Aerial Fire Suppression Research at Forest Research

H.G. Pearce and S.A.J. Anderson

Rural Fire Research Programme
Forest Research, PO Box 29-237, Fendalton,
Christchurch, New Zealand
Telephone +64-3-364 2949
Email grant.pearce@forestresearch.co.nz
Email stuart.anderson@forestresearch.co.nz
Web www.forestresearch/fire

Overview

Aircraft have been used for firefighting in New Zealand since the 1940s and are now commonly used during initial attack and ongoing suppression of forest and rural fires. Over the years, new and specialised equipment has been developed, and the aircraft industry regularly assists at forest and rural fires. In fact, use of aircraft now plays such a major part in the suppression of most large rural wildfires, that almost a third of the overall cost of fire suppression relates to aircraft use.

Some inefficiencies in aerial fire suppression have been noted at wildfires throughout the country in recent years. These experiences, the significant costs associated with aerial suppression, and the results from an initial series of aerial drop trials, highlighted the need to improve the knowledge and understanding of how to use aircraft for fire suppression. Between 1996 and 1998, Forest Research's rural fire research programme undertook a series of studies on aspects of aerial fire suppression effectiveness, with the results being presented in issues of the programme's *Fire Technology Transfer Note* (FTTN) newsletter* and in several conference and workshop papers (e.g., Fogarty 1997, Fogarty and Robertson 1997a, Robertson and Slijepcevic 1998). This poster presents a summary of this work, together with some recommendations for future research.

The Research

FTTN 8: Comparison of the cost-effectiveness of some aircraft used for fire suppression (Fogarty and Smart 1996)

This research estimated the cost of delivering each litre of water to a fire by aircraft, and the volume of water delivered to the fire over a period of time. It included options for use of different filling methods (dip filling, and filling with high and low volume pumps) over a range of distances from the fire. The general conclusions drawn in FTTN 8 were:

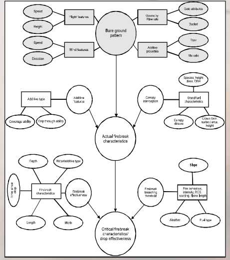
- Fixed-wing aircraft can deliver large volumes of water to a fire at very competitive rates, especially when suitable filling points for helicopters are greater than 2 km from the fire.
- The selection of smaller helicopters based on lower hourly running costs is a false economy that may result in larger fires, because larger helicopters can deliver greater volumes of water than smaller ones.
- Dip-filling will enable a helicopter to deliver the greatest volume of water and suppressant at the lowest cost, provided adequate filling points are located near the fire and the aircraft has the capacity to inject foam concentrate when needed.
- Delays in filling due to poor filling point management and/or the use of lower volume pumps will result in considerable "opportunity costs".
- The use of buckets that are below the safe carrying capacity of a helicopter will result in considerable "opportunity costs".

FTTN 11: Firebombing effectiveness - where to from here? (Robertson *et al.* 1997a)

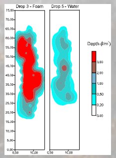
The aim of this FTTN was to extend the discussion on aerial suppression effectiveness to consider some of the technical factors that influence the impact of individual drops during the suppression of actively spreading fires (i.e., knockdown). In addition to an overview of the properties and uses of the different fire suppressants employed (i.e., water, foam and retardants), FTTN 12 was based around a detailed review of the three elements of aerial drop effectiveness and the main factors that influence them:

- the drop distribution or "footprint" that results when a drop is conducted in the open (*bare ground pattern*);
- adjustment of this to incorporate canopy interception and influences from the type of water-based firebreak being used (*actual firebreak characteristics*); and
- the firebreak and fire behaviour characteristics which influence how effective the actual drop pattern will be at preventing fire spread (*critical firebreak effectiveness*).

While many factors influence the effectiveness of aircraft operations, better quantification of the drop characteristics required to knock down fires in a range of fuel and fire danger conditions is an essential first step in defining the performance measures needed to develop guidelines on how to select aircraft types, delivery systems (e.g., bucket design), and flight characteristics (e.g., height and speed) for effective firebombing.



FTTN 12: Guidelines for determining aerial drop patterns in open areas (Robertson *et al.* 1997b)



The main conclusion from FTTN 11 was that to improve standards of firebombing, much more needed to be known on how firebreak characteristics (i.e., width, depth, additives, time since drop, etc.) affect the ability of a fire to cross a firebreak (i.e., the firebreak breaching threshold), in different fuel, topographical, and fire danger conditions. FTTN 12 described a series of guidelines and a procedure for quantifying the first part of this problem, the aerial drop patterns or "footprints" obtained from various aircraft in open areas. While the bare ground pattern is only one of many elements (e.g., additives, fuel types, canopy, slope, and weather) that interact to determine firebreak breaching thresholds, knowledge of the basics of footprints allows us to understand:

- how available equipment, aircraft, additives, and wind and flight conditions interact to produce a footprint;
- how to achieve nominated footprints (i.e., depth thresholds) for open grasslands;
- how to produce guidelines on the production of wet, fluid, and dry foams under different flight and wind conditions; and
- how to improve the design and selection of equipment, additives, and aircraft used for firebombing.

FTTN 13: Firebombing effectiveness - interim recommended foam consistencies and aerial attack guidelines (Fogarty and Robertson 1997b)

In this research, some *interim* recommendations for foam consistencies and aerial attack guidelines were proposed. The guides are an adaptation of those used in Canada, which are based on the assumption that decisions about the most appropriate foam types should consider the factors of canopy cover, fuel depth, the length of time until follow-up by ground crews, and the chances of re-ignition. While the interim guidelines require further testing and refinement, they provide a useful starting point for air attack decision making. Information from further research, as well as feedback from operational testing, is necessary to produce more comprehensive aerial attack guidelines.

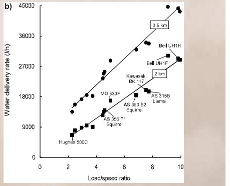
Trees or Scrub	**Ground support within 5 to 10 minutes**	
	Understorey Shallow	Deep
Open canopy	Foam type: WET Example fuel types: Light logging slash (S-1), pasture (O-1) and low open tussock grasslands, recently thinned coniferous forest (C-6) with litter understorey.	Foam type: FLUID Example fuel types: Heavy logging slash or slash with scrub understorey, scrub or tussock less than 1.5 m, and recently thinned coniferous forest with fern, sedge or scrub understorey.
Closed canopy	Foam type: FLUID Example fuel types: Coniferous forest (C-6) or tall manuka/kanuka with litter understorey.	Foam type: WET followed by FLUID Example fuel types: Coniferous forest and tall scrub/tussock fuels (> 1.5 m) with fern, sedge or other scrub understorey, "old man" gorse.

* Full copies of the *Fire Technology Transfer Note* newsletters listed here are available for download from the Rural Fire Research Programme's website at www.forestresearch.co.nz/fire

FTTN 15: Comparison of the cost-effectiveness of some aircraft used for fire suppression - Part 2 (Fogarty *et al.* 1998)

This study extended the information presented in FTTN 8, by collating information collected from a survey of aircraft companies on the cost and performance of commonly available aircraft makes, models and types (see Figure 3a & b). This information was aimed at helping fire managers to select and better utilise aircraft for aerial fire suppression operations. Methods for estimating when a filling point is likely to be over-utilised, and the rate of fuel, water and additive usage were also developed. In doing so, the following general conclusions were drawn:

- Aircraft with higher load/speed (L/S) ratios should have priority for filling.
- The total time that a filling point is utilised should not exceed 50 to 55 minutes per hour.
- When the available filling capacity has been exceeded, aircraft with the lowest L/S ratios should be stood down.
- The "2 × 2" rule should be adopted as a general *rule of thumb*. This suggests that when 2 aircraft are flying more than 2 km to the firebombing zone, additional filling points should be established closer to the fire.



FTTN 16: Reducing the influence of helicopter rotor wash on fire behaviour (Slijepcevic and Fogarty 1998)

Ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	63	50	42	37	32	29
5	31	25	21	18	16	14
10	23	18	15	13	12	11
20	17	13	11	10	9	8
30	14	11	9	8	7	6
40	12	10	8	7	6	6
50	11	9	8	6	6	5

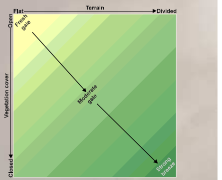
In some instances, the fanning effect of rotor wash from helicopters involved in fire suppression can negate the impact of their drops. This is most evident when drops are made from a hover and placed inside the burning zone. This work used research findings from the US Forest Service to provide guidelines on how to minimise the impact of rotor wash on fire behaviour. This can be achieved by specifying helicopter speeds and heights where only minimal rotor wash will reach the surface, thus increasing effectiveness of the air attack operation. Not all helicopters cause the same amount of rotor wash, and this FTTN allows fire managers to select machines that least influence fire behaviour.

As an alternative to calculating individual flight characteristics, two general *rules-of-thumb* were developed for helicopters less than and greater than 2000 kg, where rotor side-wash will be negligible in most instances (for helicopters up to 5000 kg). If applying these rules, lighter machines should fly at a height of 25 m and at a ground speed of 25 km/h (the "25 × 25" rule), whereas larger machines should follow the "35 × 35" rule. If they do nothing else, fire managers should ensure that pilots deliver drops from outside the fire perimeter and avoid drops from a near-hover.

FTTN 17: The influence of wind speed on the effectiveness of aerial fire suppression (Fogarty and Slijepcevic 1998)

The aim of this study was to better quantify the impact of wind on helicopter operations, and to describe how the interaction of wind with other elements of the fire environment (i.e., steep terrain and dense vegetation) alters the effectiveness of aerial suppression operations. Results from a survey of owner/operators show that most helicopters are able to fly in strong to whole gale wind force classes (75-102 km/h). When a bucket is underslung, the more typical operating range is reduced to the fresh to strong gale wind force classes (62-88 km/h).

An *interim guide* was developed which shows how the maximum wind speed (as described by the Beaufort wind speed classes) for effective firebombing decreases as vegetation cover increases, and the terrain becomes more steeply divided. The reduction in wind speed threshold is shown by the move from lighter to darker shading, and relates to the need to lay deeper and wider firebreaks, as increased interception of the drop and reduced drop precision occurs. The guide is not intended as a prescription for determining when firebombing will be effective, but as an aid to help managers determine when other resources (e.g., additional ground crews, heavy machinery) or suppression strategies (e.g., indirect attack, burning out) may be needed for initial and ongoing attack. Most importantly, it indicates when close monitoring of drop effectiveness is necessary.



FTTN 18: Aerial fire suppression workshop (Robertson 1998)

This FTTN documents an aerial fire suppression workshop that was held in Southland in early May 1998 to discuss these and other issues surrounding the use of aircraft at wildfires. As well as presenting an overview of the research undertaken by the Rural Fire Research programme and summarised in the FTTNs above, this workshop also identified a number of operational issues relating to the effective use of aerial fire suppression resources, use and application of retardants and suppressants, and aircraft management at wildfires. These included:

- When aircraft are being used at any wildfire, everyone including pilots must be part of the command structure, and the operations must be supervised by a dedicated position in this structure.
- Everyone, including pilots must be briefed prior to being engaged on any fire suppression activities.
- There must be communications between the ground and aircraft.
- Fire managers must be aware of and cater for pilot rest breaks.
- Helipads should be maintained on a regular basis, especially to keep flight paths open.
- Safety issues regarding the use of foam and retardant must always be considered, including use of appropriate protective clothing for filling personnel.
- A filling pump of adequate capacity (or multiple pumps) must be provided for the operation to be cost effective.

Conclusion and Recommendations

Aircraft use in New Zealand for wildfire suppression and the associated costs continue to grow. Yet, since this research was conducted, little or no further work has been undertaken locally on aerial suppression effectiveness. In addition, many of the recommendations from the research have not yet been fully taken up. It is essential that aircraft use be both effective in suppressing fire as well as cost-effective. It is therefore vital that this research progress from where it was left off, and that the rural fire industry take the lead in this regard. The results from the preliminary aerial drop trials and observations at wildfires outlined above indicate that, as a minimum, the following issues require further investigation:

1. Quantification of the influence of height and speed of aircraft, wind speed and direction, foam percentage and bucket design/setting on foam types and expansion ratios on aerial drops.
2. Quantification of the necessary depth and type of water-based firebreak required to hold fires in different fuel, weather and fire danger conditions.
3. Validation of interception rates from overseas data for New Zealand's forest fuels and to estimate rates for other local vegetation types.
4. Development and testing of guidelines on bucket design, flight characteristics and mixing rates so that pilots can produce various types of water-based firebreak as required.
5. Evaluation of what pilots/aircraft actually do at wildfires is necessary to benchmark current aircraft operations.

Acknowledgments

The research reported here was lead by Liam Fogarty, and supported by Kimberley Robertson and Alen Slijepcevic, who were at the time all staff with the Forest and Rural Fire Research Programme based at the New Zealand Forest Research Institute in Rotorua. The research was funded by Foundation for Research, Science and Technology (FRST), together with an industry collaborative comprising the NZ Forest Owners Association, Department of Conservation, National Rural Fire Authority, NZ Defence Force and individual territorial local authorities.