submitting the second volume of his report to Congress, Hough worked on assembling all known legislation designed to prevent forest fires and punish those responsible for starting them. He collected information on both original statutes and updated versions when available, arguing that States could learn just as much from one another's failures as their successes. In October 1880, Hough distributed a circular to a list of correspondents in counties, States, and territories to determine the number of wildland fires nationwide, the causes of the fires if known, and the methods employed for preventing and suppressing them. He summarized the responses he received in volume III of his *Report on Forestry* (Hough 1882a).

According to Hough's many respondents, most fires were human caused. Intentional or escaped fires were caused by burning brush for clearing land, careless use of fire in hunting camps or for driving game, and sparks from railroad trains. The reports did not all agree with Hough's assertion that forest fires were destructive, however. Some reported that farmers, particularly in the South, started fires on purpose to reduce the potential for severe fires. One respondent from Georgia noted that people in the South referred to starting fires as "burning the woods," a technique practiced annually to "safeguard against destructive forest fires" and to encourage the growth of grasses for livestock in the spring. "It is the accumulation of years that creates these destructive forest fires," the writer continued, suggesting that protection of some forests might be contingent on regular exposure to fire. "Were they burnt off regularly every

winter or early in the spring there would seldom be any trouble in controlling the fires. Whether the annual burning is injurious or not to the land is a debatable question" (Hough 1882a: 172).

A similar reply from Idaho reported that wildfires in that region were common, and that the entire area burned over "about once every four years, not all at once, but in streaks here and there, as the dead grass of former years makes good fuel for the flames." The account, sent by J. Brigham from Lidyville, ID, also advanced the idea that if grasses and other understory were burned early in the year (presumably on purpose), the trees would be safe, "and the spread of accidental fires would be prevented for probably two or three years, as these prairies will not burn oftener" (Hough 1882a: 197).

Hough compiled the fire data he received from the field, but because much of it was anecdotal and/or reported secondhand, he expressed little confidence in the completeness or accuracy of his report. Still, to the best of his and his respondents' abilities, he had documented what individuals knew or had heard about recent fire activities in their States or territories, what was known about local laws designed to prevent forest fires, and what penalties were in place to punish those who started them. This was, for Hough, one of the keys to forest sustainability because he still believed that "There is no subject in Forestry more important than the prevention and control of forest fires" (Hough 1882b: 154).

Although the results were not as systematic or thorough as the meticulous Hough desired, his work marked one of the earliest attempts to research and compile what was known about wildland fire nationwide. In 1884, Hough's successor, Nathaniel Egleston, published another volume of *Report on Forestry* to which Hough also contributed. Volume IV also included information from the States and territories on wildland fire (Egleston 1884).

In 1886, Bernhard Fernow replaced Egleston as chief of what was by then known as the Division of Forestry. The first trained forester to work in this position, having been educated in Europe, Fernow viewed fire as "the great bane of American forests," and famously quipped that "conflagrations are due largely to bad habits and loose morals" (Fernow 1891: 87). Thus, the obvious solution was not more research but rather more policing. That is not to suggest Fernow was not interested in research; he initiated investigations of how to use wood more efficiently, a field he referred to as "timber physics." This early forestry research was ended in 1896, however, because the Secretary of Agriculture "deemed such research not relevant to forest cultivation and protection" (West 1992: 56).

That could have been the end of forestry research, fire or otherwise, within the agency that would become the Forest Service. By hiring Franklin B. Hough as its first forestry agent, however, the USDA had laid the foundation of the agency's initial activities: investigations into the condition of the Nation's forests. Because

Hough reported his findings to Congress, which published the reports for dissemination, national opinionmakers and legislators alike began to see the importance of protecting the sustainability of the Nation's forests, and they connected that sustainability, in part, to better understanding and controlling wildland fires.

Gifford Pinchot: Chief Forester

When Gifford Pinchot became chief of the Division of Forestry in 1898, replacing Bernhard Fernow, who left to teach forestry at Cornell, Pinchot advanced Hough's early concerns about the threat posed by wildland fires. Indeed, Pinchot expressed surprise that so little was known about fire's causes and effects. "The nature and ways of action of forest fires and their effect on the composition and reproduction of forests have been very little studied," Pinchot wrote in his first annual report in 1898. "Such knowledge is so essential to the most effective work in preventing and fighting them that the absence of systematic attempts to collect it is to some degree a matter of surprise" (Pinchot 1898: 172).

To address this lack of knowledge, rather than send out a circular to individual correspondents to request information as Hough had done, in 1898, his first

▼ Gifford Pinchot, ca. 1890 to 1910. Photo courtesy of the Library of Congress.

year on the job, Pinchot instead organized cooperative investigations with States and Federal agencies to determine the extent, causes, and/or effects of fires in Colorado, Montana, New York, Washington, Wisconsin, and Wyoming and planned for additional on-the-ground investigations of fires in southern California and in Oregon. He also initiated a study of forest fires reported in American newspapers over the years, for which Division of Forestry employees reviewed, in their first year of study, more than 4,000 records of wildland fires documented in 1,155 volumes of newspapers from 17 States. By 1901, they had recorded data from more than 10,000 fire-related articles (Pinchot 1901).

In a 1902 fire investigation in the Midwest, which included stops in both Michigan and Wisconsin, investigator and photographer Alfred Gaskill wrote to Pinchot that many areas that had once experienced "serious forest fires," were now cut over, or experienced much less danger of fire because lumbering operations were much more careful than in the past (Gaskill 1902). In another, even more detailed study of Marinette County, WI, conducted in the spring and summer of 1903, Robert Reynolds interviewed local leaders and residents for their view of "the fire question." He also distributed self-addressed, stamped envelopes and stationery to all railroad station agents in the area to report all fires, but only 1 of the 10 fires that burned while Reynolds was in the county was reported. "They are so accustomed to fire in this country," he explained, "that the sight of smoke rolling up provokes little comment" (Reynolds 1903: 28.) Reynolds compiled a list of those 10 fires identifying the cause (railroads, smoker, fisherman, etc.) and estimated losses from each fire, ranging from $23 to $18,000, when a fire burned through a sawmill and lumber yard (Reynolds 1903).

Pinchot (1903: 525) described these early fire-related investigations as assembling the best information possible in order to understand both the financial losses caused by forest fires and also the indirect damage to the forest and to local interests of various kinds. His goal, he wrote, was to have regional field studies and "carefully gathered facts" replace "the vague general notions that now exist about forest fires." Pinchot ultimately hoped that an ongoing study of wildland fires around the country would lead to improved methods of prevention and control. Although the actual management of the Nation's forested lands was still in the hands of the U.S. Department of the Interior, Pinchot predicted that after detailed field studies of fires such as those he had initiated, the Bureau of Forestry would be able to recommend effective methods for fire protection and control, and, "when called upon to do so, to suggest fire legislation for the various states" (Pinchot 1903: 525).

An undated internal memo from around 1904, probably written by Pinchot himself, outlined how the Bureau of Forestry had been studying forest fires. Bureau studies included analysis of the extent and immediate damage done by large fires ("in the nature of national calamities"); details from on-the-ground studies of the effect of fires and the best methods for their prevention and

control; and historical studies of fires through the compilation of available reports from newspapers. By the time the memo was written, the historical study of all forest fires in America had been suspended because it had achieved its stated goal of providing an overview of losses over time. The more urgent work, according to the unidentified writer of the memo, was "not the necessarily imperfect record of the extent and damage done by fires in the past, but the study of forest fires on the ground with a view directly to recommendations for their prevention and control" (USDA n.d. [ca. 1904]: 2).

Pinchot was soon called on to do more than just make recommendations on fire prevention and control, however. On February 1, 1905, under the leadership of President Theodore Roosevelt, Congress transferred the national forest reserves and its annual budget to the USDA. Starting in 1905, all public lands formerly administered by the U.S. Department of the Interior were to be managed by the newly established Forest Service. The new agency's fire-related investigations now needed not only to understand the causes and effects of fire but also to protect the Nation's forest resources from burning. The Forest Service's first book of rules and regulations states the following:

> Officers of the Forest Service, especially forest rangers, have no duty more important than protecting the reserves from forest fires. During dry and dangerous periods all other work should be subordinate. Most careful attention should be given to the prevention of fires. Methods and equipment for fighting them should be brought to the highest efficiency. No opportunity should be lost to impress the fact that care with small fires is the best way to prevent large ones (USDA Forest Service 1905: 65).

The Use of the National Forest Reserves, Regulations and Instructions (or "Use Book" as it was known) required all foresters to fight every fire "unless he clearly can not reach it, or is already fighting another fire.... The fact that it may not be on his district has no bearing unless he is certain another ranger is there already." Moreover, after a ranger reached the scene of a fire, he was required to stay with it until he extinguished it, leaving early only if the fire threatened his life. Protecting the Nation's wildlands from fire was one of the new agency's greatest responsibilities since, in the words of the new Forest Service, only the Federal Government can "give the help so urgently needed" (USDA Forest Service 1905: 64). With national forest reserves now under the Forest Service's control, the new agency could pursue its fire-related investigations in concert with management, one informing the other.

Henry S. Graves and the Fires of 1910

In January 1910, Henry S. Graves became the Forest Service's second Chief Forester after President William Howard Taft unexpectedly fired Gifford Pinchot over his vocal opposition to the Taft administration's privatization of some

public lands. During his decade-long tenure, Chief Forester Graves worked to restore low morale over Pinchot's dismissal, while focusing on what Graves believed to be the premier responsibility of the Forest Service: protection of the national forests from fire.

In March 1910, Graves submitted for publication a brief bulletin titled "The Protection of Forests From Fire," stating that forest fire protection is the "first measure necessary for the successful practice of forestry" (Graves 1910: 7). Written much like an instructional manual on how to fight fires, it must have seemed significant and timely when Graves completed it. Yet, by the time it was actually printed in August, it must have soon seemed out of date and even naïve, as the Nation and the Forest Service itself struggled to understand the uncontrollable forest fires that burned that same month in the Pacific Northwest and northern Rocky Mountains. The fires of 1910 certainly did little to lend credibility to Henry S. Graves' overt optimism expressed in his just-published treatise on fighting fires.

▲ Henry S. Graves, ca. 1890 to 1910. Photo courtesy of the Library of Congress.

After writing on behalf of the Forest Service that fighting fires was central to the practice of forestry (and, thus, the Forest Service itself), the 1910 fires left Graves more committed than ever to investigating and perfecting a system of fire protection. During the winter and the spring of 1911, Graves turned the Forest Service's attention to "the study of the forest-fire problem, in order that the highest possible state of preparedness might be reached" (Graves 1912a: 29). Forest administrators developed fire protection plans and identified where improvements such as roads, lookouts, and better communication networks were most needed. The fires of 1910, however, although "invaluable as a lesson," according to Graves, also raised many questions about fire prevention and suppression that administrators and researchers throughout the relatively new agency sought to answer. The general public also expressed its concern, with Californians in particular raising a specific question about Forest Service fire research and management: Why did the Forest Service not investigate the practice of "light burning" to take more proactive action in preventing catastrophic fires?

As a partial response to this persistent question about light burning, in 1911 the Forest Service's district forester in California, Frederick E. Olmsted, published a short paper on the use of light burning in the State's forests. In the paper's introduction, Olmstead explained that light burning advocates criticized the Forest Service for not deliberately burning the grounds of forested lands in either the spring or fall to "get rid of the brush, undergrowth, and ground rubbish, so that fires which start during the dry season will not have this material to feed

upon. In other words, the theory contemplates a cleaning up of the ground by means of fire" (Olmsted 1911: 1). Olmsted countered that the Forest Service did indeed use fire to clean up slash after logging, but the agency did not promote the use of what advocates also referred to as "Indian fires," which he believed turned excellent stands of timberland into worthless slopes of brush and chaparral (Olmsted 1911).

Although the Forest Service officially denounced the idea of light burning in publications and in policy, some within the agency also conducted research that would justify their position. In 1911, Forester S.B. Show tested the idea on the Shasta National Forest in northern California, conducting a light burn on 8 acres and monitoring the results over three seasons. Although the litter on the ground was burned off with minimal impact to any of the standing trees, Show wrote that "practically every individual seedling and small sapling of all species was killed; in other words, reproduction up to 15 years old, or 2 inches in diameter, was almost annihilated" (Show 1915: 430). He concluded that because the goal of forestry was not only to manage current growth but also to protect trees into the future, light burning proved to be "absolutely untenable when the establishment of new reproduction is desired." Even though "this fact is generally recognized by foresters," he added, "the advocates of light burning have refused to admit it" (Show 1915: 426).

Although Graves promoted the importance of understanding all aspects of controlling wildland fires, he initially opposed research into the benefits, if any, of light burning. Graves wrote in his 1912 annual report that some commercial interests had the resources and manpower to lightly burn their privately held timberlands, but the idea of burning national forested lands "would finally wipe out the forest altogether by putting a stop to reproduction." So he opposed it. "The doctrine of light burning as popularly understood in California is nothing less than the advocacy of forest destruction," Graves wrote, "and those who preach the doctrine have a large share of responsibility for fires which their influence has caused" (Graves 1913: 43). With the effects of the fires of 1910 still fresh in the minds of both professional foresters and the light burners alike, however, neither group was willing to surrender their position to the other.

Coert DuBois and Fire Research in California

In 1911, Coert DuBois became the head forester of District 5 in California. Like Franklin B. Hough before him, Coert DuBois sent a circular to all California forest supervisors requesting information from all over the State. In his query, sent out in March 1913, DuBois defined forestry as "the continued production of wood on the lands the people have set aside for that purpose" (DuBois 1913: 1). This perspective led him to a conclusion similar to that of Henry S. Graves: forestry's primary goal could never be achieved "until the area burned over annually is reduced to and kept at a negligible figure" (DuBois 1913: 1).

That said, foresters knew enough about fire protection overall, DuBois argued in his correspondence, that the time had come to reduce the subject to a science and "really find something out about it" (DuBois 1913: 1). According to DuBois, to control wildland fires, foresters should focus their research on four elements tied to prevention and suppression. These elements provide a good snapshot of wildland fire research and related concerns in the early part of the 20th century:

- First, foresters needed to better understand where and why fires started and who was responsible, so they could identify those who were careless with fire or who started them intentionally. DuBois also called for better social science research to identify effective public education programs and the essential principles needed in fire protection legislation.
- Second, foresters needed to know how to determine relative fire risk so that managers could better distribute resources for combating fire. They should identify what directly impacted protection costs and benefits, what determined the need in different areas, and the prospects and mechanisms for establishing cooperative protection with others outside the Forest Service (e.g., private landowners or State or local governments).
- Third, foresters needed to organize the necessary firefighters, money, and facilities to guarantee that a minimum amount of time elapsed between the start of a fire and the mobilization of forces organized to begin fighting it. DuBois called for a better understanding of fire detection, identifying the best forms of communication, including telephones and heliographs, and investigating the best methods and equipment used by fire patrols. He also wanted to know how to reduce fire hazards by constructing firelines and preparing campgrounds. Perhaps the most controversial of his suggestions was asking foresters to describe the theories and practices of light burning and the motives of its advocates. "How shall [light burning] be dealt with?" DuBois wanted to know.
- Finally, DuBois called for identifying the best methods for suppressing wildland fires, from organizing volunteer forces to estimating the number of people needed on a fireline. He even asked questions about the organization of camps, the most efficient methods for distribution of tools and equipment, and reasonable rates of pay for various firefighting support, from teamsters to cooks.

DuBois included a list of assignments, requiring all forest officers in the district to gather all the known facts about the subject and questions assigned to them. Doing so would not only bring together the best practices known to date but, in the process, it would identify what still needed to be known. DuBois informed his officers: "This work means big things. Those who contribute largely to it are going to be known in American forestry" (DuBois 1913: 16).

Based in part on the results of his inquiries, in May 1914 DuBois published *Systematic Fire Protection in the California Forests* as a guide for forest officers in District 5. Specifically marked "not for public distribution," the publication laid out what DuBois, his assistant district forester Roy Headley, and forest supervisors and rangers throughout the State had compiled to date on wildland fire suppression in California. Much like Henry S. Graves' earlier work, DuBois' book takes the form of a guidebook or manual, but the publication is as much an argument for why fire control was needed—particularly important in a State with a tradition of "light burning"—and provides a guided tour through the issues affecting fire protection and suppression at the time. It also describes fire-related research that was still needed (DuBois 1914).

In his guidebook, DuBois equated fire protection to the practice of forestry generally. The goal of fire protection, he wrote, was "to secure from each acre in the forest the maximum of all forest products which its soil is capable of producing" (DuBois 1914: 6). Because complete fire prevention and control would never be achievable, DuBois sought instead to "state how far short of [complete control] will be considered a practical accomplishment of the end desired" (DuBois 1914: 6). Before this goal could be reached, however, DuBois believed foresters needed to define the problem of fire control and then solve it through research (DuBois 1914).

Research was especially needed to quantify fire danger (e.g., inflammability, season, risk, controllability, liability, and safety), and determine the rate at which uncontrolled wildfires burn. Under DuBois' early direction, researchers set out to determine the rate of spread of wildland fires and to create a method for quantifying the relationship between fire danger and weather. He believed that until researchers addressed this challenge, fire danger rating was based primarily on observation, anecdotal evidence, and, in practice, anyone's best guess. To advance research in this area, DuBois created a fire report form to secure the data needed to answer a host of questions, from how fires start in the first place to the relationship between fire danger and protection costs (DuBois 1914).

In his 1914 publication, DuBois also included a chapter on effective "educational work," and investigations that needed to be done. "The object of a study of educational work in connection with fire protection," he wrote, "is to determine who must be reached, and by what message, and where and how that message must be presented" (DuBois 1914: 23). DuBois believed more educational research could also determine what messages worked best, including "the mechanics of the preparation and presentation of those notices to determine the most efficient" (DuBois 1914: 23).

Forest Investigations and the Branch of Research

District 5 was not the only region in the Forest Service conducting on-the-ground research during this period. Chief Forester Henry S. Graves wrote in his annual report for 1912 that research within the Forest Service had become both broad and varied, ranging from basic silviculture to forest products and the effects of fire. With only $300,000 of a $5.5 million budget dedicated to investigations and publications, Graves believed that better coordination was needed to ensure that the new knowledge was used, that research efforts were not duplicated, and that the most important research questions were addressed first and in the right way. To this end, Graves established a central committee on investigative work that included a representative from each of the three branches—silviculture, grazing, and forest products—to advise him on research and to review all scientific projects with reference to their practical purpose, their relative need and cost, their contributions, and their lack of duplication (Graves 1912b).

Graves reported in 1912 that the new committee helped make Forest Service research more efficient and economical, but the next year he went even further, creating a new Office of Forest Investigations within the Branch of Silviculture, headed by Raphael Zon and S.T. Dana. The two men assumed responsibility for the agency's library and computation functions, and also all silviculture-related research, including fire. Assistant Forester W.B. Greeley announced this new office, explaining that its purpose was to bring all researchers closer together and to make "the entire force engaged upon investigative work more directly available" to carry out the investigations of the branch (Greeley 1913: 2).

Graves appears to have still been dissatisfied, however, because he sought additional advice on how to continue to improve research within the agency. Zon and Dana weighed in, supporting Graves' idea of creating a new branch of research, but not if its primary goal was simply to manage disparate projects from Washington. Rather, a branch of research should be formed with unity of purpose, they advised, with all Forest Service research contributing to an overarching goal. Zon and Dana recommended that this purpose should be to develop (1) a better understanding of the forest, and (2) a greater and more efficient utilization of its products. The two predicted that a unity of purpose, coupled with protection of researchers from distractions from this purpose, would lead to more productive outcomes agencywide (Zon and Dana 1915).

Given what he believed to be the importance of research, on June 1, 1915, Graves consolidated all Forest Service research into a new Branch of Research, under the direction of Assistant Forester Earle H. Clapp. Graves initiated the change, in part, to protect researchers from the demands of day-to-day management; he also wanted to give investigative work and personnel the fullest possible recognition, equal to administration. This reorganization strengthened

research as a distinct division within the agency and brought together, under one executive head, the various lines of research or investigative work conducted by the Forest Service. In the long run, it also gave researchers greater objectivity and independence. Research swept up into this new administrative structure included silvicultural investigations, the Forest Products Laboratory in Madison, WI (established in 1910), industrial investigations, and a short-term lumber industry study. It also included fire protection investigations (Graves 1915).

Years later, in a letter cited by historian Harold K. Steen, Clapp wrote that one real reason Graves wanted research in its own branch, separate from administration, was because researchers at the time had a very uncertain status in the Forest Service. Before 1915, it was a general practice to transfer unsuccessful administrators to research. According to Clapp, this policy of dumping unwanted people into research had so discredited the program that qualified individuals were reluctant to enter the field. Graves' new organization would hopefully attract the highest quality researchers who would receive the recognition they deserved (Steen 1976; 2004). As predicted by Coert DuBois, one area in particular where Forest Service researchers could pursue national recognition was in fire-related investigations.

National Fire Research

In 1916, the new Branch of Research reported on four fire-related research programs. The first was a short, year-long project to develop a uniform and practical method for rating the risk of fire; its purpose was to guide distribution of funds for a scientific fire protection plan for the entire area covered by national forests. The other three fire research programs were investigations of longer, indeterminate duration:

- The first long-term study focused on understanding the relationship between weather conditions, fire hazard, and protection. Researchers were charged with dividing national forest areas into climatic units to identify the best means of predicting fire danger, and compiling adequate meteorological data in all districts for use in fire predictions. Within each area, researchers attempted to determine dangerous weather conditions and better methods of predicting such conditions. They also sought to identify the relation of local disturbances, such as valley winds, to general climatic conditions, and attempted to describe the effect of weather and other conditions such as topography and cover on the rate of spread of fires. This work built on research initiated in District 5, but was now to be conducted in Districts 1 through 6 in cooperation with the U.S. Weather Bureau.

- The second long-term investigation specifically focused on methods of fire prevention, detection, and control. District 5 researchers investigated the use of light burning as a fire prevention measure; several districts researched the

▲ Helen Dowe, the lookout for the 1919 season at Devil's Head fire lookout on the Pike National Forest in Colorado. Photo courtesy of the Forest History Society, Durham, NC.

effective use of lookouts for improving fire detection; and District 2 (Black Hills, SD) investigated special equipment for firefighting, including the development and testing of chemical fire extinguishers.

- The third long-term investigation sought to develop uniform principles for estimating the effects of fire and to study the relative damage done by fire in different types of forests under varying conditions, including a study of forest recovery. Based on a study of fire effects on immature timber that began in 1911 in California, this project studied the recovery of burned trees in District 6 (Oregon) on the Deschutes National Forest.

The Forest Service had put in place a new branch dedicated to research new methods to ensure the long-term sustainability of the Nation's forests and rangelands. To this end, the three long-term fire-related studies were meant to minimize or eliminate all wildland fire. This early research into fire prevention, detection, and suppression, fire behavior and fire danger, and the effects of wildland fire—the focus of the next three chapters—laid the foundation for early fire research and, indeed, continued well into the 21st century.

Fire Prevention, Detection, and Control

You have verbally asked me to outline ... the viewpoint of Southern Pacific Company in publishing the pamphlet prepared by Captain Joseph A. Kitts and in advocating the methods therein set forth.... Captain Kitts advocates winter and early spring burning with the idea in mind that such practice will render unnecessary a large portion of the time, energy and money now being expended in preventing dry season fires. The Forest Service depends wholly upon discovering fires and fighting them during the dry season.

—B.A. McAllaster, Southern Pacific Company, 1919

Chapter 2

The 10th anniversary of the U.S. Department of Agriculture, Forest Service in 1915 provided a timely milestone to look back on the relatively new agency's successes and challenges and to formulate future plans. If the overarching goal of the Forest Service in the early 20th century—and the practice of American forestry generally—was to ensure a sustainable yield of timber for economic and industrial development, then how well the agency protected the forests from fire could serve as a major marker of its success.

Secretary of Agriculture D.F. Houston viewed the agency's progress on fire protection in just that way, writing in his 1915 annual report that the Forest Service's primary responsibility, listed first—even over timber production—was fire protection. It was presumed that you could not have one without the other. To that end, Houston reported that the 10-year-old agency had made great gains. It had put in place an impressive infrastructure, including extensive improvements to

roads, trails, and firelines. It had increased construction of lookout stations and housing for firefighters, and developed state-of-the-art communications systems. All of these actions were designed to better detect and ultimately suppress wildland fires (Houston 1916).

Successfully protecting the Nation's forested lands from fire came at a significant price, however. In his own report from 1915, Chief Forester Henry S. Graves described an unusually hot and dry fire season, exceeding even that of 1910. Rapid response on the part of the Forest Service had helped control the size of fires, he reported, demonstrating that with "efficient organization, preparedness, and adequate funds," the Forest Service could minimize the impact of wildfires and save money (Graves 1916: 167). Rapid and comprehensive response to fires also left Graves scrambling for funds, however, forcing him to both transfer money supporting other programs and appeal to Congress to make up a funding deficit.

Clearly, support of firefighting operations would continue to pose a significant challenge, not only technically but also financially. In addition to securing additional funding, the Forest Service also needed to develop improved methods for detecting and suppressing wildland fires in a timely fashion. Moreover, the agency needed to find ways to prevent fires in the first place, particularly through the use of public education, because the percentage of fires attributable to human agency had increased more than 10 percent in just 1 year (i.e., from 46 percent in 1913 to 57 percent in 1914; Graves 1916).

Regarding the goal of fire prevention, Graves believed that private timberlands owners should be relatively easy to persuade to work with the Forest Service, even though some still clung to the idea of light burning in places such as California. The Nation's forests, however, faced a new threat reflected in the growing number of human-caused fires: a new generation of adult males who worked, hunted, or vacationed in the Nation's forests, and who had responded to the first mass marketing of machine-produced cigarettes in 1913 (Burns and others 1997). The chief forester wrote that "the insistent problem is how to make the man careful who knows the danger but throws his match away thoughtlessly" (Graves 1916: 167). Finding new methods for educating a growing number of smokers and others working and recreating in the Nation's forests presented a challenge almost as formidable as investigating ways to suppress fires after they started.

Fire Prevention

The fires of 1915 had Chief Forester Henry S. Graves seeking additional funding and calling for "improved methods of detecting and putting out fires" (Graves 1916: 167). The fire seasons that followed proved to be an even greater challenge. Even before the end of June in 1919, Graves reported that the worst fire season the Northwest had faced had begun, with costs far exceeding the annual

appropriation for that purpose. Foreshadowing the challenges that would face the Forest Service a century later, the Forest Service had to ask for an additional $2,950,000 to make up the difference (Graves 1920).

In part because of the heavy financial challenges posed by fire, Graves called for a new national forest policy that would, in part, take a proactive approach to reduce the flammability of the forests. His policy statement listed a variety of possible prescriptions for preventing fires, from lopping the tops of trees and burning brush in piles, to clearing firelines and felling dead snags. The most controversial of Graves' suggestions was employing "carefully controlled burning … as is practical in certain open pine forests." He added, however, "Uncontrolled light burning should be prohibited everywhere" (Graves 1919: 6).

Graves was suggesting a fire prevention idea that, in 1919, was again gaining both traction and notoriety after another two big fire seasons in the American West: "light burning," as they called it in California or "burning the woods" as it was known in the American South. Proponents of this technique, used by private landowners in both regions for decades if not centuries, argued that deliberately burning the forests in the winter and early spring protected them from catastrophic fires in the summer. For a new generation of American-trained foresters, people who worked to protect the Nation's forests from fire, the idea contradicted everything they had been taught. Indeed, they believed that fire of any kind in the forests prevented the practice of scientific forestry that they had spent years studying and perfecting. Simply put, it made no sense.

▲ Firefighters on the Timberwolf Fire on the Rainier National Forest in Washington, 1919. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

Light Burning

In 1919, civil engineer and landowner Joseph A. Kitts published articles on how to prevent destructive forest fires in California. In a speech he gave that same year to the American Society of Engineers, also published as a pamphlet by the Southern Pacific Company, he argued, just as the Forest Service did, that fires posed the greatest single risk to forests. Finding a solution to this problem "forms the foundation to sound forestry," he said (Kitts 1919: 3).

Kitts made a simple argument. When European settlers moved into the American West, particularly into California, they found some of the oldest living trees in "forests clean and open." These new pioneers, as Kitts referred to them, observed that American Indians living in the area "fired the forests with some regularity" (Kitts 1919: 9). This observation led Kitts to what he believed to be an obvious conclusion: Thousand-year-old trees survived in an area otherwise prone to wildfire because of the Native use of regular fires that eliminated the dead trees, branches, and grasses on the forest floor, saving the forests from larger, more catastrophic fires. He noted that because Native people depended on these forests for their livelihoods, over generations American Indians had become "the most practical of foresters" (Kitts 1919: 9-10). He maintained that private landowners and the Forest Service alike would do well to learn from a long history of Native land use.

▼ Joseph A Kitts' land (and possibly Kitts himself), which furnished the evidence for his publications on light burning. Photo courtesy of the Marian Koshland Bioscience and Natural Resources Library, University of California, Berkeley.

In 1919, the *Journal of Forestry* received a letter from B.A. McAllaster, the Southern Pacific Company's land commissioner, denouncing the Forest Service's firefighting policy. McAllaster insisted that it was anything but a "PREVENTION [sic] policy," accusing the agency of letting nature take its course in the woods, and then sending in Forest Service personnel to suppress the fires after they had been started. In essence, McAllaster seemed to suggest that the agency's policy had been designed to highlight the firefighting prowess of the Forest Service, as opposed to protecting the Nation's forested lands from catastrophic fire. If such a policy continued, the commissioner warned, "there will come a day when a forest fire will sweep the entire coast from Mexico to Canada and leave little or no vestige of our existing forests" (McAllaster 1919a: 2).

Like Kitts, McAllaster noted that the forests of the Pacific coast had thrived for centuries while being exposed to regular fires, "with perhaps some assistance from the Indians," who used fire to flush game and improve habitat. Thousand-year-old forests growing all along the west coast provided living proof, he argued, that fires "did not injure the forests, otherwise, they would not have existed when the Pacific Coast was discovered" (McAllaster 1919a: 1). For that reason, McAllaster proposed that the Forest Service adapt the light-burning approach championed by Joseph A. Kitts in 1919.

Forest Service leaders showed little interest, at least initially, in conducting any authentic research to test the concept of using light burning as a way to prevent or minimize the risks of fire. Their "research" had only one objective in mind: to prove light burning was "little short of disastrous" and, according to S.B. Show, to get rid of the idea once and for all (Show 1915: 430). Moreover, advice from Native Americans, "practical foresters," and their advocates, such as the Southern Pacific Company, did not sit well with professional foresters, who were trained to bring an educated, scientific efficiency to their management of public lands. Deliberately setting any forest ablaze, when it was the Forest Service's first and foremost duty to prevent and suppress all fires, was in direct opposition to everything they had been taught about forestry.

When District 5 Forester Paul Redington corresponded privately with McAllaster in 1920, correspondence he forwarded to Henry S. Graves, he made it clear that if the Southern Pacific Company or any other private landowners wanted to conduct light burning experiments on their own land, that was up to them. "But," Redington wrote, "we cannot approve or be associated with such experiments or sanction the use of the National Forest areas for this purpose" (Redington, in McAllaster 1920: 1). That should have been, in theory, the end of the argument, but McAllaster was still not convinced. He and other proponents of light burning were not going away.

This was not the first time the Forest Service had attempted to squelch an argument for light burning. In 1915, for example, the Forest Service had stationed S.B. Show at the Feather River Experiment Station in California, where his assignment, according to Show, was "to get going on the fire studies" (Show n.d. [ca. 1955]: 80). That fall, Show toured a 3,000-acre holding of the Red River Lumber Company in northern California, which had been lightly burned in 1910 and re-burned in limited areas in 1915. Contrary to what he no doubt expected, Show found the timberland relatively undamaged, but it had cost the company approximately $.50 per acre to prepare the land for burning. Just as Redington would later argue with McAllaster, this was an amount a private company could elect to spend, according to Show, but an expense that seemed unreasonable for a public agency, given the size of the national forests. Moreover, Show continued, the burning resulted in increased litter and the sprouting of shrubs, making the effect of light burning probably last little more

than 2 years in his estimation. He therefore concluded that "there is little doubt that the same degree of protection could have been secured for less money" (Show 1916: 18). Many private landowners still were not convinced, however, and they probably would not be until the Forest Service produced conclusive research demonstrating the error of their light-burning ways.

Many in the Forest Service, including Graves, were reluctant to conduct any systematic research on the preventative value of light burning. Yet, with Kitts and McAllaster advocating light burning in public forums, in 1919, S.B. Show conducted another study in the Snake Lake area of northern California with his colleague (and brother-in-law) E.I. Kotok. The stakes were so high for disproving the value of light burning that the two men actually sabotaged their own "research." For example, while light burners at the time often raked and cleared areas around valuable trees before burning to ensure the trees' survival, Show and Kotok placed pine limbs alongside a few large fire-scarred pines to ensure that they would burn and demonstrate the danger of the technique to marketable timber. Show later boasted that his "research" achieved "the gratifying result that [the trees] burned down and became damage statistics" (Show n.d. [ca. 1955]: 96–97).

Based on their convictions if not their data, in 1925 Show and Kotok wrote that "light burning is a costly and dangerous practice, involving the sacrifice of part of the values which it attempts to preserve and with at best temporary reduction of fire danger…. 'Light burning' fires act on the forest in the same destructive ways as summer fires, differing only in degree." As far as Show and Kotok were concerned, any attempt to use fire to fight fire in California was going nowhere, and Show concluded that "nothing less than fire exclusion will promote real progress toward a fully productive forest property" (Show and Kotok 1925: 18).

Coert DuBois had predicted that successful fire research would bring investigators a level of prominence, and Show did indeed become better known within the Forest Service. He often stood up in meetings to oppose others who supported or at least showed some interest in the use of light burning as a wildfire prevention method. Show applied his antiburning beliefs to all of his work, building his research career in part on extinguishing any support for the idea, and he held in contempt those within the Forest Service who entertained the idea of allowing even private landowners to burn their own land. The worst offender, according to Show, was Roy Headley, who served as the acting forester in District 5 while DuBois was away during World War I (WWI). Show referred to Headley's openness to allowing some burning as his "cursed permitted burning policy" and his "sinful policies of evil memory" (Show n.d. [ca. 1955]: 84).

In 1919, at the end of WWI, Show argued against light burning at a meeting of forest supervisors. Things "got hot," according to Show, "with Headley challenging sneeringly, the Supervisors, who hated his guts, on my side, me

standing pat, and DuBois [just back from the war] getting the idea, to his hatred and disillusionment." As a result of that particular confrontation, Show recalled, "Headley got kicked upstairs and my official life got saved. Also I got some loyal friends among the Supervisors and DuBois, for the first time, acted as though I existed." At the same time, however, he had also earned "an unswerving enemy" in Headley (Show n.d. [ca. 1955]: 94).

Back from WWI and on duty again with the Forest Service, DuBois "promptly restored the earlier policy of hitting fires fast and hard and holding them to minimum size," according to Show, and reinvested in building the lookout and guard services. Later, when Roy Headley commented negatively on one of Show and Kotok's fire manuscripts, Chief Forester William B. Greeley responded in a note to Headley: "Face the facts." Show would later boast that he was "recognized by all highest as having something to say," particularly when it came to keeping all fire out of California's forests (Show n.d. [ca. 1955]: 106).

That is not to suggest that all Forest Service personnel outright opposed light burning or refused to see its fire prevention possibilities. In addition to Roy Headley, some foresters were willing to, at minimum, give advice to those seeking to "burn the woods," a traditional practice in the American South. For example, replying to a letter from a landowner in Georgia in 1918, J.W. Stokes, acting chief of forest investigations, wrote that although the Forest Service did not recommend the practice, private landowners in certain regions where fires were not controlled might find it "advisable" to burn their land "lightly at the right season [to] prevent more serious damage by fire late in the season." He cautioned that the "burning must be done in the winter or early spring when the litter and vegetation are just dry enough to burn" and the landowner must take care that the fire never escaped beyond the limits of his own holdings (Stokes 1918: 1).

Overall, however, with only a handful of exceptions, the Forest Service continued to discourage the use of any fire in the woods, and apparently did not believe that any research had the potential to change the agency's position. This one-size-fits-all blanket policy regarding the use of fire as a preventative measure changed little by little over time, often in agencies outside the Forest Service. In the 1930s, for example, Harold Weaver, the forest supervisor on the Colville Indian Reservation in Washington State, began to experiment with fire to both reduce fire danger and thin saplings in ponderosa pine forests (Arno and Allison-Bunnell 2002). In 1943, Weaver argued in the *Journal of Forestry* that 30 to 40 years of fire suppression had resulted in unintended changes to ecological conditions and threatened "sound management and protection of ponderosa pine forests." As a result, he believed that "too little thought and research" had been applied to better understanding the positive ecological effects of regular exposure to fire, which he considered "a job worthy of the best minds in forest research" (Weaver 1943: 7). Interestingly, the Indian Service (now the Bureau of

Indian Affairs) asked that a footnote be added to qualify Weaver's recommendations, noting that they represented "the author's views only" and not the views of the Indian Service for which Weaver worked (van Wagtendonk 2014: 2).

The *Journal of Forestry* also included a response from Arthur A. Brown, who would later become head of fire research in the Forest Service. Brown argued that "the forester must substitute harvesting by logging for nature's method of harvesting by bark beetles and fire…. The first urgent step was to control fire and insects." Brown, however, also recommended more research (Brown 1943: 15). According to fire ecologist Stephen F. Arno, in the 1940s and 1950s, Weaver convinced some Forest Service employees to join him in researching the benefits of prescribed fire, but it would take decades before the idea of fighting fire with fire would gain any legitimacy within the agency (Arno and Allison-Bunnell 2002).

Education and Outreach

Because human actions started about one-half of the fires on public lands in 1919, research into more effective education and outreach provided an opportunity to investigate a different approach to improving fire prevention. One administrative outcome was the creation of a Branch of Public Relations in 1920 to test effective public education campaigns and get the word out about how to safely

work and recreate on the Nation's forests. Foresters experimented with different kinds of signs and their placement, and tested instructions on how to safely extinguish a match and safely build and extinguish a campfire. Educational programs were also introduced in schools.

One program proved particularly successful according to Henry S. Graves' successor, Chief Forester William B. Greeley. In many Western States, the Forest Service tested the idea of a forest protection and fire prevention week to educate the public, including school children, about the damage and losses caused by forest fires. Approximately 21,000 news articles and letters were sent out, and 200 motion picture stills were projected at theatres throughout California (California State Board of Forestry 1921). Although the Forest Service did not yet have its icon in Smokey Bear, who made his first appearance in 1944, the agency's message in the early 20th century was clear: "Only you can prevent forest fires."

It would take more than the education of the general public, however, to minimize the risk of fires. During the Priest River meeting in 1941, greater research in fire prevention was recommended. As Kenneth B. Davis noted, for fire prevention activities to be effective, "the underlying reasons why and how people start fires must be known, and convincing counter reasons must be advanced and put in such terms and form that they will reach and influence the right people" (Davis 1942: 46, 84). In a clear call for more social science research to enhance the research

▼ Promoting forest fire prevention in Washington, DC, April 1924. Photo courtesy of the Library of Congress.

already underway, Davis pointed to recent advances in applied psychology and in methods of sampling and studying public opinion that seemed to offer potential avenues for research, and that might result in new educational tools to increase the effectiveness of fire-prevention work. For fire protection to be most successful, Davis seemed to imply, the Forest Service needed to investigate new methods to involve the people of the entire Nation as full partners.

Fire Detection

In addition to investigating diverse methods to improve wildfire prevention, the Forest Service aimed to improve fire detection as part of its overall fire control strategy. Ground and aerial patrols, fire lookouts, and even rural mail carriers were enlisted to detect and report wildland fires, but many more areas of fire detection could potentially contribute to the agency's fire suppression goals.

▲ Signal tower used as part of the 1911 Arkansas test of methods for preventing and controlling forest fires. Photo courtesy of the Forest History Society, Durham, NC.

As early as 1910, for example, the Arkansas National Forest constructed five lookout and signal towers equipped with a portable rangefinding device for identifying the location of fires, and telephones and heliographs for communicating that information to firefighting teams. To test the effectiveness of these towers in detecting and reporting fires, researchers kept records of the number of fires reported from January to July 1911 in areas protected by the five signal stations and those that were not; both areas had access to the same horse-pack and shoulder-pack water bags for fighting fires. In the north, where no signal stations had been constructed, 16 fires were reported, with 109,514 acres burned over. In the southern part of the forest that included the signal stations, 20 fires were reported, but only 14,267 acres burned. The net savings for that 1 year were estimated to be $49,000. "When we consider that this saving represents that from only one-half of a single one of the 159 National Forests in the United States," the Arkansas forest examiner noted in his report of the study, "the magnitude of the possible results may be appreciated" (Adams 1912: 23). The successful outcome of this small pilot project, along with similar demonstrations at the time, resulted in additional research into improved communication and fire detection, including visibility studies.

Visibility Studies

The individuals manning lookout stations factored in the effectiveness in detecting and, thus, suppressing fires in a timely fashion. In 1920, researchers in the District 6 office in Portland, OR, revisited a project that had been set aside during WWI. This research sought to determine the distance at which small fires can be seen, and how visibility is affected by the size of the fire and atmospheric and other conditions such as the relative visibility from high-mountain (i.e., 10,000 feet or more) and ordinary (i.e., 5,000 to 7,000 feet) lookouts (National Research Council 1920).

In the early 1930s, the Portland researchers expanded their studies to test how well individual fire guards could identify small fires at a distance. Researcher Richard McArdle, who would go on to become Chief of the Forest Service, and his field assistant George Byram sought a way to measure air transparency with a haze meter and to test the eyesight of fire lookouts using a relevant and consistent system. Because smoke is usually the first sign of fire identified by a lookout, McArdle's and Byram's studies set out to answer two questions: (1) How far could a smoke column be seen through a hazy atmosphere? (2) How could that distance be measured to be useful in fire control? Their early research resulted in two new instruments, the Byram haze-meter for use in mountainous areas, and the plains haze-meter for use in flat or rolling terrain (Byram and Jemison 1948).

At the same time, McArdle developed the "McArdle Lookout Eye Test," which used a uniform method to test the eyesight of fire lookouts. After initial testing in the Pacific Northwest Region, the McArdle kit was distributed to all Forest Service districts and to Hot Springs National Park, not as a qualifying test for lookouts initially, but rather to test the effectiveness of the kit and gather agencywide data on the eyesight of fire lookouts. McArdle also conducted experiments to determine the best type of goggles or sunglasses for lookouts to use. He reported that smoked high-quality optical glass worked best, using easily adjustable pear-shaped (i.e., "sport") lenses that protected the eyes from the sides and also from the front (McArdle 1934).

Aerial Patrols

The Forest Service had relied on fire lookouts perched on the tops of mountains and even trees since the early 20th century. At the end of WWI, with military equipment and personnel potentially available to assist with firefighting, California worked with the U.S. Army Air Service to initiate a series of aerial patrols to improve early fire detection and reporting. In the spring of 1919, pilots conducted several test runs but found that traditional Forest Service colors painted on lookout stations made them difficult to spot from the air. Because pilots needed to use the stations to identify their position in relation to a fire, the Forest Service painted all lookout station roofs in the test area red and white. With

these new guideposts or markers in place, aerial fire patrols started in earnest that summer. By September 1919, the U.S. Army Air Service had discovered 118 fires, but with communication difficult from the air, they reported only 23 fires earlier than on-the-ground lookouts reported them (Arnold 1920, Godfrey 2005). These results suggested that the use of air patrols might not improve on results from more traditional lookouts that had been in use in California for more than a decade; they also highlighted the need for more research into improved fire communication.

Firefighting Communication

Even when fires were located by air or well-placed lookouts, communication of this information to firefighters posed a significant barrier. Again, a military response was tested. During WWI, both the U.S. Army and Navy had employed carrier pigeons for communication in difficult or dangerous conditions. After the war, the Army still held birds in lofts in Eugene, OR, at Camp Lewis in Washington State, and at both March and Mather Fields in California. With the war over and little rationale for continuing the pigeon program, the Army expressed a willingness to sell the birds to the Forest Service for $.50 each, considerably less than the commercial rate of $2.00 per bird. This offer made testing them economically feasible. With limited access to more expensive communication methods, many in the Forest Service came to see aerial patrols and the use of carrier pigeons as part of a fire detection and communication package.

Indeed, after a successful experiment using pigeons on Oregon's Deschutes National Forest in 1919, District 6 Forester George Cecil in Portland, OR, submitted a budget to the Forest Service's Washington Office for a national program of aerial patrols. His budget included the funding needed for pilots, equipment, and other air-patrol-related expenses, but also for the costs associated with constructing pigeon lofts, purchasing pigeon food, and paying pigeon tenders. Cecil's request for approximately $60,000 to fund the year's aerial patrol and communications program does not appear to have been acted on; however, experimental use of pigeons for fire communication continued in at least two States: Idaho and Oregon.

Even Theodore Roosevelt, Jr., then acting Secretary of the Navy, got into the act, outlining a series of recommendations on how to use pigeons effectively in western forests based on the U.S. Navy's experiences with its well-organized "Pigeon Service." With budget cuts restricting the Navy's ability to assign aviators or planes to assist with forest fire patrols in 1922, Roosevelt suggested the use of pigeons instead. "The Pigeon Service could not, of course, replace the reconnaissance feature which the airplanes perform," Roosevelt wrote to the Secretary of Agriculture, "but it could replace the communication means" (Roosevelt 1921: 1).

▶ Forest ranger holding a pigeon used for sending fire messages, Oregon, 1920. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

By 1922, the Forest Service's experimental use of pigeons appears to have lost its attraction, probably in part because of the greater availability of telephones and radios requiring much less day-to-day maintenance and care. Even the birds' greatest champion, District Forester George Cecil, was not interested in receiving any more pigeons, even though they were offered to him free of cost by the Bureau of Animal Husbandry. Cecil wrote that the "benefits derived in this District from experimental use of Service-owned carrier pigeons are much less than the cost of maintaining them" (Cecil 1922: 1). So ended one of the more interesting experiments in fire communications.

Fire Control

Even before WWI, the Forest Service had looked to the military for inspiration when it came to fighting fires. In 1911, for example, when Coert DuBois was still the associate district forester in District 5, he characterized the advance of a forest fire to that of a hostile force, suggesting that the Forest Service needed to employ the methods of war to combat it. Indeed, in California, a "forest fire game," inspired by Army war games, was introduced in some ranger meetings to sharpen the skills of rangers in quickly determining the location of and best methods for suppressing a fire with just a mark on a map (DuBois 1911).

To be most effective, DuBois argued, the Forest Service should "take one very large leaf out of the Army's book—the title of which is 'Preparation'" (DuBois 1911: 2). Each national forest should develop a fire protection plan, he argued, but for these plans to be effective, DuBois called for data on what was known about effective fire control, and then for additional research into what information and insights were still needed (DuBois 1913). By 1916, the Forest Service had made an agencywide commitment to developing better "methods for scientific fire control" (USDA Forest Service 1916b: 1). These included investigations into improved fire suppression methods and retardants.

▲ Using a radio for communication on a fire line in Washington State, 1937. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

Retardants

As early as 1911, the Forest Service began experimenting with ways to enhance the effectiveness of using chemicals for forest fire suppression. After WWI, the Forest Service became intrigued not only by the potential of aerial fire patrols but also with the promise of aerial firefighting, even to the point of dropping "bombs" to fight fires. This idea sent researchers looking for ways to develop more effective fire retardants, to be delivered both on the ground and by air.

In 1929, for example, Leonard Barrett at the Central States Forest Experiment Station conducted a series of experiments in Ohio to test the fire-extinguishing properties of the water-soluble salts of certain alkali metals. In the experiments, Barrett found that solutions of potassium carbonate were more efficient than water alone for extinguishing fires in dense grass and weed cover, and had a more lasting effect without "flash back" as sometimes experienced when water alone was used. With additional methods available for delivering retardants (e.g., tank trucks and backpack pumps), he wrote that it was "a logical step forward" to use retardant chemicals to improve the suppression efficiency of water alone (Barrett 1931: 214). The same year that Barrett investigated the use of retardants, however, Paul Stickel at the Northeastern Forest Experiment Station found the value of calcium chloride as "practically nil on actual fires" (Stickel 1933b: 542). Then, in 1932 and 1933, the Michigan Forest Fire Experiment Station conducted approximately 40 tests of the effectiveness of calcium chloride as a fire retardant, finding that it proved particularly useful for indirect attacks on surface fires (e.g., when a fire is too hot to attack directly; Mitchell 1935). A need clearly existed for a definitive study to set the record straight on the effectiveness of using chemicals for fighting fires.

One advantage of holding national research meetings at the Forest Products Laboratory in Madison, WI, was that fire researchers had an opportunity to interact with lab scientists who had the expertise and laboratory facilities needed to help resolve technical questions regarding fire control. The retardant question emerged as one that scientists at the Forest Products Laboratory might help address. According to senior wood technologist T.R. Truax, the complex nature of forest fires posed the greatest challenge to developing an effective retardant. Unlike home fires, where chemical fire extinguishers were often effective, Truax noted, forest fires occur in the open with an abundant supply of oxygen and often under substantial winds; the fuels are almost entirely woody plants and grasses of various sizes; and the fires often burn in inaccessible areas, limiting suppression operations to hand tools and limiting the delivery method to manually carried backpacks. Even though chemists "familiar with combustion and its control" had little confidence that a chemical retardant would be more effective than water, Truax agreed to try (Truax 1939: 1).

Starting in 1936, Truax initiated the first continuous and comprehensive testing of chemical fire retardants in the Forest Service. For 3 years, he and his colleagues at the Forest Products Laboratory tested a variety of retardants in the laboratory and in the field. Truax reported mixed results. The researchers found that, although some chemicals were less effective than water, the extinguishing capacity of water could be increased by adding certain chemicals (e.g., monoammonium phosphate), particularly when used to fight fires burning in windy conditions. Chemical retardants also showed promise when water was scarce or difficult to get to the fire and/or if used during the initial stages of fighting a fire. Truax's research also suggested, however, that retardants appeared to have little impact on large, ongoing fires.

After 3 years of study, Truax concluded that where water was abundant and could be easily accessed and delivered, chemical retardants were not particularly useful. He wrote that, although additional research might yield some valuable results, "miraculous results with chemicals are not to be expected, nor are chemicals equally effective under all forest fire conditions." For the Forest Service to take advantage of those chemicals that could improve firefighting capabilities, the agency would also need to "develop or adapt apparatus and methods for their application" (Truax 1939: 12).

Quick Action Strategy

Since 1905, when the first "Use Book" declared that the best time to fight a fire is at the beginning before it had time to spread, the Forest Service had built its fire control programs around early detection and suppression. This belief was reinforced in the early 1930s when wildfires burned through 220,000 acres on the Los Padres National Forest in California in 1932 (the Matilija Fire), 240,000 acres of Oregon's Tillamook Forest in 1933, and 250,000 acres in Idaho in

1934 (the Pete King-McLendon Butte Fire). When fires such as those in the early 1930s did burn out of control, the reasoning tended to be that they could have been prevented if not for a "sluggish" response.

To ensure that all firefighting capabilities were focused on a fire in time, Ferdinand A. Silcox, Chief of the Forest Service, implemented a new "quick-action strategy" in 1935. This new policy required that all fires were to be controlled by 10 a.m. of the day following discovery, and required "fast, energetic, and thorough suppression of all fires in all locations." If quick response and immediate control were not possible, then "the policy [called] for prompt calculation of the problems of the existing situation and probabilities of spread, and organizing to control every such fire within the first work period" (Headley 1943: 8). With the pressure on to suppress fires within a day of their discovery, researchers and administrators alike faced the challenge of finding new methods to get firefighters to the site of a fire on time.

The Parachute Project

Although the idea of parachutes dates back at least to the time of Leonardo da Vinci (ca. 1495), parachutes were not widely used until the introduction of manned observation and reconnaissance balloons or blimps, particularly during WWI (although not in fighter jets; Barker 1990). After the war, many talked about the possibility of using parachute jumpers to land in inaccessible mountainous areas to fight fires. Early tests were conducted in the Intermountain Region (Utah) in 1934, but the idea was dismissed as too risky (USDA Forest Service 1980). In the summer of 1939, the Pacific Northwest Region revisited the idea, corresponding with the military and with parachute manufacturers to obtain their assistance in testing the idea. The Eagle Parachute Company from Pennsylvania came to the Chelan National Forest in Washington to demonstrate its equipment and supervise initial tests of preflight preparations and walk-throughs of how to handle tree landings. This early demonstration project revealed that, for smokejumpers to be successful, protective clothing and maneuverable parachutes with a low rate of descent would be needed. If those conditions could be met, the idea appeared to be promising.

With funding from the Chief Forester, researchers then set out to determine the feasibility of landing firefighters from airplanes; to develop and test protective clothing; and to investigate communication systems, methods for reaching the ground after being lodged in the trees, and retrieving parachutes, personnel, and equipment. Fifty-eight jumps were conducted in Washington in different terrain, including one in which the jumper steered into a 115-foot Douglas-fir. King and Davies reported the following:

> The canopy caught on the side of the tree and in the limbs. The chute and its shroud lines hung like tentacles to a few limbs. The jumper came down unaided using his climbing rope. Several minutes were used posing for news reel photographers (King and Davies 1939: 27).

The researchers did not observe any "uncontrollable fear or hysteria" during any of the jumps. Indeed, as the jumper on the 58th test reported, he experienced "a surprisingly easy landing" (King and Davies 1939: 26).

Although the authors of the report did not outright call for the introduction of smokejumping as part of the Forest Service firefighting strategy, they did recommend an analysis of the favorable test results to determine under what conditions this method should be used. With the 1935 advent of the quick-action strategy to suppress all fires before 10 a.m. the morning after they were discovered, getting firefighters to the site using airplanes seemed a logical solution. In the summer of 1940, the Forest Service employed two small teams of smokejumpers in the Northern and Pacific Northwest Regions, thus moving research from field tests directly into operations within a matter of months. In 1941, the Parachute Project, as it was known, was centralized in Missoula, MT (USDA Forest Service 2008).

▲ As described in the original caption, "This parachutist fights timber fires for the U.S. Forest Service. Much of his equipment is similar to that used at the battlefronts, since he encounters many of the same perils." Photo courtesy of the Library of Congress.

With firefighters providing rapid response to wildfires in Western States, meeting the agency's 10 a.m. goal seemed not only possible but also almost probable. Dropping firefighters into remote areas to protect the Nation's forested lands, far from backup or support, however, created another problem: protecting the firefighters themselves from fire. The deaths of 12 smokejumpers and one fire guard at the Mann Gulch Fire in Montana in 1949 created even more urgency for the Forest Service to provide improved training and safety measures for these firefighters, and to improve research into fire danger rating and fire behavior so that firefighters could better understand the potential danger they were parachuting into. Some of this research could be conducted in the field and through analysis of past fires, but researchers pushed with greater urgency for improved research facilities, similar to those available for forest product research in Madison, WI.

Firefighting and Predictable Control

The Forest Service had come a long way in the early decades of the 20th century in achieving its goal of producing a sustainable yield of timber for the Nation's future. Although advocates of light burning periodically protested the Forest Service's lack of support for the technique, the agency appeared to be in better control of both public opinion and the Nation's lands overall. With a new Branch of Research focused on investigating sustainable management practices and more aggressive methods of fire prevention, detection, and control, the development and application of scientific forestry methods appeared to be within the agency's grasp.

As the economic and social pressures to control all fires increased nationwide, however, Forest Service researchers faced pressures of their own: to better predict and prepare in advance for fires, not only for effective fire suppression but also for the protection of those firefighters who put their lives on the line in front of a fire. With the costs of firefighting on the rise, the Forest Service believed it more important than ever for fire suppression efforts to be planned and budgeted for in order to bring more predictability to fire control.

▼ This staged photo of aerial fire control and the quick action strategy illustrates the Forest Service's firefighting techniques, including a helicopter laying hose, motor equipment and a pack horse for getting into backcountry, a bulldozer, and a smokejumper, on the Shasta-Trinity National Forest in California, 1955. Photo courtesy of the Forest History Society, Durham, NC.

Chapter 3

Fire Danger Rating and Fire Behavior

Protection of the National Forests from fire is one of the first and most important duties of the Forest Service.... There now exists a wide-spread feeling that much can be accomplished by devising accurate means of predicting when and where fires are most apt to occur and knowing how they will behave under different conditions of wind, exposure, ground cover, and brush disposal.

—Forest Service, Office of Forest Investigations, 1916

Early in the 20th century, with the fires of 1910 still fresh in their minds, land managers and firefighters alike wanted to be better prepared for what each new fire season might bring. To reach that level of preparedness, however, they needed to understand all the factors involved and be able to use a "uniform, scientific, and practical method for rating the fire hazard and liability" (USDA Forest Service 1916a: 49). As early as 1916, the agency proposed to develop and apply such a method not only to increase the effectiveness of fire suppression but also to ensure a more equitable and proactive allocation of fire protection funding (USDA Forest Service 1916a).

To make this and other wildfire research goals a reality, in 1916, the new Branch of Research called on all U.S. Department of Agriculture, Forest Service experiment stations not already doing so to include fire-related research in their work plans (Hardy 1983). The Forest Service also organized the first national meeting of agency researchers, to be held in Washington, DC, in 1917, in part to coordinate fire research activities.

In preparation for the meeting, a small committee put together a working plan in late 1916 to study the relationships between weather, fire hazard, and fire protection nationwide. The goals of the resulting studies would be to "ascertain the existence of danger periods, to predict the approach of such periods … to prepare for them, and to predict the behavior of fires under given conditions of weather, cover, and topography…." The proposed studies ultimately would develop an efficient system for warning of the approach of dangerous fire conditions and help ensure that firefighters knew how best to attack those fires that might occur (USDA Forest Service n.d. [ca. 1916]: 1).

The committee's working plan laid out the basic research approach for researchers around the country to use: (1) divide forests into climatic units; (2) identify those factors that could help predict dangerous fire conditions; (3) collect weather data in all districts; (4) study fire and weather records to determine which conditions might predict fire danger; (5) identify the relation of local climatic phenomena such as wind to regional conditions; and (6) determine the spread rate of fires under various conditions of weather, topography, and cover (USDA Forest Service n.d. [ca. 1916]). These tasks, with an emphasis on fuels added later, would drive much of the fire danger rating and fire behavior research in the Forest Service for decades to come.

Fire Hazard

With the costs of firefighting burning through the Forest Service's annual budget, and requests to make up deficits for fighting fire ranging from $1 million in 1918 to almost $3 million in 1920, reducing those costs by being better prepared, became almost as high a priority as fire suppression itself. Early research already had focused on finding a more equitable and effective method for distributing firefighting funds to ensure that those forests at greatest risk of fire and related economic losses had access to the personnel and equipment needed should a fire occur. In 1915, for example, Forest Service researcher William. N. Sparhawk began working on a method to distribute protection funds based on (1) the total value of the resources, and (2) the chance for destruction of these resources by fire (i.e., the risk). "To be scientifically correct," Sparhawk wrote, "the distribution of protection funds should be based on the value of property which is liable to be destroyed" (Sparhawk 1915: 1). The project was not without its challenges, however.

Forest supervisors routinely estimated the economic value of their forests, but because each used a different method and estimates to reach that dollar amount, none of the valuations were comparable or particularly useful for distributing firefighting funds. Sparhawk admitted that it was probably impossible to determine the exact value of timber and other resources on national forest lands,

but if all supervisors used the same method, "it should be possible to determine relative values," he wrote. These relative valuations, he believed, should be close enough for the purpose of allotting funds (Sparhawk 1915: 3).

To this end, Sparhawk set out to create one of the first uniform methods to determine the total value of resources, regardless of their location, and identify the associated risk of resources being lost as a result of forest fires. Sparhawk's ultimate goal was to use these values to develop a mathematical formula for computing the fire danger on a given unit. He would later explain that the goal of such a formula was not necessarily to eliminate all losses, but to minimize them and justify the costs of fire suppression in relation to that potential loss (Sparhawk 1925).

Potential fire hazard could not be estimated by assessment of resource values alone, however. Sparhawk also needed fire data, including consistent records and maps. He also wanted to integrate how weather conditions impacted fire hazard and fire protection, and how weather affected the behavior of fires. Although he initially had only 5 years of data to work with (i.e., 1910 to 1915), Sparhawk demonstrated how such a system could be developed and used to distribute firefighting funds in a scientific fashion, particularly if better fire records were kept in the future (Sparhawk 1925).

America's entry into World War I (WWI) in 1917 cut short Sparhawk's early investigation of quantifying fire danger. Moreover, with limited access to data and the lack of time and personnel needed to pursue the research in earnest, Sparhawk had to admit that his work could be only preliminary at best, presenting guidelines but not final results. His initial research, however, did highlight the importance of keeping fire records in real time and, as he recommended, stored permanently in one place for each district or region. Sparhawk also laid the groundwork for asking basic questions such as when a fire season begins and ends, and what weather conditions create potential fire emergencies and what conditions pose no danger.

Soon after WWI, others in the Forest Service pursued these and related questions. For example, in 1924, researchers at the Lake States Forest Experiment Station initiated their own analysis of 9 years of available fire data (1915 to 1923) for Michigan, Minnesota, and Wisconsin. Their goal was to determine the occurrence of fires in the region so that they could better predict fire danger and prepare accordingly. The Northeastern Forest Experiment Station initiated a similar study using 3 years of fire records (1921 to 1923) from Massachusetts, and, in 1925, researchers at the Northeastern Station initiated a 5-year study of forest fire weather to determine the relation between forest fire hazard and weather conditions, to investigate whether fire danger could be estimated using meteorological instrumentation, and to demonstrate the application of such a hazard index and weather forecast to specific problems of fire control.

▲ A fire burns along a road outside Patzau, WI, ca. 1922. Forest Service Eastern Region photo, courtesy of the Forest History Society, Durham, NC.

While researchers at the Priest River Forest Experiment Station in Idaho tested a duff hygrometer developed in Wisconsin by the Forest Products Laboratory in 1923, researchers at the Northeastern Station looked for a method to determine duff moisture based on air temperature, number of hours since last measurable rainfall, and evaporation per hour. They also studied duff inflammability in part to assess future fire hazard (Stevens 1932, Stickle 1934).

By 1929, Forest Service researchers from the Northeast to the Pacific Northwest were investigating relationships between weather and fuels, collecting and studying data on lightning storms, conducting statistical studies of fire hazards and causes of fires, and forecasting fire weather and lightning (Shepard 1930). Although most researchers pursued investigations unique to their region, most of them also called for improved weather forecasting methods with a goal of improving the prediction of fire weather and forest inflammability nationwide. For example, a fire researcher at Priest River called for better weather data to determine the factors influencing the rate of spread of fire and the probable degree of fire danger (Gisborne 1928). Greater preparedness, combined with overall cost reduction, appeared to be the outcomes researchers sought as they investigated how to predict potential fire danger.

Fire Weather

Established in 1911, the Priest River Forest Experiment Station had installed both permanent and temporary weather stations to determine the general climatic characteristics of the region and to identify the ecological site differences for what they considered to be the most important forest types (e.g., western white

pine). With 5 years of onsite data and additional records from U.S. Weather Bureau stations to work with, in 1916, Julius A. Larsen began to study how weather, topography, and forest types affected fires. Like W.N. Sparhawk before him, Larsen focused on available fire records, but he also correlated those reports with available weather data, which enabled him to track and compare rainfall, relative humidity, and other conditions to the moisture content and inflammability of ground cover. By 1921, his progress report included climatic conditions and fires from 1909 to 1919, and his work, he noted with some pride, had begun to influence how fire protection forces were being organized in the region (Larsen 1921).

While Larsen made good progress on his fire studies, researchers at Priest River and other experiment stations had multiple assignments and responsibilities, which limited the time they could focus on fire-related problems. So even though District 1 approved two additional weather-related research projects for the Priest River Station, neither was acted on, no doubt because of a lack of personnel rather than lack of interest (USDA Forest Service 1922). Larsen believed that it was indeed possible to "unravel the causes of climatic fluctuations" to predict fire risk, but he also argued that to be successful, Forest Service researchers needed to focus their full attention on solving the problem. In particular, they needed more time to scrutinize daily weather maps. "Like Sherlock Holmes and crime," Larsen wrote, "it is only open to those who concentrate on the subject" (Larsen 1921: 1).

Forester Harry T. Gisborne, the first full-time Forest Service investigator assigned to fire research, transferred to the Priest River Station's administrative headquarters in Missoula, MT, in 1922. His first assignment was to address a question of national concern: the relationship of weather and fire. He focused initially on two weather-related projects preapproved by the district and tackled them with an intensity that would soon make him known agencywide. His goal, he wrote, was to make information on fire danger available to decisionmakers so that firefighting organizations could "expand to meet increasing danger and contract to save unnecessary expense whenever possible" (Gisborne 1925: 58).

▶ Harry T. Gisborne in Baker, OR, 1921, a year before he transferred to the Priest River Forest Experiment Station. Photo courtesy of the Forest History Society, Durham, NC.

In his first study of lightning storms in relation to forest fires, Gisborne used the existing network of weather stations in and around Priest River to document that the area was at higher risk of lightning storms than previously believed. Because researchers S.B. Show and E.I. Kotok in California had demonstrated that the peak load of fire caused the greatest strain on protective organizations, Gisborne believed that, to minimize this risk, the focus of fire research should be to "forecast the widespread occurrence of numerous local storms" as they moved across the region (Gisborne 1923: 5).

As Gisborne settled into his new research position in 1923, he proposed to devote more time to differentiating between dangerous and nondangerous types of storms. He also called for working with the U.S. Weather Bureau, especially to study the causes of storms and the possibilities of forecasting them several hours in advance. Like Sparhawk before him, he called for better data collection—in this case, records of all lightning strikes, their location, a description of what and where they struck, if they ignited fires, and what conditions were like on the ground (Gisborne 1923).

Although Priest River conducted much of the early fire weather-related research to predict fire danger, as early as 1916, the Wind River Experiment Station in Washington State initiated a related study, which focused on the relationship between weather conditions and the degree of dryness of materials on the ground, and their influence on the spread of fire. Although the station's initial results were inconclusive, research picked up again after WWI pointed to relative humidity as a controlling factor (Hofmann 1922). In 1922, the Fremont Experiment Station in Colorado also initiated research to determine how closely evaporation is related to fire hazard conditions; this study compared evaporation rates with fire records (Bates 1924).

Fire Danger Meters

In 1928, Harry Gisborne published his progress to date on measuring forest fire danger in northern Idaho. To understand the context of his and others' work, Gisborne first attempted to define what he meant by the term *forest fire danger*. His working hypothesis, as he referred to it, stated that fire danger consists of three factors: the number of fires burning or the probability that fires will be started; the rate of spread of fire or the probability that fires will spread; and the loss occurring from existing fires or the probability that fires will result in loss (Gisborne 1928).

In 1930, to synthesize his research into how weather affects fire danger in a way that others could apply to make fire-control decisions, Gisborne used a Kodak light meter as a model for creating the first "forest fire danger classes" meter for the northern Rocky Mountains. Starting with variables such as weather and human activities that could potentially start a fire, combined with the time of

year, visibility, fuel moisture content, and wind, Gisborne sought to predict fire danger in advance based on conditions on the ground. Using advice and changes recommended by field users, Gisborne slowly made adjustments, with the meter going through several revisions and adaptations. The Model Eight meter, finalized in 1955, was used nationwide until the national fire danger rating system was introduced in the mid-1960s (Hardy and Hardy 2007).

Gisborne's research was put to the test in early 1934, when his fire danger system warned of extreme fire weather conditions and the potential for a big fire in the months ahead near the Pete King Ranger Station in Idaho. Gisborne's system, however, had not yet been applied in the field on a large scale, so agency personnel were slow to react, leaving the Forest Service ill prepared when the Pete King-McLendon Butte Fire burned through a quarter of a million acres in August before being suppressed by September snows. As a result, the Forest Service not only reconsidered how it responded to fire danger but also made a commitment to obtain better fire weather data based on Gisborne's inflammability stations, and to improve methods for predicting fire danger and how fires spread (Hardy 1983, Hardy and Hardy 2007).

Fire Spread

When Coert DuBois published *Systematic Fire Protection in the California Forests* in 1914, he called for developing a method not only for quantifying fire danger but also for determining the rate at which uncontrolled wildfires burn. In 1915, when S.B. Show reported to the Feather River Experiment Station in northern California, his first project was a study of fires' rate of spread. He considered this work to be the most pressing of all the questions he had been assigned to investigate (even over light burning).

Show put together a working plan, found a suitable place to conduct test burns, and enlisted individuals to assist him with the burning and recording. With his colleagues, Show conducted a total of 33 experimental fires that were allowed to burn for 15 minutes, with slope, temperature, and wind direction measured and also the distance burned in four directions from the starting point recorded (Mitchell 1915a, 1915b). At the same time, Show tried to quantify the relationship between the speed of reaching a fire and the time needed for suppression. The goal, at least for California, was to furnish Forest Service managers with an estimate of how large an uncontrolled fire would grow within a certain length of time given conditions on the ground. Variables in the field, however, proved complex and difficult to control, so Show could not establish any direct relationship between the rate of fire spread and any one environmental factor (Mitchell 1915b).

Even though the research at the Feather River Experiment Station was inconclusive, it was promising, and as the first such research in the Nation (according to

Show), it opened the door to future studies. Indeed, based on Show's preliminary results, Trueman Woodbury, District 5 assistant district forester, pushed for further investigations into how moisture in different fuels impacted flammability. Because research outcomes would be tied to environmental conditions, Woodbury also suggested that researchers burn larger areas to better replicate the size of wildfires in the field, and to burn their test fires when stronger winds could be expected so that they would better understand the role played by wind in rate of spread (Woodbury 1916). By 1930, fire behavior studies were under way in California, the northern Rocky Mountains, and the Pacific Northwest, with additional studies proposed by researchers in District 4 (Intermountain Research Station headquartered in Utah) and the Appalachian and Southern Forest Experiment Stations in the Southeast.

Fire Control Planning

With many researchers focused on ways to improve preparedness and distribute budgets, proposed research in the 1920s included calls for mapping forest areas according to susceptibility to fire and rating fire danger for allocation of guards. Planning and preparing for wildfire control became such a common concern that, in 1931, the Forest Service initiated a research program to focus on the problem, and transferred Lloyd Hornby, supervisor of the Flathead Forest, to Priest River to head a new Research, Development, and Application program to adapt and apply the findings of research in the field (Wellner 1976). Hornby was sent to Priest River in particular so that he could "apply Gisborne's research in a form that could be used to make fire control planning decisions" (Graham and others 2014: 496). Hornby described in his own work that sustainability of forests meant protecting not only timber production but also protecting recreation, controlling erosion, and safeguarding water resources. In the northern Rocky Mountains in particular, these resources required a high degree of protection, given the area's long fire history.

In 1914, Coert DuBois had called for developing a method to describe six factors—inflammability, season, risk, controllability, liability, and safety—in concrete terms, so that any forested area, after careful study, could be given a rating that would convey an exact measure of total fire danger (DuBois 1914). This vision guided most of what Harry Gisborne and Lloyd Hornby did at Priest River to rate fire danger and plan for fire control. Decisionmakers needed a method to rate conditions at a fire, based on science rather than just personal opinion. Making better informed decisions would help ensure that preparedness and action corresponded with the degree of danger.

In 1936, Hornby submitted a comprehensive report on his progress to date. Although fire control planning was not new, he believed his work was the first time a plan had integrated methods such as evaluating roads to meet firefighting needs, mapping of fuels, and using classes of fuel rather than general cover types, to

determine the speed and strength of initial attack needed for fire control (Hornby 1936). In a memo written right before his unexpected death in 1937 from a heart attack while at a fire in Idaho, Hornby listed what he saw as essential considerations for fire control planning: first and foremost, the goal should be to have fewer fires overall and to handle those that did burn so effectively that no large fires would develop; when moderate and large fires did occur, however, the Forest Service needed concrete plans prepared in advance to fight them (Hornby 1937).

In 1942, when Gisborne looked back on fire research accomplishments nationwide, he acknowledged the pioneering significance of Hornby's work, especially his weighting of each factor and integrating them into one system. Although fire-control planners had always prepared for future fires, Hornby systematized that planning, making it so methodical and incorporating so many new features that "all future fire-control planners were greatly aided," according to Gisborne (Gisborne 1942: 605).

Looking Forward, Looking Back

By the early 1920s, the Forest Service was pursuing fire research in eight forest experiment stations, several districts, and even the Washington Office. These research projects focused on improving the Nation's understanding of wildland fire, using that understanding to predict fire risk and spread, and finding ways to detect and suppress fires early. In 1923, for example, investigations addressed:

- Ways to understand fire hazard (conducted in Priest River, District 5, and the Washington Office).
- Ways to predict fire conditions from weather conditions (conducted in Fremont, Wind River, and Priest River).
- Effects of light burning (conducted in District 5 and the Appalachian and Southern Stations).
- Effects of fire and successive burnings on forest composition (conducted in District 5).
- Relationships between lightning and forest fires (conducted in Priest River and District 5).

So much activity was underway all across the Nation in fire and other research areas that many in the Forest Service believed a national meeting should be convened again to share and coordinate it all.

In the spring of 1924, researchers, administrators, and representatives from the U.S. Weather Bureau met in Madison, WI, to discuss silvicultural and other research and to look for ways to "coordinate the work of the research men in

forest fire investigations" (USDA Forest Service 1924: 1). Much like the original goals for the Branch of Research, the goal for the meeting was to "unite the entire research force into a more homogenous organization, and to bring about a closer coordination of the work of the men at the different stations which are more or less isolated from one another" (USDA Forest Service 1924: 1). Madison was selected in part because it provided an opportunity for experiment station personnel to meet and interact with the researchers at the Forest Products Laboratory located there.

During the meeting, researchers and administrators discussed fire-related problems throughout the Nation, looked at factors impacting fire danger and the ability to forecast that danger, presented what was known about the behavior and control of fires, and argued for consistent data collection. Researchers at the Forest Products Laboratory also presented information on new instrumentation developed at the lab to measure the moisture levels in fuels under various conditions.

Fire danger rating was a high priority during all the discussions. What was needed, many participants argued, was a better system of predicting dry conditions and the approach of lightning storms. Many called for 2 weeks' warning of potential fire weather conditions, but others said they would be satisfied with even 1 week's warning, if the warnings were accurate. Others, including a representative from the U.S. Weather Bureau, advised that knowledge of low humidity (absolute and relative) held the key to understanding fire danger, and in California, researchers cautioned their peers not to underestimate the influence of the wind.

In the context of this back and forth of probable causes of wildland fire, Harry Gisborne clarified the difference he saw between weather forecasts and fire forecasts. The Weather Bureau provided weather forecasts, he noted, to show the probable weather for a certain area, and its predictions had proven dependable in the area around Priest River at least 80 percent of the time. Fire forecasts, on the other hand, were needed to show the probable effects of this weather on fire conditions; they too should be dependable at least 80 percent of the time. Gisborne described it this way: "Weather is the cause, fire danger is the result, and the preparation of fire forecasts require accurate translation from cause to effect" (Gisborne 1924: 44). If it were a simple cause-and-effect relationship, it would be relatively easy to translate one to the other, but, as Gisborne pointed out to meeting participants, it was not. Many complex factors needed to be considered if foresters were to predict the risk of a large fire sweeping over an area (Gisborne 1924).

A fire research committee was formed at the Madison meeting, with representatives from forest experiment stations and the Washington Office. They produced several recommendations related to fire research that would impact future investigations, including the agency's overall commitment to fire

research. In particular, the committee recommended that those currently working on fire-related research should continue to do so but, when possible, researchers should attempt to focus on common questions. They also recommended, however, that as important as fire studies were, they should not overtake other aspects of forest management research, in essence questioning, if not outright reversing, the decades-long belief that the Forest Service could not have forest management without first having fire control. Although fighting fires might consume a good portion of the Forest Service's budget every year, that expense had to be balanced against "the loss in possible production due to improper methods of forest management" (USDA Forest Service 1924: 101). The fire research committee also suggested that no more than 20 percent of the entire research budget be dedicated to fire studies, probably to mirror the amount required from the Forest Service's annual appropriation to fight fire (USDA Forest Service 1924).

▼ Weather station at the Bartlett Ranger Station on the White Mountain National Forest in New Hampshire, ca. 1931. Forest Service Eastern Region photo, courtesy of the Forest History Society, Durham, NC.

Many researchers focused on questions about fire danger and fire behavior; however, although the committee recommended that fire researchers should pursue a common purpose, they surprisingly did not call for standardization of methods, which they considered counterproductive. Rather, they encouraged researchers to test various approaches to addressing fire-related problems and to communicate with one another about their method's advantages and disadvantages.

Fire Science and Research

In March 1928, near the end of his tenure as Chief Forester William B. Greeley sent out a letter to regional foresters requesting help defining fire-research needs, with the goal of establishing a new, nationally focused fire research program. When Greeley resigned the next month to take a job with the West Coast Lumbermen's Association, his replacement, Robert Stuart, had to sort through and make sense of the responses Greeley had received. Recommendations ranged from continuing research into fire behavior and fire effects, to improving education and organizational responses to fire. He also received at least two calls for the Shasta National Forest in California to be recognized and operated as a fire research and demonstration area, where the best knowledge and innovative approaches to fire prevention, detection, and suppression could be tested.

The advice Stuart received on how to respond to these widespread recommendations from the field was equally diverse. Assistant Forester Roy Headley advised

against consolidating fire research, at least not until researchers had agreed on what research questions were most pressing. In Headley's view, the goal of all fire research should be to minimize the cost and damage caused by fires. Without that goal driving research, forestry in many areas could not be "a going concern," he advised (Headley 1929).

Assistant forester Clapp, on the other hand, believed that the diversity of fire research projects underway did not lend themselves to "the drafting of a national program for fire research," and that not enough had been done from an administrative perspective to put into action what was already known (Clapp 1929: 1). Clapp also advised against standardization of research because regional fire conditions and needs were so diverse. In addition, he did not want to discourage innovative ideas that might result in new approaches to fire control, arguing that no one knew "exactly where the most profitable leads are going to lie" (Clapp 1929: 4). Clapp's final, and perhaps most significant, argument was that applied research should not be the agency's only goal when addressing questions related to fire. Fundamental research had been responsible for the advances of a large part of the economic industrial programs of the world, and "neither the Forest Service nor any other agency can afford to rule it out of its research programs—fire or otherwise" (Clapp 1929: 5).

Ward Shepard, in the Branch of Public Relations, also weighed in on the responses to Greeley's query, which Shepard synthesized in a lengthy report for the new Chief Forester. Shepard considered investigations into the human influence on fire (e.g., organization, suppression, education) more urgent than the physical factors, where most fire-related research to date had been focused (e.g., weather, fuel, topography). He believed an effort should be made to observe and analyze how fires were fought in real time, and he pointed to the experimental forest proposed for the Shasta National Forest in California as one way to better understand "a complex fire control machine in operation" (Shepard 1930: 8). Shepard wrote that developing such an experimental forest would allow researchers to integrate research and practice, and "settle many mooted questions" such as the efficacy of training, fire prevention versus suppression expenditures, and the role of education in prevention. A demonstration forest could also serve as a hands-on learning opportunity and fire school for managers (Shepard 1930: 13).

Madison Conference

In 1930, when the Branch of Research met again in Madison, WI, another fire research committee was organized to review current research and identify what more land managers and decisionmakers needed to know to better protect the Nation's forests. The 15-person committee represented the eight forest experiment stations, three district offices, the Forest Products Laboratory, and the Washington Office.

This research committee believed that fire researchers had not done a good enough job analyzing past experience in fire control using available fire records. Such a study was still needed, they argued, to describe a host of factors, including the acres burned; the speed of attack needed to keep damage to a minimum acceptable acreage; the number of firefighters and fire protection improvements needed to attain that control; the strength of initial attack; and the methods, techniques, and training needed to use manpower and equipment effectively on a fire. The committee noted that the review of past records was the "only means by which adequate hour control—the fundamental basis of organized protection—can be determined" (USDA Forest Service 1930: 5). They also expressed support for the Shasta National Forest and the Lake States Station's proposed work with experimental methods of fire control, because both could serve as case studies for those looking to implement proven and cost-effective methods of fire control. These demonstrations might also help justify the high costs of fire suppression and control at a time when budgets were tight, timber sales were down, and manpower was limited.

The committee also called for better information on the effects of fires, direct and indirect, and how fire effects might impact firefighting decisions. Questions raised by the committee included the following:

- What kinds of losses did different forest types experience and what was the actual physical damage?
- What was the maximum area the Forest Service could afford to let burn in any one unit or forest type?
- How should the agency measure the indirect and intangible losses to other factors such as soil and watersheds?

▶ A firefighter uses a knapsack handpump to suppress a fire on the Bent Creek Experimental Forest (Southern Forest Experiment Station) in North Carolina, 1930. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

The conclusion of the 1930 meeting in Madison was that the Forest Service needed to research and develop more uniform methods to distribute firefighting funds and to effectively analyze and compare the effects of fire. In particular, the committee called for a better understanding of the effects of fire for use as a basis for allocating protection funds, because too often the comparative ratings used for these assessments were still based on personal judgment and/or insufficient data. "Close inspection of these comparative ratings," the committee reported, "indicates more adequate data are badly needed" (USDA Forest Service 1930: 10).

Chapter 4

Fire Effects

The query arises, if fires have always prevailed in the forest and nature has been able to adjust itself in their reestablishment, why do foresters place such emphasis on the importance of complete fire exclusion in the American forests? The answer, of course, lies in the fact that the forester is concerned in producing and maintaining maximum values in the forest. Fire is not compatible with this objective.

—E.I. Kotok, 1930

In 1898, when Gifford Pinchot called for a better understanding of fire's effects on the composition and reproduction of forests, he—and later his successors in the U.S. Department of Agriculture, Forest Service—worried about fire's impact on forest productivity, watersheds, and the practice of forestry generally. Even though the study of the effects of fire was in its earliest stages, Pinchot still believed that if fire had been excluded during the past thousand years from forests such as those he had visited in Washington State, the composition of the forests would have been entirely different.

> In a word, the distribution of the red fir [Douglas-fir] in western Washington, where it is by all odds the most valuable commercial tree, is governed, first of all, so far as we know at present, by fire. Had fires been kept out of these forests in the last thousand years the fir which gives them their distinctive character would not be in existence, but would be replaced in all probability by the hemlock …. I hasten to add that these facts do not imply any desirability in the fires which are now devastating the West (Pinchot 1899: 402-403).

Although Pinchot did not view fire as a positive force shaping the landscape, he did see its effects directly impacting the distinctive character of some western forests that he had personally visited. This insight led him to bemoan the agency's meager knowledge of the "creative action of forest fires" (Pinchot 1899: 393).

A 1907 report on the effect of fire on lodgepole pine in the central and northern Rocky Mountain region also mentioned fire's "creative action." The unnamed author of this brief, unpublished report noted that the species was "well equipped to reproduce itself in spite of fire," and for that reason, "fire is often looked upon as beneficial and even necessary" (USDA Forest Service 1907: 1-2). Much like Pinchot, who had cautioned in 1899 against viewing fire as a positive force, so too did the author of this brief research note caution that it is "still safe to hold that fire in the forest is always dangerous and that it is not necessary" (USDA Forest Service 1907: 2).

Some of these early studies into the effects of fire suggest that research during this period presented a real challenge, with investigations at times appearing to counter the widespread belief "that fire has wrought havoc" by revealing some of "the easily seen good effect" (USDA Forest Service 1907: 2). That said, most if not all in the Forest Service still viewed the effects of wildland fire as a net loss, both to forest productivity and, as significantly, to the science and practice of forestry itself.

In northern California, for example, foresters investigated the effects of a 1910 surface fire that had blazed through a mixed stand of pines and Douglas-firs on the Klamath Forest. In 1915, when researchers measured the effects of that fire on the trees' rate of growth and survival, they found that even trees with badly scorched crowns had recovered, and only one tree had succumbed to fire injury. They also found, however, that the fire had slowed the trees' rate of growth overall, resulting in what researchers estimated to be a loss of $1.00 per acre in merchantable timber during the 5-year period (USDA Forest Service 1919). It was these negative economic impacts that researchers in the early 20th century focused on and sought to document when they investigated the effects of fire.

As fire protection and suppression became tied more directly to potential financial losses of merchantable timber, the question of how to provide adequate but still affordable fire control to protect the economic value of forested lands posed one of the more pressing challenges throughout the Forest Service. To respond to that challenge, researchers and managers alike needed a better understanding of the financial and other effects of fire, so they called for more comprehensive fire reports and improved data.

Fire Damage

In 1921, at a meeting at Mather Field in California, Forest Service investigators from around the country affirmed that fundamental fire research, even without

a clear and immediate deliverable in mind, should play an important role in the development of improved fire protection. They also argued, however, that important breakthroughs would not come from fundamental research alone. Working in seven separate committees that reported back to the group as a whole, one committee, which included a representative from each district, identified the collection and correct analysis of fire damage data as one of the most promising lines of investigation currently underway in the Forest Service. This committee reported that it was of "fundamental importance that the role of damage be thoroughly understood and appreciated if protection policy and practice are to go ahead on a sound basis" (USDA Forest Service 1921: 1).

After the meeting, to meet the call for more comprehensive data on the effects of fire, the investigators developed new data record sheets based on the ones already in use in California. These forms required the estimation of merchantable timber loss as soon as possible after a fire, based on regional timber values. In 1925, Chief Forester William B. Greeley distributed an updated version of these forms to all district foresters, noting that the lack of consistent data collection had resulted in a "lack of conviction in putting the case for proper fire protection before the public, and more important, in a tendency in our own organization to underrate the losses we sustain and consequently to overvalue the effectiveness of our existing system of fire control" (Greeley 1925: 1).

▲ Inspecting the effects of a fire on Del Rosa Ridge on the San Bernardino National Forest in California, 1938. Forest Service Pacific Southwest Region photo, courtesy of the Forest History Society, Durham, NC.

In 1928, District 1 Forest Inspector Howard Flint proposed an even more economically focused approach, using "simple, common-sense business terms," much like those used for any other investment. At a time of rising corporate profits and a belief that the chief business of the American people was business, Flint argued that if "timber growing as an enterprise [was] to establish itself and continue," then forests should be kept as safe from fire as any other form of destructible property "in which moderately conservative investors are willing to place their funds." The challenge, according to Flint, was to find the most favorable ratio between gross revenue and fire losses, explaining that adequate forest protection places "forests on equal or level basis with the average of other forms of property, period of time and general region being given due consideration" (Flint 1928: 625). Sustainability was still the overarching goal of fire control, but some Forest Service personnel now called for, at minimum, some sort of economic qualifier.

Burning the Woods

In the early 1920s, the Forest Service established three new forest experiment stations in the eastern part of the country to complement those already established in the West and to provide better coverage of the Nation's resources. The Appalachian and the Southern Forest Experiment Stations were added in 1921, and the Northeastern Forest Experiment Station was established 2 years later. Early on, all three stations turned their attention to the study of wildland fire.

Because they were coming to fire research late, researchers at the Southern Station initially believed it impossible to conduct meaningful indepth investigations of fuels and fire behavior due to a lack of personnel. The station director explained that the "work of the Southern Station must be directed toward answering certain very practical questions, rather than toward so-called 'fundamental,' and long-term, research." As applied to fire research, the station "made no attempt to [analyze] methods of firefighting, to predict fire weather, or to undertake other such projects current at other experiment stations. We have confined ourselves strictly to investigating the effect of fire on the forest" (Forbes 1926: 3, 5).

Research in the American South generally confirmed the widespread belief in the negative effects of fire and the "impracticability of attempting reforestation measures without providing for adequate protection from fire" (USDA Forest Service, Southern Forest Experiment Station 1929: 7). Because little was known about the overarching costs and effects of those fires in different conditions, however, researchers continued to look for ways to better quantify them. One 400-acre plot in Louisiana, for example, had not experienced any fire for several years and, as a result, the undergrowth and litter were heavy. The Southern Station set controlled burns during damp periods or at night. They found that, even though some small trees were killed, "they were not an essential part of the stand," and that the fire hazard was greatly reduced (USDA Forest Service, Southern Forest Experiment Station 1934: 13). This successful test opened the door to viewing the use of fire more positively by researchers at the station.

After several fires in the South in 1932 and 1934 that burned through thousands of acres of private and public land, the Southern Station took a second look at the burning practices of local landowners and investigated the use of fire as a protective measure, particularly in southern Georgia and northeastern Florida. Several Forest Service land managers in those areas tried using controlled fires proactively in the winter, first experimentally and then on a regular basis. They found that, contrary to Forest Service policy, the use of fire provided "a substantial aid to the successful management of slash and longleaf pine forests" (Bickford and Curry 1943: 1).

Because of these promising studies, researchers at the station called for additional investigation of the use of controlled burns. It took a severe drought during the

▲ Controlled burn of undergrowth in Georgia, ca. 1937. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

winter fire season of 1942–1943, coupled with the shortage of fire-control personnel after the loss of the Civilian Conservation Corps (CCC) crews discussed later in this chapter, to bring the use of "burning the woods" as a preventative measure to the forefront in the South. The new station director, E.L. Demmon, explained in 1943 that aggressive fire control in the previous decade had resulted in "the establishment of dense, vigorous stands of young slash-pine, along with a heavy undergrowth of high inflammability." Wildfires could burn fiercely through these stands, Demmon reported, and cause extensive damage. Landowners were understandably looking for better methods to minimize this risk and "many timber owners and managers [sought] advice from the Station" (Demmon 1943: 5).

In response to the persistent and growing interest in the use of fire in the South, C.A. Bickford and John R. Curry, Southern Station silviculturists, prepared a guide on the practical use of fire in protecting forested lands. The two researchers addressed their 1943 publication to the owners and managers of forested lands "on which the growth of forest products is the main objective." Based on research on fire behavior and fire effects at the station and elsewhere in the South, the authors sought to clarify "the objectives, dangers, and full potentialities of this tool in forest management" (Bickford and Curry 1943: 1). Their paper provided guidelines for landowners and helped establish an approved way to manage fire proactively in the region, countering, at least in this instance, long-standing Forest Service policy.

The Southern Forest Experiment Station was not the only station in the eastern part of the country interested in how to determine the negative costs and potential positive benefits of fire on forested lands. The new Appalachian Forest Experiment Station in Asheville, NC, established at the same time, also focused primarily on the effects of forest fires, investigating the negative effects of fire in both mountain and coastal plain forests. In the mountain studies, researchers sought to quantify fire damage to hardwoods such as yellow poplar and oak varieties, the results of which could help them improve fire protection policies. They also hoped to better understand restoration and management of burned areas. On the coastal plains, however, researchers focused directly on "burning the woods," to establish "the desirability or undesirability of annual burning in the longleaf and loblolly pine types" (USDA Forest Service 1932: 10). In both studies, researchers set out to determine the long-term negative effects of wildland fire, but in at least one study, they were open to documenting its benefits.

In 1933, Paul Stickel at the Northeastern Forest Experiment Station in New Haven, CT, proposed a similar study of the effects of fire, explaining that, even though more money was spent in the Northeast on forest fire control than on all other forestry activities combined, "practically nothing is known regarding the extent of the real physical damage to standing timber, let alone to regeneration" (Stickel 1933a: 3). If the Forest Service desired to make sound arguments before legislative bodies for support of fire control efforts, then they urgently needed improved fire damage appraisals to make their case.

Stickel, however, called for more. He also wanted to better understand the influence fire had on an entire site, including forest soils, forest microbiology, and forest ecology. Moreover, in contrast to "all the dogma of forest policy," he wanted to investigate fire's beneficial effects, to see if it could be used as a silvicultural agent in "creating optimum seed bed conditions for desirable species" (Stickel 1933a: 8). He understood that studying fire on controlled burned and nonburned sample plots had its dangers from both a silvicultural and a public-relations point of view, but Stickel still believed that "some investigation of the use of fires should be undertaken at an early opportunity" (Stickel 1933a: 9). Like those who had argued for "light burning" in California before him, Stickel wanted to know if "the judicious use of fire" might help save money and contribute to the overall growth of important commercial forests (Stickel 1933a).

Civilian Conservation Corps

The election of Franklin D. Roosevelt in 1932 may not have directly affected fire-related research, but it did have an almost immediate effect on how the Forest Service controlled fires. Roosevelt took office in March 1933, and by April, Congress had established one of the cornerstones of the new President's New Deal programs: the CCC. In exchange for planning and conducting work

projects on the national forests (and some State and private lands), the CCC assigned more than 3 million young, unemployed men to work for the Forest Service on projects such as reforestation, erosion, and forest fire prevention and control (Otis and others 1986).

CCC employees also worked to combat what they referred to as the "three horsemen" threatening the Nation's forests: fire, insects, and disease. To improve the infrastructure needed to fight fires more effectively, CCC crews built roads and trails, bridges, lookout towers and houses, telephone lines, airplane landing fields, and firebreaks. In its first 5 years alone (from 1933 to 1938), CCC crews constructed more than 60,000 miles of firebreaks, including a 600-plus mile stretch of firebreak in California known as the Ponderosa Way. As significant, during that same 5-year period, the CCC put in more than 3.5 million person days in fire prevention efforts, and more than 4 million person days in fighting forest fires nationwide, sometimes sending a thousand individuals or more to fight a single fire (CCC 1938).

Not all Forest Service employees viewed the CCC accomplishments positively, however. As introduced by the editors of the *Journal of Forestry* in 1935, Forester Elers Koch raised "an important and controversial question of land use: 'What shall be done with the low-value back country'" (Koch 1935: 98). Koch noted in his accompanying article that, in an effort to better suppress fires in the Selway

▲ Civilian Conservation Corps fire suppression crew in California, 1933. Forest Service photo, courtesy of Forest History Society, Durham, NC.

and Clearwater drainages in Idaho, the CCC had carved roads, strung telephone lines, and built airplane landing fields into the backcountry, resulting in "one of the saddest chapters of the history of a high-minded and efficient public service" (Koch 1935: 99). He questioned if all that work would even make a difference in a region with such a long history of wildland fire. Even though millions of dollars had been spent, lives lost, and some fires controlled, "when the time is ripe for a conflagration," Koch warned, "man's efforts have been puny in the face of Nature's forces" (Koch 1935: 99).

Koch used the same cost-benefit analysis others had used to justify fire control, but in this case, he argued against spending the money. Even though it was a low-value timber area, from 1912 to 1934, the Forest Service had spent more than $3 million for "all purposes" (i.e., roads, airfields, telephone lines, etc.) while timber receipts brought in only $76,000 during that same period. Koch estimated that if the other forests in the adjoining "low-value zone" were added to the Selway National Forest, the amount spent would be at least $5 million, or $200,000 to $300,000 annually, "with practically no hope of timber-sale receipts or more than a trivial amount in grazing fees to offset the expenditures" (Koch 1935: 100).

Because of the low value of the timber, Koch believed that recreational use and watershed protection were the only values worth protecting in the area. Koch used an argument similar to those used in defense of abandoning sub-marginal agricultural land, asking if it did not make more sense to abandon timber harvesting on some low-value timberlands. "The good land will merit intensive treatment, the less good land less cultivation, and the least good lands something entirely different." Using the same argument against fire control, he wrote, "it is time to withdraw from a losing game before more millions are expended with little or no results" (Koch 1935: 104). Although the Forest Service initiated several studies of fire economics to justify the expenses of fire suppression, not until the early 1970s did the agency test Koch's "important and controversial" idea in earnest, when the Northern Region and the Northern Forest Fire Laboratory in Missoula proposed to allow some fires to burn in the White Cap area of what was then known as the Selway-Bitterroot Wilderness (Smith 2014).

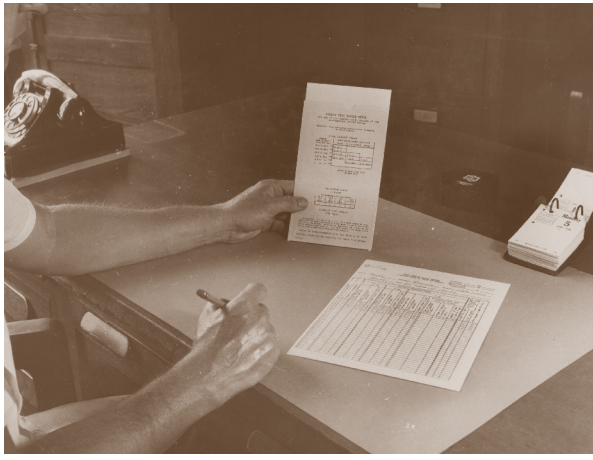
As if in response to the questions raised by Koch, Forest Service researchers and administrators from around the country convened a fire control conference in Washington, DC, in November 1936 to develop a method for a more equitable distribution of fire control funds. As the attendees soon discovered, however, without a systematic approach to fire control planning that could be correlated between the regions, it was difficult if not impossible to assign equitable values to the need for fire control. Instead, meeting attendees turned their attention to better understanding fire control problems that the Nation faced, standardizing the major elements needed in fire control plans so they could be compared, and identifying areas that needed additional research.

A guide for fire control planning was developed at the meeting, and C.M. Granger, the acting Chief of the Forest Service, instructed all the national forests and regions to complete comprehensive fire control plans. In April 1940, the research office also developed a problem analysis outline and requested that all research stations with a regular fire research project prepare a regional analysis covering the entire field of fire studies. Because of the relevance of research to fire control planning, researchers were asked to consult with fire control and other officials as they developed their own regional plans.

Priest River Conference

In early 1941, with a new region-by-region analysis of investigative needs in fire control available, another national meeting was convened, this time at the Priest River Experimental Forest in Idaho. Twenty-seven people attended, including representatives from research, regional forest administration, and the Washington Office. During this period, the Forest Service pursued an informal policy of attempting to limit the average annual burned area to one-tenth of 1 percent of the entire area the agency protected (Headley 1943). In an overview of the Priest River conference in *Fire Control Notes*, Kenneth P. Davis reported that the agencywide goal of keeping all fire seasons to one-tenth of 1 percent of any forest each year was nearing a reality, and had been exceeded on some forests. He claimed that "substantial progress" had been made in fire control overall, as indicated by a downward trend in the average acreage of lands burned from 2,421 acres per million acres protected from 1930 to 1934 to 1,418 acres from 1935 to 1939 (Davis 1942).

Fire-related research also reported advances. The use of fire danger meters, first developed at Priest River in 1930 by Harry Gisborne, had become relatively routine in most regions, and the design was under refinement. Visibility studies had made significant contributions to fire detection, improved knowledge of fire behavior had given fire dispatchers and land managers a better tool for responding to and fighting fires, and new methods had been developed for determining the effects of fire and better evaluating the costs. The time was ripe, Davis wrote, "for a constructive over-all appraisal of the direction, emphasis, and organization of the fire-research program and the formulation insofar as feasible and desirable of a coordinated national program" (Davis 1942).



▲ The Coastal Plain fire danger rating meter, adapted from the original slide rule design, 1948. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

One other change loomed large over the thinking of fire researchers that year: the withdrawal of the CCC from the Nation's forests. A resource that had provided millions of hours of relatively free labor for a decade was winding down. Davis noted that the degree of fire control achieved during the tenure of the CCC would have, at one time, seemed a "far-off dream," but the Forest Service now had to wake up and address the "keen pressure to define how much protection is justifiable and how much it costs" without thousands of people standing by, ready and able to suppress them all (Davis 1942: 46).

As Coert DuBois and others had done before, meeting participants called for improved insights into fire prevention, particularly understanding why and how people start fires. Davis (1942: 84) reported: "Recent advances in applied psychology and in methods of sampling and studying mass opinion seem to offer effective tools that research could investigate and develop to aid administration in increasing the effectiveness of fire-prevention work." Fire prevention education also stayed high on the list of priorities developed at the Priest River meeting. One example, published in the same issue of *Fire Control Notes,* was from the "Fire Psychology Unit." This program included posters, handouts about fire, and a button stating "It's BAD LUCK to start a forest fire" (Editor, Fire Control Notes 1942: 64). This message in particular sought to enlist what the Forest Service perceived as the superstitious culture in the South, as evidenced by residents' burning of the woods each year.

Meeting participants, however, identified the greatest fire research need as a better understanding of the economics of fire control. For that, they recommended that investigative work be started to identify and develop methods of measuring the direct and indirect effects of fire on all forest resources—not just timber—with those damages expressed in dollars whenever possible. These improved valuations would be used to justify expenditures and distribute funds for fire control. They also identified an equally significant need, calling for methods to determine "values not now measurable in dollars," (Davis 1942: 46) with the same goal in mind. By looking for ways to evaluate less tangible resources, researchers were opening the door, as Paul Stickel had done in the Northeast, to more fully quantifying the effects of fire on forested landscapes.

▼ Firefighters en route to a fire in North Carolina, 1923. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

Participants in the Priest River conference were not naïve about the difficulty of evaluating all the resources affected by forest fires and reached a general agreement that "much hard-headed appraisal and study were needed of values at stake and liable to damage in relation to protection costs" (Davis 1942: 46). Without an understanding of the values at risk, however, it was impossible to make informed decisions about how much fire control was justifiable.

Fire Economics

In 1928, Forest Inspector Howard Flint had described the practice of forestry as similar to, if not the same as, running any other profitable business. He was not alone. Even earlier, in 1926, R.D. Forbes, director of the Southern Forest Experiment Station, wrote that contrary to popular belief, forestry was indeed a business enterprise. "The only difference between public and private forestry," he wrote, "lies in the interest rates which are demanded of the enterprise, and the valuation which is placed upon such indirect benefits of forest growth as watershed protection and influence on climate, and upon recreational and aesthetic values" (Forbes 1926: 2).

Within this economics framework, the value of the product produced by the practice of forestry should help define the kind and amount of fire protection justified, if any. Even for those within the Forest Service who resisted this kind of business analysis in the 1920s, the idea of a cost-benefit analysis of fire protection, based on the potential losses of timber and other resources, would become central to sustaining America's timberlands. It would become even more critical after the stock market collapse in 1929, when budgets became tighter and every expenditure needed to be justified. That need only intensified in the early 1940s, with the loss of the CCC crews to suppress most fires.

In 1942, with the national fire planning process initiated in 1937 completed and recommendations in hand from fire researchers attending the meeting at Priest River, I.T. Haig, chief of the Division of Forest Management Research, moved again to establish a national program of fire economics to be conducted out of the Washington Office. Although he doubted any new Forest Service program could be established until the end of America's involvement in World War II (WWII), Haig wanted a plan in place as soon as circumstances permitted (Haig 1942b). He included an overview by Kenneth P. Davis that outlined how such a plan might be organized.

Haig and Davis' plans laid out three basic objectives: To identify and evaluate the effect of fire on all forest resources (i.e., not just timber production); to determine the intensity of fire control needed to protect those resources; and to achieve the most economical balance between prevention costs, and fire damage. As many foresters had before him, Haig argued that fire control was "essential to the practice of forestry of any kind," and it was therefore "urgent

to bring protection into balance with real need" (Haig 1942a: 1). He recommended that someone be assigned to the project full time, and that researchers take advantage of the extensive resources available in forest fire statistics and information about the negative effects of fire (i.e., dollar amounts when possible; Haig 1942a).

Rethinking Forest Fire Control

With the loss of the CCC to fight fires and increased interest in the economics of fire control, it seemed natural that Roy Headley, former chief of the Division of the Fire Control and an early proponent of some light burning, would lay out his own thoughts on "Re-Thinking Forest Fire Control." His 350-plus page manuscript, apparently written on his initiative and time, covered everything from fire prevention and suppression to fire planning and organization. His introductory chapter on the objectives of fire control provides a good overview of fire control and, by extension, fire research thinking in the early 1940s. With the assistance of millions of CCC workers, the Forest Service had achieved its informal goal of keeping fire losses each year to 1,000 acres per million protected (or one-tenth of 1 percent) in the original six districts of the Forest Service. At the time of Headley's writing, these districts, now referred to as regions, included 79 percent of the land protected by the Forest Service (i.e., not including Alaska), a major accomplishment—and a goal that the Forest Service had met for 8 years in a row (Headley 1943).

The problem as Headley saw it, however, was that the same weight was given "to the burning of a thousand acres of unusable cheatgrass as it does to a thousand acres of thrifty plantation representing an investment of $20 or more per acre" (Headley 1943: 3-4). He made a similar argument about initial burns and reburns of the same area, the first of which might result in loss of merchantable timber, and the second of which actually might have a positive benefit, burning off snags and reducing debris that impeded reforestation. He argued that the effects of fire depended not only on changes in timber value but also on the land itself, and whether the fire degraded or improved nontimber uses such as wildlife habitat, recreation, and water resources. "The habit of thinking of fire control in terms of acres burned has become so deeply rooted that it will require a determined effort to break away from it and take the logical next steps toward truer ways of thinking about objectives and the measurement of fire damage" (Headley 1943: 5). The quick action strategy or 10 a.m. policy established by the Forest Service in 1935 also failed as an experiment, according to Headley, because of lack of uniform application and the use of CCC firefighting crews, which made it difficult to determine the actual costs of fighting fires (Headley 1943).

Headley distributed his manuscript asking for comments and reviews from former colleagues and "younger men," who were in the best position to judge what would be most helpful to them in the future. It does not appear, however,

that his book ever made it into print. Perhaps his argument included more economics than the Forest Service ultimately wanted. Or perhaps his manuscript, based on insights from decades of fire-related research, simply was not helpful in the eyes of a new generation of researchers, who at the end of WWII looked to the future for new ideas.

The Next Generation of Fire Research

In 1944, President Franklin D. Roosevelt wrote that the "frontiers of the mind" lay ahead for the Nation after WWII, and the country had a real opportunity to apply the progress made during the war to achieve peacetime ends. "Science: The Endless Frontier," the report prepared for the President by Vannevar Bush, director of the Office of Scientific Research and Development, outlined the many ways science could be put to work to ensure the Nation's health, prosperity, and security (Bush 1945).

The Forest Service was paying close attention. Melvin Bradner, director of the Northern Rocky Mountain Forest and Range Experiment Station, jumped on the idea of firefighting as the new war effort, as suggested by his colleague P.D. Hanson. Bradner went even further, however, wanting to capitalize on the relationship between war research and forest fire research. In a letter to former fire researcher

▼ Fire on the Los Padres National Forest in California, 1948. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

E.I. Kotok, who was now assistant chief in charge of all forest research, Bradner pointed to Bush's report that called for "lump sums" of investment in research over several years. Research needed to be funded and planned out over 5 years or longer, Bush argued, and Bradner agreed (Bradner 1945).

Kotok's office reported back that the agency had studied Bush's comments closely and were in the process of preparing a 5-year research program to present to Congress that winter. There was "no question at all that one of the chief drawbacks to a good research job is the ups and downs in appropriations and the stability of such funds over a period of years" (Larrimer 1945: 1). The Forest Service fully intended to capitalize on Bush's recommendations for funding research to pursue a better understanding of the effects of fire and to meet other research goals, which still included improved methods of fire control and better understanding of fire behavior (Larrimer 1945).

The Forest Service had a new metaphor for communicating its drive to eliminate fire: it was war. Much like those in charge of any battlefield, the Forest Service needed to turn its management and research attention to those fighting the battles on the ground and find ways not only to sustain the Nation's forested lands but also to better ensure firefighter safety and the safety of the American people.

Chapter 5

The War on Wildland Fire

It is not at all strange that the greatest single product of war research, the atomic bomb, involves the establishment and maintenance of an atomic "chain re-action," while the greatest problems of our fire research are (1) the measurement of conditions favorable to the maintenance of the molecular chain-reaction, called "fire," and (2) the development of methods of stopping that chain reaction among the molecules of our fuels.

—Melvin Bradner, 1945

In 1944, incendiary bombs from Japan started landing along the American west coast from Alaska to California. The U.S. War Department initially kept the discovery of the balloon-borne bombs secret, hoping to avoid panic and also to suggest to the Japanese that the program had failed because no bombs or bomb-generated fires were reported by the U.S. media. Although no known fires were started by the bombs, the military responded to the potential threat by transferring the 555th, a group of African-American paratroopers, to the west coast to learn how to defuse the bombs and to be trained by the Forest Service on how to fight any fires the bombs might start. The paratrooper training included background on fire behavior, fireline location, and smokejumping.

The 555th regiment, also known as the Triple Nickles, never encountered any bombs or fires during their deployment. They did, however, fight fires alongside the U.S. Department of Agriculture, Forest Service smokejumpers in the summer of 1945, resulting in the first documented smokejumper fatality. Pfc. Malvin L. Brown, a medic who had volunteered to fill in for a colleague on that day, fell to his

▲ Members of Malvin Brown's firefighting team, 1945. U.S. Army photo.

death when parachuting near a fire in Oregon (Woodard 2016). In Oregon in 1945, firefighting was indeed war, and a smokejumper was in essence the first military casualty of that war.

Firefighting and War

With World War II (WWII) behind them, researchers and managers in the Forest Service fully embraced wartime language as a powerful way to communicate its campaign against wildfires. If American forces could defeat the Nation's enemies around the globe, surely Americans could defeat one of the Nation's biggest threats at home: wildland fire. The Forest Service looked to new military technologies and trained personnel to help the agency develop improved methods to end the threat posed by forest fires. Much like those in charge of any battlefield, the agency sought to introduce better preparation into its response. To this end, the Forest Service hoped to revive research on fire control planning that had stalled with the unexpected death of Lloyd Hornby in 1937.

The Forest Service used war metaphors to campaign for both fire control and fire research. When Melvin Bradner, director of the Northern Rocky Mountain

Forest and Range Experiment Station, wrote to E.I. Kotok about Vannevar Bush's report *Science, the Endless Frontier,* he endorsed a recent comment from one of his colleagues that had noted the "remarkable resemblance between war and forest fire control" (Bradner 1945: 1). Bradner wrote that even the research needs of war and wildland fire control were remarkably similar, "in kind, although not in quantity, of course." He also added that fire itself burns in a way similar to the "chain re-action" of an atomic bomb (Bradner 1945).

Priest River fire researcher Harry Gisborne found Bradner's comparison of wildland fire to an atomic bomb so compelling that he adapted it for a 1947 talk he gave in which he referred to fire as "a molecular instead of an atomic chain reaction." Gisborne explained that "when our fuels are in their most critical condition, i.e., their driest, we have some molecular chain reactions which are so violent that we cannot stop them, just as there is no stopping an atomic bomb once its chain reaction is started." Indeed, he continued, some large fires even had been known to explode (Gisborne 1947: 4).

The availability of new technologies and new personnel after WWII had given Forest Service researchers new hope. Their confidence was renewed, too, by Vannevar Bush's call for new, long-term funding for research nationwide. Forest Service researchers around the country returned to work after the war with a belief that the war against wildland fire finally would be won.

New Technologies and New Personnel

One person who returned from WWII and applied to help the Forest Service advance its postwar research agenda in the Rocky Mountain West was Jack Barrows. A forester by training, before the war, Barrows had worked as a park ranger at Rocky Mountain National Park in Colorado and served as the National Park Service's fire control specialist, fighting fires and training firefighters around the country. More recently, he had served in the U.S. Army, planning aerial bombing strategy and tactics in the Pacific. Harry Gisborne wrote to E.I. Kotok that this was "a rare opportunity" to hire the next generation of project leaders the Forest Service needed to advance fire research (Gisborne 1946). Indeed, it was much the same opportunity that the Priest River Forest Experiment Station had capitalized on earlier when it hired Gisborne as its first full-time fire researcher after WWI. The agency took Gisborne's advice and, in 1946, Barrows joined the Priest River research team at what was then known as the Northern Rocky Mountain Forest and Range Experiment Station, with headquarters in Missoula, MT.

Other research stations, from the Pacific Northwest to the Southeast Stations, also sought to capitalize on new personnel and peacetime priorities as the Nation turned its attention away from Europe and Japan and back to the home front. Even though research budgets did not keep pace with increased research demand as recommended by Vannevar Bush, Forest Service managers and researchers

around the country turned their focus back to the sustainability of the national forests. With an expressed interest in ensuring an adequate supply of wood for both civilian and industrial purposes in the anticipated boom years ahead, they picked up those investigations where Forest Service researchers interested in fire control had left off before the war. George Jemison, director of the Northern Rocky Mountain Station, wrote in his 1950 annual report, "Fire research is a field in which results are likely to be spectacular" (Jemison 1950: 22). After the Nation's success in WWII, the American people stood by, ready to be impressed as Forest Service researchers began a renewed assault on the three problems they had been struggling with from the beginning: fire prevention, detection, and control; fire danger rating and fire behavior; and fire effects.

Fire Prevention, Detection, and Control

In 1946, E.I. Kotok gave a talk to State and Federal forest products research programs in Madison, WI, about the objectives of forestry research. As the head of Forest Service research, he argued that to develop successful programs, everyone involved needed to understand the problem that forestry research sought to solve: "an inadequacy of wood supply." Kotok also believed this goal required sound management practices, "grounded on determined facts and natural laws" (Kotok 1946: 1, 3). In his talk he emphasized that stable silviculture and forest management "must continue to be a primary and general object of research in forestry," predicting that this overarching goal would result in new and better forests (Kotok 1946). Unsaid by Kotok at the time, but no doubt understood by managers and researchers alike, was that pursuit of this goal required the agency's ongoing commitment to developing improved methods of fire prevention, detection, and control.

Fuel Reduction

In 1945 and 1946, the California Forest and Range Experiment Station established a series of plots to test the effectiveness of chemical herbicides for clearing underbrush on forested lands. Intrigued by the power of breakthroughs in modern chemistry designed to solve a whole host of problems, California foresters wanted to investigate whether recently developed chemicals (e.g., 2, 4-D and ammonium sulfamate) might be applied to reduce the threat of wildland fire (Blanchard 1947). Researchers also investigated the use of these and other chemicals for maintaining firebreaks, roads, and trails used by firefighters. Although not a panacea for permanently reducing all unwanted fuels, as one researcher admitted, the use of herbicides did show some potential for killing off brush, at least in the short term.

Investigating the use of herbicides and other chemicals as a means of fire prevention did not eliminate the call for research on controlled or light burning in California, however. Those advocating the use of fire to assist with prevention

and control continued to dog forestry officials. Indeed, Forest Service officials faced a "vociferous demand from Federal, State and local sources for facts on which to base both State and Federal controlled burning policy," (Buck 1947: 18) particularly when it came to burning mountain and foothill range to improve livestock grazing. C.C. Buck, chief of the California Forest and Range Experiment Station's fire research division, warned that the clamoring for more information would continue to grow "until an adequate research program can be carried through" (Buck 1947: 18).

Not waiting on the Forest Service and its research station to act, in 1945, the State passed legislation requiring the California Division of Forestry to regulate controlled burning of brush for livestock and to help stabilize soil and improve game habitat. With the State acting without the Forest Service, Buck still saw an "acute" need for an "adequate research program" to study the use of fire to improve fire protection and forest and range conditions; he gave such a study high priority within the research station. Buck admitted, however, that "considerable time may elapse before actual work can be undertaken" (Buck 1947: 18).

Project Skyfire

During this same postwar period, the Northern Rocky Mountain Station pursued a different form of fire prevention: weather modification. In late 1946, Vincent Schaefer, who worked for General Electric in New York, had demonstrated the use of dry ice to make snow. The prospect of seeding clouds to create rain or snow over a fire so impressed those attending the December 1947 meeting of the Western Forestry and Conservation Association that the group passed a resolution urging more research into Schaefer's ideas.

In early 1948, Harry Gisborne traveled to New York to investigate the possibilities of employing Schaefer's rain-making research in the Forest Service's fight against fire. When Gisborne explained the extent of lightning-caused fires in western forests, Schaefer reportedly suggested that dry ice might also be used to stop the formation of lightning. Charles Tebbe, director of the Northern Rocky Mountain Station, regarding that meeting, wrote that the idea of preventing lightning at its source was "really revolutionary" and had the potential to reduce or even eliminate what was believed to be the "one unpreventable cause of forest fires" (Schaefer 1949: n.p.).

In the summer of 1948, Schaefer and his family drove out to Priest River to work with Gisborne and Jack Barrows on what became known as Project Skyfire. While all three men were in Idaho, they discussed theories of mountain lightning storms and took time-lapsed movies. The following year, Gisborne conducted a preliminary, albeit primitive, test run to seed clouds from the air, during which he and others with him were tied by a rope in case they fell from the plane. In the process of dumping dry ice onto the one cumulous cloud they could find,

▲ Don Fuquay, Vincent Schaefer, and Jack Barrows (left to right) working on Project Skyfire, 1956. Forest Service photo.

someone stepped on or dislodged their oxygen hose, and the plane had to make a hasty decline before the researchers all passed out from lack of oxygen (Hardy 1977).

In 1952, the Project Skyfire researchers established a network of fire lookout stations to record data on thunderstorms. Irving Langmuir from General Electric visited Missoula to help organize a training school, where lookouts learned how to record when and where thunderstorms occurred, how long they lasted, and how much lightning they produced. The resulting records provided a rich database that researchers could compare with fire activity in the region (Arnold 1964).

After these initial investigations, in 1956 the project conducted cloud-seeding experiments in northern Arizona and in Montana. In 1957, Skyfire researchers used a network of cloud-seeding generators to shoot silver iodide crystals into passing cumulus clouds from the summit of the Bitterroot Mountains in the Lolo National Forest. They also adapted surplus military radar to detect, track, and analyze lightning storms in the region (Barrows and others 1958).

Project Skyfire, like most fire-related research in the Forest Service, sought to identify new technologies and more effective methods to prevent and suppress wildland fires. Suppressing the weather itself appeared to be one more way to control nature. Seeding clouds on one side of a mountain unfortunately meant less moisture reached the farms and ranches on the other side, which could help explain, at least in part, why the Forest Service, in the early 1960s, abandoned its cloud-seeding research as a weapon in its war against fire. After WWII, however, fire researchers had other technologies in its arsenal that also needed testing.

Aerial Fire Detection

Researchers in California tested the use of airplanes to detect forest fires as early as 1919, but as Roy Headley noted in his 1943 manuscript, from the Forest Service's perspective, air patrols could not substitute for trained individuals working in lookout stations. Besides, at that time, the Forest Service owned only one airplane (Headley 1943). After WWII, a surplus of military equipment, new technologies, and personnel trained in aerial reconnaissance raised the prospect again.

▲ Pilot and Forest Service ranger preparing for an air patrol over national forests in southern California, 1930. Photo courtesy of the Forest History Society, Durham, NC.

The Pacific Northwest Forest Experiment Station had been interested in fire detection and visibility of smoke at least as early as the 1930s, with several researchers investigating how well lookouts and others could detect fires from the air and from strategically placed fire lookout towers. In 1945, researchers employed airplanes on the Chelan National Forest in Washington, trying to identify "the best detection with a given amount of flying" (Morris 1946: 1). After they were in the air, observers tested a variety of techniques for improving visibility. They compared the use of a red filter, a polarized smoked-glass filter, and smoked goggles with observations by the naked eye. They found that detecting small smokes from the air depended on so many factors (e.g., visibility conditions and terrain) that even with airplanes flying directly over a fire, early detection could be difficult (Morris 1946). In the early 1960s, however, Stanley Hirsch at the Northern Forest Fire Laboratory in Missoula, MT, developed the use of even more advanced airborne technologies, including radar, infrared scanners, and heat sensors to detect fires, using WWII technologies to improve on the human eye (Committee on Fire Research 1966).

Aerial Fire Control

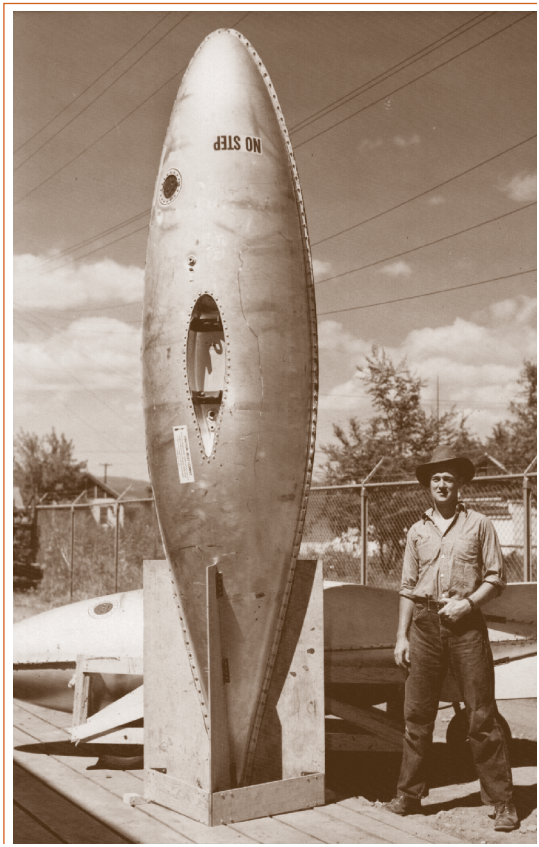
Foresters had long imagined that airplanes could be used not only for fire detection but also for delivering timely responses to a fire in the form of aerial water bombs. In accordance with the war metaphor, this was referred to as an "aerial attack." As early as 1919, the Forest Products Laboratory in Madison, WI, had been asked to determine whether bombs dropped from planes or dirigibles could help with fire suppression, while others tested the effectiveness of water and chemical bombs dropped from towers (Jemison 1950). In the early 1930s, Howard Flint, the Northern Region's fire chief, conducted at least one test when he "kicked a beer keg full of water out the door of an airplane flying over Felts Field, Spokane" (Hanson and Tebbe 1947: 2). The results apparently did not appear promising, but that did not stop others from water-bombing small fires at the airfield in Missoula, MT, and in California, where researchers generally agreed that, to be successful, bigger and more precise bombs and airplanes with greater carrying capacity were needed (Hanson and Tebbe 1947). After WWII, with the military looking for ways to stay relevant and engaged in a civilian economy, and with newly trained pilots returning home, Jack Barrows—recently discharged from the U.S. Army—wrote that the time had come to "give the bombing idea a thorough test" (Barrows 1946: 1).

Firefighting bombs were given their first thorough test in the spring of 1946 at Eglin Field in Florida to determine whether the equipment of the Army Air Forces could be recommissioned for use in fighting fires. For the Eglin tests, researchers retrofitted large bombers with "jettisonable" 55-gallon oil drums and various-sized gasoline tanks filled with water, and conducted 17 separate bombing missions, dropping a total of 44 bombs on fires from the air. Although

this project successfully demonstrated the ability to suppress small fires using water-filled bombs in fairly open, level terrain, researchers thought they needed to test the idea under conditions more representative of wildland fires. They also wanted to determine the best types of military equipment for this kind of firefighting.

In the summer of 1946, researchers moved their investigations to the Northern Region, with two objectives: (1) to determine how accurate they could be when dropping water-filled bombs on small forest fires in mountainous terrain and (2) to determine the effect of water-filled bombs on small fires burning in various fuel types. The Forest Service assumed responsibility for the fire management side of the research (i.e., fire foremen, fire guards, fire communications, and radio operators), and the U.S. Army assigned a unit commander to oversee the flight and ground crews. The military also oversaw the needed retrofits to the planes and bombs, with work conducted both in Missoula, MT, and at the Army Air Forces facilities in Great Falls, MT. The planes were to be stationed at the Missoula airfield.

Researchers selected a bombing test area on Montana's Lolo National Forest that included a variety of forest and slope conditions, and they installed a fire weather station and established field headquarters at the Lolo Hot Springs fire lookout, where they added a radio for ground-to-air communications. A shipping delay to the military team working in Great Falls unfortunately meant that no tests could be conducted that summer but, in 1947, researchers successfully conducted a series of bombings of both test fires and a few lightning-caused fires in Montana. Reports from the Army and the Forest Service documented the successes of those tests and made recommendations for additional research, particularly for testing the use of chemical retardants. Moreover, the military and the Forest Service agreed that the tests to date had been



▲ A 310-gallon tank bomb retrofitted with plywood fins to assist with delivery, Missoula, MT, 1946. Forest Service photo.

promising and that it was an opportunity for the U.S. Air Force to contribute during peacetime. By 1948, however, the military chose not to continue their involvement and, therefore, did not provide the necessary aircraft and personnel to continue the work.

Charles Tebbe, director of the Northern Rocky Mountain Forest and Range Experiment Station, reported in his annual report for 1948 that the military would no longer furnish aircraft or personnel to continue "this promising work," and would, in the future, require an agreement between the Air Force and the Forest Service. Again relying on military terminology, he insisted that the Forest Service needed more than infantry methods alone to effectively fight fire. Even with an early ground attack, he noted, some fires could not be controlled using hand-tools alone. "More fire power is needed. In forest fire fighting, aerial bombing may provide some of the needed fire power" (Tebbe 1948: 59). Without planes and pilots of its own, however, the Forest Service had to postpone this research. Instead, researchers worked on planning and other activities that might contribute to more effective aerial control in the long run.

Operation Firestop

War served not only as a useful metaphor for fighting fires but also as a motivator for additional fire research. Firebombing had been used as an effective and terrifying weapon during WWII. As the "hot war" in Europe and the Pacific ended and erupted instead into the Cold War, administrators and researchers in both the military and the Forest Service asked themselves what would happen if weapons the American military had employed in WWII were used against the U.S., particularly in the Nation's highly flammable forests. What if the Russians or others employed bombs with even greater fire power than the Japanese balloon bombs? As more concern was raised about this possibility, firefighting became viewed as equal to civil defense.

Operation Firestop became an opportunity to use fire research to meet two objectives: civil defense against fire used as a weapon, and the "reduction of loss from large wild-land fires through the development of new or unconventional fire control measures" (Arnold 1955: 1). The mission for the 1-year research project, which was conducted from 1953 to 1954 at Camp Pendleton in southern California, was to "develop ideas for improving fire suppression methods and equipment and to study fuels and fire behavior" (Burke n.d.).

Operation Firestop assembled a unique partnership: the U.S. Marines, Forest Service, California Division of Forestry, U.S. Weather Bureau, Office of Civil Defense, Los Angeles city and county fire departments, and University of California (forestry and engineering). Private industries (e.g., chemical, aircraft, oil, and communications) contributed equipment and personnel, and the marines provided offices and barracks for the researchers, and also access to thousands of

acres of wildlands managed by the military for their tests (Arnold 1955, Burke n.d.). The Forest Service used this opportunity to pursue its own outstanding fire research questions, while contributing to the overall project. For example:

- Why do fires burn as they do?
- How can researchers predict fire spread and behavior?
- What conditions set the stage for blow-ups?
- What chemicals are available to retard or stop wildland fires?
- How can fires be attacked quickly in inaccessible places? (Arnold 1955)

Jack Burke, who worked as the operation's officer for the project, recalled in his 1972 overview of Firestop that the actual research (studying the use of chemical retardants, helicopters, airplanes, and weather and atmospheric monitoring techniques) did not result in any "earthshaking" results. Still, he reported, it proved to be a "great catalyst," which set the stage for the fire research that followed (Burke n.d.), and, as had been demonstrated in Oregon in 1945, it illustrated the idea that fighting fire could be just like war; indeed, it could be one and the same thing.

Fire Danger Rating and Fire Behavior

Much like an army, forest fire control organizations nationwide had tested and implemented many of the principles of fire control planning developed by the Northern Rocky Mountain Station in the 1930s under Lloyd Hornby. Land managers and researchers alike, however, believed that the Forest Service needed to confront "new values" in protecting the Nation's forested lands, as it faced "changed fuel types, a detection system beginning to be antiquated by new roads and by airplanes, loss of CCC, WPA [Works Progress Administration], and military reserve manpower, the development of inter-agency fire control, and other features" (Tebbe 1946: 25).

In 1946, the Northern Rocky Mountain Forest and Range Experiment Station had hired Jack Barrows to develop the next generation of fire control planning. Building on an agencywide push to better analyze past fire data, Barrows initiated his research by compiling 25,000 punch-carded fire reports from 1931 to 1946. He also planned to integrate data from Indian reservations and State and national park fires into his survey to ensure that he could produce an accurate regional picture of the "fire problem." As part of Barrows' analysis, he also sought to determine if specific fuel types might be needed for fire danger ratings to be accurate and useful (Tebbe 1946).

Even while Barrows was working on the aerial bombing project, he still managed to continue his research into fire control planning. He focused on analysis of past fire records and also fuel type classification and mapping procedures. By

1948, the experiment station reported progress in understanding fire detection, behavior, and control in the northern Rocky Mountains. The report stated that the new understanding was leading to the development of principles and techniques of fire control engineering and, ultimately, improved fire control (Tebbe 1948).

It took 5 years, but in 1951, Barrows published his landmark study *Fire Behavior in Northern Rocky Mountain Forests*. The goal of his book was to provide managers and firefighters with an understanding of fire behavior to ensure good decisions in the field, leading to safe and effective suppression of all fires. The book included four areas of research at the Northern Rocky Mountain Station—fire danger rating, fuel classification, fire weather, and fire history—as captured in his analysis of thousands of reports of actual fires. Barrows noted that he drew on existing research to better understand how fires start and spread under various conditions. Additional research on "fuel classification, burning index variations, topographic influences, and rate-of-spread estimates" was, according to Barrows, reported for the first time in this study (Barrows 1951: iv).

During this same postwar period, other research stations sought to analyze fire and fire-weather data from their States and regions to better understand and prepare for combating wildland fires. In 1946, for example, the Central States Station published a study of fires in Indiana and initiated a study of fires in Missouri. That same year, the Lake States Station planned to conduct "a thorough-going analysis of 10 years' accumulation of fire and fire-weather data" (Demmon 1946: 7) to better understand hazards (i.e., fuel conditions) and inflammability (i.e., burning conditions). Lake States researchers also identified an "urgent need" for a study of risk, that is, the chances of a fire starting, "to determine its importance as a factor of fire danger and how it can best be evaluated" (Demmon 1946: 7).

Fire Effects

Not all research after the war focused solely on the application of military technology and solutions, although many researchers continued their battle against long-held beliefs about fire, particularly in California and the American South. Research stations continued their evaluation of fire effects, attempting to quantify losses experienced by a variety of values (i.e., not just timber) to better defend the costs of fire protection, but, in some instances, they initiated more research designed to investigate any positive benefits of fire, particularly any cost savings they might be able to document through the use of prescribed fire.

Starting in the late 1940s, California initiated a study of fire damage in southern California and then adapted those techniques to examine the effects of fire in northern California. This work led to the development in 1952 of a model to estimate loss of timber, a common marker of economic loss. At the same time,

however, researchers also sought to quantify the loss of range and recreation resources, and measure the effects of fire on watersheds (i.e., runoff and erosion).

The 1948 floods in the Columbia River Basin, although not caused by recent fires in the area, sparked concerns about the role fire could play in "altering the ability of watersheds to retard the run-off" (Tebbe 1948: 55) in the Pacific Northwest. As in California, researchers focused their attention not only on how to quantify timber losses from fire but also on how high-elevation fires could become "watershed fires." One report in particular, prepared for flood control along the Missouri River Basin, emphasized the highly variable conditions in the high mountain watersheds of the Missouri. The Northern Rocky Mountain Station report identified a need for greater flexibility in fire control to provide adequate resources during critical burning periods, while cutting costs during "easy periods" (Tebbe 1948: 55).

Watershed protection also motivated research in the Central States Forest Experiment Station, which sought to counter the culture of "burning the woods" entrenched in rural Missouri. In late 1950, researchers initiated a "modest fire research project" to develop better fire prevention and control programs to address the large number of man-caused fires. The director of the station wrote, "These incendiary fires point up a conflict in land use that is deep-seated in the social and economic background of the people…practiced since the first settlers came to Missouri" (Mitchell 1950: 32). Researchers hoped that by increasing understanding of fire danger and fire effects, they might be able to contribute to more effective fire prevention and control.

The Forest Service also continued its war against "burning the woods" in the Southeast, trying to counter that tradition with hard data on the effects of fire. These long-term research projects led to improved understanding of the effects of fire over time. For example, in 1947, the Southern Forest Experiment Station, in cooperation with the national forests in Mississippi, conducted a field survey of prescribed burning of 17,000 acres of longleaf-slash pine forests. They found that controlled fire produced a net benefit of about 9 cents per acre, when factoring in costs associated with disease control, wildfire damage and control, and seedbed preparation (Connaughton 1947).

By 1950, the Southeastern Forest Experiment Station had also accepted that some "prescribed burning, if properly done," could help reduce fire hazard, control hardwoods, prepare seedbeds, and improve forage and wildlife habitat. To use fire properly, however, foresters needed a better understanding of which conditions allowed for safe burning with a minimum of damage. Thus, one of the Southeastern Station's major research initiatives investigated fire intensity, fire behavior, and the effects of fire on living vegetation. The experiment station also sought to standardize how damage to a forest was assessed in regard to timber and reproduction. In addition, they hoped to quantify damage to other

resources. The station reported that "Almost nothing is known about the effects of fire on soil, water, wildlife, recreation, and other forest values" (USDA Forest Service, Southeastern Forest Experiment Station 1950: 4).

Defeating Enemies on All Fronts

During the post-WWII period, the Forest Service was optimistic, thanks in part to the enthusiastic vision laid out by Vannevar Bush, about the future of research in the United States. Moreover, the Nation itself experienced a general sense of well-being after a successful conclusion to the war, based in part on the advancement of science. Agency researchers, as expressed in 1945 by Melvin Bradner, envisioned a world in which the Federal Government invested in research, including research on fire, to ensure the sustainability of the Nation's forested lands and the long-term prosperity of the country. That vision did not come to fruition as rapidly as researchers hoped, however.

Charles Tebbe, Bradner's replacement at the Northern Rocky Mountain Station, wrote in his 1947 annual report that fire research funds and personnel were "still out of balance with both the size of the fire problem and the distribution of research on other phases of forestry. Very little improvement has been made in the situation as reported a year ago," he admitted (Tebbe 1947: 38). Tebbe wrote again the next year that research funding was out of balance with needs and fire research had been restricted to a handful of small-scale projects (Tebbe 1948). If fires were to be understood and controlled, Tebbe's reports suggested, the Nation needed to focus its attention and resources on the war on fire being fought every year on American wildlands and to invest more in research to make this effort more effective. Otherwise, he seemed to warn, the war could be lost.

▲ Fire burning near Wenona, NC, 1958. Photo courtesy of the Forest History Society, Durham, NC.

Chapter 6

Age of Research: Forest Service Fire Laboratories

New knowledge is the foundation for the progress of our civilization. Applying this axiom to our own field, we recognize that future progress in the protection and management of western forests rests heavily upon research... In the era already referred to as the space age, we too must make our mark.

—J.S. Barrows, 1958

On August 5, 1949, 15 smokejumpers parachuted into an area near Helena, MT, to fight what would become known as the Mann Gulch Fire. High winds, hot and dry conditions, and steep terrain helped create a fire that "blew up," covering thousands of acres and killing 12 of the smokejumpers and a local fire guard who had joined them on the ground. Both the board of review that reported on the tragedy and Regional Forester P.D. Hanson, who prepared an overview of the fire, agreed: the Mann Gulch Fire provided "evidence of a need for developing still further a better understanding of indictors of fire behavior to the degree this can be done … so that the objectives of early fire control can be met, and the chances for a repetition of such losses of human life reduced to the minimum possible" (Hanson 1949: 7).

On August 10, 1949, while the Mann Gulch Fire still burned, Jack Barrows began to prepare a summary of conditions at the site on the day the fire started to assist the board of review with its work. Harry Gisborne also joined in the study, realizing that to understand fire behavior similar to that at Mann Gulch, he would need much more information about this fire and similar ones. Although he personally

▲ Responders remove the bodies of firefighters from the Mann Gulch Fire near Helena, MT, 1949. Forest Service photo.

feared that the Mann Gulch Fire might have to be explained as "an inexplicable Act of God," Gisborne vowed "to keep working on the case … [and] to make special observations on future fires which may help" (Gisborne 1949: 1). As part of his long-term plan to better understand fires such as the one at Mann Gulch, Gisborne asked that the head of fire control instruct all field personnel "to make much more detailed observations and reports on all big blow-ups or explosions in all regions" to ensure they had more comprehensive data to analyze the next time they faced such a big and unpredictable fire (Gisborne 1949).

Doctors had warned Gisborne that he suffered from a dangerous heart condition and advised him to avoid strenuous activities. Gisborne planned to visit the site of the Mann Gulch Fire in November with District Ranger Robert Jansson, who had been at the scene of the fire when it occurred and had helped with the recovery of victims. Because of Gisborne's health, the two men planned to drive around the site of the fire in a Jeep. Conditions on the ground unfortunately limited the Jeep's mobility, so the two proceeded on foot so that Gisborne could take photographs and gather data. On their way back to the Jeep, Gisborne sat down to rest and to reflect on the day, when he suffered a heart attack and died at the scene.

With Gisborne's death, Jack Barrows assumed responsibility for fire research at the Northern Rocky Mountain Station, and one of his highest priorities was to pursue the recommendation made after the Mann Gulch Fire: to better understand fire behavior. To do that, he insisted, required laboratory conditions in which variables (e.g., wind, terrain, fuels, and moisture) could be controlled and

their influences on fire behavior measured. By 1950, with the tragedy at Mann Gulch still fresh in everyone's minds and questions still lingering about the fire's behavior, the station prepared its first proposal to construct a dedicated fire research laboratory, to be built in Missoula, MT. It would take Barrows and others a decade to get approval and funds to make the plan become a reality.

This laboratory, however, was not the first proposed fire research facility—in the region or in the Nation. With so many variables affecting fire behavior and control, early U.S. Department of Agriculture, Forest Service investigators had desired access to research facilities and dedicated field study areas to make advances in fire control, their primary concern. For example, as early as 1918, Priest River Director Julius Larsen wanted to conduct his research in a more controlled environment, but he was unable to find suitable facilities to use at the time. In 1931, Gisborne expressed a similar need, describing an ideal research laboratory that would include a 10- or 12-foot diameter wind tunnel and the ability to test the influence of factors including fuel moisture, slope, temperature, and humidity (Hardy 1977).

While Gisborne argued for a state-of-the-science facility in which to conduct controlled fire research, in 1930 the Michigan Department of Conservation and the Lake States Experiment Station established the Michigan Forest Fire Experiment Station, and in 1931 the Shasta Experimental Fire Forest was established in California. Both functioned primarily as field laboratories rather than controlled experimental facilities, however, focusing on field testing and improving fire control methods and equipment.

In 1954, the Northern Rocky Mountain Forest and Range Experiment Station, headquartered in Missoula, MT, merged with the Intermountain Forest and Range Experiment Station in Ogden, UT. The newly consolidated station organized what it referred to as a "forest fire laboratory" in the Federal building in Missoula, adding new staff through cooperative arrangements. For example, the station added two new meteorologists to its fire research team: Donald Fuquay, who worked for the Munitalp Foundation (which helped support Project Skyfire), and DeVer Colson, who worked for the Washington, DC, office of the Weather Bureau, but joined the Intermountain Station during the fire season. Although the research office had moved to Missoula, field research continued at what was then known as the Priest River Experimental Forest. This work included fire danger rating and ongoing lightning research (Bailey 1955).

The new Missoula-based fire research group developed makeshift facilities "as a stopgap measure," probably retrofitting the space Gisborne had used for research in the basement of the Federal building. Their long-term goal was to develop both the facilities and staff needed to solve "important forest fire problems," which required "the most earnest scientific research efforts" (USDA Forest Service, Intermountain Forest and Range Experiment Station 1957: 4).

Although the records suggest that the initial push to establish a standalone fire research facility in the late 1950s originated in Missoula, the legislation submitted by the Montana delegation included requests for three regional facilities. These requests would have made political sense, helping secure necessary congressional support, but it also made research sense, considering the fire needs of three very diverse areas—the Rocky Mountain West, the Southeast, and California—while also addressing fundamental research questions that would benefit fire researchers and managers nationwide.

In spite of Barrows' leadership and researchers' conviction that more should be invested in fire behavior research, nothing much changed until another incentive beeped across the sky in 1957. The Soviets' launch of Sputnik was seen by many Americans as a warning that U.S. science and technology might be lagging behind that of the Soviet Union. The event alarmed policymakers and the public alike, and freed up new sources of funding for science, education, and research in ways that could not have been imagined a decade earlier—even by Vannevar Bush.

The Northern Forest Fire Laboratory

On March 1, 1957, the Intermountain Forest and Range Experiment Station prepared a detailed white paper containing a plan for a standalone forest fire research laboratory in Missoula, MT. Written to advance their case with legislators, the proposal stressed many of the same arguments made by Franklin B. Hough and others almost a century before: the Nation's forests represented the wealth of the Nation and, therefore, required "better protection from fire to meet the increasing demands of an expanding population" (USDA Forest Service, Intermountain Forest and Range Experiment Station 1957: 1). The white paper also argued that progress in forest fire control depended primarily on research (USDA Forest Service, Intermountain Forest and Range Experiment Station 1957).

The tragedy of the Mann Gulch fire appears to have been one of the major motivations for pursuing a dedicated fire research facility in Missoula. That the land proposed for building the Montana laboratory adjoined the smokejumper center west of town symbolically helped make their case. The background information compiled for legislators, however, did not emphasize firefighter safety but rather the argument that had regularly been made in support of fire research: to improve fire prevention and control.

The key to achieving these goals, according to the proposal, centered on six pressing needs:

1. Controlling and preventing lightning-caused fires.
2. Developing methods for preventing man-caused fires.

3. Improving systems for reducing fire hazards.
4. Discovering more accurate means for measuring, evaluating, and predicting variations in fire danger and fire behavior.
5. Investigating fire suppression methods with a "knock-out" punch for use in rough, heavily timbered mountain country.
6. Developing the use of controlled fire to protect managed forests from wildfire.

"Each of these problems requires aggressive forest fire research," the proposal stated, and each, therefore, "requires the services of a well-equipped and staffed forest fire laboratory." Moreover, the fundamental research conducted in such a facility would not only contribute to fire control in the Intermountain West, but it would also "provide basic information of value to all forest regions" (USDA Forest Service, Intermountain Forest and Range Experiment Station 1957: 2).

Early in the summer of 1957, with the proposal outlining the benefits of a dedicated fire research laboratory in hand, Jack Barrows visited Montana's delegation in Washington, DC. His meetings must have gone well because in July, Montana Senators Mike Mansfield and James Murray introduced Senate Bill 2596, to "authorize the Secretary of Agriculture to conduct a comprehensive program of fundamental research to improve the prevention, detection, and control of forest fires…. [and to] establish, equip, and maintain three regional research laboratories" (Mansfield 1957: 2). Montana Representative Lee Metcalf introduced a companion bill in the House of Representatives.

As he promoted the project to his fellow Senators, Mansfield picked up on the longstanding belief that fire prevention and control were key to the practice of forestry. He argued that the proposed forest fire laboratory would assist in "the development of a strong scientific research effort aimed at solving critical problems in the protection and management of America's forest resources." Moreover, an even stronger program in forest fire research would "more than pay for itself in savings in fire control costs and reduction of damage to essential natural resources," he told his budget-conscious colleagues. "The prevention of a single disastrous forest fire will pay for the cost of this project," he argued and, as significantly, will bring much-needed economic development to a region of the country that badly needed it (Mansfield 1958: 6).

It was not just sustainable forests, cost savings, and jobs, however, that Senator Mansfield emphasized. He had another argument that he must have known would be just as compelling, if not more so: Project Skyfire. As Mansfield reminded his fellow legislators, many of them had expressed concerns not only about nuclear weapons but also about the potential effects of weather control, particularly if used as a weapon. Although the Forest Service had invested in cloud seeding research as a method of fire prevention and control, the technology the agency tested might have secondary benefits in a civil defense capacity,

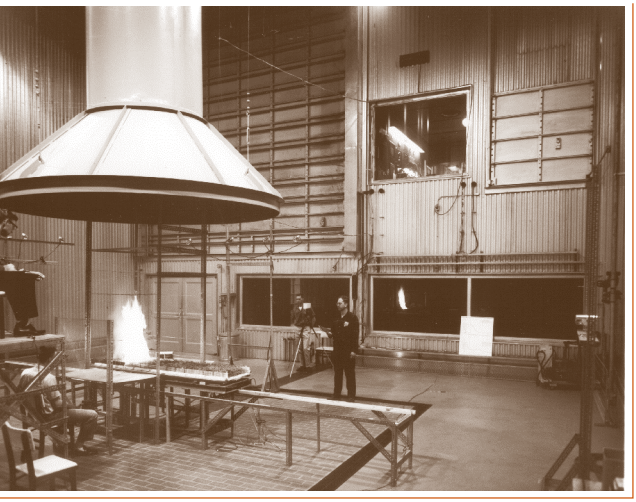
he suggested. Indeed, it potentially could be used as a weapon to destroy crops or even a Nation's entire economy. Mansfield explained that Project Skyfire was already producing promising results, and the research was being operated "on a shoestring." With more support, the Senator believed that the project had the potential to not only make great contributions to forest fire protection but also, he implied, to national security as well (Mansfield 1958).

With the Eisenhower administration focused on budget cutting and balanced budgets in the post-World War II (WWII) era, it could be argued that a fire research facility, on its own merits, may not have been enough to garner support, even if it did save the Nation money in fire suppression costs and timber loss over time. At the peak of the Cold War, however, Americans and their representatives had additional concerns, and the Russian launch of Sputnik in October 1957 may have helped seal the deal. In the spring of 1958, the Senate passed an appropriations bill that included $900,000 to construct a forest fire research laboratory in Missoula, plus an additional $100,000 for forest fire research in the new facility.

The Atomic Age of Fire Research

In 1959, Jack Barrows, now chief of forest fire research at the Intermountain Forest and Range Experiment Station, described the new Northern Forest Fire Laboratory to be completed the following year in Missoula. With a two-fold mission to perform research on critical fire problems of national interest and to investigate fire problems of the Intermountain West and Alaska, the laboratory opened "a new era for forest fire research," he wrote. With state-of-the-art facilities, the new laboratory could "dig much deeper into the mysteries of fire behavior" and develop improved methods for "proper protection and management of the increasingly valuable forest resources" (Barrows 1959: 58). Barrows also highlighted the facility's "viewing room," overlooking the combustion lab to be used in training and observing fire-behavior demonstrations. The new Northern Forest Fire Laboratory, Barrows predicted, would help researchers take "the mystery out of fire, step-by-step, until there would no longer be 'wild fires'" (Barrows 1959: 59). It would, he predicted, bring fire research into the atomic age. As if to follow

▼ The burn chamber in the Northern Forest Fire Laboratory in Missoula, MT, 1967, helped bring Forest Service fire research into the age of research. Forest Service photo.



up with that prediction, Barrows staffed the new Missoula fire research facility with two engineers, a physicist, and a technician from the recently cancelled atomic-powered jet engine program in Idaho Falls. The new laboratory would indeed bring fire research into the new research age.

After the Northern Forest Fire Laboratory was completed in late 1960, new personnel hired in 1961, and the equipment installed and calibrated, one of the new lab's first research projects was not fire behavior but testing of chemical fire retardants, an extension of work conducted earlier in southern California as part of Operation Firestop. Researchers came to Missoula, MT, from California, including Jim Davis from Riverside and Frank Hamp from the Los Angeles Fire Department. They joined Richard Rothermel, an engineer; Hal Anderson, a physicist; and C.E. "Mike" Hardy, a forester, who had worked on the fire danger rating system after Gisborne's death. The results were published in 1962 (Hardy and others 1962), and led to additional retardant research and also the testing and development of aircraft tank and gating systems for retardant delivery. This short research assignment delayed Rothermel and Anderson's fire behavior research, but it gave them time to become more thoroughly familiar with the new facilities, calibrate the equipment more completely, and develop generic fuel beds for testing.

Fire Behavior and Fire Danger Rating

Richard Rothermel and Hal Anderson's highest priority was still fire behavior research and the mechanisms of fire spread, building on the early work of Wallace Fons and George Byram in California and Georgia. The two Montana researchers conducted a series of experiments testing the effect of moisture and wind on generic fuel beds; they also tested the effect of wind on fires' rate of spread. In 1964, the two researchers presented their results at an international combustion conference in Cambridge, England, where they documented the measurable effects of certain environmental conditions on the characteristics of nearly 200 fires burned under controlled humidity, air velocity, and fuel moisture. "A general equation that predicts rate of spread in any wood fuel may be developed by incorporating fuel particle size and fuel bed compactness with fuel moisture content and air velocity," they predicted (Anderson and Rothermel 1965: 1009). (For a discussion of the early years at the Northern Forest Fire Laboratory, see Steen [2005]).

This early research did indeed lay the groundwork for a number of significant contributions to understanding and predicting fire behavior. Most significant was the Rothermel surface fire spread model, published in 1972, which was initially developed as part of an effort, initiated by Jack Barrows, at the time, director of the Division of Forest Fire and Atmospheric Sciences Research in Washington, DC, to develop a national fire danger rating system. Researchers

at the Riverside Fire Laboratory and in Ft. Collins, CO, also collaborated. The resulting national system proved to be key for assessing the risk of fire nationwide; it continues to be used in its updated form to this day.

Fuel models were also an important part of the application of the fire spread model for fire danger and fire behavior calculations, and more were soon developed (e.g., Anderson 1982, Deeming and Brown 1975, and Rothermel 1972). Easy-to-use graphical representations, or "nomograms," to help predict fire behavior under different conditions were also developed (Albini 1976) in Missoula. With the availability of small hand-held calculators in the mid-1970s, researchers developed programs to run the Rothermel model and predict fire behavior during actual fires (Burgan 1979), and Hal Anderson led an early effort with Ronald Susott and Charles Philpot to better understand fuel chemistry (Committee on Fire Research 1966). Although the study of fire science and behavior has evolved over the decades, most fire modeling systems still build on this early work initiated at the Northern Forest Fire Laboratory (e.g., see Andrews 2014 and Finney 1998).

▲ Researcher Patricia (Pat) Andrews demonstrating Frank Albini's "nomograms" at the Tall Timbers Fire Ecology Conference in Missoula, MT, 1974. Forest Service photo.

The Southern Forest Fire Laboratory

In 1957, the Governor of Georgia reportedly overheard the director of the Georgia Forestry Commission lobbying a State senator for support of a southern fire research facility and, on the spot, he offered to fund it and provide the necessary land in Macon, GA. The Forest Service's Southeastern Forest Experiment Station in Asheville, NC, equipped and staffed the new facility, which was completed in 1959, making it the Nation's first facility solely dedicated to fire research (USDA Forest Service, Southeastern Forest Experiment Station 1993).

Joseph F. Pechanec, director of the Southeastern Station, admitted in 1960 that, even though research in all areas of forest protection and management had made great advances in the region over the previous 10 or 15 years, more needed to be known to better understand the conditions "conducive to blowup fires." Research, he wrote, was not developing fast enough. "We must learn how to move faster, even though ideas, imagination, and essential solutions do not lend themselves to production-line procedures" (Pechanec 1960). He

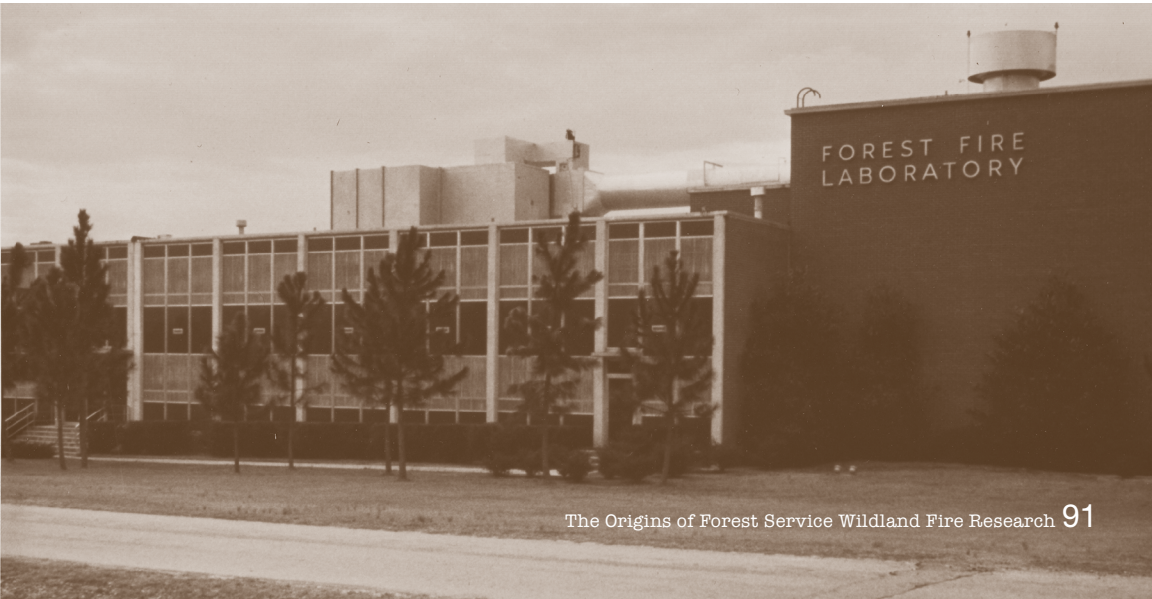
hoped that the new research facility in Macon, with its modern laboratories and equipment, would help researchers address the "serious gaps" still outstanding in fire-related research (Pechanec 1960).

Fire Prevention

In the Southeast, one pressing question in particular still needed to be resolved: how effective was prescribed burning as a tool for fire prevention and for control of big fires, and what effects did prescribed fire have on forest sustainability? Although most of the testing of prescribed burns took place in the field, one of the first research projects in the Southern Forest Fire Laboratory was the work of a doctoral student to determine how plants of different species and sizes responded to fire. Researchers at the new Southern Forest Fire Laboratory designed a propane heater to control the amount of heat each specimen was exposed to, and tests were made using several species of pine and hardwood (USDA Forest Service, Southeastern Forest Experiment Station 1993). Researchers hoped to use the results to better understand the effects of fire on tree stems (USDA Forest Service, Southeastern Forest Experiment Station 1962).

Robert Cooper at the Macon lab evaluated the effectiveness of prescribed burning as a hazard reduction tool during a 4-year period. He wrote that his review "lends support to the supposition that the use of prescribed fire in the coastal plain of the Southeast has substantially reduced and will continue to reduce the acreage burned over by wildfires" (Cooper 1962: 146). Although Cooper (1962: 146) was convinced that "the benefits of prescribed burning will exceed the costs," he called for additional research of prescribed fire under a variety of environmental factors (e.g., weather, terrain). Like the Northern Forest Fire Laboratory's early contributions to fire behavior research, the Southern Forest Fire Laboratory contributed early on to a better understanding of the benefits of prescribed fire.

▼ The Southern Forest Fire Laboratory in Macon, GA. Forest Service photo.



In 1963, the Southeastern Station acknowledged that "Prescribed fires designed to cut down the amount of forest fuels definitely reduce the damage from wildfires." Indeed, the station now had evidence that "a carefully planned prescribed fire program can reduce the acreage loss from wildfire by 80 percent" (USDA Forest Service, Southeastern Forest Experiment Station 1963: 22). This breakthrough was significant not only for fire research in the American South but also for landowners who chose, against earlier Forest Service policy, to "burn the woods" regularly regardless of agency warnings. It also led to early research into smoke management in the South. The exact date is unclear, but the Southern Forest Fire Laboratory closed sometime in the mid-1980s (1985 or 1986), when the Forest Service withdrew its share of support. Some of the Southern Forest Fire Laboratory's research was continued through the Southern Research Station and other work was pursued by the Georgia Forestry Commission, but much of the lab's research records unfortunately were lost (USDA Forest Service, Southeastern Forest Experiment Station 1993; Wade 2015).

The Forest Fire Laboratory at Riverside

Much like the origins of the Northern Forest Fire Laboratory, the fire research laboratory in southern California originated in part after a tragic loss of life. Having experienced a series of bad fire years followed by devastating floods, in 1955, the California Division of Forestry, the Forest Service, the University of California, and private industry organized the California-Nevada Forest Fire Research Council to promote fire research and develop improved methods of fire suppression. The following fire year was even worse. In 1956, the Inaja Fire on the Cleveland National Forest in San Diego County resulted in the deaths of 11 firefighters, most of whom were prison inmates on work furloughs. The evaluation after the fire noted an "extreme rate of spread and an explosive rate of combustion" (Countryman and others 1956: 2).

The "men gave their lives in defense of this country," Forest Service Chief Richard McArdle said about the deaths on the Inaja Fire, because, he said, "without the strength of our forests, water, and other natural resources, this Nation would not be a leader in the free world today" (USDA Forest Service 1957). This tragic loss of life led to a task force assigned to investigate the causes and, much like the review conducted after the Mann Gulch Fire, the official review identified the need for "better knowledge of fire behavior ... as an essential means of preventing future fire tragedies" and called for "even more comprehensive and penetrating" research to develop better methods of fighting fires (e.g., aerial attacks with water and chemicals) that have less risk to human lives (USDA Forest Service 1957: 5).

The California lab proposal had its own political champions. In October 1957, Congressman Clair Engle, chair of the House Committee on Interior and Insular Affairs, held a 2-day hearing in Los Angeles on fire control. Convened to "learn why southern California is plagued by so many fires and why so many of them get to be so large," the congressman hoped to assure residents that "every possible means is being used to keep forest and brush fires from starting and destroying so much of your valuable local watersheds" (U.S. Congress 1958: 27). In May 1959, Paul Anderson, Chairman of the Riverside County Board of Supervisors, traveled to Washington, DC, to testify at a Senate subcommittee on the need for a "'cooperative Forest Fire Research Center'" and the $2 million to construct it (Wilson and Davis 1988: 9).

California already had an active fire research program but, based on testimony at the Engle hearings, the State had not settled on the best way to prevent fires (e.g., the "light burning" controversy flared up during the hearings), and experts still seemed unsure how best to fight "mass" fires. The State had conducted some of the earliest research in fire behavior under Coert DuBois and his colleagues, and early on had established fire research facilities and field laboratories. From 1929 to 1956, for example, the Shasta Experimental Forest in northern California had served as a study area with practically "all types of forest vegetation" that could be used for forest fire research, particularly testing and demonstrating firefighting techniques. Indeed, the Shasta headquarters was known as the Pilgrim Creek Fire Laboratory. The University of California's Engineering Field Station in Contra Costa County, known at the time as the Richmond Fire Laboratory, also housed laboratory space where Forest Service researchers in northern California could conduct fire physics research and other studies related to wildland fire, such as chemical fire retardants, convection columns of fires, rates of combustion of fuel beds, and fuel moisture (USDA Forest Service 1958).

What was then known as the California Forest and Range Experiment Station had been based at the University of California campus in Berkeley. In 1959, the station moved to a new building across the street from the campus, which also included laboratory facilities (California Forest and Range Experiment Station 1958). Although some fire research continued in Berkeley, with the completion of the Riverside Forest Fire Laboratory in 1963, the new southern California facility became the "home base" for most of the station's fire research, particularly problems associated with controlling large or "mass" fires (USDA Forest Service, Pacific Southwest Forest and Range Experiment Station 1963).

▲ The Riverside Forest Fire Laboratory, part of the Pacific Southwest Forest and Range Experiment Station in Riverside, CA, n.d. Forest Service photo.

Fire Control

In the early 1960s, the post-WWII fire research in the Forest Service took on the battles of the Cold War, particularly in California. In 1962, for example, the Office of Civil Defense worked with the Forest Service and a private contractor (United Research Services) to develop a mathematical model of mass fire spread in the event of an atomic bomb attack near an urban area. What was now known as the Pacific Southwest Forest and Range Experiment Station (to include Hawaii) was tasked to isolate and identify the significant parameters of fire spread and intensity, suggest methods of measuring these parameters, and collect data to be used in testing the model; the contractor was to develop the model based on the collected data. The researchers, led by Craig Chandler, submitted their final report, "Prediction of Fire Spread Following Nuclear Explosions," in 1963 (Chandler and others 1963). The following year, Clive Countryman submitted his first interim report, also sponsored by the Office of Civil Defense in 1962, on the interaction of mass fire and its environment. "Mass Fires and Fire Behavior" described the test fires the Pacific Southwest Station conducted and initial research results from 1962 to 1964 (Countryman 1964).

▲ The Riverside Forest Fire Laboratory in Riverside, CA, n.d. Forest Service photo.

Much like Skyfire in Montana, this research provided a foundation for the new Riverside facility, with the lab's mission as described by its brochure as "Stopping the Big Ones through Fire Research" (USDA Forest Service n.d.). Most fire research conducted by the Forest Service in California moved to the new facility, which was dedicated in 1963, and it was only natural that Riverside, in the "heart of the 'big fire' country," as it was described (USDA Forest Service n.d. [ca. 1965]: 2), would take on some of the Nation's biggest fire challenges, including a potential nuclear attack.

Project Flambeau, a study of mass fire behavior, was the station's next big challenge. Very large forest fires had shown behavior similar to those caused by incendiary bombing in WWII. Believing mass fires to be one of the most pressing dangers in the event of a nuclear attack, the Riverside lab sought to "gain an understanding of the phenomena associated with mass fires" and develop a "workable theory concerning mass fire behavior" (USDA Forest Service n.d. [ca. 1965]: 9). This research, also funded by the Office of Civil Defense, investigated the effects an atomic blast might have on rural and urban environments, and

conducted test fires representing fires in a residential neighborhood. Although the research was designed to aid in the planning for civil defense, it also assisted forest land managers and fire control agencies in urban and suburban areas with preparing for large fires, regardless of their original source.

Questions of civil defense during this period also led to investigations of how best to respond to a large fire; the economics of fighting large fires posed another problem. At what point, researchers asked, does "the cost from over-loading personnel" override "the values that might be lost from a fire in certain areas" (USDA Forest Service n.d. [ca. 1965]: 10). Researchers in Riverside sought to better quantify these kinds of fire control decisions, and also computerize fire control tactics to improve decisionmaking (USDA Forest Service n.d. [ca. 1965]).

Fire Management

In the fall of 1970, the question was no longer just of general research interest. In less than a 2-week period in southern California, fires burned more than 500,000 acres and more than 700 homes. Sixteen individuals lost their lives. Developing fire control systems and tactics for "stopping the big ones" had become a pressing national need. In 1971, Congress appropriated $900,000 "to strengthen fire command and control systems research" at both Riverside, CA, and at Fort Collins, CO, and recommended that Riverside "concentrate on developing advanced airborne fire intelligence methods for detecting and mapping fires, including real time telemetry of information and display at fire command control centers" (Chase 1980: n.p.). What the Forest Service and other fire agencies needed was a centralized, coordinated system to respond to big fires in real time, and for that the agency also looked to research.

Working with other southern California fire agencies, including the California Department of Forestry, the California Office of Emergency Services, and the fire departments of Los Angeles, Santa Barbara, and Ventura counties and the city of Los Angeles, Forest Service researchers developed and tested a comprehensive fire suppression coordination system, known as FIRESCOPE (Firefighting Resources of Southern California Organized for Potential Emergencies). Using a systems approach to fire management, the goal of FIRESCOPE was to develop methods to coordinate interagency responses to fire and allocate suppression resources, particularly in multiple fire situations or in suburban-wildland areas where emergency responses can become difficult to coordinate (Chase 1980). The resulting Incident Command System is used to this day to make informed firefighting decisions, ensure continuity in management of long-duration fires, and coordinate a variety of other different emergency responses throughout the country. Fire research also continues at the Riverside facility.

Lake States Fire Research

At a 1961 forest fire research conference held in Green Bay, WI, George Jemison, who was by then the deputy assistant chief in charge of Forest Service research, outlined a vision for a truly national program of forest fire research. Such a program, he emphasized, should at minimum address four basic fire research needs: a better understanding of fire behavior; prevention of human-caused fires (i.e., "research on people"); prevention of lightning-caused fires (i.e., Project Skyfire); and development of chemical fire retardants and suppressants. It would also focus on a better understanding of the principles that can be used to develop newer and/or more efficient approaches to suppressing fires. Such a national program would also take advantage of the new research laboratories and expand fire research programs at additional locations, such as the Lake States Forest Experiment Station (Jemison 1961).

Participants at the Wisconsin meeting, which included State, Federal, and university foresters and researchers, whole-heartedly agreed that "more emphasis should be directed toward finding new and better ways to control wildfires and also toward using fire as a land management tool." Meeting participants also recommended that the Lake States Station develop its own long-term plan for fire research that built on existing research around the country and focused on the region's own research priorities. The resulting report, "A Forest Fire Research Program for the Lake States," outlined a series of research needs, particularly those that would help address the threats from crown fires (Dickerman 1962).

▲ A prescribed burn on the Chippewa National Forest conducted by the Lake States Forest Experiment Station, 1959. Forest Service Eastern Region photo, courtesy of the Forest History Society, Durham, NC.

Even though they did not get a Midwestern fire research laboratory as other regions had, the Lake States Station proceeded with a "broadened research program," with an emphasis on fire prevention and control, including the use of prescribed burning and the development of better understanding of fire behavior, particularly in conifer plantations prone to crown fires (USDA Forest Service, Lake States Forest Experiment Station 1962). Opened by Raphael Zon in 1923, the Lake States Station merged with the Central States Station in January 1966 to become the new Central Forest Experiment Station (Rudolf 1985).

Technology Development

At the same time that Forest Service researchers worked to develop new knowledge and new methods in its fight against wildland fire, the agency also sought new technologies, equipment, and techniques to assist in the battle. In the mid-1940s, the Forest Service established the Arcadia Fire Equipment Development Center in southern California (now the San Dimas Technology and Development Center) to develop and standardize equipment and technologies to assist with firefighting. In the late 1940s, another small group of specialists (now known as the Missoula Technology and Development Center) in Missoula, MT, worked to develop techniques for parachuting firefighters and cargo to the site of a wildland fire.

Since then, fire-related technology development and engineering at the San Dimas facility, although no longer under the umbrella of Forest Service research, has included evaluating fire retardants, water-handling fire equipment, and locomotive spark arresters. In Missoula, researchers have worked on a variety of fire-related problems, including the development of fire shelters, firefighter clothing, equipment (e.g., packs), and nutrition. The two facilities now operate as one unit.

Fire Effects and Fire Ecology

For years, Forest Service research had concerned itself with improved control of wildland fires and quantifying the negative effects of fire on timber, watersheds, wildlife, and even recreational values. By giving these potential losses a numeric value, the agency was able to make informed decisions about where best to focus resources, while also justifying the huge expense of fighting fires. Thanks in part to fundamental and operational research conducted at the Northern Forest Fire Laboratory, Southern Forest Fire Laboratory, and Forest Fire Laboratory at Riverside, land managers had the tools and decisionmaking abilities to apply the very best practices in fire prevention, detection, and suppression to protect those values that the agency had spent decades identifying.

By the early 1970s, with more than a billion acres of forest and rangeland under some form of organized fire protection, Forest Service researchers began to

identify a growing problem. In 1971, Carl Wilson and John Dell, who worked for the Pacific Southwest and Pacific Northwest stations, respectively, warned that both the public and foresters alike had become complacent about fire, believing that "armies of trained forest firefighters [were] sufficient to handle any threat from fire" (Wilson and Dell 1971: 471). Pointing to examples of large fires in California and Idaho, however, they argued the "futility of setting mechanized man against the destructive forces of wildland fire where fuels have accumulated" (Wilson and Dell 1971: 471). Moreover, they warned that many areas outside of cities, which had once been wildlands, had been converted to suburbs, with thousands of homes "built in critical fire areas," placing them also at risk of catastrophic damage from fires that previously would have affected only wildlands. They also predicted that, because of the success of the agency's suppression efforts, a buildup of flammable fuels was creating "critical burning conditions" that could result in more disastrous forest fires (Wilson and Dell 1971).

Fire had always been an integral part of the forests of North America, Wilson and Dell reported, providing a "natural agent for thinning, pruning, and fuel reduction" (Wilson and Dell 1971: 473). By protecting forested lands from fire, the Forest Service had suppressed this natural process, "adding to the fuels problem." Their recommendation, therefore, was not for more research on fire suppression, but for more research on forest fuels management and the use of fire for hazard reduction to prevent even bigger fires. They also called for improved communication within the agency, between researchers and land managers, and with the general public, all of whom needed to be more aware of the "conflagration potential of forest fuels buildup" (Wilson and Dell 1971: 474). As significant, the Forest Service needed to improve public education on prescribed fire as an ecological tool to make communities more accepting of its intermittent effect on air quality (Wilson and Dell 1971).

The same year that Wilson and Dell published their warning about fuels buildup in American forests, the Southeastern Forest Experiment Station in collaboration with Duke and Clemson Universities hosted a symposium on prescribed burning. Held in South Carolina in the spring of 1971, the symposium started with the acknowledgment that fire "has been an important force in the ecology of the Southeastern Coastal Plain for thousands of years" (USDA Forest Service 1971: 5). Land managers and researchers agreed that prescribed fire, when properly used, was "an indispensable management device" that did not have a negative effect on trees, soils, or flora and fauna as once believed, although they, too, worried about fire's negative effect on air quality. Despite air-quality issues, however, in the American South fire was now accepted "as one of the most readily and economically available forest management tools" (USDA Forest Service 1971: 5). The use of fire to manage wildlands had come full circle, at least in some parts of the United States.

▲ An old-growth study conducted by the Missoula Fire Sciences Laboratory, 2001. Forest Service photo, courtesy of the Forest History Society, Durham, NC.

The Northern Forest Fire Laboratory also investigated the effects of fire during these early years. One project in particular stands out as having a long-lasting impact. While most researchers tried to isolate the influence of weather factors on fuel moisture and, thus, fire behavior, in 1969, Forester Robert Mutch asked a different question. He hypothesized that it might not be moisture alone, but that some wildland species may have "inherent flammable properties that contribute to the perpetuation of fire-dependent plant communities" (Mutch 1970: 1046). Mutch conducted extensive combustion tests in the Northern Forest Fire Laboratory's burn chamber using plants from three ecosystems. His research demonstrated that plants from fire-dependent ecosystems burn more readily than those from non-fire-dependent communities. In the resulting research article, published in the prestigious journal *Ecology* in 1970, Mutch noted that fire "has been a part of certain biological balances over evolutionary periods of time. Man must wisely interpret fire's significance in ecosystems to develop balanced programs of fire protection and prescribed fire use." He also called for studying wildland fire as part of an ecosystem process (Mutch 1970: 1051).

Although not directly related, Mutch would apply this same kind of thinking in the early 1970s to a research and demonstration project in the Selway-Bitterroot Wilderness in Idaho. Even while Jack Barrows, now director of the Division of Forest Fire and Atmospheric Sciences Research in Washington, DC, continued

to advocate for more research on fire control, Mutch and Dave Aldrich from the Northern Region worked together on a plan to allow some naturally caused fires to burn in wilderness areas. The idea was simple, according to Mutch. Rather than suppress all fires, the Forest Service needed to accept "'this radical idea of letting nature do its thing'" (Wells 2009: 3). A similar plan would be implemented on the Gila Wilderness in 1975 (Hunter and others 2014).

A New Understanding of Sustainability

In addition to having a national network of experiment stations with their own fire research programs, by the mid-1960s, the Forest Service had three fully equipped and state-of-the-art laboratories dedicated to fire research in California, Georgia, and Montana. Although local and regional concerns were driving some of the research at each laboratory, all three were working to advance the agency's long-standing concerns with fire prevention, detection, and control; fire danger rating and fire behavior; and fire effects.

As the science and technology of fire control improved, researchers confronted new challenges and national values that impacted their research. For example, Americans wanted to protect recreation and wilderness areas, values that could conflict with timber production and grazing. As they tried to balance these long-term goals, researchers also came up against the nature of the wildlands themselves, with wildlands protection and sustainability taking on new meaning when it came to fire.

As Forest Service researchers began to better understand the critical role fire played in sustaining healthy wildlands, they too had to pursue new questions on how best to protect and sustain healthy wildlands. It has been a difficult balance, a challenge that has raised even more questions for fire researchers to investigate to this day.

Conclusion

Research data are appearing which show that some plants and animals depend on fire for good health. Many land managers are now willing to acknowledge that complete exclusion of fire in many areas has caused dangerous fuel accumulations which may be expected to result in catastrophic fires, disease and insect problems, deterioration of range, reduced wildlife-carrying capacity, and decreased watershed yield. Superimposed on the changing prevailing views of the majority at various times [has] been the lack of objectivity and overstatement in favor of or against fire in natural ecosystems.

—T.T. Kozlowski and C.E. Ahlgren, 1974

In 1915, the same year the U.S. Department of Agriculture, Forest Service established its Branch of Research, about 50 people at the annual meeting of the American Association for the Advancement of Science voted to form the Ecological Society of America (ESA). Drawn from the fields of botany and zoology, the new ESA members were primarily interested in the relationships of organisms to each other and their environment. Early members also had an interest in climatological work (Shelford 1917).

In theory, Forest Service researchers working in the new Branch of Research that same year should have had much in common with members of the new ESA, but, rather than viewing wildlands as diverse "habitats in which environmental dynamics are apparent" (Shelford 1917: 1) and studying that dynamic interaction as Victor Shelford and his peers in ecology recommended, fire researchers instead sought to control those interactions through the

prevention and suppression of all fires. In short, researchers pursued studies designed to control nature, not necessarily to understand it and the role fire played as a part of forest complexity.

The economics of fire control also challenged researchers throughout the Forest Service. Researchers initially sought to quantify the negative effects associated with wildland fire to justify the expense of fire control. The search for finding methods to balance costs and potential savings, however, became less pressing thanks to the new Civilian Conservation Corps (CCC). With thousands of young people available to work on fire prevention efforts and also to fight fires whenever or wherever needed, the Forest Service could suppress fires nationwide at rates that amazed even the researchers themselves. They also knew, however, that their success rates could never last after the economy revived and this army of young firefighters returned home or went off to fight in a different war.

If increased numbers of firefighters were not a sustainable answer to suppressing all fires, then researchers needed to look again for improved methods to help managers better prioritize fire suppression in the Nation's wildlands. In 1935, for example, Forester Elers Koch argued that the costs associated with fire prevention and suppression, including road construction and even landing strips in otherwise pristine areas with little timber value, simply outweighed the economic benefits. Roy Headley agreed, writing in 1943 that a thousand acres with no marketable timber should not receive the same investment in fire prevention and control as an equal acreage of high-value timber. In essence, they argued, some fires should simply be allowed to burn, if nothing else to save money.

A Unity of Purpose

In 1915, Raphael Zon and S.T. Dana recommended that the proposed Branch of Research should be established around a unity of purpose, with research focused on a better understanding of the Nation's forests. One common theme since that time has been the search for methods to improve the sustainability of the Nation's forests through the prevention and suppression of wildland fires, a unity and a purpose of which Zon and Dana would no doubt have approved. The Forest Service also united around the goal of public education, developing methods to inform school children and communities alike about the importance of protecting the Nation's forested lands from fire. The Smokey Bear campaign, introduced in 1944, proved to be particularly effective.

Protection from fire took on new meaning in the 1930s and 1940s, however, particularly in the American South, where private landowners had used fire routinely as a management tool to burn off excess fuels. Large fires in the 1930s, followed by the loss of the CCC program and its firefighters in the 1940s, led Forest Service researchers in the South to reconsider the potential benefit of using fire as a protective measure. In 1943, silviculturists C.A. Bickford and

John Curry even prepared a landowner's guide on how to use small, controlled fires to protect forested lands from bigger wildfires, a practice that appeared to directly contradict the Forest Service's public message.

While fire researchers struggled with how best to cost-effectively sustain the Nation's wildlands over the long term, another national value rose to the forefront: protection and sustainability of the Nation's designated wilderness areas. The Wilderness Act of 1964 called for select Federal lands to be managed to ensure that they were "unimpaired for future use and enjoyment as wilderness." The act also called for the protection of the land's "wilderness character," in which "the earth and its community of life are untrammeled by man," with the "imprint of man's work substantially unnoticeable" (U.S. Congress 1964).

Although the Wilderness Act allowed for the control of fire, insects, and diseases on wilderness lands, some Federal fire researchers and land managers began to question how aggressive firefighting could be compatible with the mandate to minimize the "imprint" of human interference on the land. Forest Service researcher Robert Mutch noted, "'…one of the most unnatural acts we'd been committing in the wild all these years was suppression of fire'" (Wells 2009: 3).

In the early 1970s, researchers such as Carl Wilson and John Dell also raised new questions about the ability of "mechanized man" to suppress all wildland fires, particularly those in areas in the American West where decades of fire suppression had created an abundance of fuel (Wilson and Dell 1971). These researchers worried, too, about areas outside some cities in the region that had once been wildlands. Long considered to be at an ongoing risk of burning, these lands were fast becoming suburbs that were now also at risk. These new concerns led researchers to call not only for improved fire suppression methods but also for better ways to manage fuels, particularly through prescribed fire, to prevent more fires from becoming the "mass fires" that no one could control. Like many of those before them, they also called for improved communication and education, particularly for Forest Service personnel who had their own long-standing beliefs about fire.

Since 1898, when Gifford Pinchot called for a better understanding of wildland fire, Forest Service researchers have investigated the effects of fire and looked for improved methods to ensure the sustainability of the Nation's wildlands. Pinchot, however, called for more. He wanted to understand the role fire played as a modifier "of the composition and mode of life of the forest" and how that affected the composition of the landscape. He worried that too little was understood about what he referred to as fire's "creative action" (Pinchot 1899: 393).

Forest Service fire researchers around the country took up that challenge as part of a continuing quest to protect the Nation's wildlands—and to ensure the land's long-term sustainability. Starting in the late 19th century and continuing to this day, fire researchers, now joined by a new generation of fire ecologists,

have started asking questions about both the positive and negative effects of fire, and the contributions made by fire in protecting and sustaining healthy ecosystems. They pursue these investigations with much the same goal stated by Gifford Pinchot in 1903: to provide managers of the Nation's wildlands with "carefully gathered facts" rather than "vague notions ... about forest fires" (Pinchot 1903: 525). Like Pinchot, fire researchers today want to ensure that managers can make informed decisions based on sound science and protect the long-term health and sustainability of the Nation's wildlands. The answer, these researchers are discovering, was also predicted by Pinchot, who wrote in 1899, "The documents upon the subject still reside, with very few exceptions, in the forest itself" (Pinchot 1899: 393).

▲ Priest River Valley Kaniksu National Forest in northern Idaho, ca. 1912. Forest Service photo.

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