Chapter 21
One-Hundred Years of Wildfire Research: A Legacy of the Priest River, Deception Creek, and Boise Basin Experimental Forests of Idaho

Russell T. Graham, Theresa B. Jain, Kathy L. Graham, Robert Denner and Colin Hardy

Abstract The 1910 fires, which burned more than 1.3 million ha of northern Rocky Mountain forests, provided a mission and management objectives for the newly created Forest Service. By 1911, the Priest River Experimental Station (Forest-PREF) was established in northern Idaho to help meet the needs of the Forest Service. Harry T. Gisborne, whose work was centered at PREF, proved to be one, if not *the* most influential and far-seeing fire researcher in the history of the Forest Service. Examples of his contributions include the fire danger rating system, fuel moisture sticks, short- and long-term specialized fire-weather forecasting, and the beginnings of predicting fire behavior. After Gisborne's death in 1949, Jack Barrows, one of Gisborne's assistants, led the fire program and introduced high-tech approaches to fire research. Barrows was instrumental in creating the state-of-the-art Fire Sciences Laboratory in Missoula, Montana. The McSweeney–McNary Act (1928) laid the groundwork for a nationwide system of forest experiment stations and experimental forests, and in 1933 Deception Creek (DCEF) and Boise Basin Experimental Forests (BBEF) were established. DCEF was located in a productive mixed conifer forest in northern Idaho. Fire was integral to studies conducted at DCEF on harvesting, regenerating, and tending western white pine stands. Research at BBEF in southern Idaho emphasized timber production within interior ponderosa pine forests and prescribed fire was studied as a means of preparing seedbeds and minimizing grass and shrub competition to trees. Similar to other dry forests of the West, wildfires were aggressively controlled at BBEF, causing portions of it to be overrun with seedlings and saplings, which created dense forests. As such, BBEF was well suited for investigating ways of restoring ponderosa pine forests. After nearly 100 years of fire research, we still strive to effectively manage forests in the face of ever-growing threats of urbanization and unwanted wildfires. Building on

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the legacy of research accomplished on the Idaho experimental forests and the basic understanding of fire and its effects the early researchers developed, these forests are now more valuable than ever.

Keywords Fire research · Fire danger rating system · Harry T. Gisborne · Priest River Experimental Forest · Ponderosa pine · Western white pine

21.1 Introduction

When Raphael Zon, head of the Forest Service's Office of Silvics, recommended the establishment of experiment stations in 1906, tree cultivation and planting were identified as key information needs by the newly created Forest Service (Schmaltz 1980). By 1910, the need for information regarding forest fires and predicting fire danger became a priority for the newly formed research organization. Of course, large wildfires had occurred in the northwestern USA before the Forest Service was established. The 182,000-ha Yaquina fire of 1846, the 130,000-ha Nestucca fire of 1853 in Oregon, and other large fires, as noted by John Lieberg, burned in the Priest River (Idaho) and Bitterroot (Montana) Forest Reserves prior to 1897 (Cohen 1978; Pyne 2001). The wildfires that burned in the northern Rocky Mountains during the summer of 1910, however, were of such magnitude and intensity that they shaped the American fire landscape more than any other fire of the twentieth century (Pyne 2001, 2010).

During the late 1800s and early 1900s throughout eastern Washington, northern Idaho, and western Montana forest fires were common, especially fires used to clear timber for railroad right-of-ways. Abnormally low amounts of precipitation fell during 1909 and 1910, and temperatures for the month of April were the highest on record. By August, more than 1,700 fires were burning within the nearly 16 million ha of District One[1] of the Forest Service. Pushed by dry winds blowing from the southwest on August 20 and 21, the fires burned more than 1.3 million ha of northern Idaho and western Montana forests (Pyne 2001). The fires killed at least 85 people and destroyed billions of cubic meters of highly valued western white pine (*Pinus monticola*)-dominated forests. Elers Koch, the supervisor of the Lolo National Forest in western Montana, described the 1910 fires as a "complete defeat for the newly organized Forest Service force" because of the damage they caused (Baker et al. 1993).

The devastation from the fires was extensive. The smoke drifted as far away as Saskatchewan, Canada, Denver, Colorado, and Watertown, New York. The Savenac Nursery near Haugen, Montana, the largest forest nursery in the USA, was decimated. The towns of Taft, Saltese, and De Borgia in Montana were partially destroyed as was a large portion of Wallace, Idaho (Pyne 2001). District One became the focal

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[1] In 1911, District One of the Forest Service included Montana, northeastern Washington, northern Idaho, northwestern South Dakota, northern Michigan, northern Minnesota, and southwestern North Dakota. The District office was located at the Hammond Block, Missoula, MT.

point because of the impact of the fires and its Forest Service personnel became the "experts" on fire. Nevertheless, it was apparent there was a need to have better information, equipment, and manpower. According to William Greeley, District One Forester, "Congress and the Forest Service now realize that fire protection was the number one job of the Forest Service. We knew this before, but the 1910 experience burned it in terms of sweat, labor, and human life. Protection was it—we must lick the fire problem" (Spencer 1956).

The Priest River Forest Reserve near the Canadian border in northern Idaho was one of the several forest reserves that President Cleveland established across the western USA in 1897. The Reserve was 261,071 ha and all of the forest types that grew in the western part of District One were represented. John Leiberg, a dendrologist assigned by the General Land Office to review the Reserve in 1897 described it as a "magnificent forest…of western white pine and tamarack (larch, *Larix occidentalis*)" (Graham 2004). Leiberg's description no doubt influenced Raphael Zon's choice to establish the region's experiment station within the Reserve. The Reserve had areas suitable for reforestation, access to transcontinental railroads, lands subject to withdrawal for exclusive use by the Forest Service, and suitable building sites (Graham 2004). Other areas within the District were considered for an experiment station, but 290 ha near the Benton Ranger Station, which by 1911 was located on the Kaniksu National Forest (formerly the Priest River Forest Reserve), was set aside for the Station (Fig. 21.1).

21.2 Priest River Experiment Station

In August of 1911, Raphael Zon, along with Robert Y. Stuart, Assistant District Forester- Silviculture and F. I. Rockwel, Director of Silvics, from the District Office, visited the Benton Ranger Station in the Priest River Valley and brought along the basic supplies needed to establish the Priest River Experiment Station. By September 1, 1911, Zon, Donald H. Brewster, the first director of the Station (1911–1917), and another ten men set up camp and started building the facilities (Fig. 21.2). They completed the preliminary work by the end of October and the remainder of work was left to Brewster and Douglas MacDonald (cook) who subsequently had been appointed Forest Guard (Wellner 1976; Fig. 21.3).The meteorological instruments were installed on September 4, 1911, and have been continuously recording at Priest River since then.

By the summer of 1912, the Priest River Experiment Station was firmly established and the chief of the Forest Service, the district forester, and other prominent foresters visited and approved of the area (Fig. 21.4). Julius A. Larsen[2] from the Flathead National Forest in western Montana and his family joined Brewster at the Station in 1913 and initiated studies relating weather observations to forest changes

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[2] In 1912, J. A. Larsen and some 218 of the first 300 graduates (holding M.F. degrees or certificates) of Yale were employed or had been employed by the Forest Service (Hoar et al. 1981).

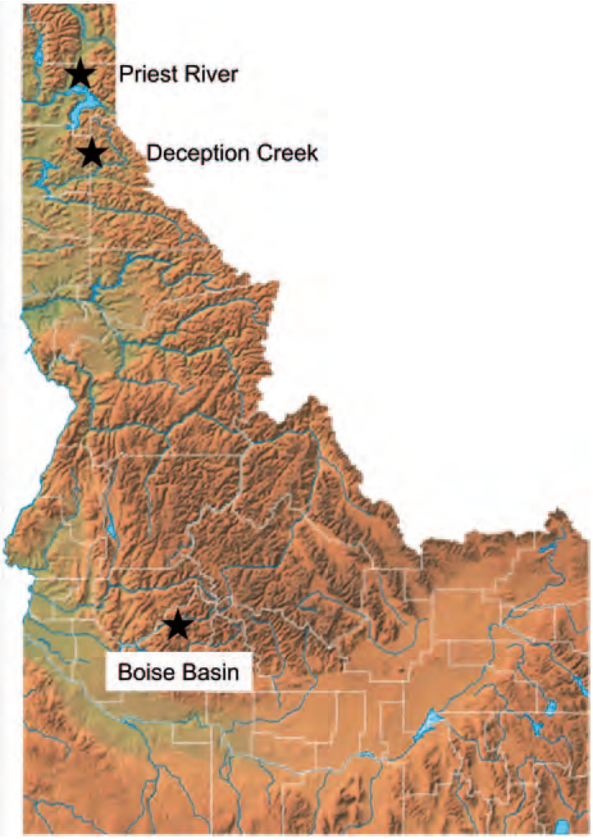

Fig. 21.1 The Priest River Experimental Station (Forest) was established in 1911, Boise Basin Branch Station (Experimental Forest) in 1933, and Deception Creek Experimental Forest in 1933. These Idaho Experimental Forests are administered by the Rocky Mountain Research Station headquartered in Fort Collins, CO

Fig. 21.2 Part of the construction party in the fall of 1911 consisted of (from *left*): Howard Simpson, Raphael Zon, W. W. Morris, Ed Brown, Donald Brewster, John Kirk, "dad" Crosby, and F. I. Rockwell

Fig. 21.3 The first living quarters at the Priest River Experiment Station in 1911. Ronald Mac Donald, the cook's son, stands in front of the tent

Fig. 21.4 The Priest River Experiment Station was inspected in 1912 by (from *left*): William Greeley District (Regional) Forester, E. B. Tanner, David Mason, Ferdinand Silcox, James Girard, M. H. Wolff, Henry Graves (Chief of the Forest Service), and Mallory Stickney

(e.g., tree growth, disease occurrence) occurring on the Experiment Station's forest (Graham 2004). By 1915, the Forest Service Experiment Stations were fully operational throughout the USA and Chief Henry Graves established the Branch of Research administered by Earle H. Clapp. During this time, the Investigative Committee within District One directed research activities at the Priest River Experiment Station. At their 1916 meeting, recognizing the proximity of the Station to the area burned by the 1910 fires, the Committee requested studies be initiated to determine ways to detect and control forest fires. They emphasized the work should identify factors that affect fire spread and rate of spread as influenced by weather and site conditions (Graham 2004).

21.2.1 Genesis of Fire Research

Based on the Investigative Committee's recommendations, Clapp advised that forest fire research be started at Priest River. Larsen had already linked the Station's weather records to duff and surface soil moisture concentrations, thereby making him the logical choice for starting studies of fire hazard and liability (Graham 2004; Hardy and Hardy 2007). In response, Larsen immediately set out to relate Priest River's weather data with fire records of the Kaniksu National Forest that adjoined the Experiment Station. He divided the Kaniksu into climatic units, determined their meteorological conditions, described their topography, acquired fire spread rates that occurred in each unit, and described the fuels the fires burned. From this work, Larsen published *Wind and Its Relation to Forest Fires, Sunshine and Air Temperature In Relation To Forest Fires,* and *Relative Humidity of the Atmosphere and Its Relation to the Fire Problem* in 1921. Larsen's work was the beginning of predicting dangerous conditions for the ignition and spread of wildfires or the earliest formulation of "fire-danger rating" (Graham 2004; Hardy and Hardy 2007, Larsen 1921a, b, c; Wellner 1976).

When Clapp provided the impetus for the beginning of fire research in 1916, he went on to say "that anyone who successfully worked out solutions would receive the highest type of recognition, both within and outside the Forest Service and the men who were the leaders of fire research would become the most important forest researchers in the country." During World War I, Congress drastically cut funds to the Station and Larsen was temporally transferred to District One to work with W. C. Lowdermilk. Together they studied ways of using fire to dispose of logging slash. In addition to conducting fire studies, Larsen published and kept the ecological, growth and yield, conifer seed, silvicultural, and many other studies alive at Priest River during these war years. Larsen went on to be an excellent forest scientist and later Dean at Iowa State University; however, he would not reach the prominence in fire research that Clapp described. In 1921 after the War, the Station received a substantial increase in funds and Clapp directed Robert H. Weidman, Station Director to transfer Harry T. Gisborne from the Whitman National Forest in Oregon to the Station. It would be Gisborne's sole responsibility to concentrate on fire research. Harry Gisborne would go on to exceed Clapp's expectations (Graham 2004).

21.2.2 Fire Danger

Upon his arrival in District One, Gisborne found the relative fire hazard descriptions for the western parts of the District (northern Idaho, northeastern Washington, and western Montana) to be in utter chaos. Forest officers had employed a variety of creative tactics to describe their fire hazards in order to acquire extra firefighting funds and forces (Hardy and Hardy 2007). Gisborne inherited the data and work of Larsen and Lowdermilk which he used as a starting point, but Gisborne aimed to develop a simple set of numbers, or a "common language," that fire managers could use to

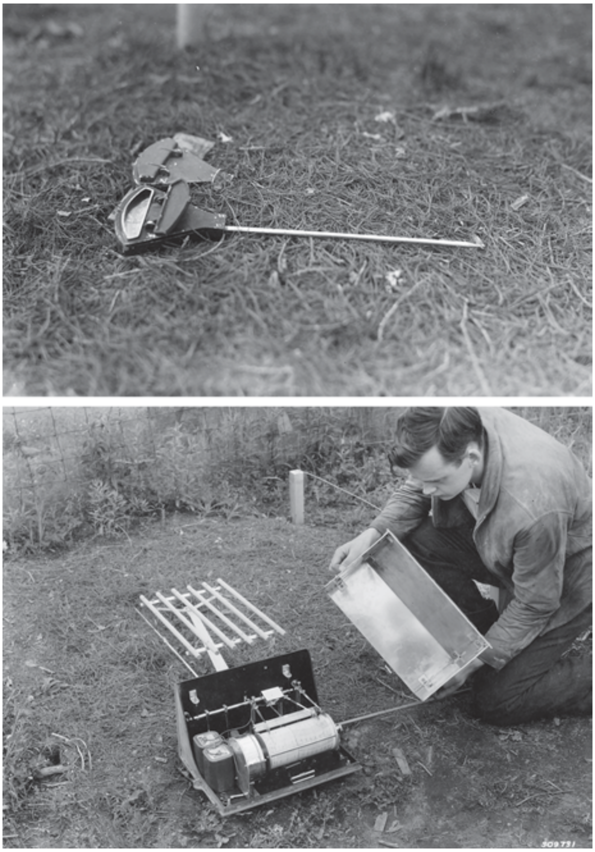

Fig. 21.5 Along with Matt Dunlap from the Forest Service Forest Products Laboratory in Madison, WI, Harry Gisborne developed a duff hygrometer (*top*), which measured the moisture content hence inflammability of the dead leaves, twigs, etc. and an anemohygrograph (*bottom*), which was intended to measure fine fuel moisture, duff moisture, and wind speed

communicate to anybody, whether a woodsworker, a settler, a ranger, or an administrator of the fire hazard for a given forest. Before the end of his first fire season at the Station (1922), Gisborne established fire weather stations throughout the Kaniksu, Clearwater, and Nezperce National Forests of northern Idaho (Graham 2004).

Gisborne quickly recognized the inadequacies of available instrumentation for determining fuel (i.e., twigs, down logs, etc.) and weather characteristics used to predict forest fire hazard. Drawing on Larsen's work, Gisborne began refining the role fuel moisture plays in fire danger. He evaluated the moisture content of duff, twigs, and down logs in relation to conditions such as air temperature and relative humidity and looked for ways to measure these fuels and weather conditions. Since the right instruments did not exist for this research in 1923, he worked with Matt Dunlap from the Forest Service Forest Products Laboratory in Madison, Wisconsin, to develop a duff hygrometer that measured the moisture content, hence inflammability, of the dead leaves, twigs, and other forest floor organic materials and an anemohygrograph intended to measure fine fuel moisture, duff moisture, and wind speed (Fig. 21.5). Both of these instruments, however, were either too expensive or difficult to calibrate, and by 1940 both were discontinued (Graham 2004).

Fig. 21.6 An anemometer that George Jemison calibrated while riding on a hood of a car as his wife drove. Note each gage was numbered

Fire research had an annual budget of US$ 5,000 in 1927, and even though the McSweeney–McNary Act of 1928 augmented research funds, none were designated for Gisborne. Major W. Evan Kelley,[3] who became District One Forester in 1929, was specifically assigned to Missoula to solve the fire suppression problem. Major Kelley enthusiastically supported fire research, and in 1931 the work of Gisborne and his associates took on both regional and national importance. With the support that Major Kelley provided, Gisborne was able to hire George Jemison, a University of Idaho forestry graduate, as his first full-time professional assistant (Graham 2004).

Jemison had been so impressed with Gisborne's lectures at the University of Idaho, he applied for a summer job working for Gisborne in 1930. After graduation and receiving his appointment, one of Jemison's first duties was to identify and collect fuel and weather data at the fuel inflammability stations at Priest River. Another task of Jemison's was to calibrate the inexpensive anemometers (wind speed gauges) that Gisborne had a local machinist build (Fig. 21.6). Each instrument varied in craftsmanship and had to be calibrated manually (circa 1932). Jemison mounted each gauge on a car fender, and as his wife drove at various speeds, he lay on the hood and counted the revolutions, thus calibrating each instrument (Graham 2004).

While on sabbatical in 1923, J. A. Larsen visited several European experiment stations and reported to Gisborne that in Denmark they were using wood blocks as a criterion of atmospheric humidity (Hardy and Hardy 2007). Gisborne took this idea further and had Jemison test various twigs, wood blocks, and dowels to find a material and configuration that behaved uniformly with humidity changes. They settled on 1.3-cm ponderosa pine (*Pinus ponderosa*) dowels and ultimately assembled sets of four dowels, trimmed to weigh exactly 100 g when oven-dried. These sticks became the standard for measuring fine fuel moisture concentrations

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[3] During WW I, Kelley went overseas with the 10th Forestry Engineers where he commanded all sawmilling, logging, and road construction operations in France. He retained his military rank after the war, hence the title of Major.

Fig. 21.7 The control weather station and George Jemison atop the 46-m western larch tree where weather instruments were maintained at the Priest River Experimental Forest in 1932

and were an essential part of all fire weather stations. Not only was the research for developing fuel sticks conducted at Priest River, but from 1948 to 1952 the manufacture and distribution of fuel sticks for all fire protective agencies west of the Mississippi River was done at Priest River (Wellner 1976). To this day, the 100-g fuel sticks that Gisborne and Jemison developed are the standard manual method for measuring the moisture concentration of small and dead woody fuels (Fischer and Hardy 1976). In the fall of 1937, Jemison transferred to the Forest Service Appalachian Research Station (now Southern Station) and subsequently established a fire research program there. Jemison came back to the Northern Rocky Mountain Station as Director in 1950 and finished his Forest Service career as Deputy Chief of Research in 1969 (Fig. 21.7).

With these and other trials, Gisborne and his associates were able to assemble a set of relatively inexpensive instruments that could be used at fire weather stations (Hardy and Hardy 2007). The basic set included scales for weighing fuel moisture sticks, rain gauges, four-cup anemometers for measuring wind speed, thermometers, and a visibility meter. By 1934, Gisborne had helped establish more than 50 fire weather stations stretching from Nevada and Utah in the Southwest to Yellowstone and Glacier National Parks in the northern Rocky Mountains. By this time with Gisborne's urging, the US Weather Bureau had also established the Fire Weather Warning Service network and Congress had appropriated money for forest fire weather forecasting. The first daily reporting of local fire weather was telegraphed from the Priest River Experimental Forest (PREF)[4] to the Spokane, Washington Weather Bureau in 1927. Since then, there has been regular broadcasting of fire weather forecasts and special warnings by radio and television stations throughout the USA (Graham 2004).

Gisborne investigated general weather conditions, and he also studied the relationship between lightning and fires, and how to predict when lightning storms were approaching (Gisborne 1931). He examined the effect of lightning on soils, rocks, forest cover, and ways to control lightning (Gisborne 1933). At Priest River, he strung a wire from a ridge top to the office so he could measure the amount of static electricity in the air. During lightning storms, he would often sit in the office and discharge electricity from his fingertips (Hardy 1983). He predicted the effects of lightning strikes and investigated ways of altering forest characteristics to control them. By obtaining more than 1,300 storm reports, he began to determine storm patterns and discovered that most storms were not single and well defined, but tended to be numerous and intermixed. Using sunspot forecasts, he investigated ways to forecast 10-day fire weather and used long-term precipitation records in an attempt to predict fire season rainfall. He hoped this information, combined with fuel moisture data and weather reports from the west coast, would provide an early warning system as to the potential fire danger within the Inland Northwest. He discovered, however, that this approach poorly predicted fuel inflammability and overall fire danger (Graham 2004; Hardy 1983).

In his quest to develop a common language for predicting fire danger, Gisborne sought ways to integrate what he defined as the three main drivers of fire danger. Using a Kodak exposure meter that combined light, exposure time, and lens opening into a single set of values, Gisborne substituted these values with fuel moisture, wind velocity, and relative humidity thus providing the first fire danger meter (Hardy and Hardy 2007). Because the relationships of these three components were not linear, the meter had to be modified. He needed to integrate these three variables, but he also wanted to get potential users to accept the meter. Gisborne brought experienced firefighters from administration and research together at the PREF and asked each to draw a set of curves expressing how they thought these three factors should fit together. Gisborne organized this expert knowledge into a composite set of curves. He packaged this information into a pocket-sized slide rule, which expressed the relative fire danger within a range of 1–6. The fire danger meter, model one was used in the 1932 fire season, and by 1942 a sixth model was developed that incorporated a burning index and also adjusted the fire danger for both human- and lightning-caused ignition risk (Hardy and Hardy 2007; Fig. 21.8).

At the 1958 national meeting of the American Meteorological Society, a National Fire Danger Rating System (NFDRS) was proposed. A joint committee com-

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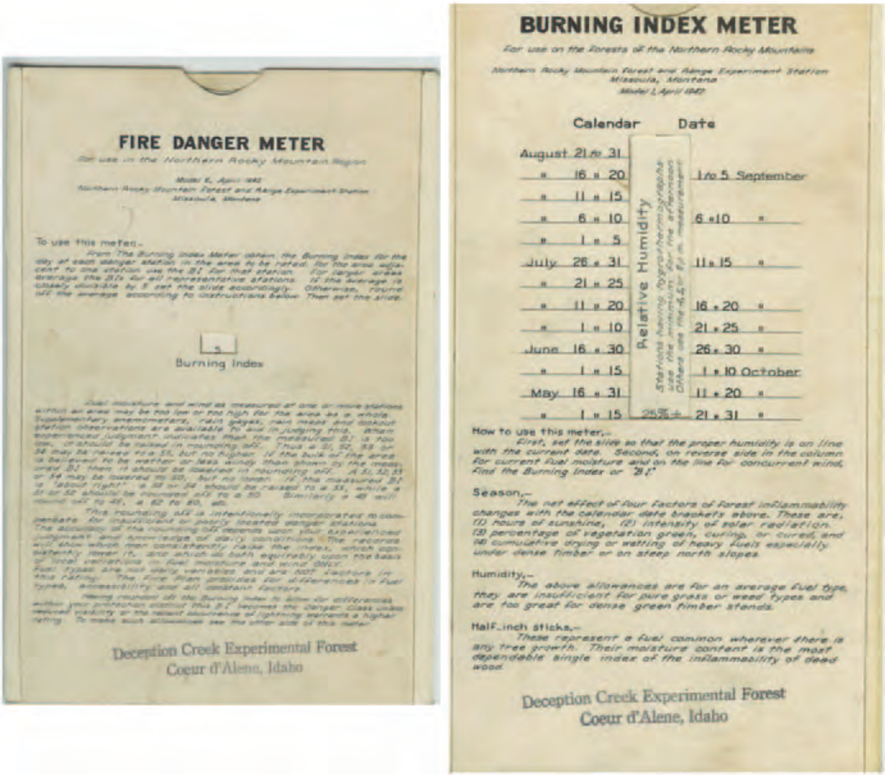
[4] In 1922, the headquarters of the Priest River Experiment Station was moved to Missoula, MT, and in 1925 the Station was renamed the Northern Rocky Mountain Forest and Range Experiment Station with Robert H. Weidman as Director. In 1930, the Priest River Experimental Forest was recognized and continued to be the center of research for Gisborne and many others.



FIRE DANGER METER

For use in the Northern Rocky Mountain Region

Model 6, April 1942
Northern Rocky Mountain Forest and Range Experiment Station
Missoula, Montana

To use this meter.–
From The Burning Index Meter obtain the Burning Index for the day at each danger station in the area to be rated. For the area adjacent to one station use the BI for that station. For larger areas average the BIs for all representative stations. If the average is closely divisible by 5 set the slide accordingly. Otherwise, round off the average according to instructions below. Then set the slide.

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Burning Index

Deception Creek Experimental Forest
Coeur d'Alene, Idaho

BURNING INDEX METER

For use on the Forests of the Northern Rocky Mountains

Northern Rocky Mountain Forest and Range Experiment Station
Missoula, Montana
Model 1, April 1942

Calendar	Relative Humidity	Date
August 21 to 31		
" 16 " 20		1 to 5 September
" 11 " 15		
" 6 " 10		6 " 10 "
" 1 " 5		
July 26 " 31		11 " 15 "
" 21 " 25		
" 11 " 20		16 " 20 "
" 1 " 10		21 " 25 "
June 16 " 30		26 " 30 "
" 1 " 15		1 " 10 October
May 16 " 31		11 " 20 "
" 1 " 15	25%±	21 " 31 "

How to use this meter.–
First, set the slide so that the proper humidity is on line with the current date. Second, on reverse side in the column for current fuel moisture and on the line for concurrent wind, find the Burning Index or "B.I."

Season.–
The net effect of four factors of forest inflammability changes with the calendar date brackets above. These are, (1) hours of sunshine, (2) intensity of solar radiation, (3) percentage of vegetation green, curing, or cured, and (4) cumulative drying or wetting of heavy fuels especially under dense timber or on steep north slopes.

Humidity.–
The above allowances are for an average fuel type, they are insufficient for pure grass or weed types and are too great for dense green timber stands.

Half-inch sticks.–
These represent a fuel common wherever there is any tree growth. Their moisture content is the most dependable single index of the inflammability of dead wood.

Deception Creek Experimental Forest
Coeur d'Alene, Idaho

Fig. 21.8 Using expert knowledge, Harry Gisborne produced the first fire danger meter (model 6 shown). By 1942, model 6 incorporated a burning index along with fuel moisture, wind velocity, relative humidity, and visibility into fire danger

prised of both fire management and research personnel determined that a national system was feasible and a team was formed to implement the program. By 1961, a system was developed and it was tested in 1962 (Hardy and Hardy 2007), but the system lacked quantitative rigor and was very subjective necessitating further work. In 1968, a NFDRS Forest Service Research Work Unit was established in Fort Collins, CO. By extending Gisborne's work and the research from the facilities and experiments conducted at Missoula and other fire laboratories, the NFDRS began being used throughout the USA in 1972 (Deeming et al. 1972). The rating system informed fire management decisions, but did not readily communicate fire danger to the public as Gisborne stressed such a system should. To address this shortcoming, in 1974 the metrics (e.g., energy release component, ignition component) within the NFDRS were distilled to five classes—low, moderate, high, very high, and extreme which have been widely displayed in conjunction with Smokey Bear on signs (Helfman et al. 1975, Hardy and Hardy 2007; Fig. 21.9).

Fig. 21.9 The National Fire Danger Rating System developed for fire management was distilled down to five fire danger classes (low to extreme) and readily communicated to the public by Smokey Bear

21.2.3 Fire Research Expansion

Lloyd G. Hornby was hired by the Northern Rocky Mountain Forest and Range Experiment Station in 1931 to launch the first Research, Development, and Application program within the Forest Service. The program was housed at Priest River with Gisborne so Hornby could apply Gisborne's research in a form that could be used to make fire control planning decisions. Hornby, trained both as an engineer and forester, had spent 15 years working within National Forest Systems in positions ranging from a smoke chaser to forest supervisor. He developed fuel classifications that described fire spread rates and their resistance to control from low to extreme (four levels) and mapped the fuel types (classifications) for District One. He also developed methods for mapping the "seen-area" from lookouts that influenced the probability of a fire being detected. Using his engineering background and the new field of operations research, he produced eight principles of fire control planning relevant to District One, but also to fire control planning throughout the USA (Gisborne 1939). Hornby's research and development contributions and collaboration with Gisborne were cut short in 1937 by his heart attack and death on the Toboggan Creek Fire in the Clearwater National Forest of Idaho (Graham 2004).

Gisborne described the elements of fire danger, but he also worked on determining how these elements influenced fire behavior. In the early 1930s, again drawing on the work of J. A. Larsen, Gisborne began investigating the effect terrain, aspect, and elevation had on fire danger and fire behavior (Larsen 1922). In the fall of 1934, G. Lloyd Hayes, who came to Priest River in the summer as an Assistant Silvicultural Technician, was assigned to Gisborne's staff as a Junior Forester. Hayes's first assignment under Gisborne was to conduct the altitude and aspect study. In 1941, using weather observations and fuel conditions occurring on north- and south-facing slopes over a range of elevations (700–1,675 m), Hayes described how fire danger varied with aspect and altitude. In 1942, he added diurnal changes to his fire danger findings and firmly established the occurrence of a thermal belt in mountainous terrain. Within a thermal belt (e.g., at 900–1,220 m at Priest River), burning conditions change less from daytime to nighttime than they do in either the valley bottoms or on the mountaintops (Gisborne 1948). Hayes (1942) described the thermal belt as the "altitude of most dangerous fire behavior."

Gisborne and his assistants Jemison and Hayes evaluated fire behavior by observing burning wildfires as close to the fire line as possible. As the fires approached, they would measure the slope angle and aspect of where the fire was burning and characterize the size, kind, abundance, and arrangement of fuels it was burning. These observations of fire behavior were supplemented with studies Gisborne established at Priest River determining the inflammability and heat retention of different sized fuels with varying moisture levels. These studies provided the fundamentals of fire behavior that are still used today (Graham 2004).

The McSweeney–McNary Act (1928) laid the groundwork for a nationwide system of forest experiment stations and experimental forests. Funds from the New Deal programs in the 1930s such as the National Industrial Recovery Act (NIRA), the Emergency Work Corps (EWC), and the Economic Recovery Act (ERA) helped foster experimental forest establishment. In 1933, the Investigative Council of Region One (formerly known as District One) recommended the establishment of four additional experimental forests within the Region. One of the forests approved by the Washington Office was the Deception Creek Experimental Forest (DCEF; Fig. 21.1; Graham 2004).

21.3 Deception Creek Experimental Forest

In 1933, DCEF (1,315 ha) was established in the heart of one of the most productive forest areas in the Rocky Mountains (Jain and Graham 1996; Fig. 21.10).The activities at Priest River had been supervised directly by Northern Rocky Mountain Station Director Lyle Watts,[5] but when he left the responsibility largely passed to Gisborne's Fire Research Division. With the influx of money and manpower from the New Deal, fire research activities at Priest River were flourishing, leaving no room

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[5] Lyle Watts became director of the Northern Rocky Mountain Forest and Range Experiment Station in 1931 and left in 1936 to become Regional Forester in Milwaukee, Wisconsin, and later Chief of the Forest Service.

Fig. 21.10 The Deception Creek Experimental Forest, established in a western white pine forest, had areas that once contained trees more than 60 m tall. Such stands still exist today (2012), however most pines were killed by blister rust. (Fig. 21.11)

Very dense, almost pure, 160-year western white pine stand on lower north slope. Montford Creek Natural Area, Deception Creek Experimental Forest, Idaho. September 1937.

for a strong silvicultural program. So within the Northern Rocky Mountain Forest and Range Experiment Station, Priest River became the center for fire research and Deception Creek, some 22 miles east of Coeur d'Alene, Idaho, and 88 miles from Priest River, became the center for silvicultural studies with considerable rivalry between the two divisions (Wellner 1976).

Kenneth P. Davis,[6] a former ranger on the Gallatin Forest in Montana, first worked at PREF during the summer of 1932 while he studied at the University of Michigan. After earning a master's degree, he returned to Priest River in 1933 and was sent by Director Watts to the newly established DCEF to serve as its first superintendent. In 1935, he was assigned the responsibility for studying the silvics and silviculture of western white pine and its associates. At DCEF, Ken Davis, Charles

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[6] In 1937, Ken Davis became chief of the Silvics Division of the Northern Rocky Mountain Forest and Range Experiment Station until 1940 when he became an assistant to I. T. Haig in Washington, D.C. In the late 1930s, he took educational leave to work on a Ph.D. at the University of Michigan. Davis later became Dean of the Forestry School at the University of Montana, then a professor of forestry first at the University of Michigan and later at Yale University.

Fig. 21.11 White pine blister rust, an imported disease from Eurasia in 1910 attacks and most often kills western white pine throughout the western United States

Wellner, and others conducted major studies on harvesting, site preparation, planting, and growing western white pine (Graham 2004).

21.4 Boise Basin Experimental Forest

The McSweeney–McNary Act also paved the way for the Intermountain Forest and Range Experiment Station in Utah and adjoining states. The station's headquarters were established on July 1, 1930, in Ogden, UT, thus providing strong ties to the Region 4 headquarters. As it did for the Northern Rocky Mountain Station, the New Deal also facilitated the expansion of the Intermountain Station with the Boise Branch Station facilities at Idaho City, Idaho, being built by the Civilian Conservation Corps (CCC) in 1933 (Fig. 21.1). This Branch Station included 1433 ha within the Boise National Forest, which ultimately became part of the Boise Basin Experimental Forest (BBEF; Sloan and Steele 1996).

The BBEF was established in highly productive ponderosa pine (*Pinus ponderosa*) forests near Idaho City, Idaho. In the late 1800s, the city was a major mining center and used large amounts of wood from the surrounding forests. Because of the harvesting and mining activities, all ages of ponderosa pines from seedlings to mature yellow-barked trees were included in the forest when it was established.

Research on BBEF emphasized timber production within interior ponderosa pine forests and prescribed fire was studied as a means of preparing seedbeds and minimizing grass and shrub competition to trees. Different methods of selecting mature trees for harvest were also studied along with how cutting impacted the remaining trees, regeneration, and competing vegetation. These silvicultural studies produced methods for producing timber and protecting the pines from insects (bark beetles), animals (e.g., porcupines), and fire (Sloan and Steele 1996).

21.5 Fire Control

Research funding was drastically reduced in the 1940s due to World War II. Annual appropriations for the entire Forest Service research program averaged US$ 105,000 or about half the record high of the 1930s (Jemison 1950). The war also caused staff reductions and in 1942, more than 30 % of regular Forest Service personnel entered military service. In 1944, only 13 technical staff kept the research programs functioning at the Northern Rocky Mountain Forest and Range Experiment Station, the lowest number since 1930, with the majority of their work conducted at the PREF and DCEF. Similarly, the Intermountain Station[7] suffered severe cuts in funding and the Boise Basin Branch Station was closed for the duration of World War II (Klade 2006).

By 1945, some return to normalcy occurred within both experiment stations and new studies were started. One of the most notable changes occurring after the war was the increase in the number of women working in research; however, they were mainly clerks and stenographers. Within the Northern Rocky Mountain Station, the Division of Silviculture and the Division of Forest Protection were reestablished and Gisborne, now the head of Forest Protection, was able to enlarge his staff (Graham 2004).

Jack Barrows joined Gisborne's staff in 1946. Barrows exhibited many of the work and research traits of Gisborne and he was able to incorporate many wartime technologies into fire research (Hardy 1983). In the 1930s, Barrows conducted fire control and behavior workshops for the National Park Service and later became their Chief of Fire Control Training. During this time, Gisborne and Barrows became close friends and Gisborne asked Barrows to continue the fire control planning research started by Lloyd Hornby. But after less than a month of refining Hornby's work, Barrows was detailed to lead a new aerial bombing project. Even with this assignment, he was able to compile the backlog of National Forest fire reports that had been recorded on 23,000 punch cards. This work improved fire control planning by incorporating new fire behavior knowledge and new equipment and techniques that became available for firefighting (Graham 2004).

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[7] On January 1, 1954, the Northern Rocky Mountain Forest and Range Experiment Station merged with the Intermountain Forest and Range Experiment Station with its headquarters in Ogden, UT.

Barrows's energy, organizational skills, and military and political connections allowed him to introduce "high-tech" methods into wildland fire research and management (Klade 2006). Because Barrows was a Lieutenant Colonel during World War II and prepared aerial bombing strategies and tactics, he was a natural choice for leading the aerial bombing project. Gisborne had tried such methods in the 1930s when he dropped water in barrels, iron cans, and in 100-gallon tanks from airplanes. These methods proved to be ineffective in making an impact on even the smallest fire. Gisborne turned the entire project over to Barrows. Even though dropping water from airplanes to extinguish wildfires showed promise and received abundant publicity, the program was terminated in 1948. It was not until 1954 after California tested dropping cascading water on fires and new retardant technology was developed, that aerial application of water and retardant became a vital part of fire research and control efforts throughout the world (Klade 2006).

Though the aerial bombing program was terminated, Gisborne and Barrows started another high-tech project by testing cloud seeding as a way to control lightning. Gisborne used his connections to collaborate with Irving Langmuir and Vincent J. Schaefer of the General Electric Company. In 1948 at Priest River, Barrows and Gisborne, along with Schaefer, devised a strategy for seeding clouds and in the summer of 1949 they rigged a C-47 aircraft to do so. Bob Johnson, founder of the Johnson Flying Service in Missoula, Montana flew a C-47 to 26,000 ft with a dry-ice hopper manned by Gisborne and Barrows in the rear. Apparently, the oxygen tubes that Gisborne and Barrows were using as they chopped dry ice became disconnected requiring a panicky and blue-faced Gisborne to tell Johnson to descend rapidly. The C-47 proved unsuitable for cloud seeding, but Barrows was able to acquire a B-29 from Fairchild Air Force Base in Spokane, WA. Although this plane made several test runs near Priest River, no clouds appeared that were suitable for a proper experiment (Hardy 1983; Klade 2006).

On August 5, 1949, the Mann Gulch fire on the Helena National Forest in Montana trapped 12 smokejumpers and 4 other firefighters. Eleven men were burned to death by the fire and two others died the next day from their injuries. Because of his heart condition, Gisborne's activities were limited, but his interest was piqued by the abnormal behavior of this fire. Gisborne was eager to see the effects of the fire and was asked to investigate the fire's behavior. On November 9, 1949, accompanied by Robert Jansson, the Ranger of the Canyon Ferry District and a survivor of the fire, Gisborne visited the fire site. Because of Gisborne's physical condition, the half-hour hike turned into a 2-h trip. Knowing that Gisborne was showing signs of distress, Jansson convinced the stubborn Gisborne to stop, so that they could return to the gulch the next day to evaluate what they had found. Although excited about the potential of a new theory on fire behavior, Gisborne reluctantly agreed. But, about 800 m from their truck, Gisborne suddenly had a fatal heart attack. In August 1999, on the 50th anniversary of the Mann Gulch fire, Forest Service Chief Mike Dombeck and Montana Governor Marc Racicot recognized Gisborne as the 14th victim of the fire (Graham 2004; Maclean 1992; Rothermel 1993).

Lightning detection, cloud seeding, and related work by Barrows and Gisborne, along with Irving Langmuir and Vincent Schaefer of General Electric provided the genesis of Project Skyfire (Gisborne 1931). At Priest River in 1952, its first project was training lookout personnel to track lightning storms and make cloud surveys. Barrows included many cooperators (e.g., Boeing, universities, US Weather Bureau, and Park Service) and in 1953 Project Skyfire became a formal research program within the Northern Rocky Mountain Forest and Range Experiment Station. Meteorologist Don Fuquay was hired to gather basic information on the occurrence, behavior, and control of lightning-caused forest fires (Barrows et al. 1957). This work led to lightning detectors being placed on mountaintops throughout the Rocky Mountains, which ultimately became part of a network of remote automated weather stations (RAWS) recording lightning conditions and feeding the data into the National Interagency Fire Center in Boise, Idaho (Klade 2006).

Both Barrows and Gisborne were dedicated fire researchers and had the skills and work ethic to meet the ambitious goals they set. However, Gisborne demanded perfection from himself, his subordinates, and cooperators and often alienated both coworkers and cooperators. Barrows also appreciated excellent work, but he tempered it with diplomacy. Barrows was able to heal divisions Gisborne created with the Weather Bureau in Project Skyfire and brought them in as an important fire research partner. Gisborne openly criticized the Forest Service's budget for fire research, which in turn complicated the budget process rather than helped. In contrast, Barrows worked indirectly with key individuals within the Forest Service and political circles, which allowed him to acquire the million dollars to build the Fire Sciences Laboratory at Missoula, Montana. It was a need that Gisborne recognized as early as 1936 noting that his field experiments lacked the precision and controlled conditions he needed for estimating fire danger (Graham 2004; Hardy 1983; Klade 2006).

The Fire Sciences Laboratory opened in 1960 and as chief administrator, Barrows hired physicists, mathematicians, engineers, and technicians. Barrows found such talent at the Idaho National Engineering Laboratory (INEL) where a nuclear-powered aircraft program was being closed. From this program, Barrows hired Hal Anderson, Stan Hirsch, and Dick Rothermel. These men proved to be leaders and innovators in producing information on how to detect wildfires, as well as providing an understanding about how they developed and spread (Klade 2006).

21.6 Prescribed Fire and Mechanical Fuel Treatments

White pine blister rust (*Cronartium ribicola*) was introduced into western North America in 1910. White pines in the Puget Sound area of Washington became infected by 1913, and by 1923 the disease was found in several locations in Idaho (Geils et al. 2010). During this time, western white pine was by far the most valuable tree species growing in the northern Rocky Mountains and it was being attacked and killed by the disease (Fig. 21.11). Blister rust requires two hosts to complete its life cycle, a white pine and a *Ribes* (current) bush. Hand-pulling of *Ribes* was tested in

Fig. 21.12 In the 1920s through 1960s, intense controlled burns were the preferred method of disposing of logging slash and the inferior tree species left after clearcutting in western white pine forests

1923 by the Office of Blister Rust Control at PREF as a method for controlling the spread and impact of the disease. During this test, 15 men pulled 53,555 bushes on 690 ha of the Benton Creek drainage at PREF, but it proved to be unsuccessful in stopping the spread of the disease (Wellner 1976).

At DCEF and the adjoining Coeur d'Alene National Forest, the first work that Davis and Wellner undertook was to investigate ways of ensuring that western white pine regenerated after harvest. They also studied ways to create conditions that minimized the blister rust hazard. In the 1930s, it was believed the spores that traveled from *Ribes* to infect white pines lost their effectiveness in approximately 550 m (Spaulding 1922). Thus, approaches were tested that would provide such a buffer between western white pines and *Ribes* bushes. Large clearcuts were created (e.g., hundreds of hectares in size) and the inferior species such as western hemlock (*Tsuga heterophylla*) and grand fir (*Abies grandis*) were felled and/or sometimes poisoned (Foiles 1950). The resulting fuels (often large amounts) were intensely burned with the heat generated by the fire stimulated the sprouting of *Ribes* (Fig. 21.12). These plants would subsequently be hand-pulled or sprayed with a herbicide, thereby protecting the western white pine plantation from blister rust. It was discovered that *Ribes* spores were viable over distances greater than 550 m and no matter how many "workings" an area received, *Ribes* could not be eradicated. Hutchinson and Winters (1942) described *Ribes* control like "bailing an ocean with a teacup." Even though *Ribes* control was futile in protecting western white pines, tree improvement programs started in 1949 by Richard Bingham, a research scientist at the Moscow, Idaho Forest Sciences Laboratory, were very effective in producing rust resistant trees suitable for planting (Bingham 1983). Using silvicultural methods such as, but not limited to, planting rust resistant stock, tree pruning, and mass selection, the future in 2012, not without some problems, is very bright for western white pine (Geils et al. 2010; Graham et al. 1994; Schwandt et al. 2010).

Control burning research in the 1930s and 1940s at Deception Creek and the surrounding Coeur d'Alene National Forest was aided by Gisborne's inflammability and fuel moisture studies. Controlled burns developed the fundamental understanding of what is now called prescribed fire. These studies investigated different tools to ignite fires including drip torches, backpack propane torches, and truck-mounted flame throwers. Season of burn, time of day the burn occurred, and onsite weather variables vital for having a successful burn were tested. Most often, a successful burn was one that stayed within the fire line perimeter and severely burned the woody material and left the forest floor clean (Fig. 21.12).

At PREF in 1952, studies were conducted to identify variables besides fuel moisture and weather that could be used to plan and execute prescribed fires. The site of old F-127 Civilian Conservation Corp Camp along the Priest River was used for the slash burning experiments conducted by George Fahnestock from the Station and Dave Olson from the University of Idaho. Most of the experiments were completed by 1957 when Fahnestock transferred to the Southern Station, but he returned in 1960 to complete the study by burning 5-year-old slash (Fahnestock 1953, 1960; Wellner 1976). Similar to how Larsen's work influenced Gisborne, Fahnestock's work provided the foundation for Jim Brown of the Fire Sciences Laboratory to develop slash inventory methods and other allied information on slash and its consumption by fires (Brown 1974; Brown et al. 2003).

Fire danger and fire control research decreased at PREF when the Fire Sciences Laboratory in Missoula opened. However, PREF along with the BBEF and DCEF became integral in studying the effects of prescribed fire in the moist and dry forests. At BBEF, as in most ponderosa pine forests of the western USA, wildfires were aggressively suppressed. As a result, both ponderosa pine and Douglas fir (*Pseudotsuga menziesii*) regeneration proliferated over much of the forest and dense multi-canopied forests prevailed (Fig. 21.13). At Boise Basin, mechanical and fire methods are being studied as ways to restore the character of these forests. In addition, because tree densities increased in the dry forests due to fire exclusion, the forest floor accumulated layers of needles and bark slough. The amount of these materials would have been minimal if the native fire regimes would have continued. These uncharacteristically deep layers are most noticeable around large yellow-barked trees (Fig. 21.14). Fine roots can accumulate in these layers and, if they are destroyed through fire or mechanical means, the tree can be stressed and often succumbs to bark beetles. Studies are being conducted on ways to reduce these layers by increasing decomposition through mechanically mixing the surface layers and burning the organic layers in snow wells (Fig. 21.14). The results of these

Fig. 21.13 Prior to masticating, many small trees occurred in this ponderosa pine stand (*top*). After masticating with a track-mounted machine, the majority of the small trees were removed leaving the larger trees (*bottom*)

tests have shown that up to two snow well burns or surface mixings may be required depending on the layers' depth before the majority of the fine roots will occur in the mineral layers. It has also been shown that the best time to disturb the surface organic layers is when the lower duff layers (e.g., humus and fermentation layer) have a moisture concentration near or exceeding 100 % and their temperatures are below 4.4 °C. After such duff layers have been reduced, a prescribed fire can more readily be used without unduly stressing the residual trees (Graham et al. 2007, 2010; Fig. 21.15).

In the moist forests at Priest River and Deception Creek, treatments are being tested that reduce the fuels, but leave a high forest canopy (Jain et al. 2004, 2008). Such conditions are often valued for wildlife and provide a sense of security and/or place to people. Treatments are being tested both in the wildland urban interface and matrix lands. The tests have shown that using a mechanical masticator that leaves large chunks will create material and conditions that favor wood decomposi-

Fig. 21.14 Because of fire exclusion, uncharacteristically deep layers of needles and bark slough can accumulate beneath large yellow-barked ponderosa pine trees (*top*). These layers can contain abundant fine roots and if the layers are destroyed mechanically or by fire, these valuable trees can be stressed and succumb to bark beetles. By judicially applying fire when the lower organic layers are moist and cool, the fine roots when they start growing (when the soil warms) will remain in the mineral soil (*bottom*)

tion (Fig. 21.16). Even though fine fuels are increased immediately after treatment, within 3 years the fire hazard is reduced as the material readily decomposes. Similar results were found in masticating ponderosa pine fuels in the BBEF as long as summer monsoon rains occasionally wetted the forest floor (Graham et al. 2010; Fig. 21.13).

There is a great deal of research on how to manipulate moist forests for the purpose of timber production. Priest River and Deception Creek provided valuable in-

Fig. 21.15 It may take multiple snow well burns in ponderosa pine forests where fire has been excluded before the root architecture is such that prescribed fire can be broadcast through the forest safely (Fig. 21.14)

formation on growth, yield, site preparation, planting, disease resistance, and other information applicable for growing timber crops (Bingham 1983; Haig 1932; Haig et al. 1941). Using this foundation, both forests are being used to test how fuel treatments (e.g., mechanical, fire) can be designed and implemented over landscapes to affect wildfire behavior and burn severity if a fire was to occur (Jain et al. 2008). FARSITE and FlamMap, two fire models developed at the Fire Sciences Laboratory, have been used to project how fuel treatments may alter fire behavior (Finney and Andrews 1998; Finney 2006). These analyses have shown that the fuel treatments would not stop a fire nor necessarily reduce its ultimate size. However, the fuel treatments, no larger than 1.6 ha in size would disrupt the progression of a fire and offer suppression opportunities. Also within fuel treatments, predicted flame lengths were less than 30 cm compared to more than 3.0 m in untreated areas. After the simulations, it was noted that the heterogeneous forest landscapes created by fuel treatments would leave a mixture of green, brown, and black forest conditions distributed across the forest compared to all black conditions left after the simulated fire in the untreated landscape. Such mixed burn severities present in the treated forest would offer greater opportunities for a forest to recover compared to forests that were completely blackened after a forest fire (Jain et al. 2008).

Fig. 21.16 Decomposition of fuels can be maintained and enhanced by mastication if pieces left are of sufficient size as to not wet and dry readily and are in close contact to the forest floor. With the increase in fine fuels, the fire hazard can be exacerbated in the short term from mastication but within 2–3 years it can be minimal

21.7 Post-Wildfire Treatments

Information about the impact of post-wildfire forest treatments (e.g., salvage logging) on vegetation, soil, and water is needed throughout the western USA (Peterson et al. 2009). Most often data are not available on forest structure and forest floor conditions before a wildfire burns. Replicates of a wildfire, in conjunction with well-documented post-wildfire treatments, are also hard to come by. Therefore, at both PREF and BBEF sediment catchments were installed at the mouths of eight small watersheds (e.g., 4–6 ha; Fig. 21.17). Vegetation (mixed conifer forest) was burned on two watersheds at each forest and for one, the burning was followed by a salvage treatment (Fig. 21.18). The salvage operation was conducted to leave conditions that offered the greatest opportunity for forest recovery and, depending on how severely the watershed was burned, the number of trees remaining ranged from a few to many. In addition to these wildfire treatments, two watersheds at each forest remained undisturbed and in two watersheds the fuels were treated. The results of these studies are still forthcoming, but will show how wildfire, wildfire followed by salvage logging, and fuel treatments affect the soil, water, and vegetation in the moist and dry forests (Elliot et al. 2006).

Fig. 21.17 Sediment catchments were established at the mouths of eight small watersheds at the Priest River Experimental Forest to test the effects of prescribed wildfire (shown) and wildfire followed by logging on soil, vegetation, and water properties

21.8 Conclusion

After nearly 100 years of fire research, we still strive to effectively manage forests in the face of ever-growing threats of urbanization and unwanted wildfires. Building on the legacy of research accomplished on the Idaho experimental forests and the basic understanding of fire and its effects that the early researchers developed, these forests are more valuable now than ever. They are outdoor laboratories where observational and manipulative studies can occur. Fire and fire-related studies have been a part of the Idaho experimental forests since in 1912 when J. A. Larsen began quantifying duff moisture and related this information to fire occurrence. The drive and perfection demanded by Harry T. Gisborne set the standard for fire scientists that many would aspire to, but few would achieve (Graham 2004; Hardy 1983; Klade 2006; Maclean 1992). The tone and direction of fire research he started at Priest River in 1922 is still relevant for meeting today's challenges (Hardy and Hardy 2007).

The experimental forests of Idaho produce short- and long-term studies and data applicable for understanding and managing dry and moist forests. In particular, they

Fig. 21.18 Prescribed wildfire (pictured at PREF) and wildfire followed by salvage logging are being evaluated at both the Priest River and Boise Basin Experimental Forests for their impacts on soil, water, and vegetation. In addition, fuel treatments and undisturbed watersheds are included in the studies at both forests

can help inform how fire can be used to manage North American forests. All three forests have replicates of interdisciplinary studies investigating ways stands to landscapes can be treated to interrupt and decrease the burn severity of a wildfire if one was to occur (Elliot et al. 2006; Jain et al. 2008). Fuel treatments such as mastication, grapple piling, and prescribed fire are being studied singly and in combination as to how they can emulate the effects of low and mixed severity fires. Because of fire exclusion, especially on BBEF, these Idaho experimental forests provide abundant research opportunities to study innovative methods of forest restoration. No one knows exactly what issues or informational needs will arise in the next 100 years. By ensuring that experimental forests provide a wide variety of forest structures and compositions they will be high value assets to researchers, managers, and the citizens of the USA for addressing future information needs.

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References

Baker RD, Burt L, Maxwell RS, Treat VH, Dethloff HC (1993) National Forests of the northern region: living legacy. Intaglio, College Station

Barrows JS et al (1957) Project skyfire. In: Final report of the advisory committee on weather control, vol 2. Unnumbered reprint. United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT, pp 105–125

Bingham RT (1983) Blister rust resistant western white pine for the inland empire: the story of the first 25 years of the research and development program. General Technical Report INT-GTR-146, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT

Brown JK (1974) Handbook for inventorying downed woody material. General Technical Report INT-GTR-16, United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT

Brown JK, Reinhardt ED, Kramer KA (2003) Coarse woody debris: managing benefits and fire hazard in the recovering forest. General Technical Report RMRS-GTR-105, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT

Cohen S (1978) The Big Burn: the Northwest's forest fire of 1910. Pictorial Histories Publ Co, Missoula

Deeming JE, Lancaster JW, Fosberg MA, Furman WR, Schroeder MJT (1972) Fire-danger rating system. Research Paper RM-RP-84, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO

Elliot WJ, Miller IS, Glaza BD (2006) Using WEPP technology to predict erosion and runoff following wildfire. 2006 ASABE annual international meeting, Portland, OR. ASABE Paper No. 068011, Sponsored by ASABE, Portland Convention Center: American Society of Agricultural and Biological Engineers

Fahnestock GR (1953) Inflammability of the current year's logging slash. Research Note INT-RN-120, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT

Fahnestock GR (1960) Logging slash flammability. Research Paper INT-RP-58, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT

Finney MA (2006) An overview of FlamMap fire modeling capabilities. In: Andrews PL, Butler BW (comps) Fuels management-how to measure success: conference proceedings; Portland, OR. General Technical Report INT-GTR-213WWW. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp 213–220

Finney MA, Andrews PL (1998) FARSITE: fire area simulator—a model for fire growth simulation. Fire Manage Note 59(2):13–15

Fischer WC, Hardy CE (1976) Fire-weather observer's handbook. Agriculture handbook 494, U.S. Department of Agriculture, Washington, DC

Foiles MW (1950) Recommendations for poisoning western hemlock. Research Note NRM-RN-77, Northern Rocky Mountain Research Station, U.S. Department of Agriculture, Forest Service, Missoula, MT

Geils BW, Hummer K, Hunt RS (2010) White pines, *Ribes*, and blister rust: a review and synthesis. For Pathol 40:147–185

Gisborne HT (1931) Lightning on the lookouts. Am For 37(9):515–518, 574–575

Gisborne HT (1933) Lightning and forest fires. Pulp Pap Can 34(6):327–329

Gisborne HT (1939) Hornby's principles of fire control planning. J For 4(1):292–296

Gisborne HT (1948) Fundamentals of fire behavior. Fire Control Note 9:13–24

Graham KL (2004) History of the Priest River Experiment Station. General Technical Report RMRS-GTR-129, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO

Graham RT, Tonn JR, Jain TB (1994) Managing western white pine plantations for multiple resource objectives. In: Baumgartner DM, Lotan JE, Tonn JR (eds) Proceedings interior cedar-hemlock-white pine forests: ecology and management; Spokane, WA. Department of Natural Resource Sciences, Washington State University, Pullman, WA, pp 357–362

Graham RT, Jain TB, Sandquist J (2007) Free selection: a silvicultural option. In: Powers R (ed) Restoring fire-adapted forested ecosystems. 2005 national silviculture workshop, Lake Tahoe, CA. General Technical Report PSW-GTR-203, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA, pp 121–156

Graham RT, Jain TB, Mathews SJ (2010) Chapter 3: Fuel management in forests of the Inland West. In: Elliot WJ, Miller IS, Audin L (eds) Cumulative watershed effects of fuel management in the western United States. General Technical Report RMRS-GTR-231, pp 19–68

Haig IT (1932) Second-growth yield, stand, and volume tables for western white pine type. Technical Bulletin No. 323, U.S. Department of Agriculture, Washington, DC

Haig IT, Davis KP, Weidman RH (1941) Natural regeneration in the western white pine type. Technical Bulletin No. 767, U.S. Department of Agriculture, Washington, DC

Hardy CE (1983) The Gisborne era of forest fire research legacy of a pioneer. FS-367, U.S. Department of Agriculture, Forest Service, Washington, DC

Hardy CC, Hardy CE (2007) Fire danger rating in the United States of America: an evolution since 1916. Int J Wildland Fire 16:217–231

Hayes GL (1942) Differences in fire danger with altitude, aspect, and time of day. J For 40(4):318–323

Helfman RS, Deeming JE, Straub RJ, Furman RW (1975) User's guide to AFFIRMS: time-share computerized processing for fire-rating. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO

Hoar CA, Noyes DK, Larsen JA, Jeffers DS, Newins HS, Watzek CH (1981) "Dear professor Chapman": letters from Yale forestry graduates, 1910–1912. J For Hist 25(4):197–209

Hutchison SB, Winters RK (1942) Northern Idaho forest resources and industries. Miscellaneous Publication 508, U.S. Department of Agriculture, Washington, DC

Jain TB, Graham RT (1996) Deception Creek Experimental Forest. In: Schmidt WC, Friede JL (comps) Experimental forests, ranges, and, watersheds in the Northern Rocky Mountains—a compendium of outdoor laboratories in Utah, Idaho, and Montana; General Technical Report INT-GTR-334, U. S. Department of Agriculture, Forest Service, Intermountain Research Station, pp 45–50

Jain TB, Graham RT, Morgan P (2004) Western white pine growth relative to forest openings. Can J For Res 34:2187–2197

Jain TB, Graham RT, Sandquist J, Butler M, Brockus K, Frigard D, Cobb D, Han H, Halbrook J, Denner R, Evans J (2008) Restoration of Northern Rocky Mountain moist forests: integrating fuel treatments from the site to the landscape. In: Deal R (ed) Integrated restoration efforts for harvested forest ecosystems; Ketchikan, AK. General Technical Report PNW-GTR-733, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, pp 147–172

Jemison G (1950) Forty years of forest research in the Northern Rocky Mountain region: fortieth annual report. U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station, Missoula, MT

Klade RJ (2006) Building a research legacy—the intermountain station 1911–1997. General Technical Report RMRS-GTR-184, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO

Larsen JA (1921a) Relative humidity of the atmosphere and its relation to the fire problem. Appl For Note 6, U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station

Larsen JA (1921b) Sunshine and air temperature in relation to forest fires. Appl For Note 9, U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station, Missoula, MT

Larsen JA (1921c) Wind and its relation to forest fires. Appl For Note 7, U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station

Larsen JA (1922) Weather records at lookout stations in northern Idaho. J For 20(3):215–219

Maclean N (1992) Young men and fire. University of Chicago Press, Chicago

Peterson DL, Agee JK, Aplet GH, Dykstra DP, Graham RT, Lehmkuhl JF, Pilloid DS, Potts DF, Powers RF, Stuart JD (2009) Effects of timber harvest following wildfire in western North America: issues and scientific evidence. General Technical Report PNW-GTR-776, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR

Pyne SJ (2001) Year of fires: the story of the great fires of 1910. Penguin Books, New York

Pyne SJ (2010) America's fires: a historical context for policy and practice (Rev edn). Forest History Society, Durham

Rothermel RC (1993) Mann Gulch fire: a race that couldn't be won. General Technical Report INT-299, United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT

Schmaltz NJ (1980) Forest researcher: Raphael Zon. J For Hist 24(1):24–39

Schwandt JW, Lockman JB, Kliejunas JT, Muir JA (2010) Current issues and management strategies for western white pines in the western United States and Canada. For Pathol 40:226–250

Sloan J, Steele R (1996) Boise Basin Experimental Forest. In: Schmidt WC, Friede JL (comps) Experimental forests, ranges, and, watersheds in the Northern Rocky Mountains—a compendium of outdoor laboratories in Utah, Idaho, and Montana. General Technical Report INT-GTR-334, U. S. Department of Agriculture, Forest Service, Intermountain Research Station, pp 39–44

Spaulding P (1922) Investigations of the white pine blister rust. Bulletin No. 957, U.S. Department of Agriculture, Washington, DC

Spencer BG (1956) The big blowup. Caxton Printers, Ltd, Caldwell

Wellner CA (1976) Frontiers of forestry research—Priest River Experimental Forest 1911–1976. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden