Effectiveness of aircraft operations by the Department of Natural Resources and Environment and the Country Fire Authority 1997–98

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Summary

During the 1997–98 fire season the-then Department of Natural Resources and Environment (NRE) and Country Fire Authority (CFA) in Victoria operated the largest fleet to that time of contract firebombing aircraft of any State or Territory in Australia.

Both the fleet and the expertise required to manage it were developed by NRE and its predecessor organisations over the previous five decades. Operational experience and experiments with aircraft during a number of large wildfires led to the development of a mainly contract air fleet which minimised costs and maximised efficiency. Further, an emphasis on training of both Departmental and contract staff resulted in an operation where effectiveness is combined with high safety standards.

The 1997–98 fire season in Victoria was influenced by the *El Niño* Southern Oscillation phenomenon, the prolonged drought effects of which caused some parts of the State to experience their driest period on record. NRE attended 1056 fires for the season—a 20-year record. Aircraft and CFA resources proved important in fighting a number of the larger fires.

The 1997–98 season saw the first use in Australia of an Erickson S64F Aircrane. This 9000-litre capacity helicopter was engaged in anticipation of exceptional seasonal conditions. It contributed significantly to the existing fleet of helicopters and fixed-wing aircraft.

This study sought to gauge the effectiveness of this fleet of aircraft, particularly in first attack of fires. Information was derived from interviews with experienced fire-control and air-operations staff. Where possible, their responses were rated to facilitate statistical analysis. Fire records provided specific data about weather, fuels and fire behaviour and suppression.

The study found that the most effective use of aircraft during first attack was in direct attack to either slow or stop the head fire. Their next most effective use was in the provision of reconnaissance services to assist ground crews to reach fires.

Fire managers rated aircraft as a highly effective tool in assisting initial containment of a fire. Their responses indicated that aircraft were capable of contributing 64% of the combined effort by both aircraft and ground forces in containing a fire at the first-attack stage.

Response time was found to be the greatest restriction on the effectiveness of aircraft. A predictive model for final fire size was constructed using the response time of the aircraft, the time taken for the combined air and ground forces to achieve containment and the fire danger for the day. It showed that the earlier that both air and ground forces were able to get to a fire, the more able they were to contain it to a relatively small size.

Importantly, aircraft were directly responsible for saving more than $4 million worth of material assets that were in the direct path of fire and would otherwise have been destroyed. Savings resulting from constraining many potentially large fires to small sizes could not be determined, but were also likely to be substantial. These outcomes are important in terms of risk assessment, particularly for future considerations about the size and running costs of the aircraft firefighting fleet.

Introduction

The Department of Natural Resources and Environment (NRE) and its predecessor organisations have used aircraft in firefighting operations in Victoria since about 1929. In the 1940s rotary wing aircraft were trialled and in 1949 a Sikorsky helicopter was used for reconnaissance and transport for forest fires in remote locations. Gippsland bush pilots Ben Buckley and Bob Landsbury (of Alpine Aviation), flying Piper Pawnee cropdusters, made the first drops of water and fire retardant on bushfires in 1967 (Rolland 1996, NRE 1998).

In the 1980s, as part of the *Project Aquarius* fire experiment, the CSIRO National Bushfire Research Unit conducted extensive field trials of large firebombing aircraft in eastern Victoria (Loane & Gould 1985). These trials showed that, although large aircraft (such as the DC6, F27 and C130) were able to carry large volumes of water or retardant, their operational effectiveness was often severely restricted by their associated costs and logistics.

Victorian fire managers consequently established a more cost-effective fleet of smaller privately-owned agricultural aircraft that could be contracted for the duration of a fire season. At the request of NRE during the late 1980s and 1990s, the contractors gradually increased the size and capacity of their aircraft. In 1997–98 most of the available fixed-wing aircraft were of 2500-litre capacity or greater, with the Polish PZL-18 Dromader being the most common.

The use of medium helicopters (such as the Bell 205, 212 or 412) in the 1980s by the-then National Safety Council Australia (NSCA) enabled Victorian fire managers to evaluate their advantages. NSCA medium helicopters were used extensively in 1984/85 during major fire events in north-eastern Victoria and demonstrated their capacity for enhancing firebombing and crew transport and rappel operations. NRE subsequently included medium helicopters in its contract fleet to the extent that availability and funding allowed. Four medium helicopters were contracted during 1997–98.

A series of study tours and staff exchanges in relation to the aerial fire suppression operations of the USA and Canada, initiated by Victorian fire managers, enabled the interchange of information about some of the techniques and equipment applied in the respective countries.

NRE's Aviation Management Section has developed significant expertise in most aspects of aerial firefighting including firebombing, rappelling, hover exit, infra-red scanning, mapping by computer and from the Global Positioning System, fireground communications, airbase management and air-operations training. Considering the hostile nature of the operating environment, NRE also has a very good safety record in aerial firefighting. This is attributable to the annual training program that ensures that everyone involved with air operations is skilled and accredited.

Because of its size and reputation for effectiveness, some of the Victorian aerial fire suppression fleet was used at major incidents in New South Wales in 1994 and 1997.

The 1997–98 fire season was directly influenced by the *El Niño* Southern Oscillation phenomenon, the prolonged drought effects of which caused some parts of Victoria to experience their driest period on record. NRE attended a 20-year record of 1056 fires for the season and both Country Fire Authority (CFA) resources and aircraft were important in fighting a number of the larger ones.

The 1997–98 fire season was the first time in Australia that a large heavy-lift helicopter—the Erickson S64F Aircrane—was used for firefighting. Following advice from NRE, the Victorian Government recognised that the expected exceptional fire season justified leasing one. The CFA at that time also increased its use of the aircraft fleet for first attack, particularly the medium helicopters and, later in the season, the Aircrane.

The 1997–98 fire season was also the first in which the Integrated Firefighting Aircraft Resources (IFAR) Agreement – for the sharing of aircraft resources between NRE and the CFA – was applied during a large amount of fire activity. The IFAR fleet in 1997–98 comprised the Aircrane, 10 fixed-wing firebombers, 4 medium helicopters, 6 light helicopters and a fixed-wing aircraft fitted with an infra-red Linescan. The size of the aircraft fleet that season was greater than that of any other State or Territory in Australia and was considered necessary to address the forecast threat of damage and loss of life from wildfires – a threat historically greater in Victoria than in the other States (Incoll 1994). This report deals with the effectiveness of the aircraft fleet as a whole; the specific operational effectiveness of the Erickson Aircrane is dealt with in a separate report (Biggs 1998).

Literature review

Despite the large amount of aerial fire-suppression activity in the USA, Canada and parts of Europe, relatively few studies outside Australia deal with the operational effectiveness of aircraft. Most reports address such matters as technical innovations or developments or modelling for the optimum distribution of aircraft. The literature did reveal some interesting dates in relation to the first development of techniques that are now standards for aerial firefighting operations.

Reports from Canada include Henderson et al. (1973) on the successful use of rappelling in a joint exercise with the USA during their 1971/72 fire season and Grigel (1975) on the use of helicopters with buckets for dropping water and fire retardant. Murray (1986) includes statistics and analyses about the use of fixed-wing bombers and helitankers over the period 1978–1984. The main findings of that report were that fixed-wing bombers with skimming ability were the most productive where circumstances allowed and that helitankers were becoming more widely used due to their flexibility of operation, although their increased use did not appear to have had any significant influence on the total area burned.

Also in Canada, Quintilio and Anderson (1976) compared the performance of hand crews, helitankers and fixed-wing aircraft for containment at 485 fires in the Whitecourt Forest over the period 1961–69. Hand crews achieved the best performance with 64%, followed by the helitankers with 59%. They defined the initial attack period to be the time from first suppression action on the fire until 10 am the following day (In Victoria, the first attack period is defined as the first eight hours after initial attack.). Kourtz (1989) derived some algorithms for the allocation of firefighting resources, including aircraft, in Canadian forests given the available airbases and fire danger for the day. Ogilvie et al. (1995) reported on the use of forward-looking infra-red equipment in bird-dog aircraft to look through smoke while directing fire-bombing operations.

As well as Henderson et al. (1973), reports on the use of aircraft for firefighting in the USA include Percival and Noste (1972) on the first successful use of helicopters with buckets for fire control and Greulich and O'Regan (1982) on the use of computer modelling for the optimum allocation of aircraft resources across available bases on days of high fire danger.

The majority of reports from Russia cover technical innovations, although Kurbatskii and Sheshukov (1978) looked at the numbers and sizes of aircraft required to fight large fires in Siberia and concluded that adequate numbers of aircraft of 10 tonne capacity (or more) were required. This reflected the long travel distances and often large fires experienced in that country.

Konig (1984), in Germany, dealt with the use of agricultural aircraft for fire-control operations and concluded that successful containment could be achieved using them even under higher fire-danger conditions if response times were short. This compares well with Australian experiences where agricultural aircraft make up the bulk of the fixed-wing firebombing fleet in all States. Short response times contributing to higher containment success rates is one of the important findings in the present study.

Dellenbach (1980) reported on the use of agricultural aircraft for firebombing in France, and concluded that this was an efficient way of obtaining adequate numbers of smaller aircraft.

A specialised aerial fire-fighting service in France during the 1990s, the Securite Civile, routinely operated Canadair CL 415 aircraft (a 6300-litre capacity turbine fixed-wing skimmer firebomber) on a patrol system on days of high fire danger. They flew a preset route along forested areas during the hottest part of the day. Although expensive, this method would be likely to reduce response times for tactical aircraft.

A Polish study (Bardan 1985) reported on the establishment of a system of tactical airbases distributed around forest districts, each airbase being equipped with three fixed-wing firebombers (PZL Dromader of 2500-litre capacity) and one helicopter. NRE currently sets similar levels for its Regions, although two helicopters—one light reconnaissance and one medium tactical—would be more common for Regions in eastern Victoria.

Three New Zealand studies are relevant. Fogarty and Smart (1996) compared the cost-effectiveness of various aircraft used for fire control. Important conclusions were that fixed-wing aircraft were able to deliver large amounts of foam, retardant or water more economically than helicopters when filling points for helicopters were more than 2 km from the fire, and that larger helicopters were more economical in terms of delivery rates than smaller helicopters, despite their higher operating costs. In a follow-up study, Fogarty et al. (1998) derived a load/speed (L/S) ratio to differentiate aircraft. Aircraft with higher L/S ratios were found to be the most efficient and economical in terms of the volume of water or retardant delivered to the fire. They also derived a '2 X 2' rule which stated that, when two helicopters were flying more than 2 km to a fire, additional filling points should be established closer to the fire.

Fogarty and Slijepcevic (1998), of New Zealand, looked at the influence of wind speed on the effectiveness of helicopter operations. A wind speed threshold of approximately 80 km/h was reported for most helicopter bombing operations, although this varied considerably with topography and forest type. Larger helicopters with experienced pilots were recommended for best performance in windy conditions.

Overall, no significant operational review was found from outside Australia that could substantially assist the conduct of the present study. However, the general trend of overseas experience confirmed the directions taken in Victoria, particularly in terms of fleet size and cost/operational effectiveness.

The main aim of this report was to evaluate the effectiveness of the IFAR aircraft fleet in fire-suppression operations generally during the 1997–98 fire season and specifically in the first-attack role.

Effectiveness was assessed subjectively using the opinions of experienced air attack supervisors and fire operations officers, and objectively using information about fire behaviour, weather, fuel, topography and suppression response.

Aircraft operating costs were not collected or considered in this report, consequently the assessment of effectiveness does not include a cost/benefit analysis. Some comment on the assets saved is included to provide an indication of the economic benefit of aircraft use.

Method

Data collection

Criteria for selection of fire events for detailed study

A total of 75 fire events were included in this study, selected on the basis of meeting any of the following criteria:

- total aircraft usage exceeded 30 minutes
- tactical aircraft (rotary or fixed-wing firebombers) were used or reconnaissance or ferry aircraft were important in enabling crews to reach the fire in time for first attack efforts to be successful
- observation aircraft were important in directing ground forces to a fire or around a fire for containment.

Fuel, weather, topography and fire behaviour

Because fire outcomes are a function of fuel, weather, topography and fire behaviour, and all significantly influence aircraft performance, as much basic information on these factors as possible was collected from each of the 75 selected fire events.

Data included:

- fire size (initial and final), forward rate of spread, flame height
- component and overall fuel hazard (McCarthy et al. 1998)
- air temperature, relative humidity, wind speed and direction, drought index (Keetch & Byram 1968), Forest Fire Danger Index (McArthur 1973)
- slope, aspect, position in the landscape and/or proximity to assets.

Overall aircraft performance

Data from NRE's Aviation Management Section's aircraft flight operations database enabled evaluation of the overall performance of the IFAR aircraft fleet. The data covered all fires in the State attended by aircraft during 1997–98 and included information on the total hours flown by the whole fleet, by each aircraft, by each aircraft on each task, by each aircraft each day and by each aircraft at each major fire event.

Individual aircraft performance

Aircraft performance was gauged by the loads delivered, the time to achieve certain outcomes and through a series of questions of relevant fire managers.

Loads delivered

The total number of loads and nature of the fire-control agent (water, foam or retardant) delivered were determined for each aircraft at each selected fire event.

Timing

To indicate effectiveness in terms of first attack outcome, and as fire growth is a function of time, records of the time intervals for the following events were collated:

- detection to first suppression work by aircraft
- detection to first suppression work by ground forces
- first suppression work to checking of the fire.

Assessment of aircraft effectiveness through questionnaire

To further assist assessment of the effectiveness of aircraft in first attack and extended first attack, staff experienced in both fire suppression and aircraft operations were asked to rate aircraft performance (from 0% to 100%) in a series of attributes (see text box below). The questions (see Appendix 1) were directed at identifying significant features potentially influencing the operations. Called 'expert judgement', this method of sampling was used by Hirsch et al. (1997) to collect data on fires after the event.

Information was particularly sought where aircraft were used in conjunction with substantial ground forces.

Specific and general questions asked about aircraft performance

(A sample data-collection form is reproduced in Appendix 1)

Effectiveness in first attack and extended first attack

1. Did the aircraft effort contribute directly to the fire being contained in the first attack phase?
2. Were the aircraft able to effectively halt the head fire before ground forces arrived?
3. If the suppression effort was in conjunction with ground forces, rate the contribution of the aircraft to achieving first attack (or extended first attack) containment (%).
4. Could the ground forces have achieved first attack containment in less than 8 hours without the assistance of aircraft (or 24 hours in the case of extended first attack operations)?
5. Did the aircraft provide reconnaissance services which allowed a ground crew to reach the fire? Was this reconnaissance service critical to first attack containment of the fire?
6. Did the aircraft ferry crews to the fire? Was this ferry service critical to first attack containment of the fire?
7. Did the aircraft provide a reconnaissance service at the fire which significantly assisted suppression crews to check the fire's progress?

Campaign fires

For the few cases where the fire developed into a campaign status, questions were asked to identify the significant roles undertaken by aircraft during the campaign.

General effectiveness

1. Did the use of an Air Attack Supervisor significantly increase the effectiveness of the aerial firefighting operation?
2. Did the aircraft save significant assets which the ground forces would have been unable to? (The criteria applied in this category were that the assets were substantial structures, such as houses or sheds, or pine plantations, that they were in the direct path of the fire and that they were saved from damage by the direct suppression efforts of the aircraft. Assets not in the direct path of the fire or less tangible assets, such as the value of forests or parks, were not included. The overall asset value was calculated as the sum of the estimated current market values of the individual assets.)
3. Did the aircraft locate and suppress spot fires ahead of the main fire which otherwise may have significantly increased the suppression effort required?
4. Were the aircraft restricted by smoke, turbulence, topography, daylight, vegetation or any other factor, and did this occur at critical times?
5. Were there sufficient aircraft for the task?

As fire events meeting the criteria occurred in almost every region of Victoria, the interviewees were drawn from across the State. In most cases, the relevant Operations Officer and/or Air Attack Supervisor supplied the required information. For some fires, the interviewees were other staff involved in the suppression operation, such as rappel crew members and fireline supervisors. To aid consistency in the information obtained, the questions were explained in detail to the interviewees.

Data analysis

The purpose of collecting such a large amount of both objective and subjective information was to facilitate tests for correlations that could be used to predict aircraft performance.

The data were analysed using multiple linear regression techniques to determine the influence of all factors on the effectiveness of the aircraft. Individual means were also compared using a means multiple range test. A model for identifying the probability of a fire achieving campaign status was constructed using a logistic procedure.

For some analyses, the data were categorised into first attack outcomes (defined by McCarthy & Tolhurst 1998).

Category 1 - first attack successful

A fire was categorised as a first attack success if:

- total area did not increase by more than a factor of three between first suppression work and checking
- checking of the fire was achieved within the first eight hours after initial attack

  and
- checking of the fire was achieved with the usual first attack resources; that is, the resources (6 crew, 1–2 slip-on units and a D3 or D4 class bulldozer) usually available for first attack within the first two hours.

Category 2 - extended first attack successful

This category describes those situations where a fire was not a first attack success according to the above criteria but was controlled at a reasonable size within a relatively short period. It was defined as:

- total area did not exceed 400 hectares
- checking was achieved within the first work period; that is, within the first 24 hours following the outbreak of the fire

  and
- checking was achieved with more than the usual first attack resources.

Behaviour of ‘extended first attack success’ fires often became significant, producing higher intensities (more than 3000 kW/m) and, occasionally, crown fires. In almost every case they were controlled by a concerted effort of men and machinery, often under difficult conditions (smoke, heat and dangerous or stressful situations).

Category 3 - first attack unsuccessful - campaign fire

A fire was classified as a campaign fire if:

- the total area increased by more than a factor of three between first suppression work and checking

  and
- checking was not achieved within the first work period; that is, generally more than 24 hours following the outbreak of the fire.

Results

Overall aircraft activity

Table 1 compares the activity of the whole IFAR aircraft fleet during the 1997–98 fire season with that for the 75 fires specifically investigated in this study to indicate the degree to which the 75 fires are representative of the season's activities.

Table 1 Total aircraft use by type and activity for the 1997–98 fire season and for the 75 fires in this study

Aircraft	Activity	Total usage for 1997–98 season (hours)	Usage on the 75 fires in this study (hours)
fixed-wing	firebombing	570	480
heavy helicopter	firebombing	50	50
medium helicopter	firebombing	300	265
medium helicopter	crew transport	170	100
medium helicopter	rappel	230	140
light helicopter	reconnaissance	400	230
light helicopter	air-attack supervision	300	200
light helicopter	forward-looking infra-red	162	50
fixed-wing	infra-red Linescan	133	83

First attack outcome

Table 2 indicates that more than 77% of the 75 fires studied were checked by normal first attack.

Table 2 First attack outcome

Category	First attack outcome	Number of fires
Category 1	normal first attack successful	58
Category 2	extended first attack successful	13
Category 3	campaign fire - first attack unsuccessful	4
	Total	**75**

Note: First attack outcome as defined in McCarthy and Tolhurst (1998)

Use of aircraft

For the 75 fires selected for this study, Table 3 sets out for each category of first attack success the total hours flown and (where relevant) total number of loads carried by each type of aircraft.

Table 3 Aircraft usage by task for each first attack category

First attack outcome	Aircraft task and type							
	Reconnaissance and air-attack supervision	Firebombing Fixed-wing (average load 2500 L)		Firebombing Helicopter (medium) (average load 1100 L)		Firebombing Helicopter (heavy) (9000 L capacity)		Infra-red Linescan and FLIR[1]
	(hours)	(hours)	(No. of loads)	(hours)	(No. of loads)	(hours)	(No. of loads)	(hours)
Category 1	140	160	124	35	227	2	14	50
Category 2	70	200	152	60	350	12	120	9
Category 3	320	120	110	170	850	36	220	74
Totals	430	480	386	265	1427	50	354	133

Note 1: Forward-looking infra-red

Value of assets saved by aircraft action

Table 4 lists those fires of the 75 selected for detailed study at which material assets (primarily houses, other buildings and pine plantations) were saved by direct suppression action by aircraft during the 1997–98 fire season and the estimated value of those assets based on contemporary property values in that area.

Table 4 Value of assets saved by aircraft suppression action at selected fire events

Fire event		Value of assets saved
Date	Fire number and location	($A)
11/12/97	Ovens 035 - Flat Rock	50 000
23/03/98	Upper Murray 022 - Bullioh	100 000
12/3/98	Otways 002b - Yeodene	100 000
2/02/98	Otways 012 - Aroona Court	150 000
22/01/98	Horsham 038 - Claude Austin Reserve	250 000
12/03/98	East Port Phillip 069 - Mt. Dandenong	250 000
12/03/98	East Port Phillip 070 - Old Coach Road	750 000
25/02/98	West Port Phillip 031 - Middle Gully	1 000 000
22/03/98	Midlands 063 - Spring Hill	1 500 000
	Total	**$4 150 000**

Table 5 Means, minimum values, maximum values and standard deviations for all data variables

Variable	Unit of measure	No. of fires	Mean	Min.	Max.	Std. Dev.
ALL FIRES		**75**				
Air temperature	degree C	75	29	20	40	4.4
Relative humidity	percent	75	35	20	65	12
Wind speed	km/hr	75	13	0	45	11
Wind direction	degree	75	249	0	360	96
Forest Fire Danger Index	index	75	16	2	45	10
Surface fine fuel hazard	score	75	3.2	1.0	4.5	0.63
Bark hazard	score	75	3.0	1.0	4.5	0.90
Elevated hazard	score	75	3.3	2.0	5.0	0.75
Overall fuel hazard	score	75	3.6	2.0	5.0	0.64
Slope	degree	75	14	0	45	10.9
Aspect (direction)	degree	75	142	0	360	127
Flat ground (occurrence on)	% of area	75	23	0	100	42
Slope (occurrence on)	%	75	81	0	100	39
Ridge top (occurrence on)	% of area	75	17	0	100	38
Proximity of assets	metre	75	23	0	1000	123
Firefighters NRE	number	75	23	0	182	31.4
Firefighters other	number	75	11.5	0	200	34
D4 bulldozers	number	75	0.37	0	2	0.59
D6 bulldozers	number	75	0.64	0	11	1.83
Wheeled tractors	number	75	0.01	0	1	0.12
Slip-on units	number	75	3.9	0	40	7.7
Tankers NRE	number	75	0.4	0	5	1
Tankers other	number	75	3	0	50	9.4
Fixed-wing - firebombers	number	75	1.2	0	4	1
Helicopter, medium - firebomber	number	75	0.6	0	3	0.7
Helicopter, heavy - firebomber	number	75	0.05	0	1	0.2
Helicopter, light - air-attack supervisior	number	75	0.60	0	3	0.6
Helicopter, light - reconnaissance	number	75	0.08	0	1	0.3
Fixed-wing - reconnaissance	number	75	0.39	0	2	0.5
Helicopter, light - firebomber	number	75	0.04	0	1	0.2
Total suppression aircraft	number	75	1.9	0	8	1.4

Table 5 (continued) Means, minimum values, maximum values and standard deviations for all data variables.

Variable	Unit of measure	No. of fires	Mean	Min.	Max.	Std. Dev.
ALL FIRES		**75**				
Flame height	metres	75	1.6	0.1	9	1.5
Forward rate of spread	m/hr	75	200	10	1400	287
Spotting	metres	75	26	0	500	86
Initial fire size	ha	75	4.2	0.1	80	11
Perimeter for containment	metres	75	2175	20	35000	5887
Final fire size	ha	75	125	0.1	3732	554
Time of day of detection	hr:min	75	14:20	6:20	19:00	3:10
Detection to first work - aircraft	hr:min	75	0:40	0:06	4:00	0:30
Detection to first work - ground force	hr:min	75	1:40	0:00	15:00	2:32
Turnaround time, helicopter	hr:min	75	0:03	0:00	0:30	0:06
Turnaround time, fixed wing	hr:min	75	0:27	0:00	1:30	0:20
First work to containment	hr:min	75	8:16	0:06	96:00	16:31
Rating of aircraft contribution to containment in joint operations	percent	75	64	10	95	23
Aircraft contributed directly to containment	percent	75	80	0	100	40
Aircraft checked head fire before ground force arrived	percent	75	60	0	100	50
Aircraft reconnaissance assisted ground force to reach fire	percent	75	50	0	100	50
Reconnaissance critical to containment	percent	75	40	0	100	50
Aircraft ferried crews to fire	percent	75	22	0	100	31
Ferry critical to containment	percent	75	23	0	100	40
Aircraft reconnaissance assisted with suppression operation	percent	75	41	0	100	50

Table 5 (continued) Means, minimum values, maximum values and standard deviations for all data variables

Variable	Unit of measure	No. of fires	Mean	Min.	Max.	Std. Dev.
CATEGORY 1 FIRES		**58**				
Containment could have been achieved within 8 hours without aircraft	percent	58	32	0	100	40
Aircraft contributed directly to containment	percent	58	97	0	100	17
Aircraft checked head fire before ground force arrived	percent	58	69	0	100	42
Aircraft reconnaissance assisted ground force to reach fire	percent	58	57	0	100	50
Reconnaissance critical to containment	percent	58	45	0	100	48
Aircraft ferried crews to fire	percent	58	46	0	100	48
Ferry critical to containment	percent	58	29	0	100	45
Aircraft reconnaissance assisted with suppression operation	percent	58	35	0	100	45
Rating of aircraft contribution to containment in joint operations	percent	58	70	10	95	22
CATEGORY 2 FIRES		**13**				
Containment could have been achieved within 24 hours without aircraft	percent	13	16	0	100	12
Aircraft ferried crews to fire	percent	13	46	0	100	15
Ferry critical to containment	percent	13	23	0	100	10
Aircraft reconnaissance assisted ground forces to reach fire	percent	13	50	0	100	12
Reconnaissance critical to containment	percent	13	37	0	100	12
Aircraft reconnaissance assisted with suppression operation	percent	13	84	0	100	65
CATEGORY 3 FIRES		**4**				
Aircraft significant in reconnaissance, FLIR	percent	4	100	100	100	0
Aircraft significant in ferrying	percent	4	25	0	100	10
Aircraft significant in firebombing	percent	4	75	0	100	20

Table 5 (continued) Means, minimum values, maximum values and standard deviations for all data variables

Variable	Unit of measure	No. of fires	Mean	Min.	Max.	Std. Dev.
ALL FIRES		**75**				
Air Attack Supervisor assisted efficiency of firebomb operation	percent	75	68	0	100	10
Firebombing saved assets	percent	75	12	0	100	30
Value of assets	$m	75	0.06	0	1.5	0.2
Spots suppressed ahead of main fire	percent	75	12	0	100	30
Restriction - smoke	percent	75	7	0	100	25
Smoke restriction was critical to containment	percent	75	5	0	100	20
Restriction - turbulence	percent	75	13	0	100	34
Turbulence restriction was critical to containment	percent	75	10	0	100	30
Restriction - daylight	percent	75	21	0	100	40
Daylight restriction was critical to containment	percent	75	15	0	100	35
Restriction - topography	percent	75	13	0	100	30
Topography restriction was critical to containment	percent	75	4	0	100	20
Restriction - vegetation	percent	75	5	0	100	20
Vegetation restriction was critical to containment	percent	75	3	0	100	16
Were there sufficient aircraft	percent	75	79	0	100	40
Fixed-wing - retardant	loads	60	5.7	0	30	8
Fixed-wing - foam	loads	2	2	0	4	2.8
Fixed-wing - water	loads	0	0	0	0	--
Medium helicopter - retardant	loads	0	0	0	0	--
Medium helicopter - foam	loads	58	13	0	200	32
Medium helicopter - rappel	number	13	1	0.5	2	0.3
Medium helicopter - water	loads	0	--	--	--	--
Heavy helicopter - retardant	loads	0	--	--	--	--
Heavy helicopter - foam	loads	4	52	14	120	49
Heavy helicopter - water	loads	0	--	--	--	--
Light helicopter - water/foam	loads	3	30	15	60	26

Table 6 Mean values of selected variables by first attack outcome category

Variable	Unit of measure	Category of first attack outcome		
		Cat 1 (58 fires)	Cat 2 (13 fires)	Cat 3 (4 fires)
Forest Fire Danger Index	**index**	**14.2 *a***	**23.2 *b***	**37.0 *c***
Overall fuel hazard	score	3.53 *a*	3.65 *a*	3.75 *a*
Slope	degree	14.6 *a*	14.5 *a*	10.0 *a*
Aspect (direction)	degree	143 *a*	163 *a*	106 *a*
Crew NRE	number	11.9 *a*	46.7 *b*	203 *c*
Crew other	number	3.6 *a*	22.9 *a*	117.5 *b*
D4 bulldozer	number	0.3 *a*	0.7 *a*	2.0 *b*
D6 bulldozer	number	0.12 *a*	1.46 a	12.7 *b*
Slip-on units	number	1.8 *a*	6.4 *a*	52.3 *b*
Tankers - NRE	number	0.2 *a*	0.5 *a*	9.6 *b*
Tankers - other	number	0.87 *a*	6.1 *a*	32.5 *b*
Fixed-wing firebombers	number	1.0 *a*	1.7 *a*	3.5 *b*
Helicopter - medium	number	0.53 *a*	0.84 *a*	2.2 *b*
Helicopter - light AAS	number	0.5 *a*	0.84 *a*	2.0 *b*
Fixed-wing reconnaissance aircraft	number	0.33 *a*	0.54 *a*	1.3 *b*
Suppression aircraft total	number	1.6 *a*	2.6 *a*	9.3 *b*
Flame height	metres	1.19 *a*	2.9 *b*	3.5 *b*
Forward rate of spread	**m/hr**	**113 *a***	**410 *b***	**1037 *c***
Spotting	metres	4.2 *a*	65.4 *a*	262 *b*
First size	**hectare**	**0.9 *a***	**17.8 *b***	**20.0 *b***
Perimeter required for containment	metres	262 *a*	5192 *a*	70000 *b*
Final size	hectare	2.5 *a*	106.9 *a*	9976 *b*
Time of day of detection	hours	14.7 *a*	13.8 *a*b	11.0 *b*
Detection to first work aircraft	**hours**	**0.5 *a***	**0.96 *ab***	**1.23 *b***
Detection to first suppression work	hours	1.5 *a*	2.06 *a*	0.9 *a*
Helicopter turnaround	hours	0.04 *a*	0.08 *a*	0.07 *a*
Fixed-wing turnaround	hours	0.44 *a*	0.42 *a*	0.37 *a*
First work to containment/check	**hours**	**3.05 *a***	**24.8 *a***	**168.7 *b***
Aircraft contributed to first attack containment	**percent**	**96 *a***	**20 *b***	**0 *b***
Aircraft stopped head fire	**percent**	**69 *a***	**10 *b***	**0 *b***

Notes *a*, *b* and/or *c* after each value for first attack outcome category denote that the mean values are significantly different at the 95% confidence level for that variable. A repetition of *a* or *b* within the categories indicates no significant difference between those values. Rows in bold type indicate there is significant mean difference between first-attack outcome categories for that variable.

Table 6 (continued) Mean values of selected variables by first attack outcome category

Variable	Unit of measure	Category of first attack outcome		
		Cat 1 (58 fires)	Cat 2 (13 fires)	Cat 3 (4 fires)
Aircraft reconnaissance assisted ground crew to reach fire	**percent**	**57 *a***	**15 *ab***	**0 *b***
Aircraft reconnaissance assisted suppression	percent	35 *a*	84 *b*	100 *b*
Contribution to containment	**percent**	**69 *a***	**45 *b***	**42 *b***
Air Attack Supervisor assisted efficiency	percent	63 *a*	85 *a*	66 *a*
Aircraft saved assets	percent	7 *a*	27 *a*	0 25*a*
Value of assets	$m	0.02 *a*	0.11 *a*	0.38 *a*
Aircraft suppressed spot fires	**percent**	**3 *a***	**38 *b***	**66 *b***
Aircraft numbers were sufficient	**percent**	**95 *a***	**27 *b***	**0 *c***
Fixed-wing - retardant	Loads	2.69 *a*	15.2 *a*	327.7 *b*
Medium helicopter - foam	Loads	4.82 *a*	38.9 *a*	490.0 *b*
Aircraft total	number	2.4 *a*	4.0 *a*	10.0 *b*

Notes *a*, *b* and/or *c* after each value for first attack outcome category denote that the mean values are significantly different at the 95% confidence level for that variable. A repetition of *a* or *b* within the categories indicates no significant difference between those values. Rows in bold type indicate there is significant mean difference between first-attack outcome categories for that variable.

Effectiveness in checking head fire before ground forces arrived

Aircraft were able to effectively check the head fire before the ground forces arrived on an average of 60% of the fires attended. These were mainly the smaller fires and on days when the fire danger was less than 'Very High'.

Response times

Table 5 indicates that aircraft were able to arrive at the fire and commence work within an average of about 40 minutes after detection of the fire, while ground forces took an average of about 1 hour 40 minutes.

Turnaround times

Medium helicopters were able to achieve mean turnaround times of 3–5 minutes, while fixed-wing aircraft averaged about 25 minutes. This arose directly as a result of the helicopters' ability to use water sources close to the fire ground whereas fixed-wings must return to a, usually remote, fixed or temporary retardant-mixing facility.

Contribution of Air Attack Supervisor

The Air Attack Supervisor assisted significantly with the overall air attack operation on an average of 68% of the fires investigated.

Adequacy of numbers of suppression aircraft

While, in the opinion of the Air Attack Supervisor or Operations Officer, sufficient aircraft were available in approximately 95% of the fires where first attack was successful, this figure fell to only 27% where extended first attack was required. The most common additional aircraft desired was a medium helicopter. In some instances additional fixed-wing firebombers or the large (Aircrane) helicopter would also have been useful.

Aircraft reconnaissance assistance in suppression operations

Although aircraft reconnaissance services assisted with suppression operations in only 35% of the fires where first attack was successful, this proportion increased to 84% and 100% respectively for extended first attack and campaign fires. This strong relationship with fire size is attributable to the increased need for aircraft to reconnoitre greater distances of fireline and to further assist with direction of ground forces.

Aircraft suppression of spot fires

Aircraft were more frequently used for suppression of spot fires at extended first attack and campaign fires. This is also related to fire size, as these fires often developed to a size where spotting behaviour started to become a problem.

Contribution by aircraft to containment of the fires

Air attack supervisors and/or operations officers indicated that aircraft contributed an average of 64% (Table 5) of the combined effort of the aerial and ground forces to contain the fires. Their responses covered the complete range of fire sizes from very small (where the aircraft contribution was rated at, for example, 90%) to much larger fires, or those where the aircraft provided only a reconnaissance service and where contributions were significantly less – approximately 10–30%.

The following multiple linear regression model was able to explain approximately 20% of the variation in the data:

$$\text{Contribution \%} = 0.19*\text{ACTotal} - 0.28*\text{FROS} - 0.27*\text{FwkToChk} + 0.64 \qquad \textbf{\textit{Equation 1}}$$

($n = 68$, $r^2=0.20$, $p < 0.001$)

ACTotal = total number of aircraft

FROS = forward rate of spread

FwkToChk = time taken from first suppression work to containment - combined aerial and ground forces

Equation 1 shows that the level of contribution by aircraft increased when:

- the total number of aircraft deployed was greater

and decreased when:

- forward rates of spread were higher
- the time between first work and containment by the combined aerial and ground forces was longer.

Although this model explains only 20% of the variation in the data (the remaining 80% being due to factors other than numbers of aircraft, forward rate of spread or time to containment), its low probability value ($p < 0.001$) means there is a high likelihood of the general trend of these factors affecting contribution percentage being correct.

Factors affecting final fire size

The following multiple linear regression model was the best for explaining the variation in the data (accounting for 55% of the variation) for final size of the fires:

Final fire size = 0.31*DetnToFwkAC + 0.22*FDI + 0.47*FwkToChk - 352 ***Equation 2***

(n = 68, r^2=0.55, p < 0.001)

DetnToFwkAC = time between detection and for aircraft to arrive at the fire and commence work

FDI = Forest Fire Danger Index

FwkToChk = time taken from first suppression work to containment - combined aerial and ground forces

That is, final fire sizes were smaller when:

- the time between the fire being detected and the aircraft arriving and commencing work was shorter
- the Forest Fire Danger Index (FDI) was lower
- the time between first suppression work and containment by the combined aerial and ground forces was shorter.

Occasionally, however, under very high to extreme fire danger, the situation ran contrary to the model and fires grew to campaign proportions despite early attack.

First attack outcome category and effects of aircraft response time and FDI

The following logistic model was the only statistically valid way of processing categorical (discrete rather than continuous) data. It was the best method at explaining variations in first attack outcome for Category 3 fires (those where neither normal nor extended first attack contained the fire).

Probability of a Category 3 outcome = 1 - (1/(1+(1/e^n)) ***Equation 3***

where n = (0.17*FDI) + (1.42 *DetnToFwkAC) - 8.8

FDI = Forest Fire Danger Index

DetnToFwkAC = time between detection and for aircraft to arrive at the fire and commence work

FDI coefficient	DetnToFwkAC coefficient	Constant	p (model)	n (obs)
0.17**(s.e. 0.06)	1.42# (s.e. 0.85)	8.8	0.001	75

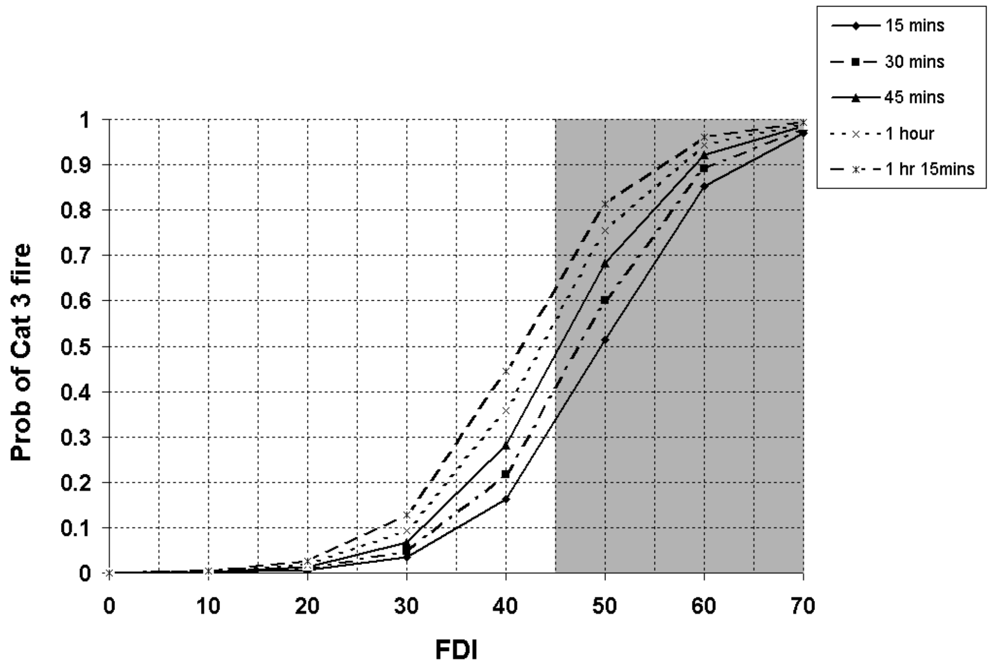
(** 99% significant. # 91% significant.)

Equation 3 shows that the probability of a fire not being contained by either normal or extended first attack, thereby reaching Category 3 status, was increased when:

- FDIs were higher
- the time between detection and when the aircraft arrived at the fire and commenced work was longer.

Figure 1 (below) was constructed from Equation 3. It shows that increasing fire danger sharply increases the probability of the fire reaching campaign (Category 3) status and that, above about FDI 50, the probability of checking a fire using aircraft in the first attack phase is low, even when response times are very low.

Figure 1 Probability of a Category 3 fire developing given the response time of aircraft and fire danger index (FDI)



Note: Shaded area indicates extrapolation beyond the range of observations.

Figure 1 indicates that aircraft response times have an increasing influence on first attack outcomes up to FDI 40, and that the differences in first attack outcome produced by response times are significant in the range FDI 30 to FDI 60. At FDI 40, a 15-minute response time will produce about a 15% probability (about one in every 6 fires) that first attack with aircraft will not be successful. A response time of 75 minutes at FDI 40, however, increases the probability of first attack failing to nearly 50% (every second time). Beyond FDI 60, the model indicates that response time will have little influence on first attack outcome.

The trend in these modelled outcomes for response times is that, for each 15 minutes reduction in response time, the probability of containing the fire at first attack increases by about 7%.

Effectiveness of rappel operations

Appendix 2 provides a qualitative summary of the use and effectiveness of rappel crews during the 1997–98 fire season.

Discussion

Some of the following discussion is based on supplemental information provided by interviewees during data collection.

The finding that aircraft contributed an average of 64% of the combined effort of the aerial and ground forces to contain the fires is indicative of the usefulness and efficiency of NRE's then-current aircraft fleet. Although this value was derived subjectively, it nevertheless showed that fire managers regarded aircraft to have been highly effective in the situations in which they were used. This finding compares favourably with that obtained by Quintilio and Anderson (1976) in their Whitecourt Forest study, where, at 64%, hand crews achieved the best containment performance followed by helitankers at 59%.

Where early first attack was successful, the major contribution by aircraft appeared to be in two main uses:

- Firebombers stopped or effectively slowed the head fire while the fire was small in 69% of the cases.
- Aircraft reconnaissance assisted with direction of ground crews, enabling them to quickly reach fires in 57% of the cases.

Aircraft attended a relatively small proportion (about 7%) of the 1056 fires that occurred during the fire season. Despite this low attendance rate, the high mean values for Forest Fire Danger Index and Overall fuel hazard for the 75 fires included in this study suggest that most were potentially serious, particularly so in view of the remoteness of some, and the proximity to assets of others.

The model best explaining first attack outcome is provided by Equation 2, which incorporates the time between detection of the fire and the first work by the aircraft.

While the data from which the contribution of aircraft to first attack containment was derived, and therefore the model provided by Equation 1, depended on the judgement of fire managers, the more objective measure of final fire size provided by Equation 2 confirms the implication that time taken by aircraft to reach the fire was important to early containment. This is to be expected when usual fire behaviour is considered. All fires go through an acceleration phase (the time between ignition and when they reach their maximum rate of spread) as they develop. Luke and McArthur (1978) found that the acceleration phase can be as brief as 20–30 minutes, although this varies considerably with changes in fuel moisture content through the day. The authors also found that wildfire acceleration can occur in a series of 'steps' as various factors such as elevated fuels, spotting and the convection process began to affect fire behaviour as it increased in size and intensity.

Equations 2 and 3 indicate that a significant delay in getting aircraft suppression resources to a fire greatly increases the probability of it increasing in size. The most important implication from this is that, if the likelihood of a Category 3 fire is to be minimised, despatch time for aircraft must be kept to a minimum. High FDIs also influenced these models, making prompt despatch on days of high FDI a priority.

Another important implication is in the location of firebombing aircraft and firebombing bases. Although aircraft and bases are strategically distributed around the State, it would be useful to review these locations using a wildfire threat analysis process.

The other timing variable used in this model – the time taken for the combined aerial and ground forces to achieve containment of the fire – showed that, although air attack was an important factor, the combined efforts of ground and aerial forces were usually required to keep the fire small. The experience of Australian bush fire-fighting agencies is that mineral-earth firelines (made by either rakehoes or bulldozers) maximise the probability of containing and holding any fire.

Neither overall nor component fuel hazard was significant in explaining any of the variation in outcome for the fires in this study. This may be because the mean Overall Fuel Hazard score (McCarthy et al. 1998) for all fires studied was 3.6; that is, in the ***High*** to ***Very High*** range. Overall Fuel Hazard scores of this level are likely to support significant fires even under conditions of relatively low fire danger (McCarthy & Tolhurst 1998); probably one of the reasons (along with remoteness) why aircraft were committed to these fires at the outset.

Equation 3 (the logistic predictive model based on the response time of aircraft and FDI) indicates that, even with the shortest response times, very high to extreme FDIs may still cause large fires. This is illustrated in Figure 1, which indicates that, even with 15-minute response times, aircraft may not be able to contain a fire at first attack when the FDI is above 60. This does not imply that aircraft should not be used under conditions of very high fire danger; rather that these conditions reduce the chances of them being able to restrict the fire to a small size.

Also significant from this model is the indication that each 15-minute reduction in response time can increase the probability of checking the fire at first attack by approximately 7% (notably between FDIs 30 and 60). The significance of this is highlighted by the fact that Category 3 fires can account for up to 70% of the area burned and 35% of the total suppression expenditure in a year (McCarthy & Tolhurst 1998).

Allocation of aircraft to task

Supplemental information indicated that the contribution rate by fixed-wing firebombers to containment was high despite them carrying fewer loads in any fire category than medium helicopters (Table 3). This indicates the efficiency of fixed-wings at containing small fires in the early development stage where long travel distances are involved.

The generally very low turnaround times of medium helicopters arises from their ability to fill from water sources near the fire. This facility is particularly useful on the forest fringes where water sources such as farm dams and lakes are more frequent. Low turnaround times permit high delivery rates. Despite them carrying about half the volume of fixed-wing aircraft per load, the short turnaround times mean that medium helicopters are able to deliver between twice and three times the volume of the fixed-wings over a similar period.

Fire-control agent delivered by aircraft

The fire-control agents available for delivery by aircraft at the time of this study were principally Angus Forexpans S Class A Foam (essentially a knockdown agent) and Phoschek D75R Fire Retardant (used to hold a fireline pending construction of a mineral-earth line). Water was only used on the very few occasions when mixing facilities were unavailable or the aircraft did not have direct foam-injection capability.

While the fixed-wing aircraft delivered mainly retardant, the medium helicopters delivered only foam. This maximised the usefulness of both types of aircraft and fire-control agents given their relative capabilities and limitations. That is, fixed-wings are particularly efficient at delivering smaller total volumes of the longer-lasting retardant over larger distances (particularly to fires in the desert and the more remote mountain areas), whereas the medium helicopters were more useful for delivering greater total volumes of the shorter-lasting foam over short distances; foam being preferred over retardant because fill times are much faster and no time is lost in mixing.

Asset protection

Fire managers reported that medium helicopters proved very useful for asset protection during the 1997–98 fire season. Assets (principally houses, sheds and plantations) were saved at approximately 10% of the fires attended by aircraft.

During two fire events in particular, Midlands 063—Spring Hill (near Trentham) and East Port Phillip 070—Old Coach Road (in the Dandenongs), many houses in the direct path of the fire were saved by the use of medium helicopters and the Erickson Aircrane.

In-flight response

Some of the shortest response times for aircraft occurred when aircraft happened to be in flight when the fire event was reported. For Orbost 053—Ewings Marsh, for example, Helitack 3 responded in 10 minutes and for East Port Phillip 070—Old Coach Road the Erickson Aircrane responded in 12 minutes; in both instances the aircraft were airborne at the time.

While it is unlikely that in-flight responses can become an operational objective, these very low response times were strong contributors to both fires being contained rapidly and at the minimum possible size.

Air attack supervision

The NRE policy of using trained and accredited Air Attack Supervisors to direct firebombing operations was endorsed by the finding of this study that their work directly improved the efficiency of air attack operations for an average of 68% of the fires. The proportional effect for individual fire operations was not identified, however.

Forward-looking infra-red and infra-red Linescan

Forward-looking infra-red (FLIR) was used primarily for locating hot spots where either long firelines or inhospitable terrain made locating them difficult from the ground, and was of particular benefit at such fires as Mildura 017, Nowa Nowa 017, Heyfield H 031 – Caledonia and Midlands 063. The FLIR equipment was mounted in a light helicopter which could fly slowly along the fireline; this aircraft was also able to assist with directing ground crews if required.

FLIR proved particularly useful at Otways 002 – Yeodene where a fire in peat fuels was very difficult to extinguish. A peat fire is able to burn under the surface to appear some distance from the original site. Relights occurred in the weeks following the original Yeodene fire, and even in the following (1998–99) fire season.

Infra-red Linescan was undertaken using a dedicated fixed-wing aircraft – Firescan 2. The aircraft – a Cessna 404 Titan – was able to fly quickly to almost any location in Victoria and undertake Linescan missions over large tracts of forested land.

Linescan proved very useful to fire controllers planning strategies for the larger fires. It was used extensively at Heyfield H 031—Caledonia, both to follow the major runs of the fire during the first three days, and to monitor fire activity along the (approximate) 200-kilometre perimeter over the following fortnight.

Linescan also assisted fire controllers during multiple fire situations; as on 26 November 1997, when lightning caused 44 fires across Gippsland and, with resources stretched, decisions had to be made regarding which fires were priorities for attack.

Conclusions

Aircraft were found to be generally effective in assisting the containment of fires but were particularly effective during the first attack phase (which is vital to prevent fires escalating to campaign status) by:

- most importantly, slowing or stopping the head fire if they arrived early enough
- of less importance, but nevertheless of significance, by directing ground crews to reach the fire.

At the fire events sampled, by expert opinion, aircraft contributed an average of 64% of the total effort of fire containment, rising to 69% where the fire was checked early and contained to a small size.

Aircraft were also effective in saving human assets. Direct suppression action by aircraft was responsible for saving more than $4 million in material assets during the 1997–98 fire season.

Response time was the main limitations to aircraft effectiveness in the first-attack role. Models for predicting aircraft contribution to first attack containment and to final fire size showed that the response times of aircraft directly influenced both. These models also showed that low response times become increasingly important as fire danger increases.

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Appendix 1

Data collection sheet proforma

Fire Research - Aircraft Effectiveness Project

Data Sheet

Fire District	
Fire No & Season	
Fire Name	
Date	

Fire Conditions at First Attack

Weather			
Temp (deg C)			
RH (%)			
Wind Speed (km/hr)			
Wind Dirn (deg)			
FDI			
Fuel			
Litter	L/M/H/VH/E		
Bark	L/M/H/VH/E		
Elevated	L/M/H/VH/E		
Overall	L/M/H/VH/E		
Topography/Site			
Slope (deg)			
Aspect (deg)			
Posn. in landscape		Flat	
		Sideslope	
		Ridgetop	
Proximity of significant assets (m)			
Effort Ground Forces			
Firefighters DNRE			
Firefighters Other			
Dozers D4 or less			
Dozers D6 or bigger			
Wheel Tractors			
Tankers Small (400l)			
Tankers Large DCNR (4000l)			
Tankers Large Other (4000l)			
Effort Aircraft			
Aircraft Firebombers FW			
Aircraft Firebombers H/C Med			
Aircraft Firebombers H/C Heavy			
Aircraft H/C light AAS (hrs)			
Aircraft H/C light recce, FLIR (hrs)			
Aircraft FW light recce (hrs)			
Aircraft HC light firebomb (hrs)			
Fire Behaviour			
Flame Ht (m)			
FROS (m/hr)			
Spotting Dist (m)			
Fire size at First Attack (ha)			
Length of headfire/flankfire requiring containing (m)			
Final fire size (ha)			

Times

Time of Detection (24hr)		
Detection to First Suppression Work - Aircraft (hrs)		
Detection to First Suppression Work - Ground Forces (hrs)		
Aircraft Turnaround	H/C FB	
	FW FB	
First Suppression Work to Checking (hrs)		

Aircraft Effectiveness 1=yes, 0=no, or 0-100%

First Attack Effectiveness

First Attack - first 8 hrs

1. Did the aircraft effort contribute directly to the fire being contained in the first attack phase? [ ]
2. Were the aircraft able to effectively halt the headfire before ground forces arrived? [ ]
3. Did the aircraft provide recce services which allowed a ground crew to reach the fire? [ ]
   Was this recce service critical to first attack containment of the fire? [ ]
4. Did the aircraft ferry crews to the fire? [ ]
   Was this ferry service critical to first attack containment of the fire? [ ]

4(a) Did the aircraft provide a recce service which assisted with the suppression operation? [ ]

5. If the suppression effort was in conjunction, with ground forces, rate the contribution of the aircraft to achieving first attack containment (0% - 100%). [ ]
6. Could the ground forces have achieved first attack containment in less than 8 hours without the assistance of aircraft? [ ]

	R	F	W
F/W			
Med H/C			
Lge H/C			

Extended First Attack - first 8-24 hrs

6. Could the ground forces have achieved first attack containment in less than 24 hours without the assistance of aircraft? [ ]
7. Did the aircraft provide recce services which allowed a ground crew to reach the fire? [ ]
   Was this recce service critical to extended first attack containment of the fire? [ ]
8. Did the aircraft ferry crews to the fire? [ ]
   Was this ferry service critical to extended first attack containment of the fire? [ ]

	R	F	W
F/W			
Med H/C			
Lge H/C			

Campaign Fire

9. If the fire was not contained at first attack, did the aircraft perform a critical role in management of the large incident? [ ]
   Was this in recce/FLIR [ ]
   crew transport [ ]
   firebombing [ ]

	R	F	W
F/W			
Med H/C			
Lge H/C			

General Effectiveness

10. Was the effectiveness of the firebombing aircraft increased by the use of an air attack supervisor? [ ]
11. Did the aircraft save significant assets which the ground forces would have been unable to? [ ] Value of assets ($) [ ]
12. Did the aircraft locate and suppress spotfires ahead of the main fire which otherwise may have significantly increased the suppression effort required? [ ]
13. Restrictions on aircraft operations
    Were the aircraft restricted by / Did this occur at critical times

	Restricted	Did this occur at critical times
smoke		
turbulence		
daylight		
topography		
vegetation		

14. Were there sufficient aircraft for the task(s) [ ]
15. Other general information/comments etc

Appendix 2

Rappel operations
(Summary of information from rappel crew reports)

General
Rappel crews are required to produce a report after every fire event to which they are deployed. Each report is on a standard form prepared by Fire Management and contains both a written description of events and a sketch plan of the fire site. The material presented in this Appendix summarises the reports produced by rappel crews.

Rappel crews were deployed a total of 73 times to 35 fire events during the 1997–98 fire season. From 31 December 1997, for a period of five weeks, 32 of the deployments were to the Caledonia fire (Heyfield H 031). Their busiest period was November–December 1997, when lighting storms caused many small fires in the remoter parts of East Gippsland.

Deployment and communications
Poor communications were mentioned for a couple of fire events. The principle cause of this was the SMR trunk/simplex system which performed poorly when portable (handheld) radios were used in many of the remote fire sites (for example, Orbost Fire 44—Mt Sardine).

Also mentioned were some communications problems between aircraft, the rappel crew and fire headquarters. It appeared (in the opinion of the rappel crew) that the fire controllers had been indecisive in the first instance on whether to deploy rappel crews to some fire events, and this had occasionally led to delays in the rappel crews reaching the fire in time to readily contain it (for example, Cann River Fire 45).

In another case (Bright Fire 86) the rappel crew and medium helicopter were given an incorrect grid reference. This led to the waste of approximately one hour, with the initial delay in not immediately finding the fire being compounded by the need for the helicopter to return to refuel before deploying the rappel crew.

Several comments were also made to the effect that fire controllers did not appreciate the difficulty involved in some rappel operations, and deployed rappel crews to tasks which could not be completed within a reasonable time, particularly where they were required to walk out from the fire site afterwards. A further concern was that rappel crews were occasionally left on firelines for extended periods without adequate supplies (principally food and water) and/or the prospect of relief from local crews.

Production rates
The task at most fires where rappel crews were deployed was to construct a handtrail of an average of between 400 and 1000 metres. This was generally completed in three hours or less, depending on the topography and the amount of debris on the ground. Rappel crews reported that they were often deployed to sections of fires where a handtrail was the only possible alternative, and therefore they often had to construct trail along the most difficult part of the fireline.

Use of rappel crews in conjunction with firebombing
Many of the reports contained comments to the effect that firebombers used in close support were able to cool sections of fireline enough to allow the rappel crew to directly attack the fire.

Accuracy of firebombing as reported by rappel crews

The following summarises comments made by rappel crews about the accuracy and effectiveness of firebombing operations:

good/very good accuracy	80%
accuracy 'just OK'	10%
poor/inaccurate	10%

Caledonia fire

Rappel crews played a significant role throughout the Caledonia fire (Heyfield H 031). The Briagalong and Myrtleford rappel crews were among the first of the initial attack forces. The leader of the Briagalong rappel crew, which tried to check the south-eastern edge of the fire, commented that one of the main problems was the lack of crew numbers at the critical time. He suggested that a crew of 25–30 persons, particularly if they had arrived 30 minutes to an hour earlier, would have had a much greater chance of putting a trail around this portion of the fire.

The Myrtleford crew assisted other ground forces on the western side of the fire near the Caledonia River. From there, they had a very good view of the firebombing efforts on the bulk of the fire area to their east. Their report from the afternoon of Wednesday 31 December 1997 stated that, although the firebombing effort was accurate and sustained, it was insufficient under the hot and windy conditions to halt the fire's progress.

Deployment of the rappel crews around the extensive fire perimeter continued for the next month. They were used to construct hand trails on the steepest parts of the fireline which bulldozers could not access, as well as for rapid-response when various parts of the perimeter flared under the hot and windy conditions. The use of rappel crews in conjunction with the medium helicopters saved the time and effort of ground crews who would otherwise have had to drive and walk to these difficult locations.

Effectiveness of rappel operations

All fire controllers and air attack supervisors interviewed for this study commented on the effectiveness of rappel crews. These crews were viewed as a unique resource, particularly for deployment to many remote fires where the time for ground forces to travel to the sites may have allowed the fires to increase to much larger sizes.