Some Random Thoughts on Fire Behavior Research and Operational Fire Behavior Considerations

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Keynote Address 2: 4th Plenary FIRE PARADOX Meeting, 9-13 June 2008, Chania, Crete, Greece

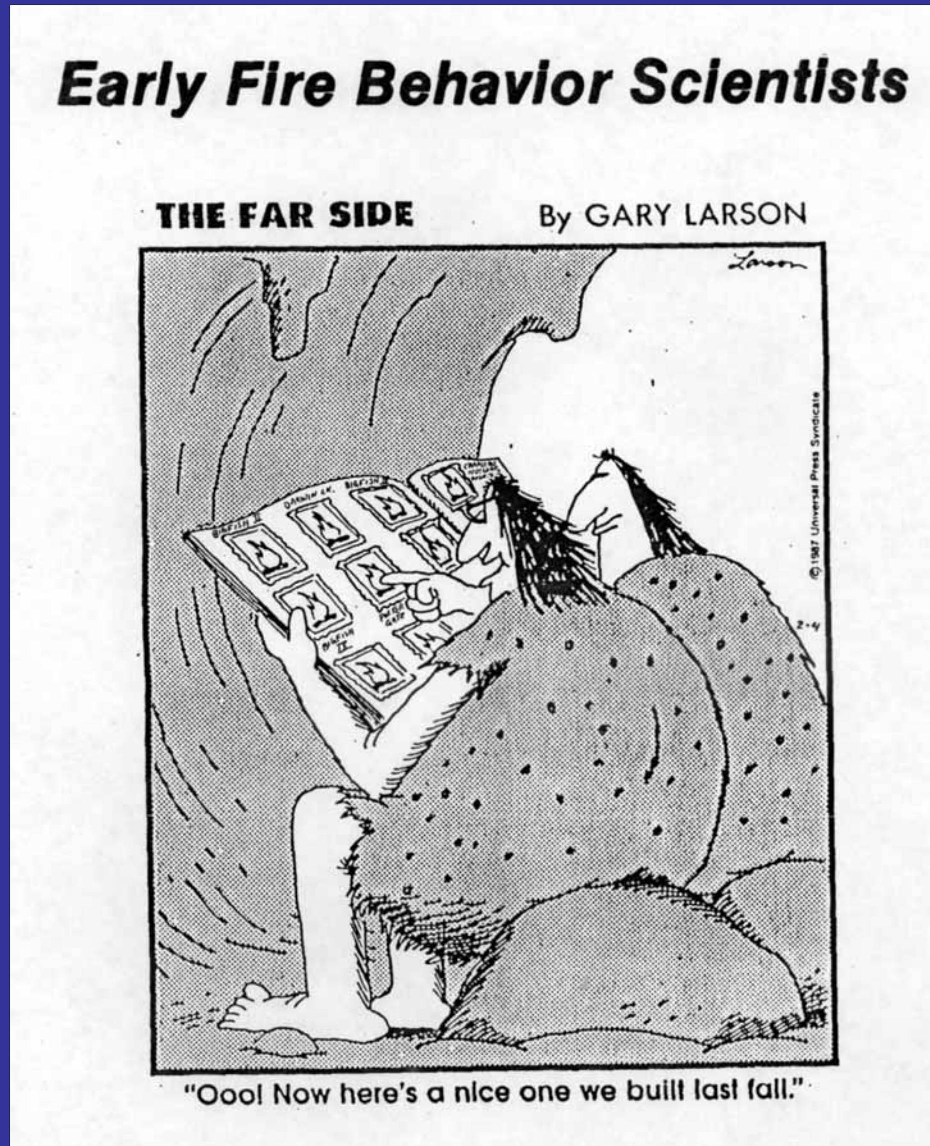
“Road Map” of Presentation

- Background of Presenter
- Origins of Fire Behavior Research
- Fire Behavior Research
- Operational Fire Behavior Considerations
- Closing Remarks
- Questions? Comments?

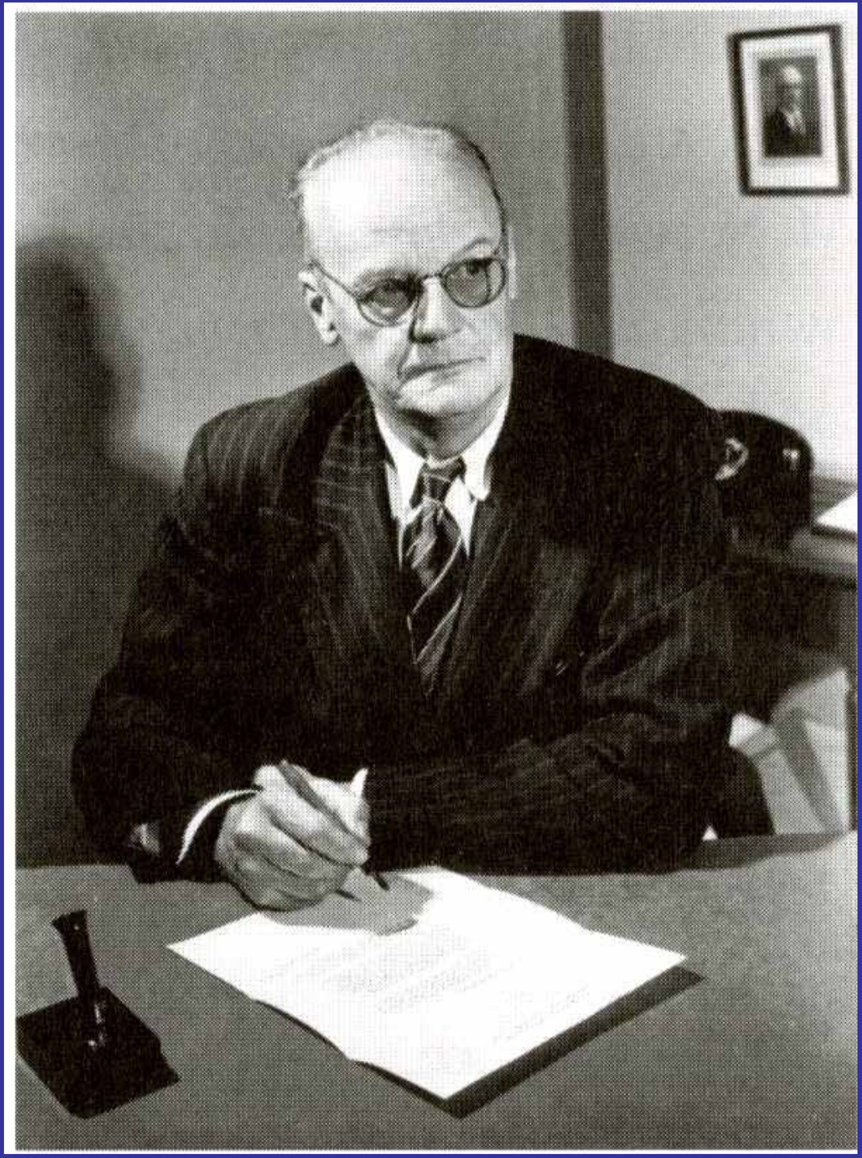
Background of Presenter

- Fought first wildland fire as a 15-year old
- Member of Interagency Hotshot Crew (Wyoming, USA), summers of 1972 & 1973
- Worked part-time for U.S. National Fire Danger Rating System Project, 1972-1974
- BSc, MSc and PhD degrees in forestry
- Employed by Canadian Forest Service since 1976, principally in fire behavior research
- Work experience in Australia, New Zealand and Alaska
- Consider myself a “student” of wildland fire research

Origins of Fire Behavior Research



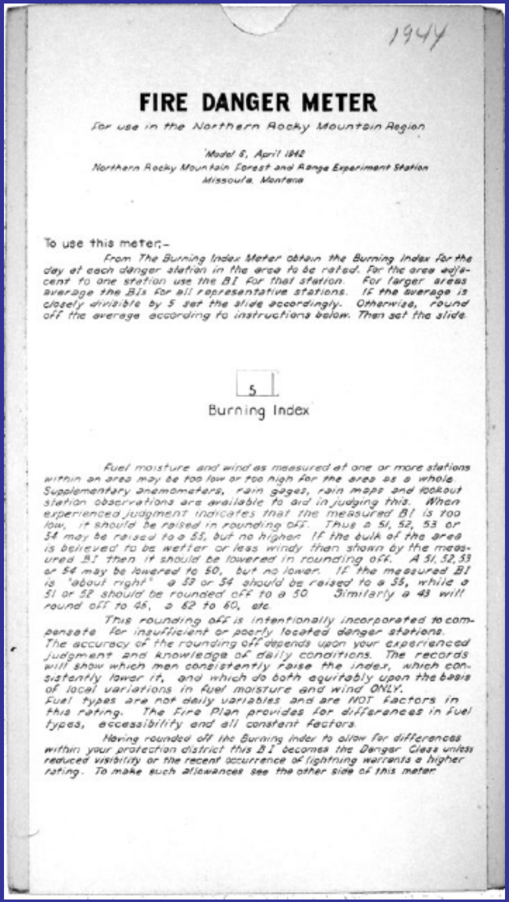
When and who started it?



Point source fires carried out in ponderosa pine in northern California in 1915-1917 by S.B. (Stuart) Show, a forester with the U.S. Forest Service.

Show, S.B. 1919. Climate and forest fires in northern California. *Journal of Forestry* 17: 965-979.

American Pioneer in Forest Fire Research: Harry T. Gisborne



1944

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.

5

Burning Index

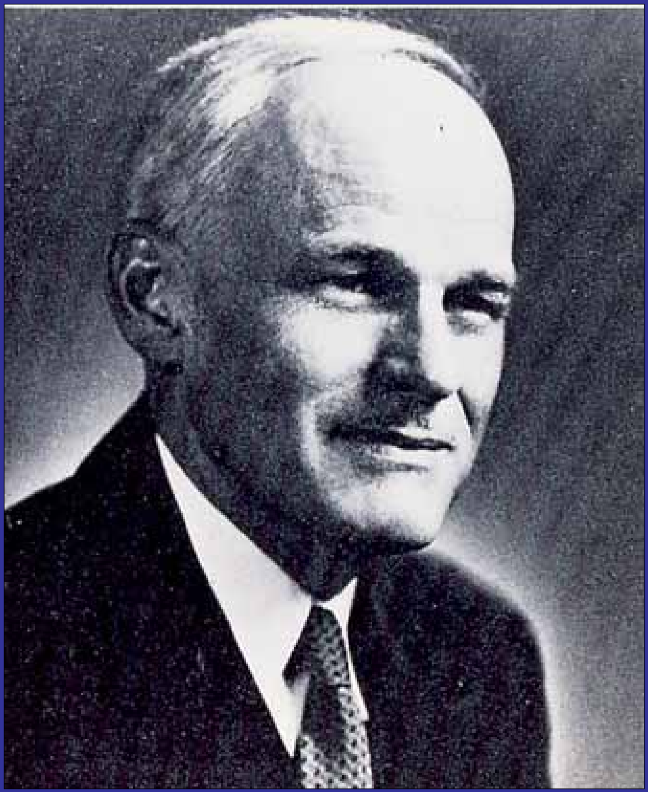
Fuel moisture and wind as measured at one or more stations within an area may be too low or too high for the area as a whole. Supplementary anemometers, rain gages, rain maps and lookout station observations are available to aid in judging this. When experienced judgment indicates that the measured BI is too low, it should be raised in rounding off. Thus a 51, 52, 53 or 54 may be raised to a 55, but no higher. If the bulk of the area is believed to be wetter or less windy than shown by the measured BI then it should be lowered in rounding off. A 51, 52, 53 or 54 may be lowered to 50, but no lower. If the measured BI is "about right" a 53 or 54 should be raised to a 55, while a 51 or 52 should be rounded off to a 50. Similarly a 48 will round off to 45, a 62 to 60, etc.

This rounding off is intentionally incorporated to compensate for insufficient or poorly located danger stations. The accuracy of the rounding off depends upon your experienced judgment and knowledge of daily conditions. The records will show which men consistently raise the index, which consistently lower it, and which do both equitably upon the basis of local variations in fuel moisture and wind ONLY. Fuel types are not daily variables and are NOT factors in this rating. The Fire Plan provides for differences in fuel types, accessibility and all constant factors.

Having rounded off the Burning Index to allow for differences within your protection district this BI becomes the Danger Class unless reduced visibility or the recent occurrence of lightning warrants a higher rating. To make such allowances see the other side of this meter.

First full-time USFS fire researcher appointed in 1922

Canadian Pioneers in Forest Fire Research: James G. Wright and Herbert W. Beall



Wright initiates FDR research within the federal forest service in 1924. Beall becomes Wright's summer student in 1928 and obtains a full-time appointment in 1932.

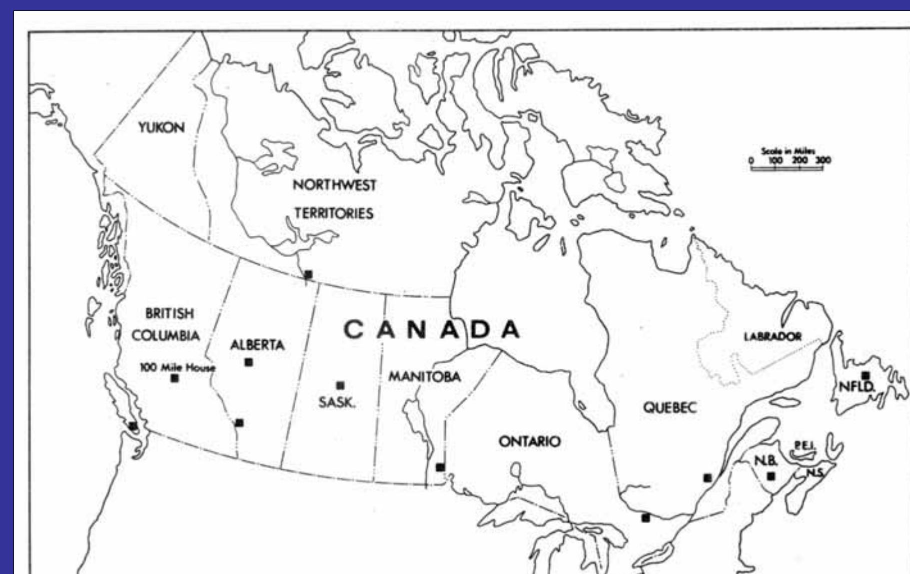
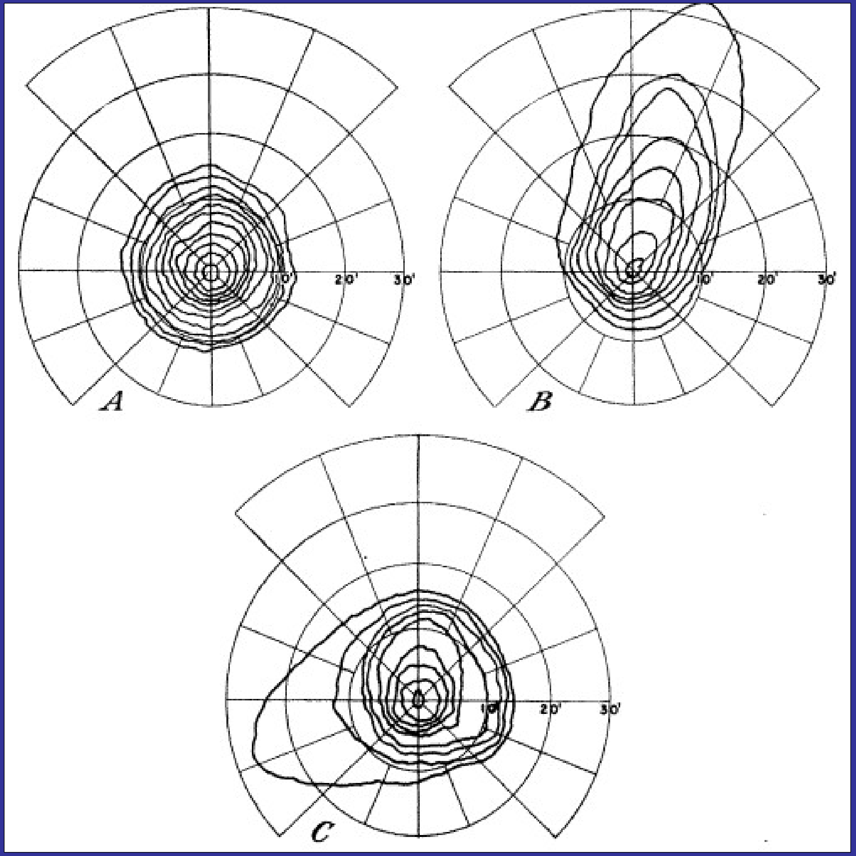
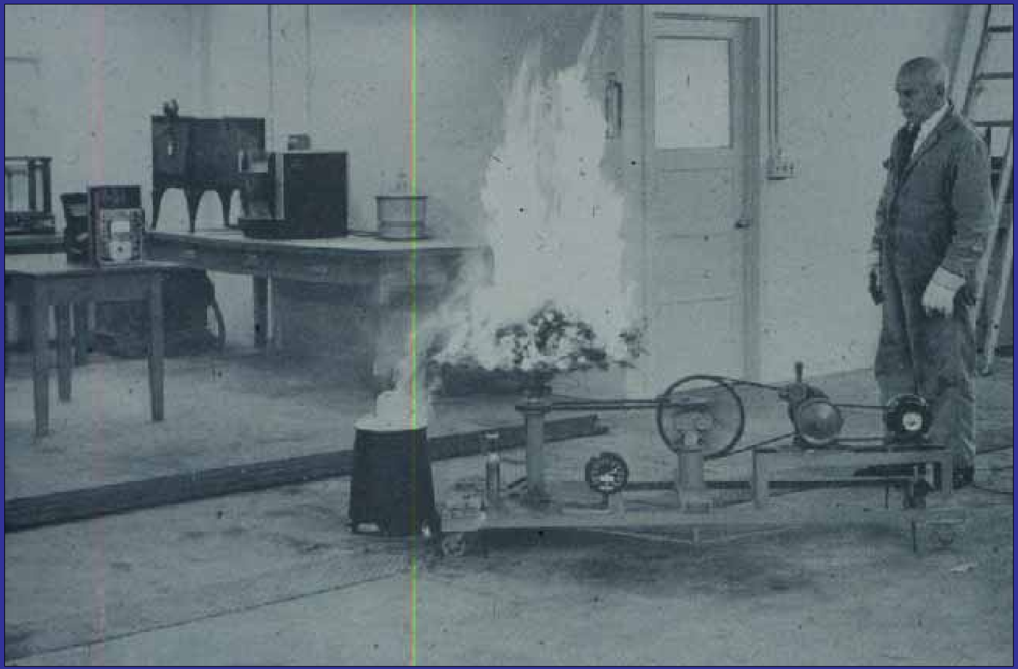


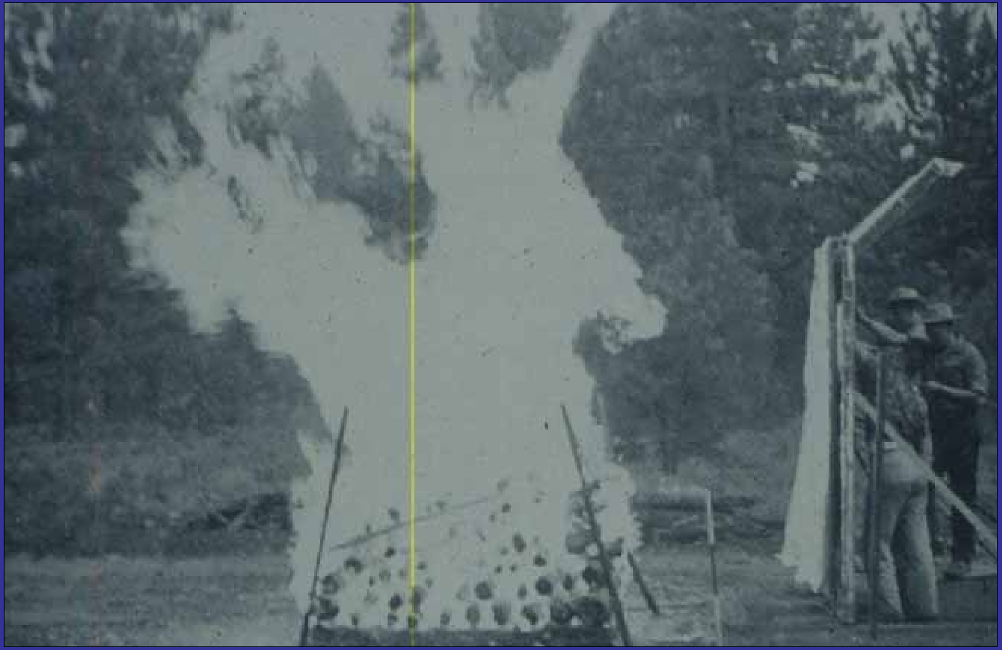
Figure 1-THE LOCATION OF FOREST FIRE RESEARCH STATIONS

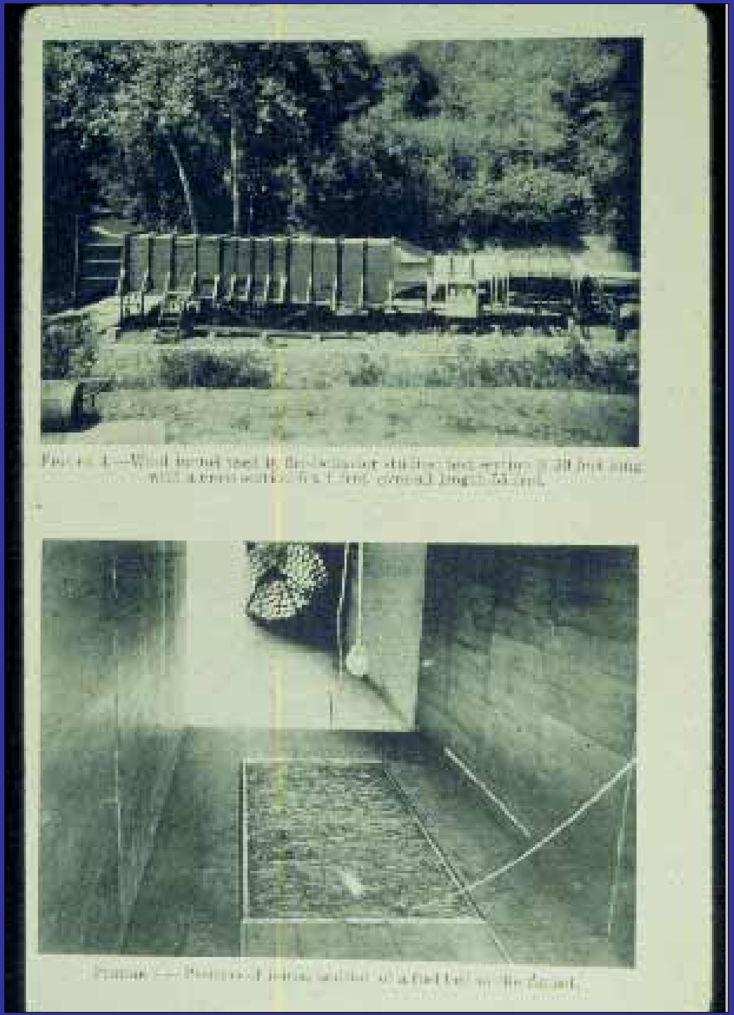
U.S. Forest Service fire researchers **John Curry** and **Wally Fons** undertake point source fire research in ponderosa pine in California in the 1930s



USFS lab fire studies in late 30s by Wally Fons

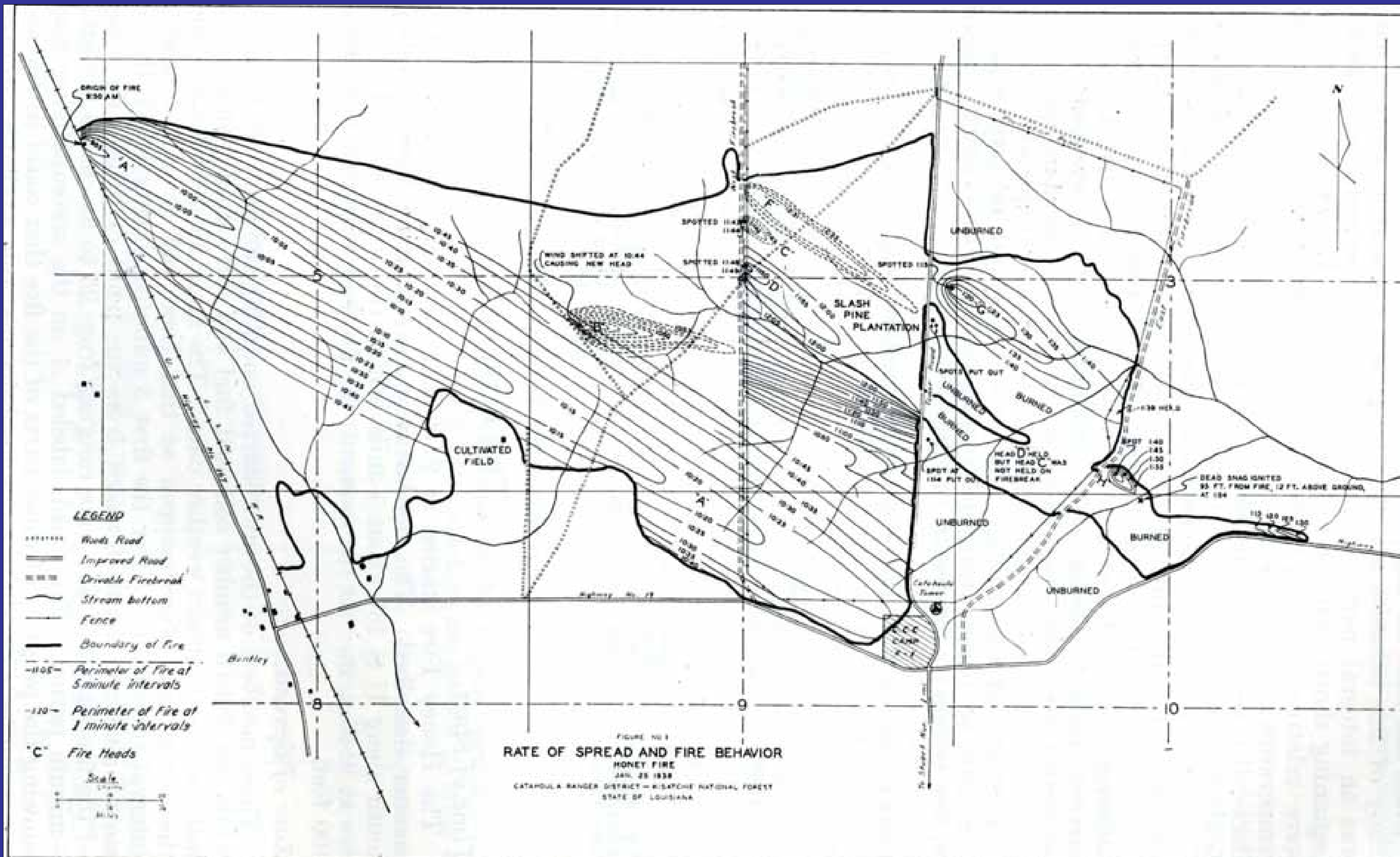






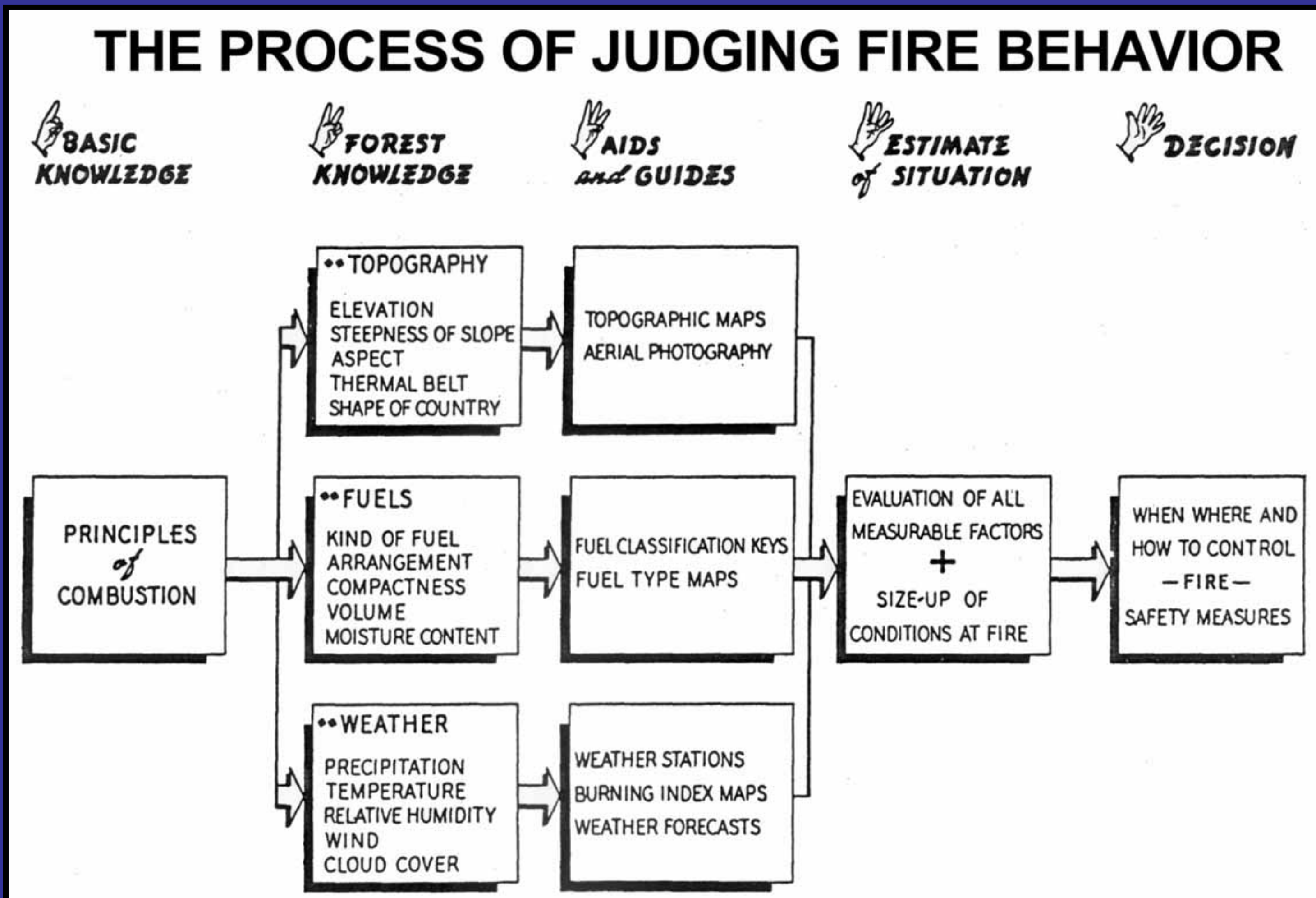
Example of Wildfire Documentation:

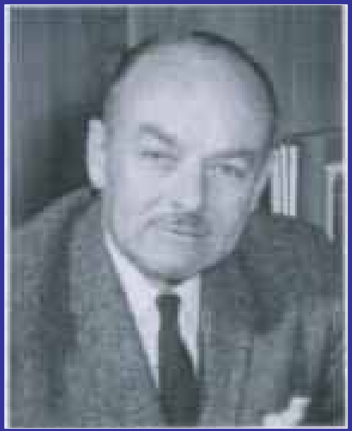
1938 Honey Fire, Louisiana



"Rates of spread vary in a bewildering way. It would be easy to yield to the temptation to throw up our hands and say that it is useless to try for anything but good guesses at the rate a given fire will spread under given conditions of fuel, weather, and topography. The saner attitude is to keep digging away at the effect of this or that factor on rate of spread in the belief that in time the intricate puzzle will be solved by the creation of something that can rightfully be called the science of rate of spread". – **George M. Jemison (1939)**

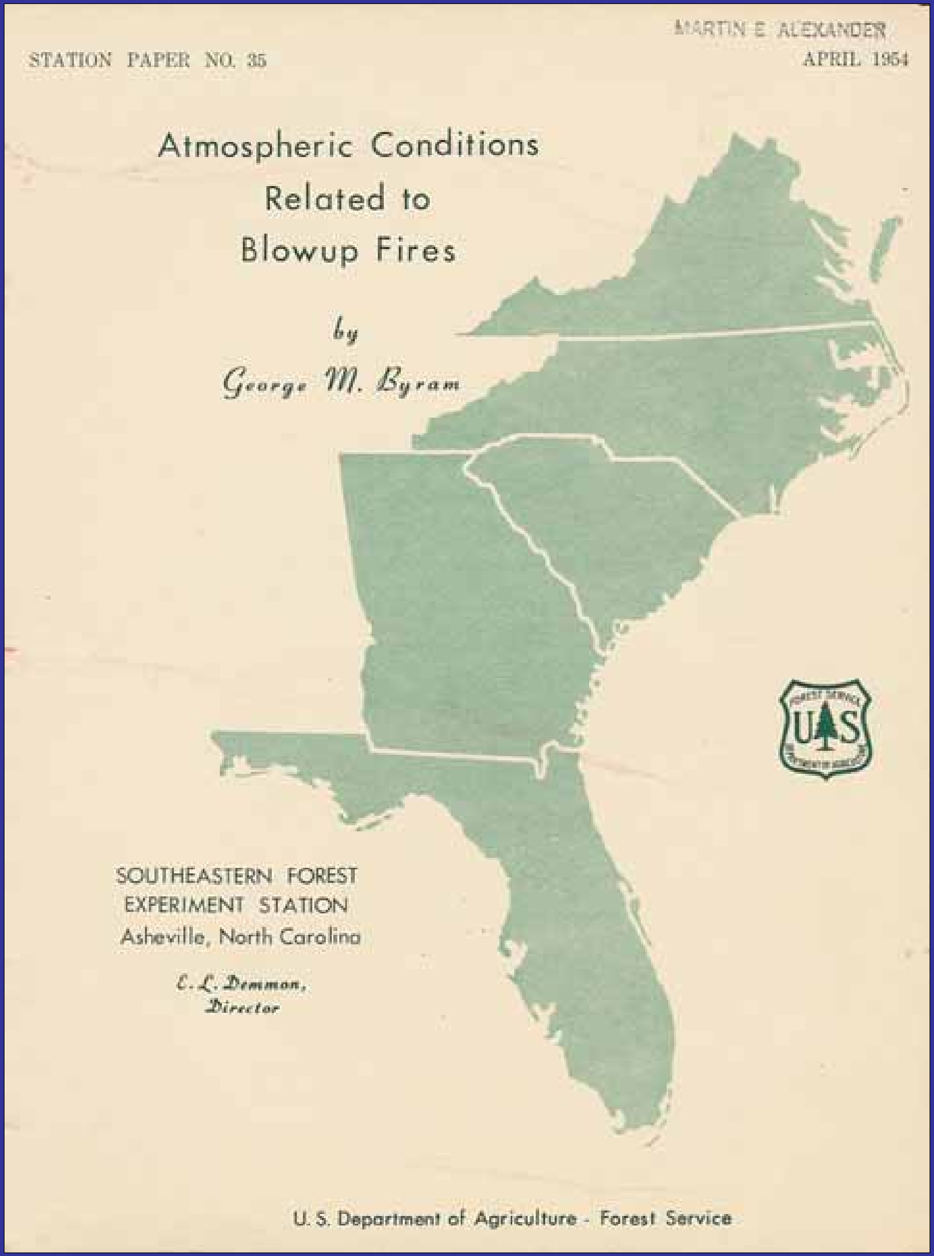
Jack Barrows publishes landmark fire behavior guide in 1951





Jack Barrows

Systematic analysis that combines "art and science"


STATION PAPER NO. 35

MARTIN E. ALEXANDER
APRIL 1954

Atmospheric Conditions Related to Blowup Fires

by

George M. Byram

SOUTHEASTERN FOREST EXPERIMENT STATION
Asheville, North Carolina

E. L. Demmon, Director

U. S. Department of Agriculture - Forest Service

U.S. Forest Service Physicist George Byram investigates "blowup" fires in the 1950s using the case study approach

Prescribed Fire Climate Survey Experimental Burns (California) carried out in the late 1950s by **Clive Countryman** and **Mark Schroeder**

Figure 14.--Prescribed burn 3-57 at 1141 hours.

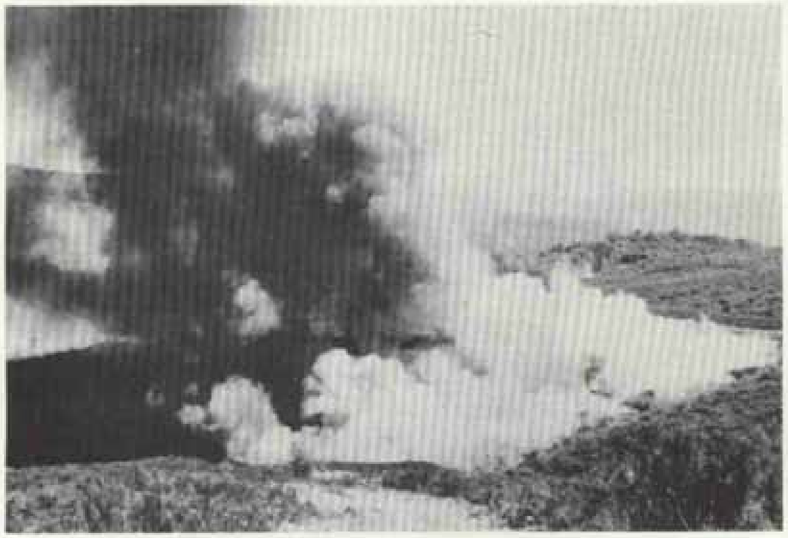
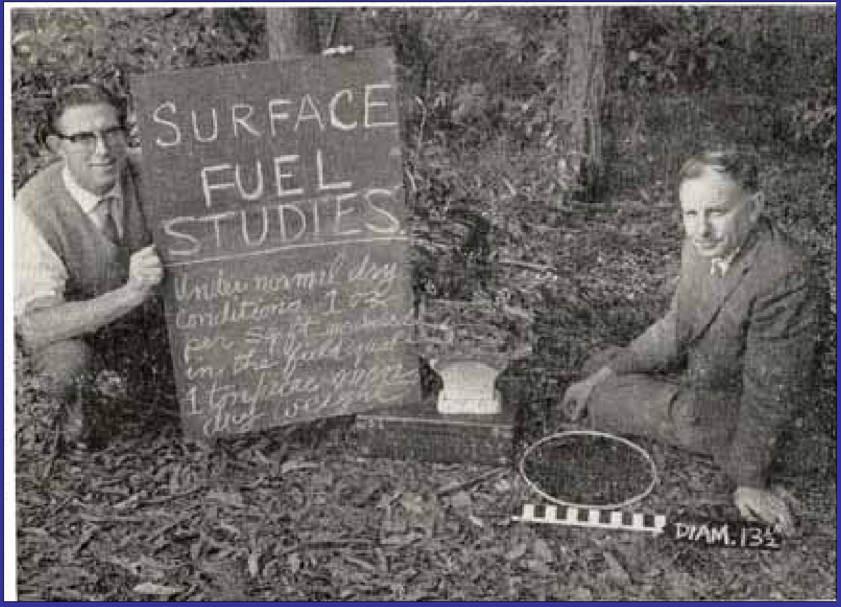
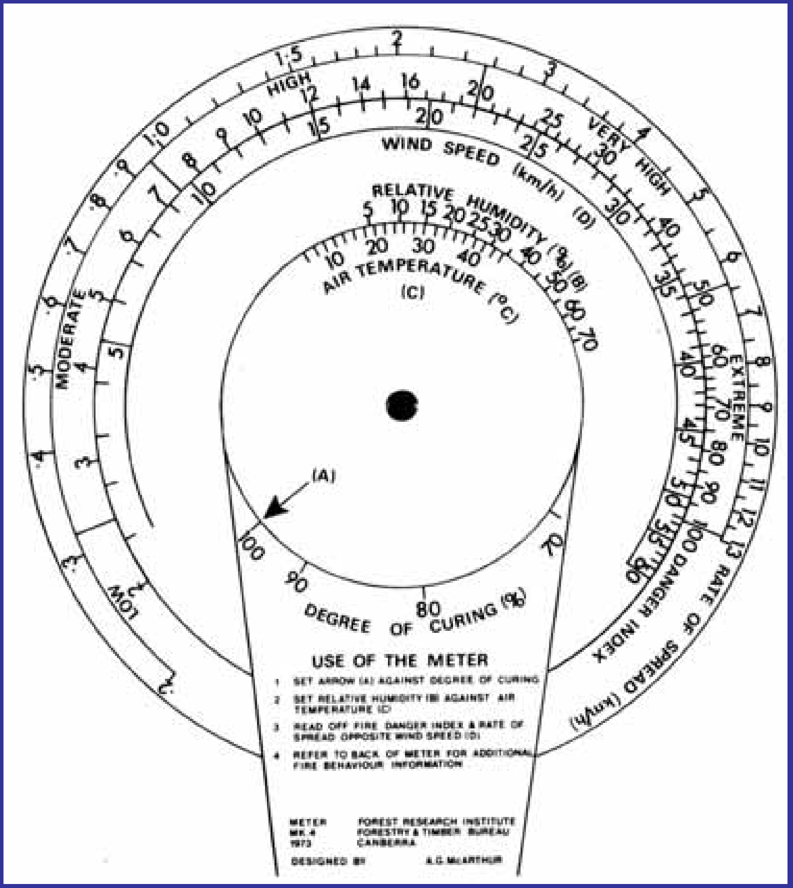


Figure 16.--Prescribed burn 3-57 at 1212 hours.

Australian fire researchers start to make there mark beginning in the mid 1950s

Experimental fire behaviour studies in dry sclerophyll Eucalypt forest; Black Mountain, A.C.T. These are low intensity fires burnt during late autumn. Metal markers are used to locate the perimeter at two minute intervals.



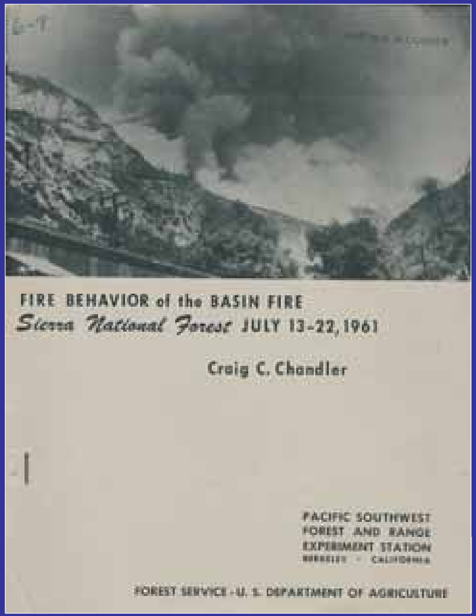


Pioneers Alan McArthur and Harry Luke

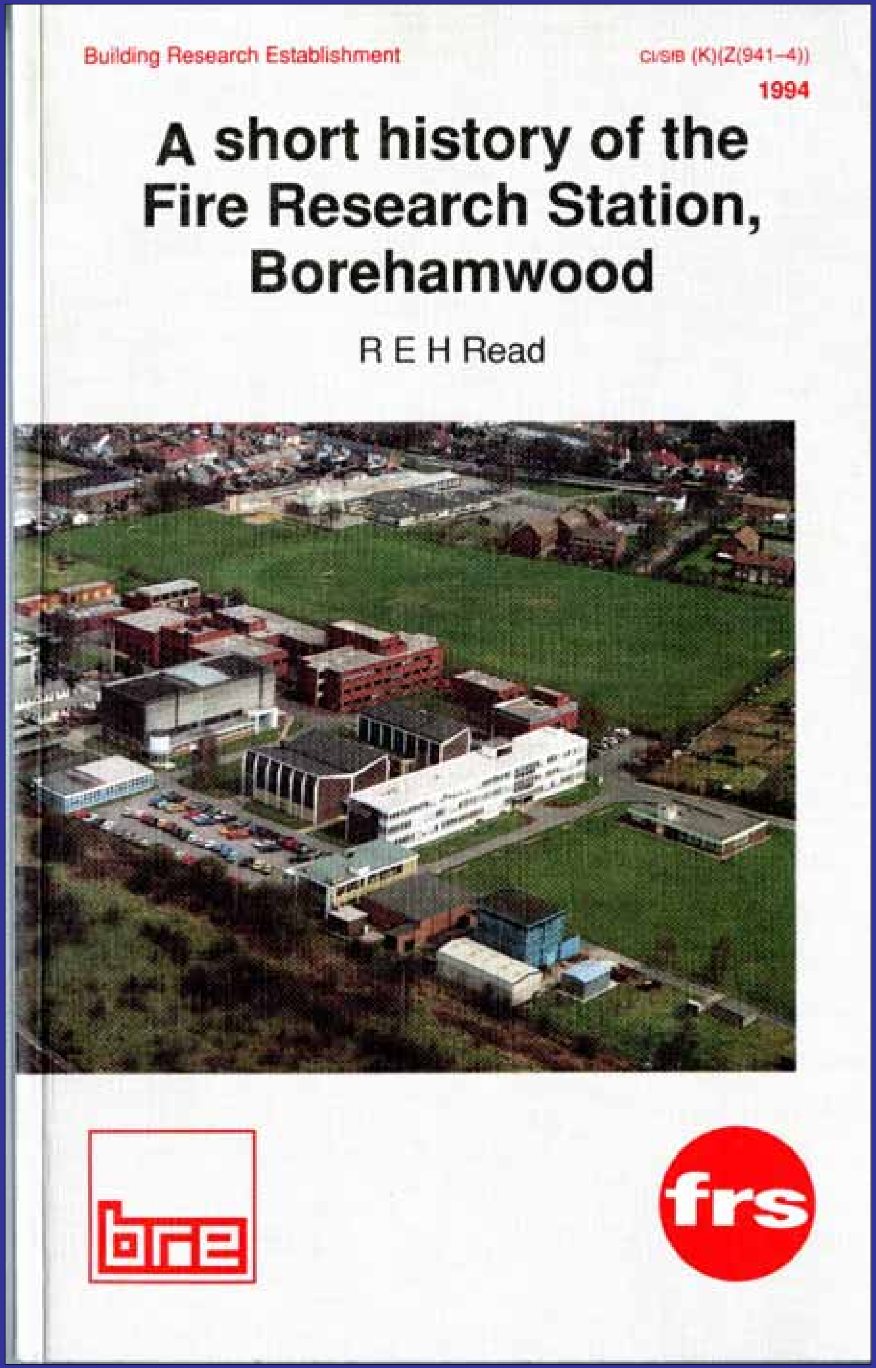
The Fire Behavior Officer (FBO) position (now called Fire Behavior Analyst or Fire Behavior Specialist) on large fire or project fire overhead suppression teams was a direct result of the 1957 USFS Firefighter Fatality Task Force.

The position was pioneered in the late 50s by U.S. Forest Service fire researchers in southern California, namely **Clive Countryman, Mark Schroeder, Craig Chandler** and **Carl Wilson**.

Fire behavior team in action

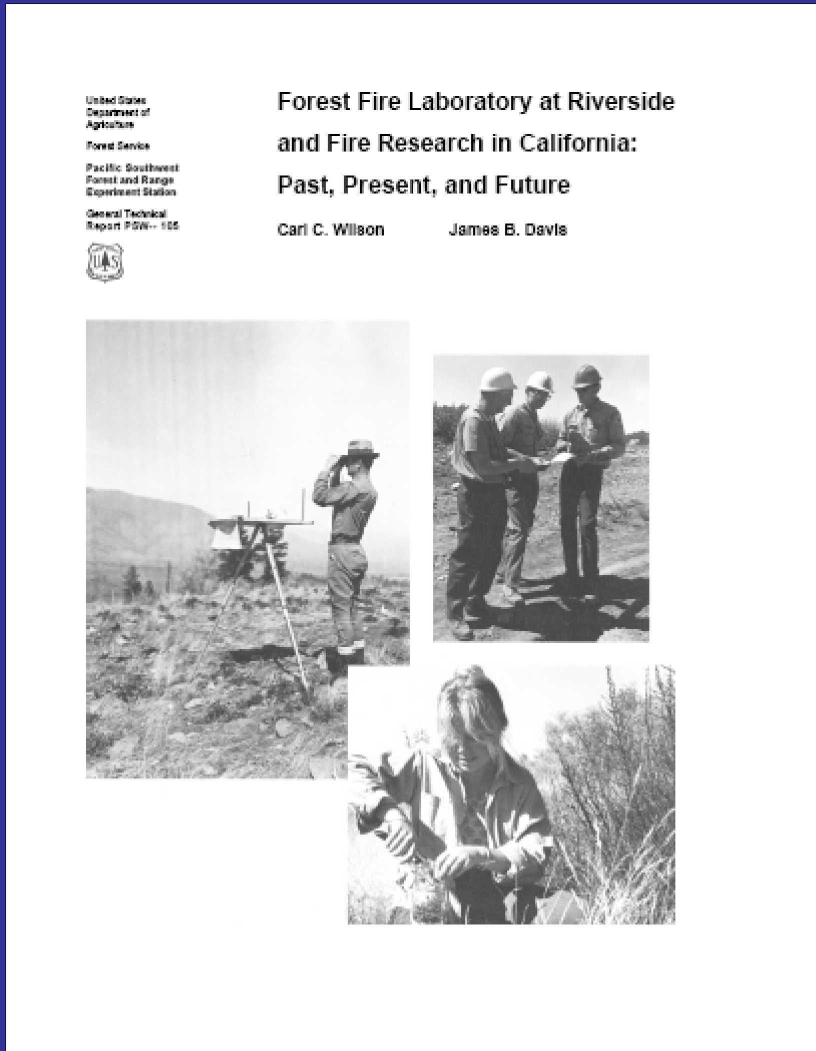


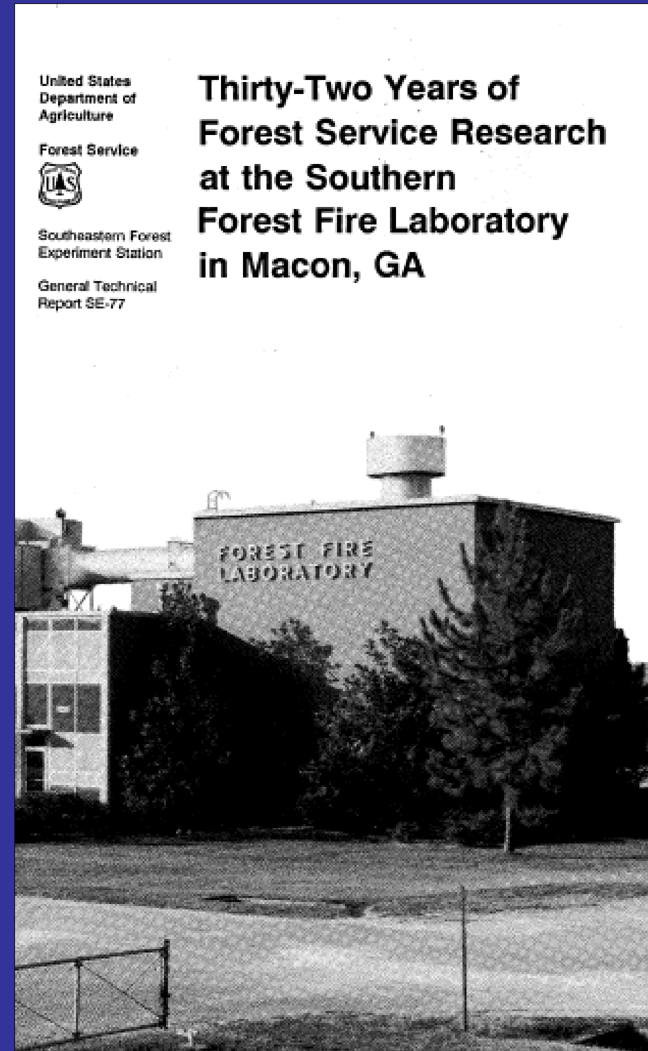
Fire behavior team field kit



"Recognizing our history while building our tomorrow"

"... the book not only sets out the background to our current knowledge and its application to fire safety, but also the culture behind it. The book will do much to help those coming into fire research in the future to build on these roots for the future". **-- Dr. D. Woolley, Director - Fire Research Station**





Also: Hardy, C.E. 1983. The Gisborne era of forest fire research: legacy of a pioneer. USDA Forest Service, Washington, DC. Miscellaneous Publication FS-367.

Flammability of Chaparral Depends on How It Grows

Southern California chaparral has long been noted for its flammability, which is usually ascribed to the general character of the vegetation, steep slopes, and severe weather conditions. Probably not enough emphasis has been given to changes in the vegetation itself that affect its fuel qualities.

All evergreen California chaparral species normally grow new twigs and leaves in the spring and drop a portion of the older leaves in the summer and fall. For the canopy to reach full development, after this type of vegetation is first established, usually requires 8 to 12 years, during which time little dead wood or litter is produced and fire presents no particular problem.

When the site becomes fully occupied, annual production of new twigs and leaves is balanced by the death of older branches and leaves. In normal years there is a seasonal cycle in flammability caused by an increase in numbers of leaves with high moisture content in the spring, then a decrease in numbers and a decline in leaf moisture in summer and fall. Normally, this annual cycle of balanced growth and death causes a gradual build-up of dead fuels. But flammability is usually kept within reasonable, though seasonally variable, limits by the slow compacting and decay of accumulated litter, and by the overstory of green leaves which shields against sun, wind, and desiccation.

This normal state of affairs has been upset since 1945—the beginning of the present southern California drought. By 1948 the shortage of rainfall began showing its effects by the appearance of individual dead bushes scattered over the landscape.

By the beginning of the 1950 fire season the topsoil was powder dry. In some areas there was little if any growth of new leaves; more old leaves, too, had fallen. Instead of full-bodied dense crowns, thin, transparent, drab-colored foliage met the eye. By midsummer the chaparral looked and felt parched. That it could be so dry and still be alive was unbelievable. The canopy over large areas was punctured with stark, dead branches, and many more than the usual number of dead shrubs could be seen.

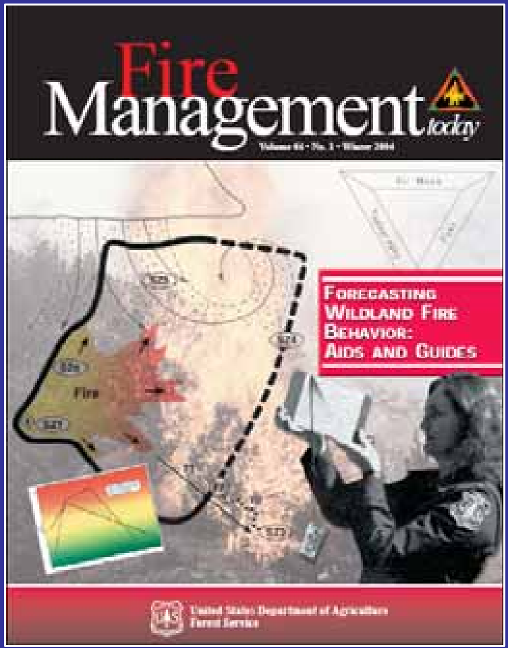
This marked change in growth—or lack of it—meant a much higher than normal ratio of dead to green fuel, extremely flammable foliage, higher fuel temperatures from increased exposure to the sun, more freedom of air movement—meaning more wind close to the ground.

Years of drought are often characterized by low humidities and high temperatures. These occurred often in the summer of 1950. The lack of moisture in soil and vegetation also held the pickup of humidity and fuel moisture at night to a minimum, resulting in extra long daily burning periods.

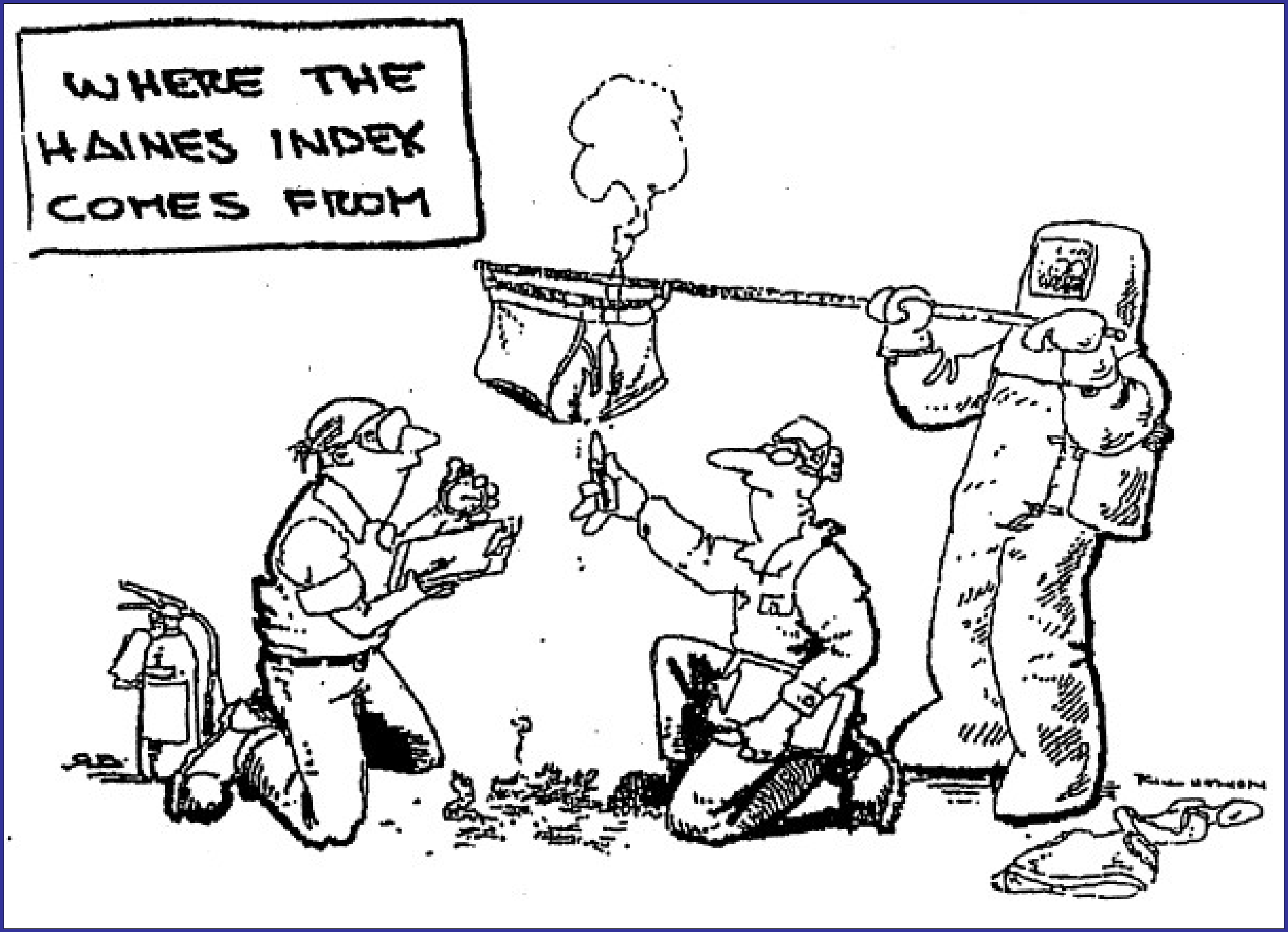
The combination of deteriorated cover and severe weather had by 1950 reached the point of near-maximum conflagration potential. By May this year the southern part of the State had received only half or less of its normal seasonal rainfall; very little more is expected. The outlook for the 1951 southern California fire season is thus for more thinning and dying out of shrubs with a consequent increase in flammability beyond anything yet experienced in our time.—CHARLES C. BUCK, *Division of Fire Research, California Forest and Range Experiment Station.*

1951. *Fire Control Notes* 12(4): 27.

Know the wildland fire literature real well, including the "older stuff".



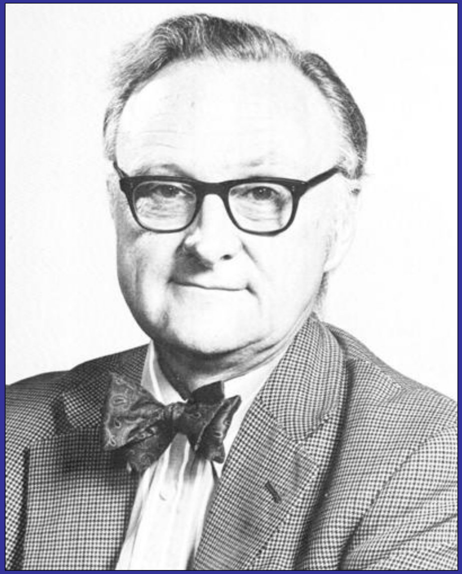
Fire Behavior Research



The ultimate goal of fire behavior research is to provide simple, timely answers to the following types of questions:

- What will be the head fire rate of spread? What will be the area, perimeter length, and forward spread distance after 1 hour, 2 hours, 3 hours, and so on?
- Will it be a high-intensity or low-intensity fire? Will it be a crown fire or a surface fire? How difficult will it be to control and extinguish? Will mechanical equipment and/or air tankers be required, or can it be handled safely by a suppression crew? Will the mop-up efforts require more time than normal?
- Is there a possibility of it "blowing up"? Is so, will it produce a towering convection column or have a wind-driven smoke plume? What will be the spotting potential – short- or long-range? Are fire whirls and/or other types of wildland fire vortexes likely to develop? If so, when and where?

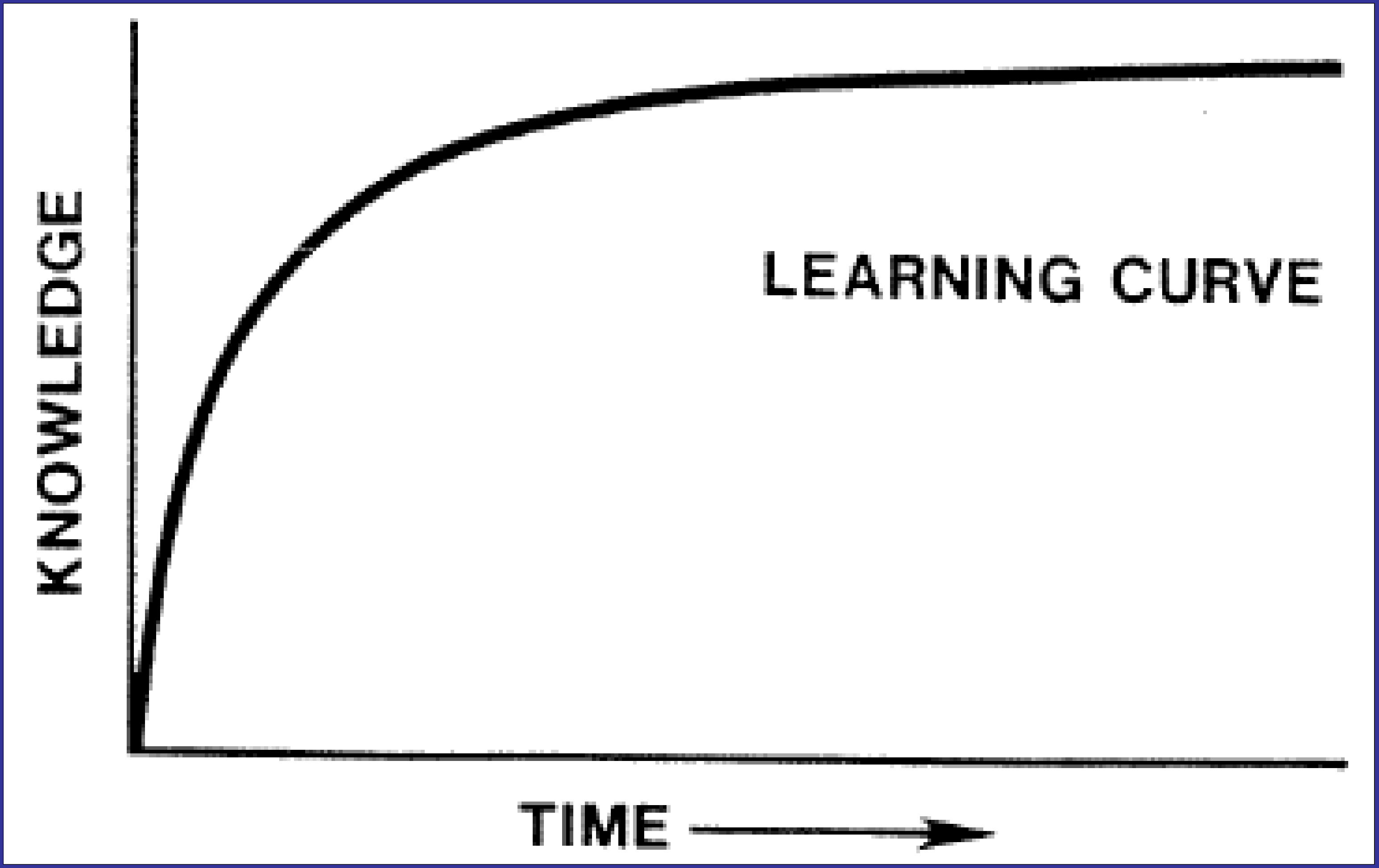
For many specific problems in fire behavior research "... *the most effective method of solution is a combination of mathematical modeling, physical insight and relevant experiments*". – **Dr. Rod Weber (1990)**



"... *a judicious mixture of theory and empiricism allows idealized experiments to represent the main features governing* ..." free-burning wildland fire behavior. – **Dr. Phil Thomas (1971)**

Typical learning showing an initial rapid increase in knowledge followed by diminishing return for time (and money) invested

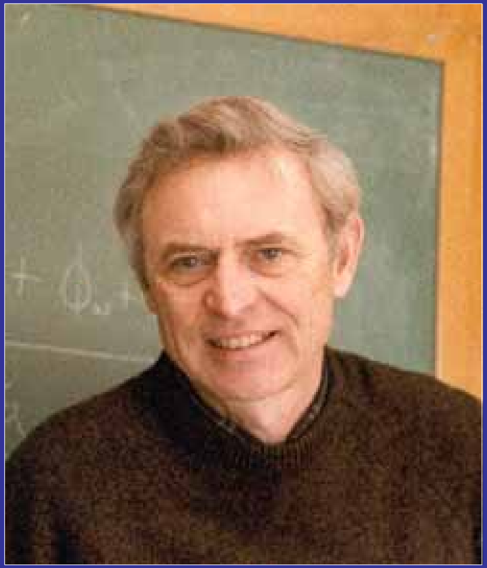
(from Rothermel 1987)



"The prediction of surface fire behavior is, in fact, probably more difficult that the prediction of crowning potential, because of the multiplicity of possible forest floor and understory fuel complexes." – **Charlie Van Wagner (1979)**

THE
FIRE BEHAVIOR PREDICTION PARADOX
(Rothermel 1987)

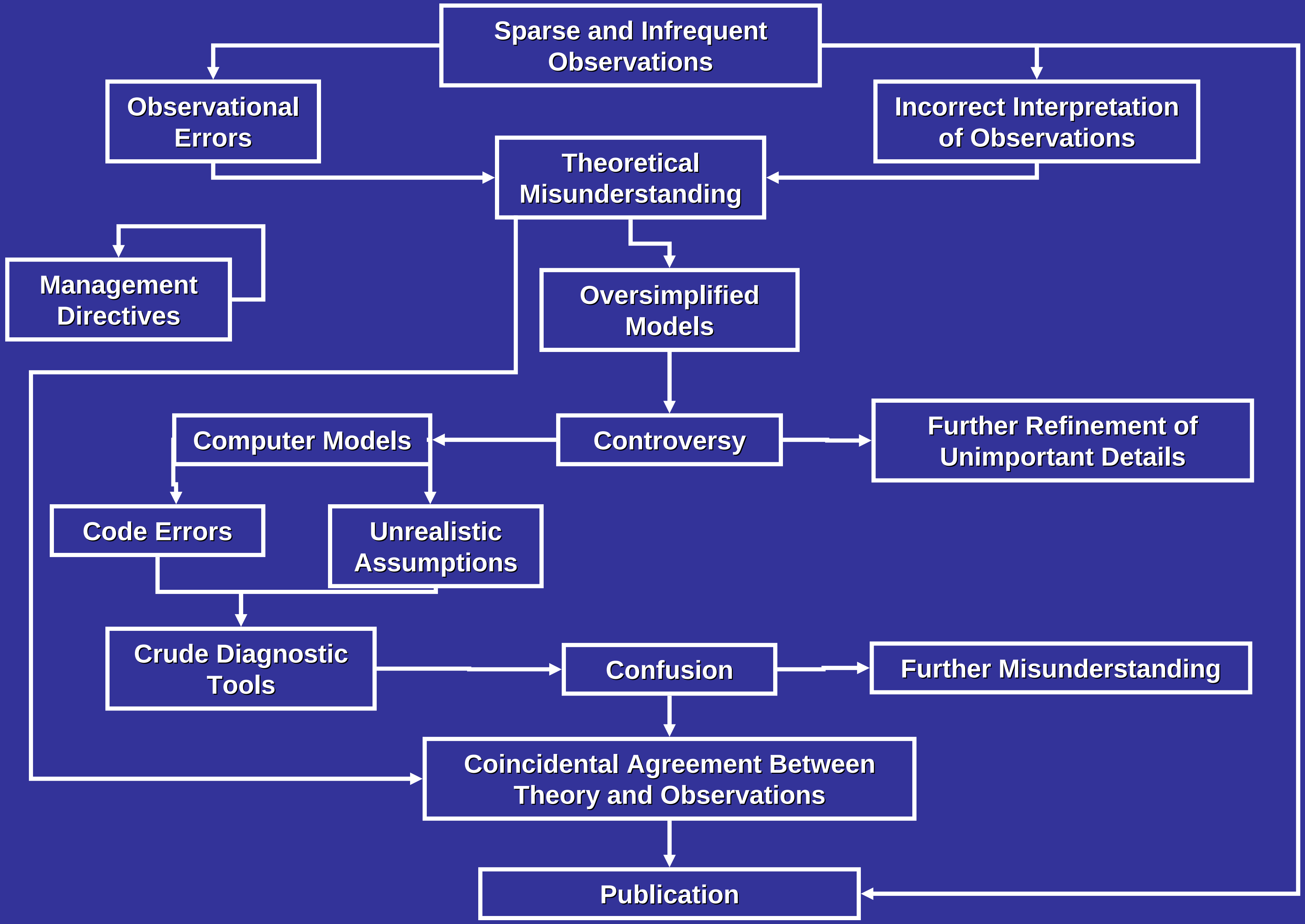
- The models and systems aren't accurate enough.
- The models and systems are too complicated.



The resolution of either one of these problems worsens the other.

Presumably, crude but reliable decision aids are needed at the field level.

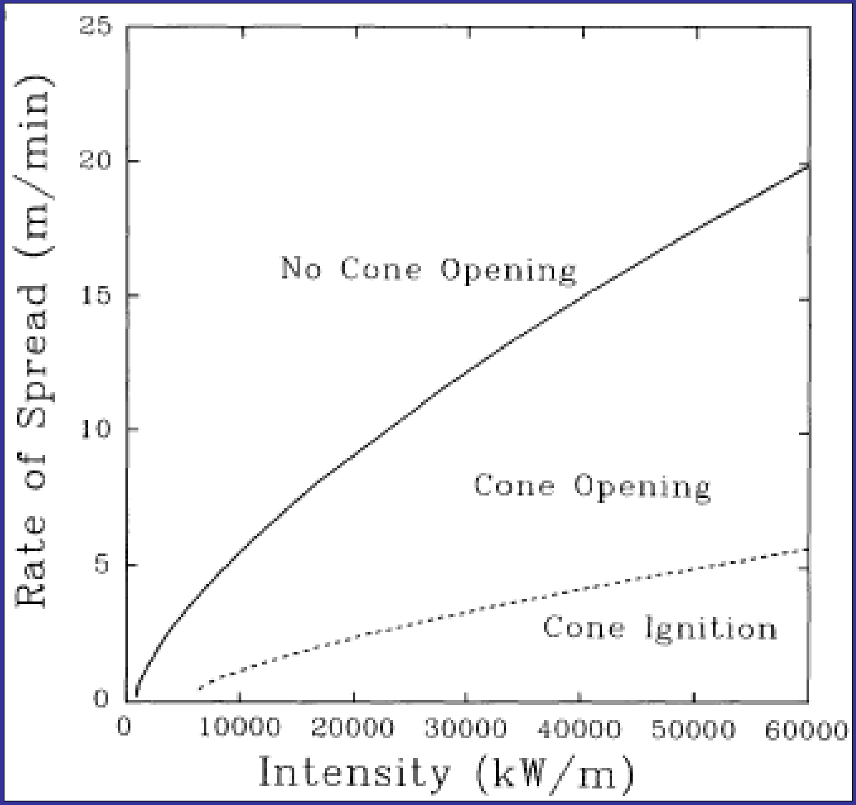
The Course of Wildland Fire Behavior Prediction Science?



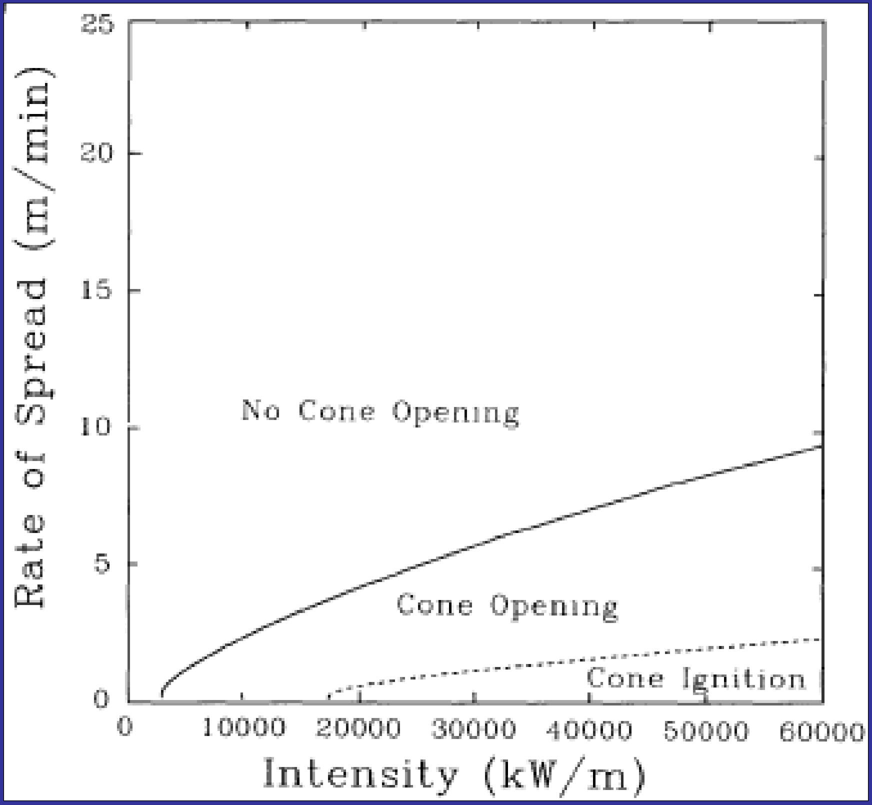
- Question things. Be skeptical.
- Insist on realism.
- Do these results make sense?
- Is this what I would expect given the burning conditions?.
- Some wildland fire researchers have a problem matching theory with reality.

- Know the literature and seek out first-hand field experience

Johnson and Gutsell (1993) modeled serotinous cone opening in jack and lodgepole pines in relation to fire behavior, obtaining highly erroneous results.



10- m tall Jack Pine Stand



20-m tall Lodgepole Pine Stand

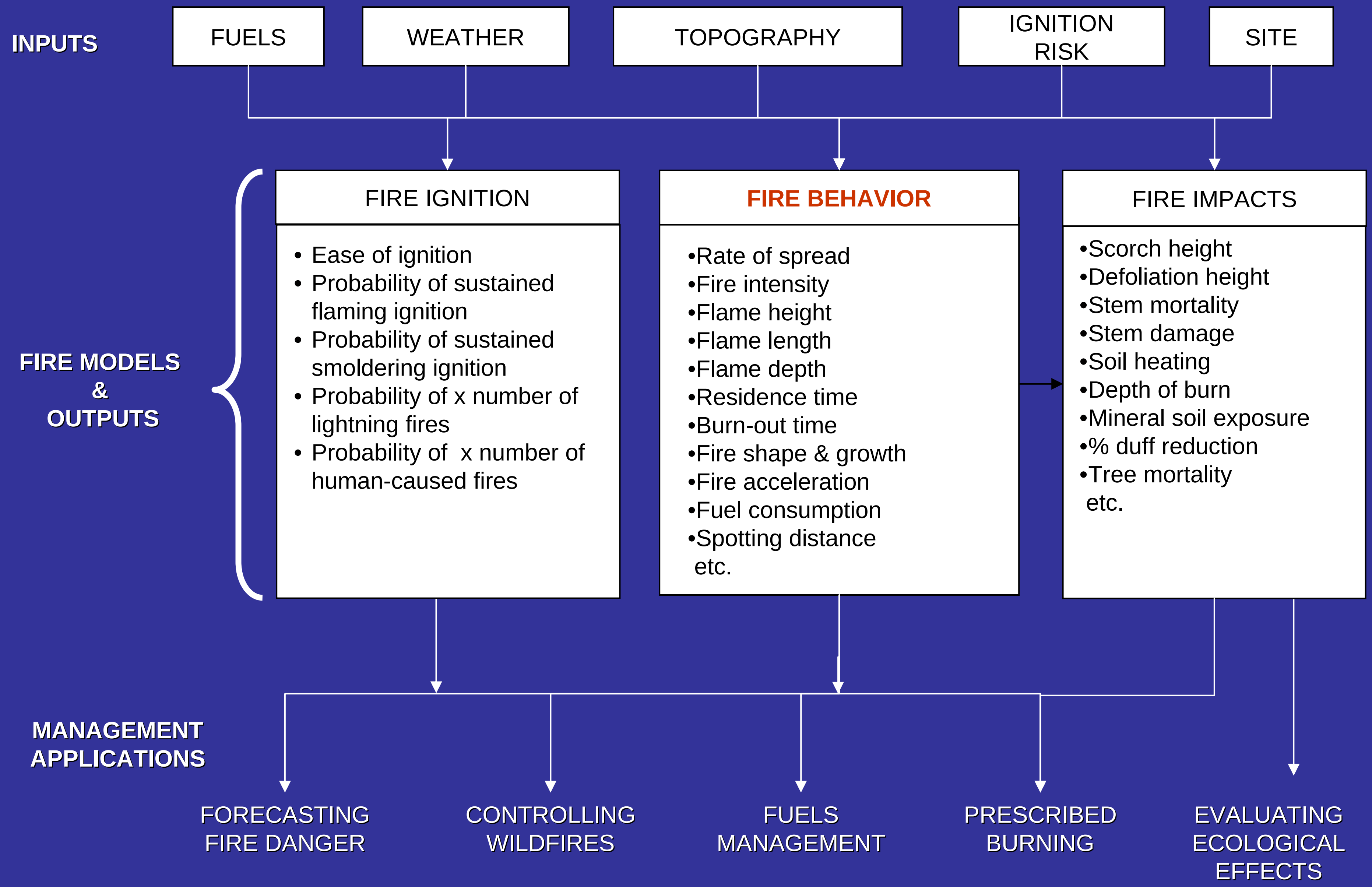
"Fire researchers are often reluctant to point out the limitations of their work in order for their research to be accepted by managers and other researchers.

Too often researchers do not give a good account of the methods they use, something which is aided and abetted by the science journals that are reluctant to publish an extensive account of methods preferring results and discussion."

Phil Cheney

Conceptual Model of Scientifically-based Forest Fire Management

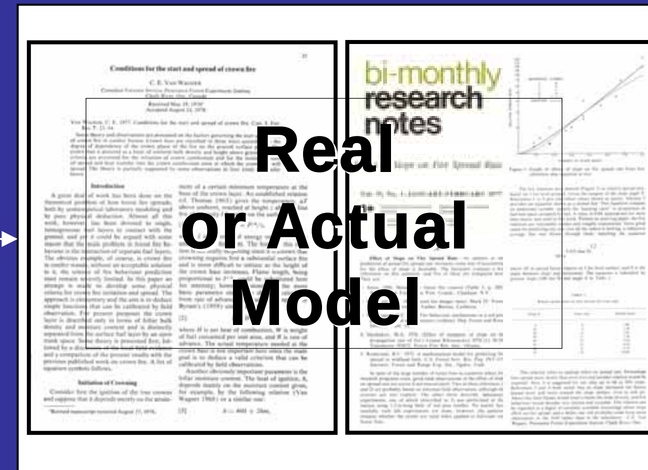
(adapted from Burrows 1994)



How well are the models working?

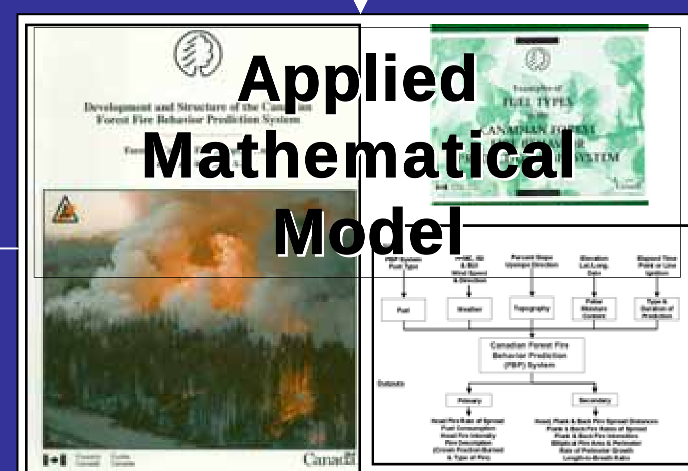
Real World

Idealisation
Approximation



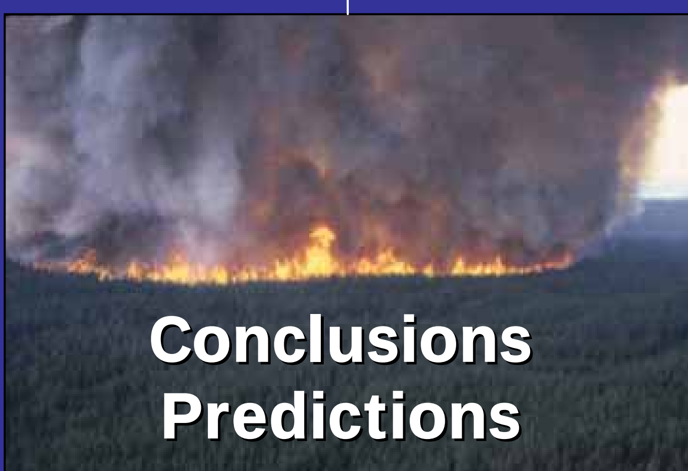
Real
or Actual
Model

Abstract or
Symbolic
Representation



Applied
Mathematical
Model

Mathematical
Processing



Conclusions
Predictions

Comparison

On Validation or “Invalidation” of Fire Behavior Models

*“If validation is a process for determining that the outputs of a model conform to reality, no model can be validated in an absolute sense; i.e., **a model can never be proved correct, it can only be proven wrong**. Acceptance of a model does not imply certainty, but rather a sufficient degree of belief to justify further action. Thus, **in practice, validating a fire model is really a problem of invalidation.** The more difficult it is to invalidate the model, the more confidence we have in it.”*

J.M Watts, Jr. 1987. Editorial: validating fire models. *Fire Technology* 23: 93-94.

Technology and Information Transfer

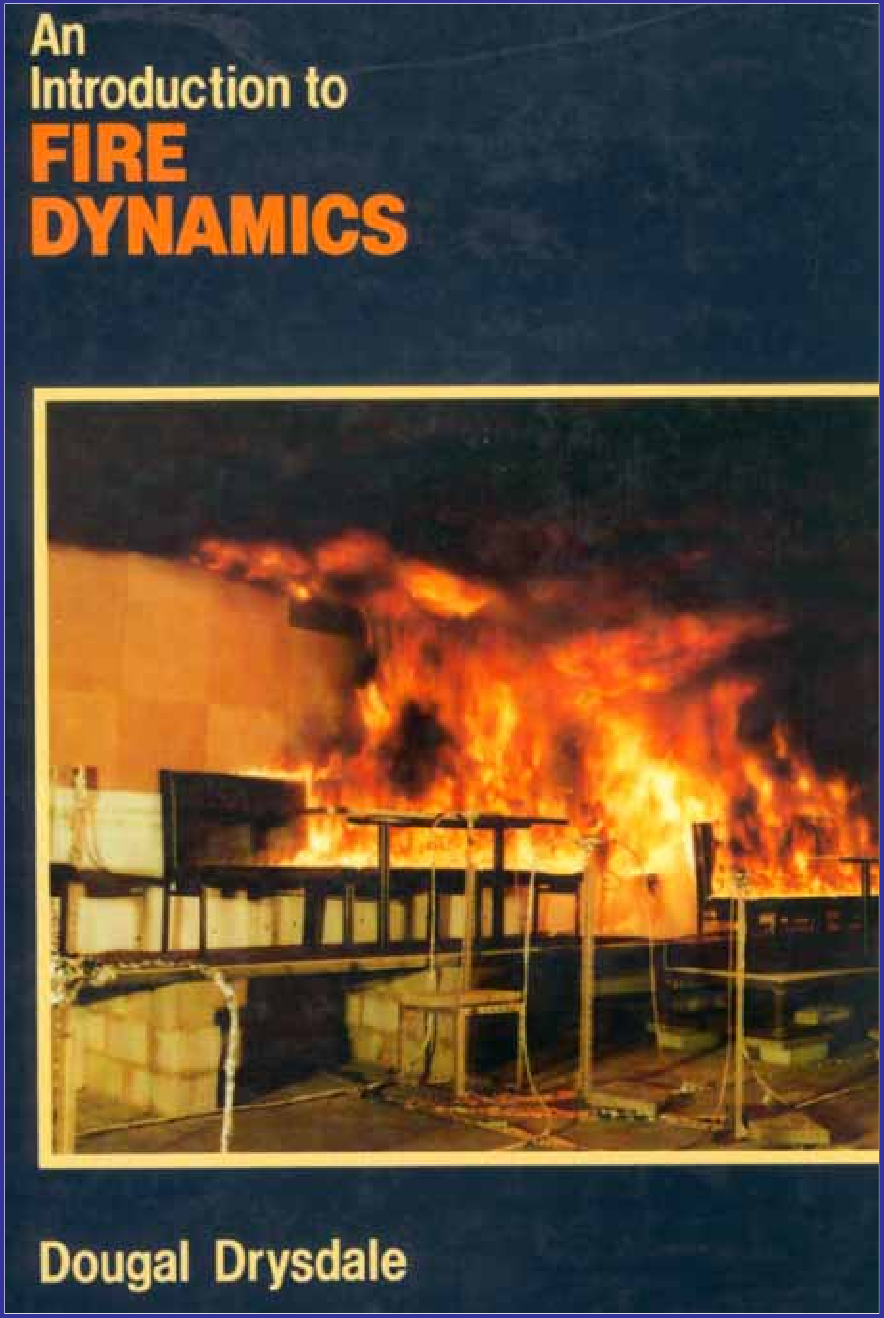
- Instructor in agency training courses
- Attend operational meetings and conferences
- Secondments to and from research organizations and operational agencies
- Monitoring wildfires and prescribed fires
- Serve on task force committees & working groups

The Silver Bullet Syndrome in Fire Behavior Prediction

This occurs when fire operations personnel look for or expect fire research to come up with new technology and/or a new model to solve their problem to the point that they don’t have to think.

Unfortunately there are no quick fixes or silver bullets.

The ability to predict or forecast fire behavior must be learned.

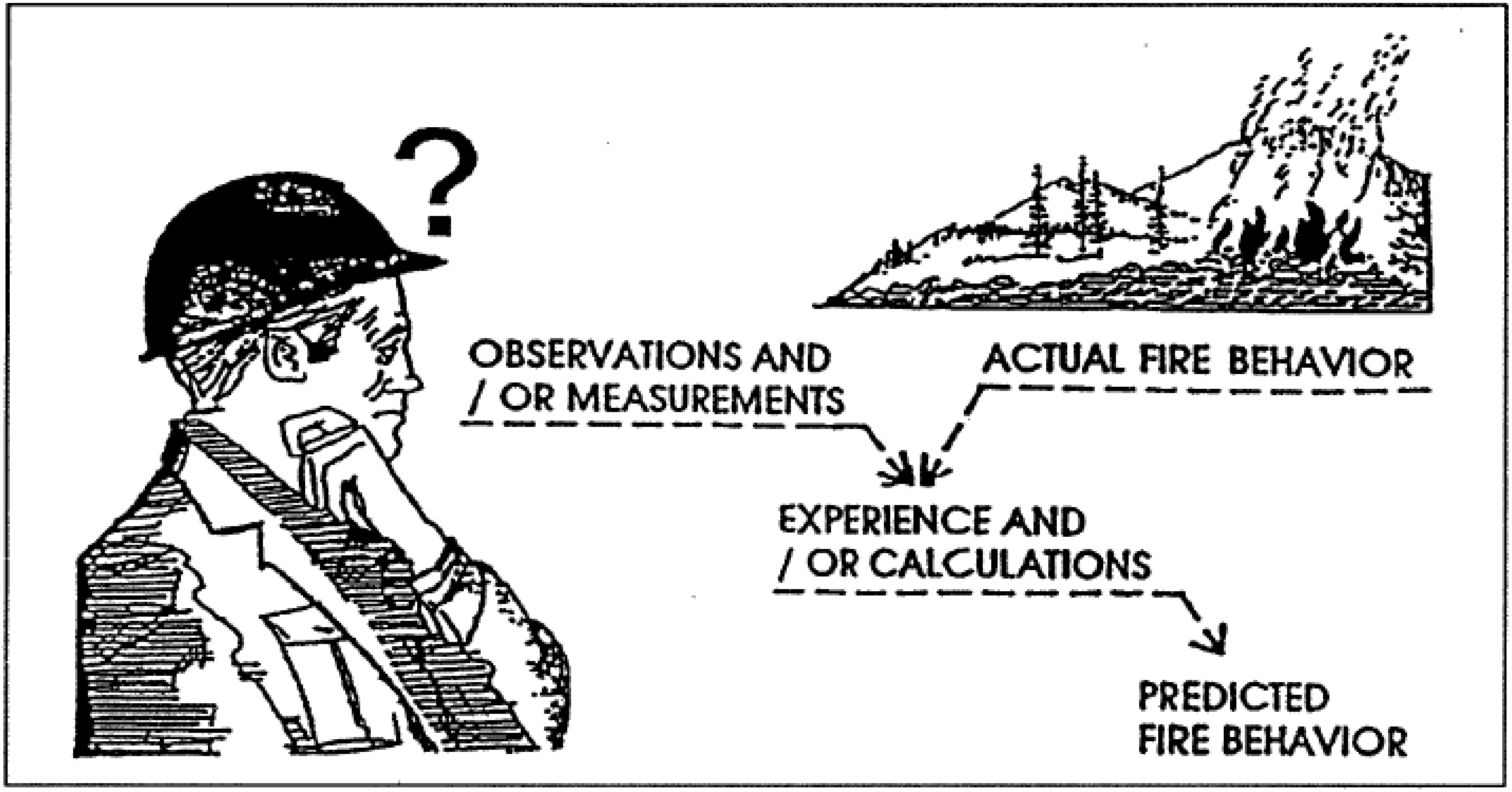


... further major advances in combating wildfire are unlikely to be achieved simply by continued application of the traditional methods. What is required is a more fundamental approach which can be applied at the design stage …

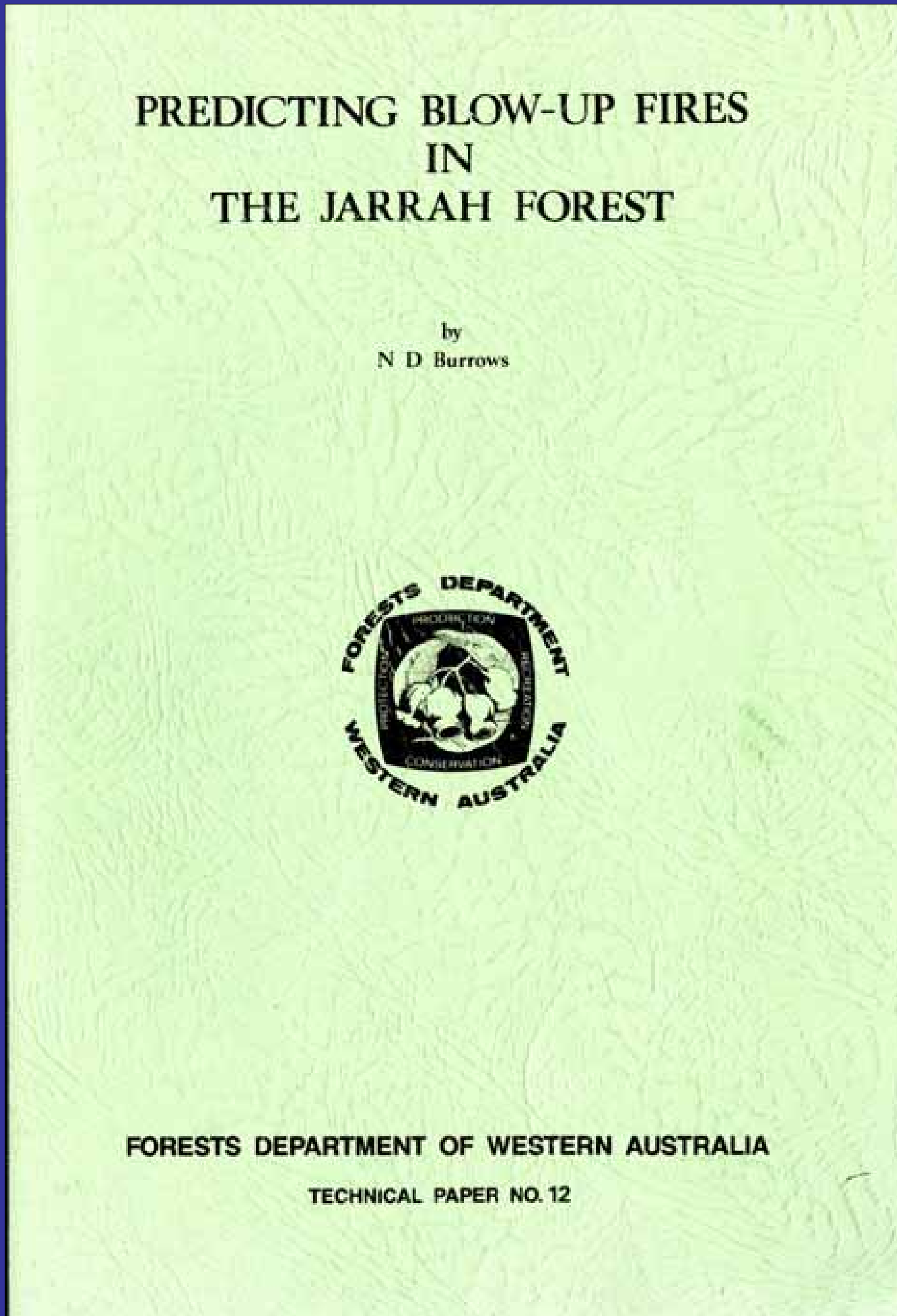
Such an approach requires a detailed understanding of fire behaviour **...**

Drysdale (1998)

Operational Fire Behavior Considerations



Practical knowledge, judgement, and experience must control your interpretation and application of the fire behaviour you predict.



PREDICTING BLOW-UP FIRES
IN
THE JARRAH FOREST

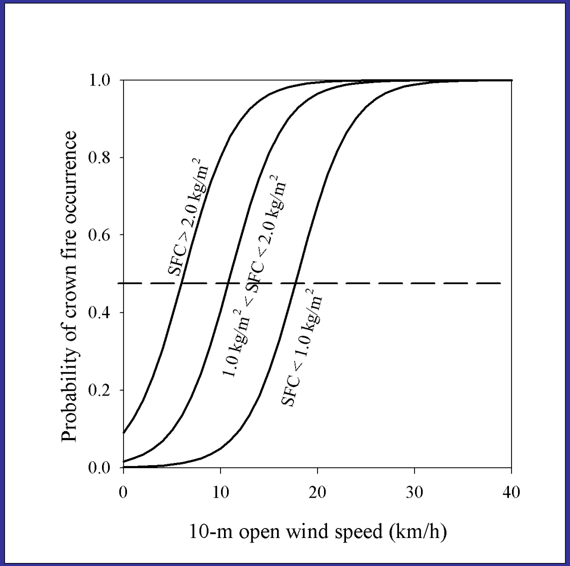
by
N D Burrows

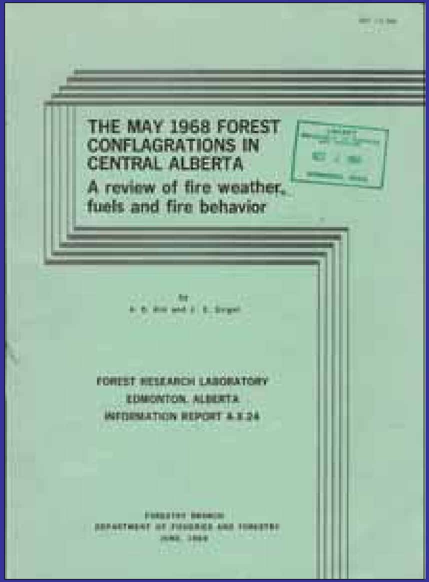
FORESTS DEPARTMENT OF WESTERN AUSTRALIA

TECHNICAL PAPER NO. 12

"Expectations of how a fire should behave are based largely on experience, and to a lesser extent, on fire behaviour guides." –
Burrows (1984)

The most effective means of judging potential fire behavior is considered to be the coupling of **mathematical modelling** with **experienced judgement** (e.g., “expert opinion”), and **published case study knowledge** (e.g., experimental, wild and prescribed fires)

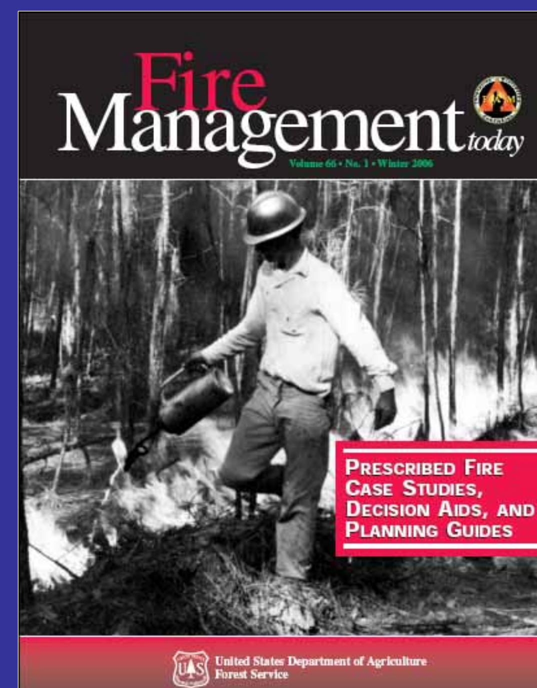




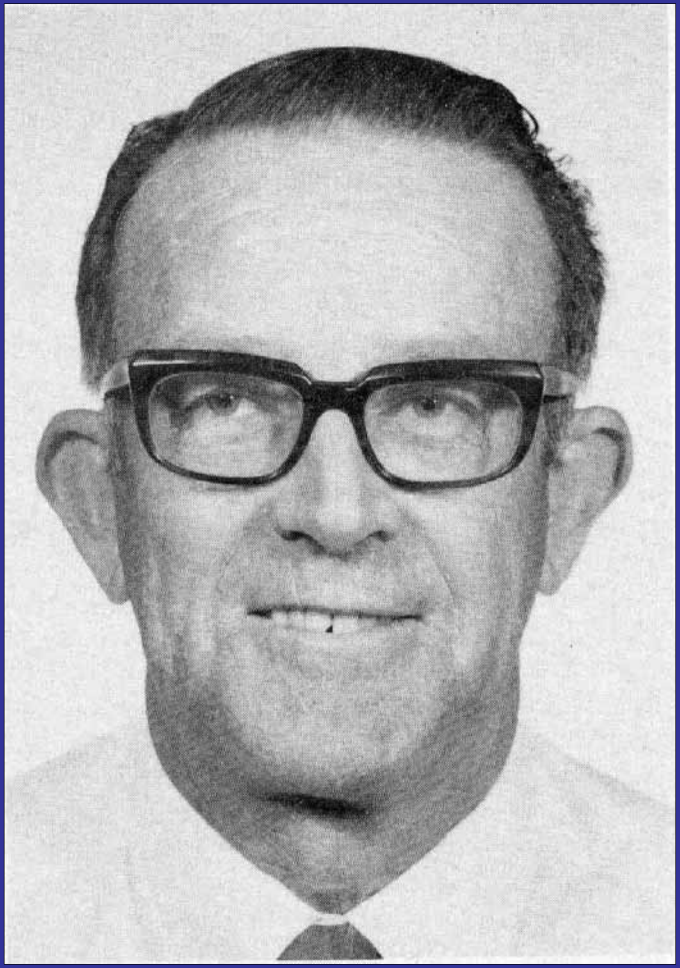
"For what is experienced judgment except opinion based on knowledge required by experience? If you have fought forest fires in every different fuel type, under all possible different kinds of weather, and if you have remembered exactly what happened in each of these combinations of conditions, your experienced judgment is probably very good. But if you have not fought all sizes of fires in all kinds of fuel types under all kinds of weather, then your experience does not include knowledge of all the conditions". **– Harry T. Gisborne (1948)**

Value of Case Studies

"Time and time again case histories have proven their value as training aids and as sources of research data." **-- Craig C. Chandler (1976)**

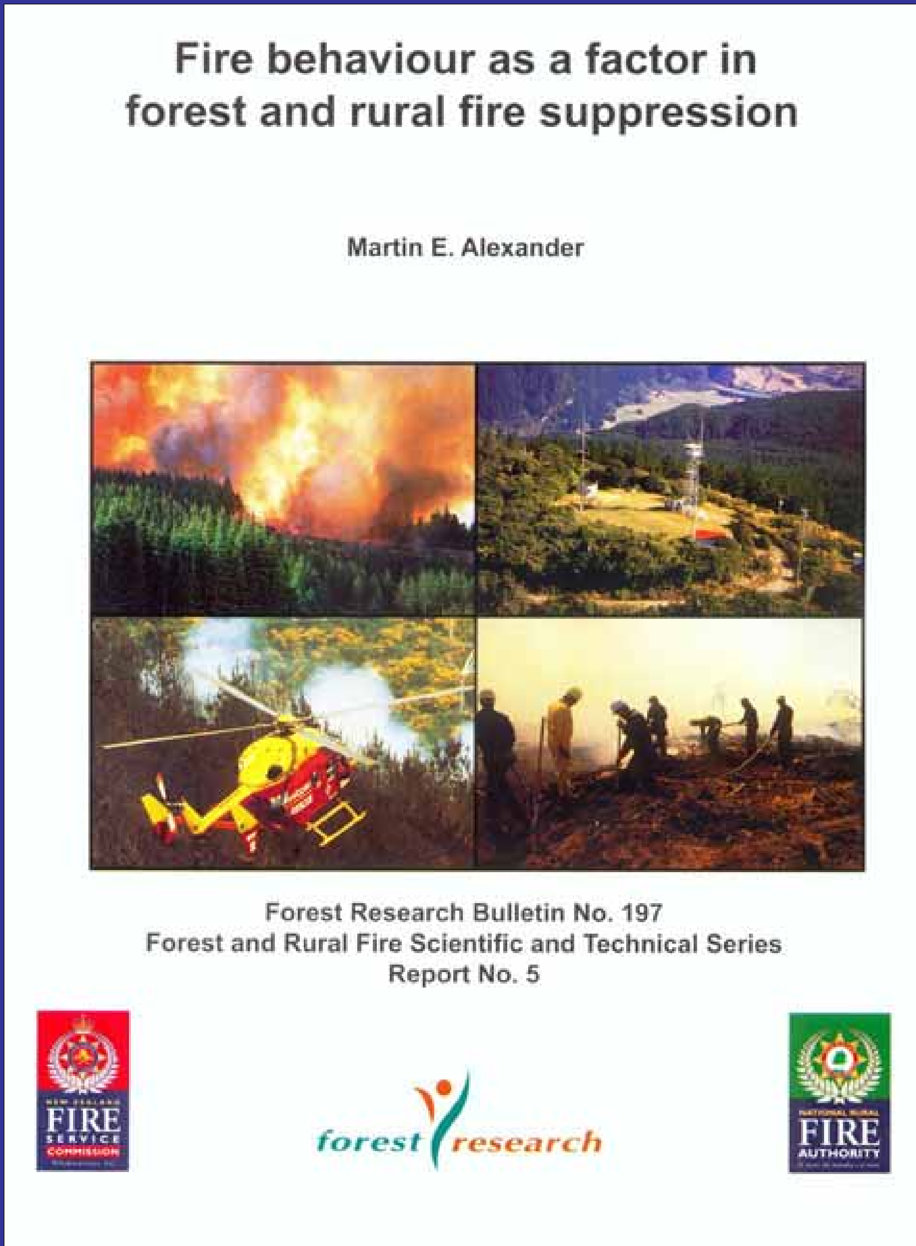


"During the first 30 minutes or so of a fire's life history, suppression forces have their greatest chance of success purely because the fire is still accelerating and has not reached its maximum rate of spread ..."



Alan McArthur (1968)

The Effect of Time on Fire Behaviour and Fire Suppression Problems

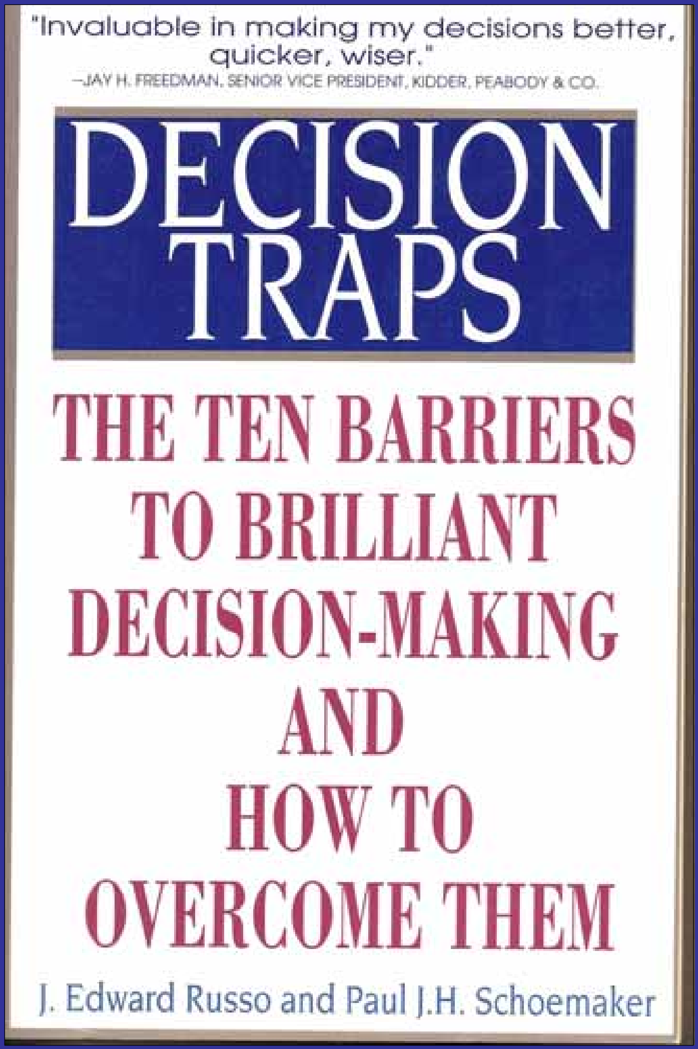

Fire behaviour as a factor in
forest and rural fire suppression

Martin E. Alexander

Forest Research Bulletin No. 197
Forest and Rural Fire Scientific and Technical Series
Report No. 5

TIME as a factor influencing fire behavior is not adequately or fully appreciated.

Common pitfalls for decision makers that are equally valid in making fire behavior predictions or forecasts



The Ten Most Dangerous Decision Traps*

1. *Plunging in:* Beginning to gather information and reach conclusions without first taking a few minutes to think about the crux of the issue you're facing or to think through how you believe decisions like this one should be made.
2. *Frame blindness:* Setting out to solve the wrong problem because, with little thought, you have created a mental framework for your decision that causes you to overlook the best options or lose sight of important objectives.
3. *Lack of frame control:* Failing to consciously define the problem in more ways than one or being unduly influenced by the frames of others.
4. *Overconfidence in your judgment:* Failing to collect key factual information because you are too sure of your assumptions and opinions.
5. *Shortsighted shortcuts:* Relying inappropriately on "rules of thumb," such as implicitly trusting the most readily available information or anchoring too much on convenient facts.
6. *Shooting from the hip:* Believing you can keep straight in your head all the information you've discovered, and therefore "winging it" rather than following a systematic procedure when making the final choice.
7. *Group failure:* Assuming that with many smart people involved, good choices will follow automatically, and therefore failing to manage the group decisionmaking process.
8. *Fooling yourself about feedback:* Failing to interpret the evidence from past outcomes for what it really says, either because you are protecting your ego or because you are tricked by hindsight.
9. *Not keeping track:* Assuming that experience will make its lessons available automatically, and therefore failing to keep systematic records to track the results of your decisions and failing to analyze these results in ways that reveal their key lessons.
10. *Failure to audit your decision process:* Failing to create an organized approach to understanding your own decision-making, so that you remain constantly exposed to all the above mistakes.

* Based on Russo and Schoemaker (1989).

Russo and Schoemaker (1989) examine common pitfalls for decisionmakers that are equally valid for FBANs and others making fire behavior predictions or forecasts.

Decision Trap #5 – Shortsighted Shortcuts:

Relying inappropriately on "rules of thumb," such as implicitly trusting the most readily available information or anchoring too much on convenient facts.

Human Factors in Fire Behavior Analysis: Reconstructing the Dude Fire*

Karl E. Weick

On the Dude Fire Staff Ride tomorrow, we will retrace the steps of people who were under pressure. Some of those people handled pressure well. Some didn't. For a richer understanding of the Dude Fire, we should focus on what happens when people are overcome by events; then we might be in a better position to prevent similar tragedies in the future.

> When the world is unpredictable, as is often the case on a fire, it is important to hold one's meanings lightly and to update one's sense of what is happening.

Making Sense

One key to safety in fire suppression is how easy it is for people to make sense of what they are facing. A good example is Caroline Paul, one of the first women firefighters in the San Francisco Fire Department (Paul 1998). The first time she was allowed to take the nozzle of a firehose and lead a crew into a burning building, the rooms were so filled with smoke that visibility was near zero. Paul nudged against what she thought was the first step of a narrow stairway leading into an attic. Again and again, she tried to find the second step and push her way into the attic, only to bump into something hard. Finally, a hand pulled her away and steered her into an unseen hallway. Later, when visibility was better, she realized that what she had thought was an attic stairway was in fact a chair standing against a wall. She had been lunging against the wall, refusing to believe it was anything but a stairway leading to the source of the fire.

What Caroline Paul stumbled onto is key to how we create the world around us. As Stephen Batchelor (1997) puts it, "Meaning and its absence are given to life by language and imagination. We are linguistic beings who inhabit a reality in which it makes sense to make sense." Meaning is a product of language, imagination, and action. The language of tables, chairs, beds, and staircases can be a constraint on the imagination and on action. The mind stays more supple and pliable, the body more flexible, when people deal with general directions rather than the specifics of mistakenly named objects. Sometimes the constraints imposed by specifics are necessary and helpful. But when the world is unknowable and unpredictable, as is often the case on a fire—with its difficult terrain, changing weather, and uneven heating—then it is important to hold one's meanings

Aerial view of "corner house" above Walk Moore Canyon, showing wildland/urban interface conditions on the Dude Fire. Photo: USDA Forest Service, 1990.

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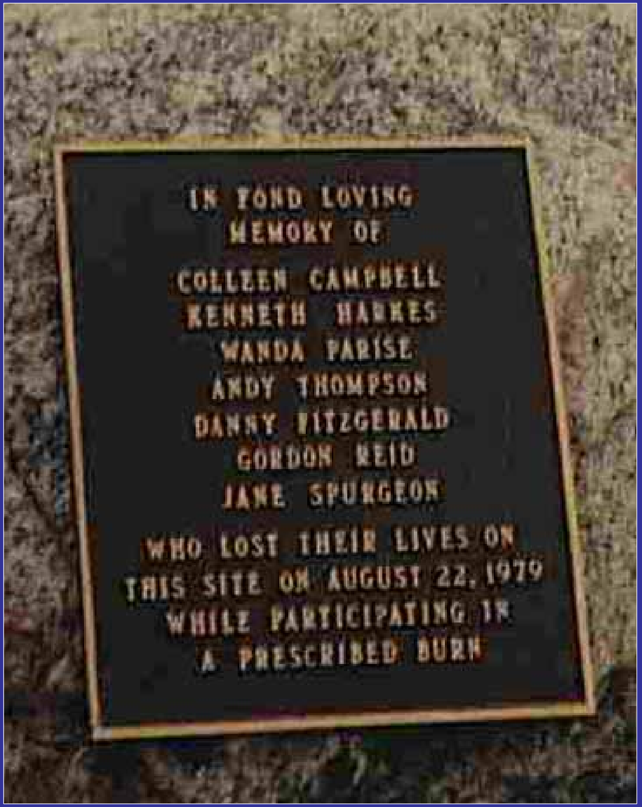
* This article is based on a presentation by the author at the March 1998 National Interagency Fire Behavior Workshop in Phoenix, AZ. The author spoke on the day before the field phase of the Dude Fire Staff Ride.

Dr. Karl Weick

1979 Geraldton PB-3 Prescribed Fire, Ontario

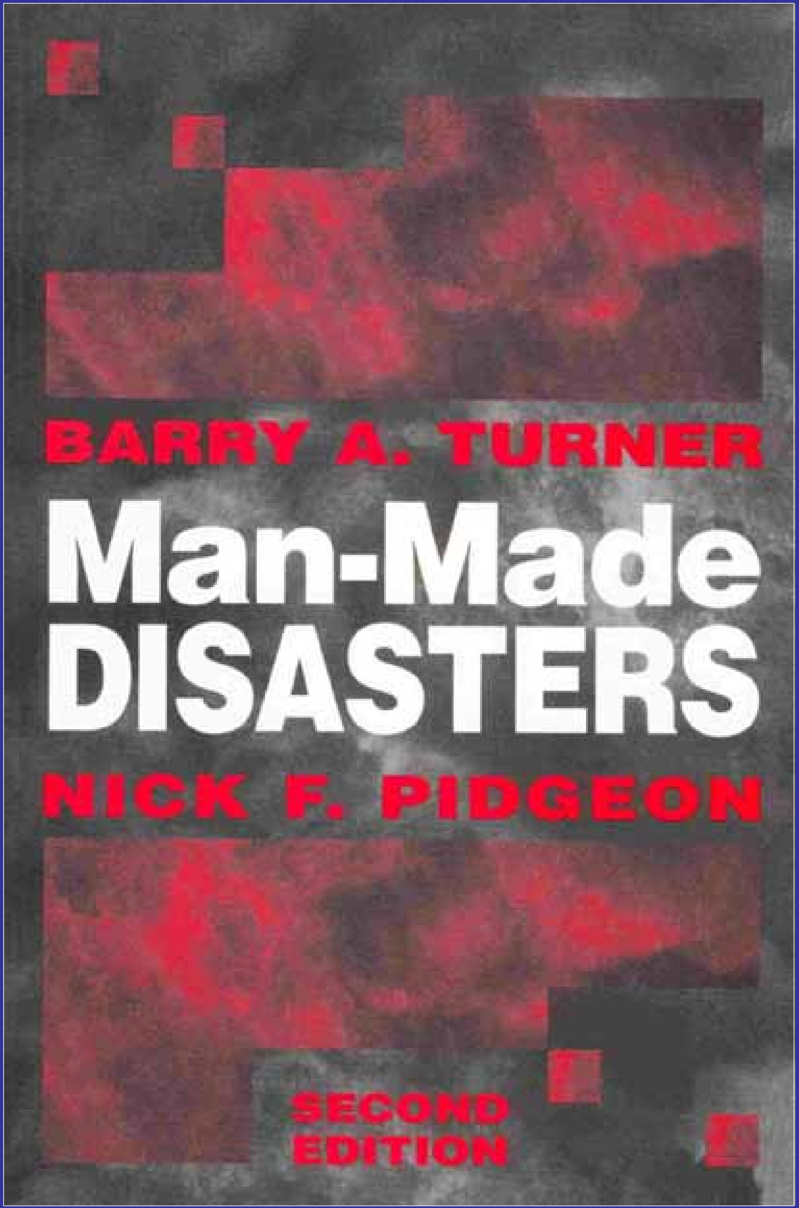
Fire technician runs through flame front to safety

7 seasonal employees did not follow and die.



Turner's (1986) Disaster Model

Stage I: Predisaster Point
Stage II: Incubation Period
Stage III: Precipitating Undesirable Event
Stage IV: Onset
Stage V: Suppression, Rescue and Salvage
Stage VI: Full Cultural Readjustment



Stage II - The Incubation Period

The accumulation of events that detracted from adhering to safe work practices.

Factors possibly involved in the fatalities associated with the 1979 Geraldton PB-3 Prescribed Fire, Ontario:

- Target Accomplishment
- Haste
- Over-Confidence
- Span of Control
- Deviation from Plans

Closing Remarks

There are many problems that remained unsolved and there are many looming issues

Point Source Ignition Pattern

Crown fire in mountain pine beetle infested forest

Need to keep in mind that there is a social responsibility when comes to our work

Author at site of the 1949 Mann Gulch Fire, Montana (July 1994),

Thank you for your attention.

Are there any questions or comments?