The Toolara No. 7 Wildfire of 22.9.91 in SE Queensland:
An Analysis of Crown Fire Potential in Relation to the Fire Environment

I was asked by R. Hamwood to examine certain aspects of this fire's behaviour in light of my Ph.D thesis project on crown fire thresholds in exotic pine plantations of Australasia undertaken at ANU (Aug. 89 — Apr. 92). This paper constitutes a brief summary of a much larger report currently in preparation.

On the basis of post-burn evidence (aerial photos, fixed-wing flight over the area, and ground inspections) during the week of Oct. 7-11, I was of the opinion that the only crown fire activity occurred largely as a result of (*i*) the backfiring operations (especially after the sea breeze influence) and (*ii*) the heavy understorey scrub in the poorer site quality stands (especially along the downwind edges of the swamp areas -- e.g., Cpt. 7, Unit 3).

Considering the level of drought and the weather conditions which prevailed during the initial run of the fire (Drought Index — 524, 31°C, 11% RH, wind 28 km/h, Very High fire danger class), why was there so very little crowning in Compartments 7, 8, 10 and 11 (1970 and 1971 plantings)?

According to present theory, the onset or initiation of crown combustion in a conifer forest is expected to occur when the intensity of the surface fire (I_s) attains or exceeds a certain critical value (I_o) based on the height of the green crown level above the ground and the moisture content of the live needles (i.e., when $I_s \geq I_o$). The following equation is used to determine this:

[1] $I_o = [0.010 \times \text{LCBH} \times (460 + 26 \times \text{FMC})]^{1.5}$

where, I_o (kW/m) is the critical surface intensity for crown combustion, LCBH is the live crown base height (m) and FMC is the foliar moisture content (% ODW basis).

On the basis of 150 tree measurements in Compartments 7, 8, 10 and 11, the mean stand height was calculated to be 21.4 m. The LCBH was accordingly judged to be around 13.6 m on the basis of previously analyzed data made available by N. Henry. The FMC was estimated to be 132.7% based on sampling undertaken in Compartment 20 of the Sugarloaf L.A. on 17.9.92. Therefore, $I_o = [0.010 \times 13/6 \times (460 + 26 \times 132.7)]^{1.5}$ = 12,263 kW/m.

In the 60 minutes between 1.00 and 2.00 pm, the head fire is estimated to have travelled 900 m or in other words, the average spread rate was 900 m/h. The amount of available fuel was, on the basis of some limited fuel sampling, to be about 20 t/ha on the average. The actual fire intensity can now be calculated from the following equation:

$$[2] \quad I = \frac{H \times w \times r}{36\,000}$$

where, I is the fire intensity (kW/m), w = amount of fuel consumed in the active flaming front (t/ha), and r = rate of fire spread (m/h).

Thus, I_s = (18,000 x 20 x 900) ÷ 36,000 = 9000 kW/m. Thus, $I_s < I_o$, so no crown combustion was predicted to have occurred. If the fuel consumed were increased to 30 t/ha, then I_s would = 13,500 kW/m which is greater than I_o of 12,263 kW/m. In fact, there was certainly evidence of some flame defoliation in the lower green crowns of Compartments 7, 8, 10 and 11.

Assuming that I_s was greater than I_o, the question of whether a continuous flame front can be maintained within the green crown layer still remains. The best objective basis for judging this is the concept of a minimal sustained rate of spread (after crown combustion) in relation to the bulk density of the green crown fuel layer. The following equation is used to determine this:

$$[3\} \quad R_o = \frac{180}{CBD}$$

where, R_o is the critical minimum spread rate for active crowning (m/h) and CBD is the crown bulk density (kg/m^3). The CBD is determined by dividing the fine fuel weight (chiefly needle foliage) per unit area (kg/m^2) by the live crown depth of the stand (m). The available crown fuel load in Compartments 7, 8, 10 and 11 averages 0.69 kg/m^2 (this was done on the basis of a DBHOB vs foliage dry weight relationship developed by the author for the Toolara SF area). Thus, the CBD = 0.69 ÷ (21.4 - 13.6) = 0.09 kg/m^3. The R_o value can now be computed -- 180 ÷ 0.09 = 2000 m/h. In other words, the fire would have had to advance at a rate greater than 2000 m/h to have sustained a fully developed crown fire which of course the fire wasn't able to attain.

On the basis of the available information and the analyses undertaken with respect to this wildfire coupled with my own thesis research in the Toolara SF area and a knowledge of past QFS fire management and fire research programmes, I offer the following observations:

1. Generally one can expect a fire to at least double or triple its forward spread rate after crowning with a corresponding increase in area burned to the power of two. Had the plantation stands not been managed to the extent they were (i.e., by pruning, thinning and prescribed burning), the area burned over could have easily been at least four to six times larger. Certainly in younger plantation areas this would have been the case (note that the 1981 Kelly Range Fire burnt under nearly identical fire danger conditions).

2. It must be acknowledged that in certain circumstances, we are incapable of controlling wildfires until burning conditions ameliorate, regardless of the degree to which fuel management is practiced (in other words, one must be willing to live with some degree of wildfire threat). However, the QFS are fortunately in the position of determining by simulation what the optimum prescribed burning interval should be on the basis of their own mensuration and fire research studies when combined with an analysis of their fire danger records.

3. Initial attack preparedness levels should be based in part on predicted or modelled fire behaviour in terms of fire intensity and rate of perimeter growth versus elapsed time since ignition with full consideration for the productivity of various fire suppression resources. An interesting exercise would be to compare the current criteria with projected fire behaviour based on existing models of fire spread (e.g., McArthur Forest Fire Danger Meter).

4. Fire suppression training, especially for initial attack situations, has to be more realistic. I favour the idea of actual simulated wildfires under field conditions (e.g., within a "training area" having a good defendable boundary, start point source fires and allow them to grow to say 0.5 ha and then call in the suppression crew and allow them to commence attack). This would be far more realistic than control burns. Considering the relative infrequent occurrence of major pine plantation wildfires in Queensland, this innovative idea is put forth with the view of maintaining the "edge" from year to year.

5. Because the QFS is very unlikely to support any high-intensity fire behavior research in exotic pine plantations, the necessity of good documentation for the occasional major wildfire run becomes even more imperative. I recently examined the case histories of 12 other major pine plantation wildfires which occurred in Queensland during the 70s and 80s in terms of spread rate data. One consistent problem was the lack of quality weather observations, especially with respect to wind velocity. In this regard, the Dwyer wind speed indicator at the Toolara FS is not only undesirable (from the standpoint of averaging) but it's also very poorly sited with respect to obtaining the 10-m open wind speed required as input in the McArthur Forest Fire Danger Meter. The solution is an automatic weather station like the one at Beerburrum (which incidentally is poorly situated).

6. A variety of documents already exist which detail strategies for plantation layout and management with a view to minimizing potential losses to wildfire occurrences (e.g., encouraging a patchwork posaic pattern of various age classes as opposed to large contiguous blocks of similar aged stands). For example, there's D.R. Douglas' "Plantation Fires" (*c.* 1974. Woods & Forests Dep. SA) and "The Impact of Intensive Forest Management on Fire Protection with Special Regard to Eucalypts" by N.P. Cheney and R.R. Richmond (1980. Paper prepared

for Eleventh Commonwealth Forestry Conference). It's probably worth reviewing this kind of material again.

7. A concluding comment about backfiring is probably in order. An excellent publication on this topic, which I think is certainly relevant to Queensland is R.W. Cooper's "Preliminary Guidelines for Using Suppression Fires to Control Wildfires in the Southeast" (1967. USDA For. Serv. Res. Note SE-102); see also N.D. Burrows' "Back Burning in Forest Areas" (1986. CALM Landnote No. 6/86). In particular, points #6 and #9, which deal with the conditions under which backfiring can and cannot be effective in terms of forward rate of fire spread, maximum spotting distances and fire danger index limits. Cooper suggested that a Spread Index of 50 (1964 version of U.S. National Fire-Danger Rating System -- see USDA For. Serv. Res. Pap. SE-13) represents about the upper limit for even contemplating backfiring operations. I've tentatively estimated that the U.S. Spread Index would have been around 65-70 at 1-2 p.m. based on the level of dryness and weather conditions which prevailed at the time. The Forest Fire Danger Meter can give a pretty reasonable estimate of forward rate of fire spread in pine plantations. The maximum spotting distances from the meter are not relevant to pine but some sort of guide could probably be developed from existing wildfire and experimental fire behaviour data sources.

I find it extremely ironic that the QFS has eliminated its Fire Research Forester position at a time when it's pondering questions about potential fire behaviour for plantation fuel types likely to be encountered in the future (e.g., wider spaced stands with heavy grass fuel loads).

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