Fire Technology Transfer Note

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Comparison of the cost-effectiveness of some aircraft used for fire suppression.

by Liam Fogarty and Peter Smart

Introduction

Even in the 1940s and 50s, the speed and versatility of aircraft meant that they were used by fire managers to achieve better initial and ongoing attack at wildfires. For example, aerial patrol during the 1946 "Taupo fire emergency" was of "inestimable value" where "many fires were quelled at the incipient stage" and firefighters and equipment used to "maximum effect" (SFS, 1946).

The 1946 Taupo fires and numerous large-scale tussock grassland fires around that time heightened awareness of the need for better environmental protection and resulted in restrictions on the burning of tussock grasslands and scrublands. Subsequent concern over increased fire hazard was the catalyst for one of the first recorded uses of aircraft for fire bombing in New Zealand (Campbell 1959).

Between 1955 and 1959, the Soil Conservation and Rivers Control Council organised a series of trials to test the use of aircraft for firefighting. From these, guidelines on the best height and speed for water and retardant drops were developed for a range of fuel types and agricultural fixed wing-aircraft. At the time, the cost of fireline construction was calculated at 4 shillings to £1 per chain of fire front and the rate of fireline construction ranged from 3 to 5 chains (i.e., 60 - 80m) per hour (Campbell 1959). Campbell (1959) concluded that only "ingenuity and initiative in developing flying and operational techniques are required to modernise the arduous, urgent and menacing work of fighting fires".

Aircraft are now common during initial attack and ongoing suppression of forest and rural fires. New and specialised equipment has been developed and the aircraft industry regularly assists at forest and rural fires.

However, despite the example set by Campbell and the thousands of hours flown at fires since 1959, there is less detailed information on the cost-effectiveness of aerial firefighting when using current methods and machines than was available for the aircraft tested by Campbell.

Fire managers need adequate training and information on the most effective use of aircraft to support decision-making during suppression operations. Some factors that influence the cost-effectiveness of air operations are:

- the most appropriate drop pattern and how to achieve this;
- the type and concentration of water additives for different fuel and fire behaviour conditions;
- the management of aircraft filling points and suppression tactics; and
- the selection of aircraft to suit the conditions.

Unfortunately, there is little or no systematically recorded information on any of the above factors for aircraft use in New Zealand. To ensure that the maximum benefits from expenditure on aircraft are received, this situation needs to be rectified.

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Information on drop pattern and effectiveness can only be derived from trials similar to those conducted in the 1950s, and by careful observation during wildfires. Better aircraft management could be achieved by adopting procedures developed overseas, such as deploying an air attack supervisor and somebody to oversee aircraft operations.

The aim of this Technology Transfer Note is to review the performance of some commonly available rotary-blade and fixed-wing aircraft. This will be done by modelling their ability to deliver water to a fireline. By adopting a similar approach, fire managers can maximise the amount of water (and additive) delivered to the fireline for every dollar they spend.

Method and Results

Using aircraft specifications and estimates of factors such as flying speed, drop capacity, refilling time (these estimates and their sources are listed in Appendix 1), it is a simple process to carry out a comparison between aircraft carrying water or retardants/suppressants over different distances from a fireline. In this analysis, the following aircraft are considered:

- Hughes 500C helicopter (with a 425 litre bucket);
- Hughes 500D helicopter (with a 550 litre bucket);
- B Squirrel helicopter (with a 700 litre bucket);
- B2 Squirrel helicopter (with a 950 litre bucket);
- Bell 204 UHIF helicopter (with a 1595 litre bucket);
- Bell 204 UHIB helicopter (with an 1800 litre bucket, that is generally filled with 1600 litres of water when fire fighting);
- 08-600 Cresco aeroplane (with a 1770 litre hopper), and
- S2R-T34DC Turbo-Thrush aeroplane (with a 2000 litre hopper).

The scenario assumes that all filling is done using a pump with an output of 1400 litres per minute. Positioning and acceleration add 20 seconds to a helicopter refill, while landing, and positioning add 1 minute to an aeroplane refill.

Figure 1 is a comparison between the rate of water delivery to the fireline from each of these aircraft over distances ranging from 1 to 20 km. The results show that if all aircraft were flying from filling points of equal distance from a fire, then the fixed-wing bomber and Bell 204 type helicopters are more productive (in terms of the volume of water delivered to the fireline) than the Squirrel and Hughes helicopters. For example, the average delivery rate at 2 km is 15 057, 25 491 and 29 333 l/hr for the Squirrels, Bells and fixed-wings respectively, compared to 9629 l/hr for the Hughes. The Bells are the most productive when working less than 1 kilometre from the fire but, as this distance increases, the fixed wings became more productive than all helicopters in this analysis.

Figure 2 shows the cost per litre of water delivered to the fireline for the same scenario. The results are clearly in favour of the use of agricultural aircraft over all distances. When filling 2 km from the fire, the average cost is 4 cents/litre (c/l) for the fixed-wing and 9.5, 9.5 and 10.5 c/l for the Bells, Squirrels and Hughes, respectively. Aeroplanes become comparatively cheaper as this distance increases.

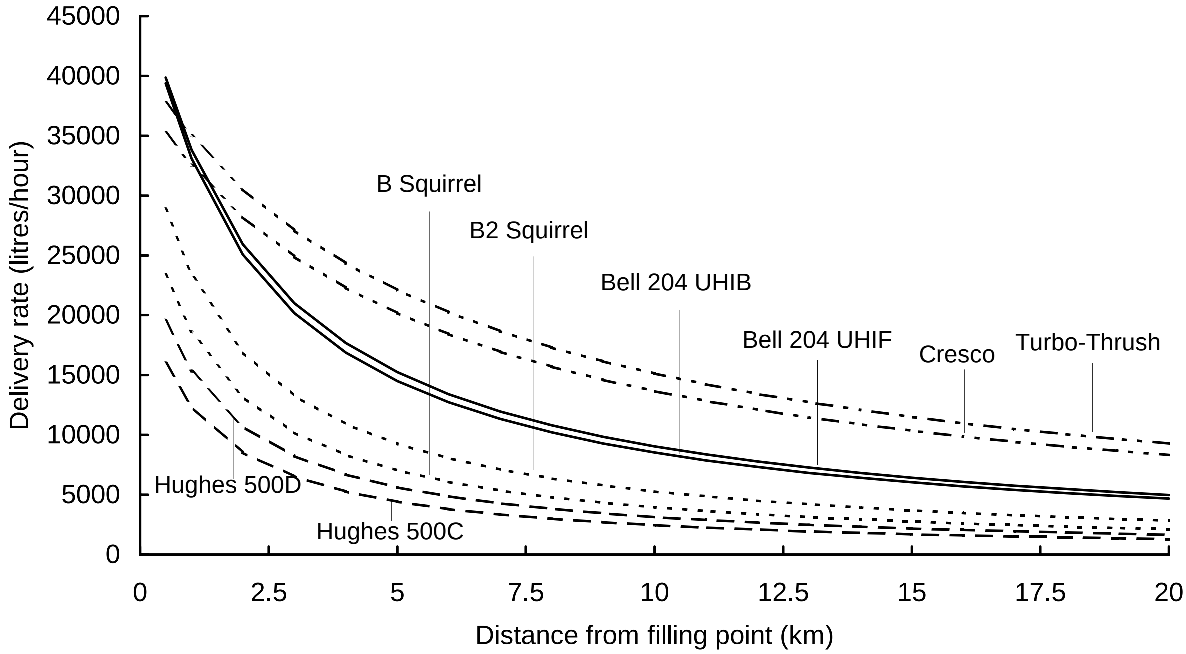


Figure 1. Comparison of the rate of water delivery per hour for selected fixed-wing and rotary-blade aircraft operating from a range of distances between the fire and the filling point.

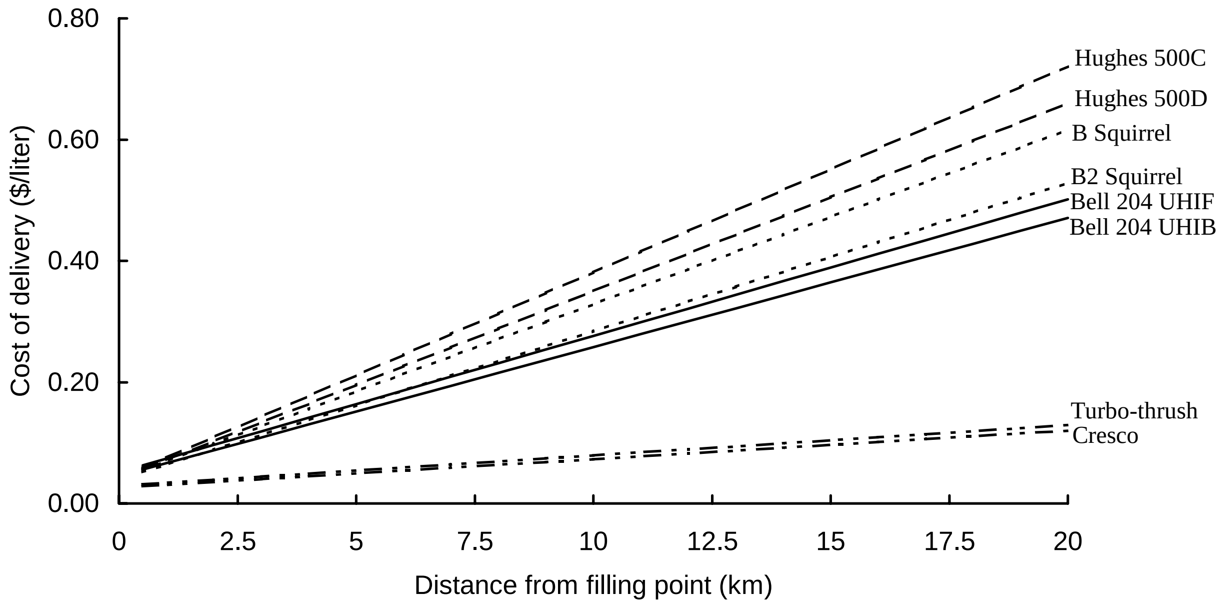


Figure 2. Comparison of the cost of water delivery per litre for selected fixed-wing and rotary-blade aircraft operating from a range of distances between the fire and the filling point.

This type of analysis can also be used to show the importance of fast turn-around at the filling point, and of ensuring that each load carries the maximum payload possible. Figure 3a shows the differences in delivery rate from a B2 Squirrel for a range of filling times. These filling times can be assumed to be the result of filling point management and/or of using pumps with different capacity, where:

- a 20 second fill assumes that dip filling is possible;
- a 45 second fill assumes a pump with a capacity of 2250 l/min is used, and there is no queuing at the filling point;
- a 60 second fill assumes that the pump capacity is 1400 l/min and there is no queuing, or that there is 15 seconds of queuing when the higher capacity pump is used; and
- a 90 second fill assumes that a 810 l/min pump is used, or that there is 45 or 30 seconds of queuing when the 2250 and 1400 l/min pumps are used respectively.

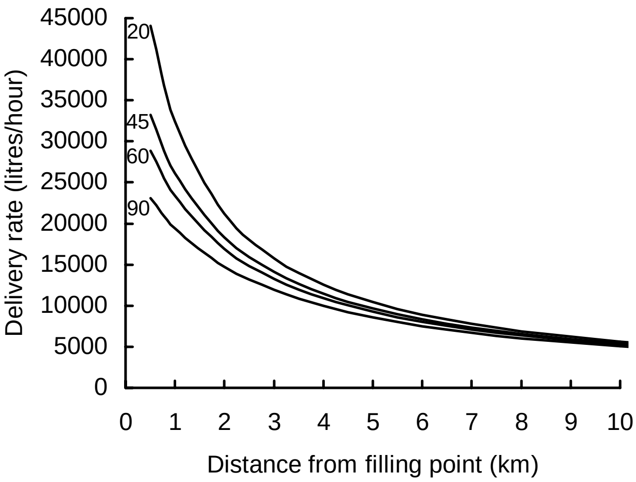
When filling 2 km away from the fireline, dip filling enabled the delivery of 21 212 l/hr, compared to 18 331, 16 935 and 14 766 l/hr for the 45, 60 and 90 second refills respectively.

Figure 3b shows the "opportunity cost" created when aircraft capacity is not optimised by comparing the difference between a 45, 60 and 90 second filling with a 20 second fill and then calculating the cost to deliver additional water to the fireline. For example, if three helicopters capable of delivering 18 300 l/h each, are only able to deliver 14 800 l/h due to inefficient filling-point management, then there is an "opportunity cost" of 10 500 l/h. To have this volume of water delivered at a cost of 0.095 \$/l, the "opportunity cost" expressed in monetary terms would be \$997.50.

While the costs of running a larger pump or of using two or more filling points are not included in this analysis, it is obvious that slow filling and queuing can add significantly to fire suppression costs. Furthermore, the opportunity cost calculations do not include the additional cost of having to contain and mop up the larger fire that would result from having less water delivered to the fireline.

Figures 4a and 4b show water delivery rate and "opportunity cost" for the B2 Squirrel where the bucket sizes used to delivery water are 950, 850 and 750 litres. These figures illustrate the importance of maximising bucket capacity. For example, the hourly rate of water delivery when filling 2 km away from the fire is 16 935 and 15 481 l/hr when using the 950 and 850 litre buckets respectively, compared to only 13 962 l/hr for the 750 litre bucket. The opportunity cost of not using the 950 litre bucket is \$290 and \$141 per hour for the 850 and 750 buckets respectively.

a



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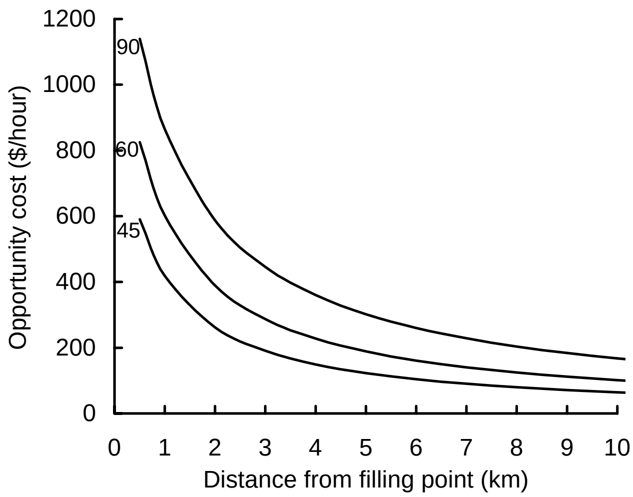
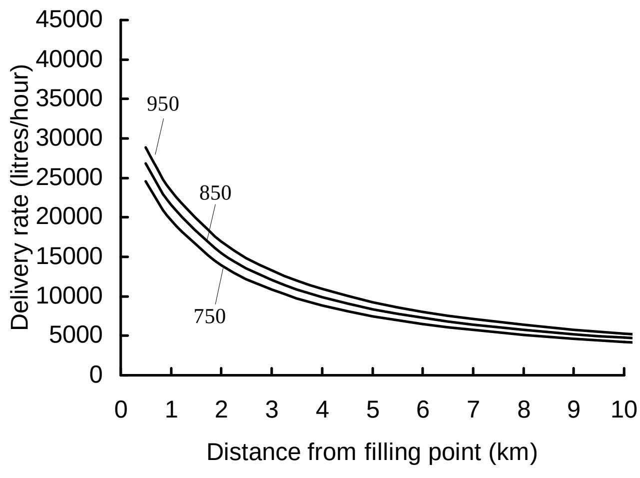


Figures 3. (a) The differences in delivery rate from a B2 Squirrel for a range of filling times; and **(b)** the opportunity cost of 45, 60 and 90 second filling when compared to a 20 second fill.

a



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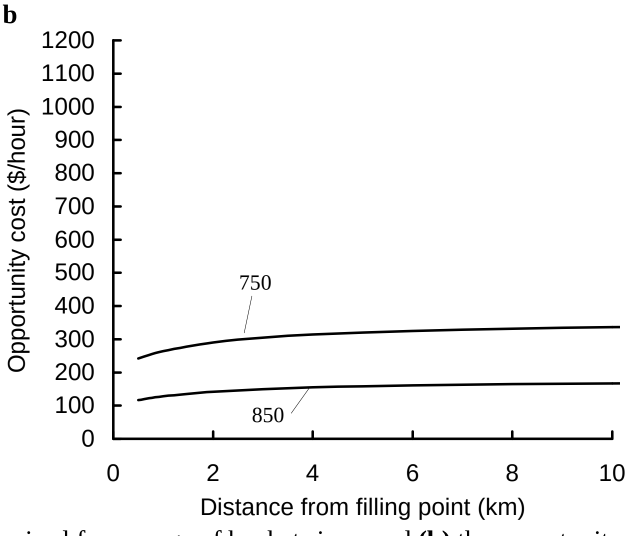

Figures 4. (a) The differences in delivery rate from a B2 Squirrel for a range of bucket sizes; and **(b)** the opportunity cost of using a 750 and 850 litre bucket instead of a 950 litre one.

Discussion and Conclusions

There are of course, many factors that need to be considered by fire managers when deciding on the configuration of aircraft, buckets and pumps that should be used at different fire situations. Importantly, this analysis takes no account of the ability of a pilot to place drops where needed, or availability of different types of aircraft.

Rapid initial attack must remain the highest priority when deciding on the type of aircraft to use at a fire. If smaller helicopters are all that is available for initial attack, then these should be used without hesitation. However, if an early assessment of the fire suggests that it is likely to be ongoing, then the additional cost of ferrying a larger aircraft (outfitted with a suitable bucket) to the fire may be warranted.

This simulation compares aircraft in an ideal situation, and cannot be considered as an absolute comparison of the effectiveness and cost of each machine because each has different requirements for airstrips/helipads. Helicopters can load from confined spaces such as streams without touching down, whereas a fixed-wing bomber requires a suitable airstrip with water supply or water-tanker access. Suitable heliports are more common and therefore usually closer to the fire than an airstrip, thus reducing flying time and increasing water delivery rate. A true comparison between the two types of machine must take this fact into consideration, and needs to be done as part of a broader assessment of the fire environment.

While these comparisons are based on a mathematical analysis using estimates of hourly hire rates, load size, flying speed and refill time, it is evident that the cost-effectiveness of a range of aircraft can differ markedly. The models developed for this analysis are supported by an operation to clear a landslip in the Manawatu Gorge where a Bell 204 UHIF and a B Squirrel were able to deliver 40 loads/hour when dip-filling approximately 500 m from the slip. In comparison, the developed models estimate that over this distance, the number of loads per hour for the Bell and Squirrel is 47 and 46 repectively. Furthermore, the model inputs and outputs have been reviewed and accepted by some fire managers and pilots who have experience in this area of fire protection. Precise results from these models are not expected, but the implications for aircraft management are clear; these are:

- fixed-wing aircraft can deliver large volumes of water to a fireline at very competitive rates, especially when suitable filling points for helicopters are greater than 2 km from the fireline;
- the selection of smaller helicopters due to lower hourly running costs is a false-economy that will result in larger fires, because larger helicopters can deliver greater volumes of water at a lower cost per litre 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 near the fireline and that the aircraft has the capacity to inject foam concentrate when it is needed;
- delays in filling due to poor filling point management and/or the use of lower volume pumps will result in considerable "opportunity costs"; and
- the use of buckets that are below the safe carrying capacity of a helicopter will result in considerable "opportunity costs".

Acknowledgments

The advice and assistance of Lindsay Golding (DOC, Palmerston North), Dave Lumley (DOC, Turangi) and Steve Webb (CHH, Tokoroa) is acknowledged and appreciated. Information on aircraft performance and costs was provided by members of the aircraft industry who are listed in Appendix 1; their assistance is also acknowledged and appreciated.

References Cited

SFS, 1976. Annual Report of the Director of Forestry for the year ended 31st March, 1946. State Forest Service of New Zealand. pp 15-19.

Campbell, D.A. 1959. Aerial fire fighting. New Zealand Science Review. December, 1959. pp 94-103.

Appendix 1. Aircraft specifications and assumptions used in cost-effectiveness comparisons

Specification/assumptions	Hughes 500C Helicopter	Hughes 500D Helicopter	B Squirrel Helicopter	B2 Squirrel Helicopter	Bell 204-UHIF Helicopter	Bell 204-UHIB Helicopter	08-600 Cresco Water bomber	Turbo-Thrush S2R-T34DC Water bomber
Capacity (litres)	425	550	700	950	1595	1600	1770	2000
Horsepower	400	420	641	732	1325	1100	750	750
Cruise speed (km/h):								
loaded	120	120	120	120	130	120	240	210
empty	140	140	140	140	150	140	260	210
Airstrip optimum size (m)	30 m circle	30 m circle	30 m circle	30 m circle	30 - 40 m circle	30 - 40 m circle	500m long x 30m wide	500m long x 30m wide
Flying duration (h)	2	2	3	2.5	1.5	1	2 - 2.5	2 - 2.5
Positioning and acceleration (sec)	20	20	20	20	20	20	60	60
Refill time (min) using 1400 l/min pump	18	23	30	40	68	77	76	86
Cost per hour ($/h)	935	1100	1300	1500	2500	2200	1000	1200
Information provided by:	Tim Barrow, Marine Helicopters Ltd, Rotorua.	Tim Barrow, Marine Helicopters Ltd, Rotorua.	Peter Masters, Helicopter Services Ltd, Taupo.	Peter Masters, Helicopter Services Ltd, Taupo.	Rick Lucas, Helipro, Palmerston North.	Rod Trot, Beck Helicopters Ltd, Eltham.	Brian Umbers, B Haskell Ltd, Taupo.	Gerard Nolan, Agair Ltd, Palmerston North.