# A comparison of 2019 Pigeon Valley Forest Fire with similar events in the past

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## 1) Introduction

The 5th February 2019 Nelson Pigeon Valley wildfire has been claimed by some as the most destructive plantation fire in the past sixty years. This paper reviews data from other wildfires to show the fire environment in the first 5 days of the fire does not warrant this characterization.

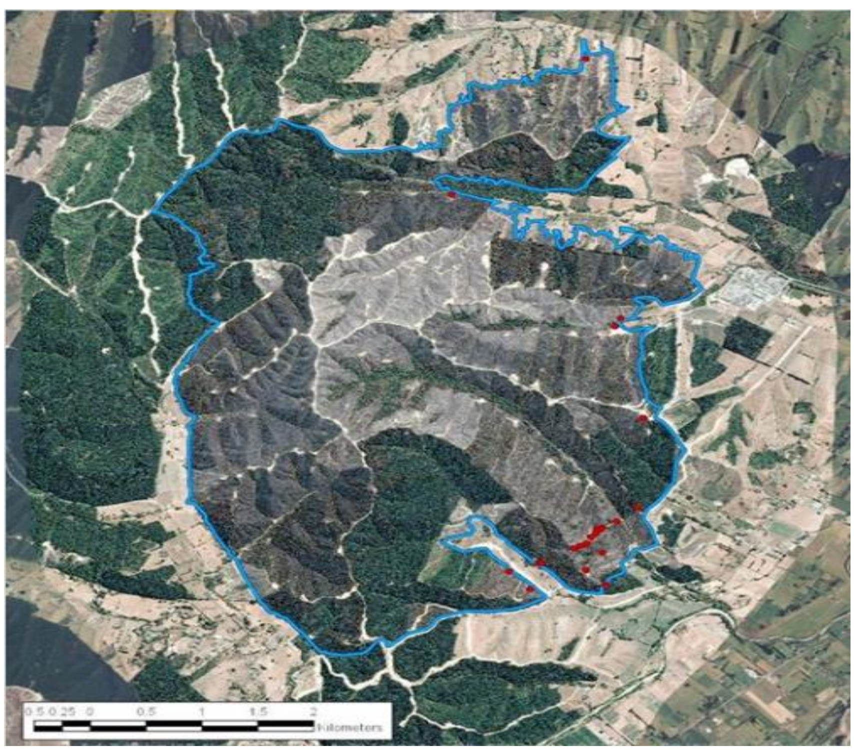
The first day of the Pigeon Valley fire involved weather conditions which had potential for spot fires[2]. Observations made on the first day confirmed that spot fires did occur as the fire spread northwards towards Eves Valley. Containment was achieved after the fire exited the plantation forested lands and spread into lifestyle blocks.

In subsequent days the fire environment (fortunately for other potentially affected neighbouring landowners) was not conducive to spot fires. The weather conditions on those days suggests that:

a) The need for the construction of firebreaks external to the eastern edge of the forested lands requires examination, and

b) The need to evacuate communities located within two kilometers from the southeastern side of the forested lands, eg., Wakefield, also requires examination.

## 2) Discussion




Based on the forecast, and the actual weather during the first week of this wildfire, this paper raises a number of questions:

a) Was full consideration given to the actual and forecasted weather information along with the fire weather indices during the first few days of this fire?

b) Did this support the decisions to construct firebreaks, external to the plantation, and the evacuation of people from communities, to the south east of this wildfire?

This paper re-examines the forecast and the actual weather information to establish what the fire weather environment was over the days following the start of this wildfire, and on the basis of this data, determine whether this wildfire had the potential to spread into open lands, external to the plantation lands on the southeastern edge, during the days following the first eighteen hour period of the fire.

## 3) Wildfire Behaviour

While the causes of wildfires vary and the outcomes are always unique, all wildfires can be characterized in terms of their physical properties, their fuel type, and the effect that weather has on the fire. Wildfire behavior, and severity, result from the combination of factors such as available fuels, topography, and weather.

The spread of vegetation fires varies based on the flammable material present, its vertical arrangement and moisture content, and weather conditions. Wildfires occur when all the necessary elements of a fire triangle come together in a susceptible area, ie, an ignition source is brought into contact with a combustible material such as vegetation that is subjected to enough heat and has an adequate supply of oxygen from the ambient air.

Subject to fuels being dry enough to sustain a fire the primary influences upon how vegetation fires move through the landscape are humidity, topography, wind and temperature. The slope of the landscape is also important. Fires burn much faster uphill than down because the radiation and convection a fire creates preheating of the unburned fuel ahead of the flame front. This is done more effectively upslope than down. A 10-degree increase in slope usually results in a doubling of the speed of the fire. Fire will spread up a 20-degree slope four times as fast as it will along flat ground.

Wind speed is the environmental variable that has the most significant effect on the spread of fires. With wind speeds below 10 km/hour, a fire will usually burn slowly without a definite spread direction. However, as winds increase in strength, the rate of fire spread increases. A change in wind direction, often from a cold front, can activate the side of a long and relatively narrow fire, turning it into a very broad flame front. In general, a wider fire will burn faster than a very narrow one.

The heat of a fire can create whirlwinds and turbulent air currents. Wind is also a major factor in transporting firebrands—pieces of burning fuel, like twigs, leaves or small embers—ahead of the main fire. This causes spotting—the ignition of new fires ahead of the fire front.

Humidity also plays a big part in fire behavior as the lower the Relative Humidity (RH), the more vigorously that fuels may burn. When the relative humidity is 100 percent, the air is holding as much water vapor as it can. More than likely, however, the water vapor is condensing onto dust or other particles which reveals itself as fog. In comparison zero percent humidity would indicate the complete absence of water vapor. However, that does not occur in nature.

Preferred relative humidity levels for managing prescribed burns[3] should ideally sit from 30 to 55 percent. Under special conditions, a wider range of RHs, as low as 20 percent and as high as 60 percent, can produce successful burns. When relative humidity falls below 30 percent, prescribed burning becomes dangerous. Fires are more intense under these conditions, fire behaviour is unpredictable and spotting is much more likely. On the other hand, when RH is 60 percent, or higher, a fire may leave unburned islands or may not burn hot enough to accomplish the desired result.

Spotting ignition is one of the three significant mechanisms of wildfire spread. It can be considered as a discontinuous fire spread mechanism (Koo et al, 2010) that is synonymous with solid mass transport (Albini, 1979, Alexander, 2009). The transport of burning fire embers outside the fire perimeter is a cause of serious concern to firefighters because it affects fire behaviour and difficulty of control, and poses a serious safety threat for them and for civilians.

Research undertaken in Portugal by Athanasiou & Xanthopoulos in 2018, involved the monitoring and documenting selected wildfires, noting the appearance or absence of spot fires during the prevailing conditions at the time. This work showed that, on a database of 166 field observations, no spotting ignitions were recorded at RH values higher than 46 percent. Massive spotting that triggered extreme fire behavior was however documented for RH values lower than 17 percent.

Research undertaken by John Weir, superintendent of the Oklahoma State University Research Range, showed that from 99 prescribed burns his conclusions were that for the 40 percent relative humidity threshold, the probability of a spot fire was 41.3 percent when relative humidity was below the threshold and only 3.8 percent when it was above the threshold—a substantial difference.

The data also showed that, below the 40 percent threshold, spot fire probability rose with each 5 percent drop in relative humidity (Figure. 1). At 25-percent relative humidity, there appears to be another threshold: Below this point, there was a 100 percent probability of a spot fire occurring. But in the 25 to 29 percent relative humidity range, spot fire probability dropped from 100 percent to just 46.2 percent; and in the 30- to 35 percent range, only one out of three burns were likely to produce a spot fire.

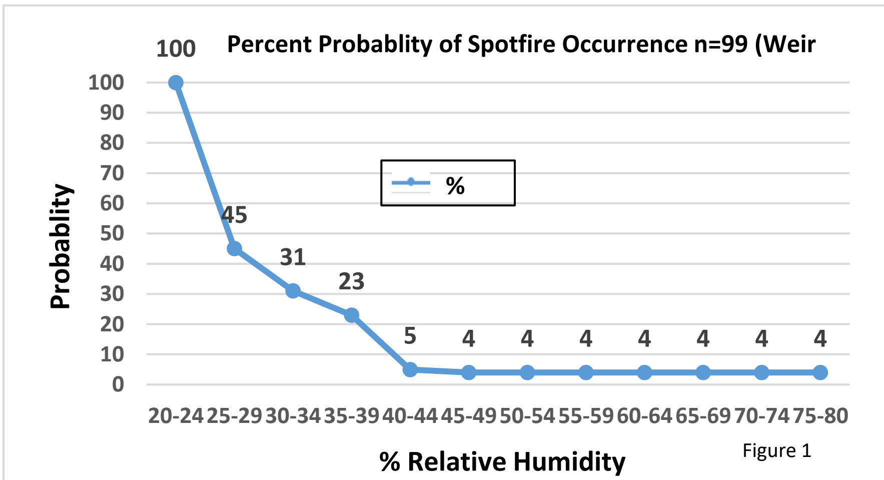


Figure 1

### 3) Crossover

A formal definition of Crossover is listed by the Canadian Forest Fire Centre as "the point at which the numerical value of the ambient relative humidity is less than, or equal to, the numerical value of the ambient air temperature". This may be used as a rule of thumb indicator of extreme burning conditions. It is a rule of thumb indicator primarily used by fire suppression staff. However, some researchers have been cautious of the crossover rule of thumb, saying that it has some value but may be overused and misinterpreted (M.E. Alexander, Forest Fire Research Officer, Canadian Forest Service, personal communication).

One of the problems, according to Alexander, is the tendency of fire managers to prepare for severe fire behavior circumstances only when crossover conditions occur. However, severe vegetation fires can occur in the absence of crossover. Obviously, fires may exhibit extreme behavior because of other factors, including wind speed, temperature, relative humidity, steepness of the slope, and dryness of medium and heavy fuels. In the interactive training course titled “Wildland Fire-Safety on the Fireline,” Alexander has stated, “Crossover can be a useful reminder that the potential for blowup or extreme fire behavior exists. However, do not rely on crossover as your only indicator of such situations. Forecasters must be mindful that there is more to extreme fire behavior potential than just crossover or wind speeds greater than 30 km/h. Crown fire behavior can occur in the absence of crossover conditions and with only moderate wind speeds (about 15 km/hour) if other criteria are met, such as dry medium or heavy fuels or steep slopes”.

### 4) Predicting Fire Behaviour

Fire intensity is one of the major determinants associated with the difficulty of controlling or containing a free-burning vegetation fire. From a fire behaviour standpoint, the other factors include the rate of perimeter increase or growth (which is a function of the rates of spread at the head, flanks and back of the fire), spotting characteristics (which is partly related to fire intensity), development of fire whirls, etc.

A further reference, with regards to the Pigeon Valley wildfire environment and fire behaviour, is a 1994 report prepared by Marty Alexander (a Canadian forest fire scientist who helped re-establish our forest fire research programme, and revised the Fire Danger Class Criteria[4] for NZ's forest and rural areas). This report refers to the Canadian Forest Fire Behaviour Prediction (FBP) System (Forestry Canada Fire Danger Group, 1992) which allows for the quantitative prediction of fire behaviour (including fire intensity) using, among other inputs, the Initial Spread Index (ISI) and Build Up Index (BUI) components of the Fire Weather Index (FWI) System. Overviews of the FBP System can be found elsewhere (Alexander and Maffey 1992-93; Hirsch 1993). Fire spread rates are based on the Fine Fuel Moisture Code (FFMC), wind speed, BUI, slope steepness and fuel type (Figure. 2).

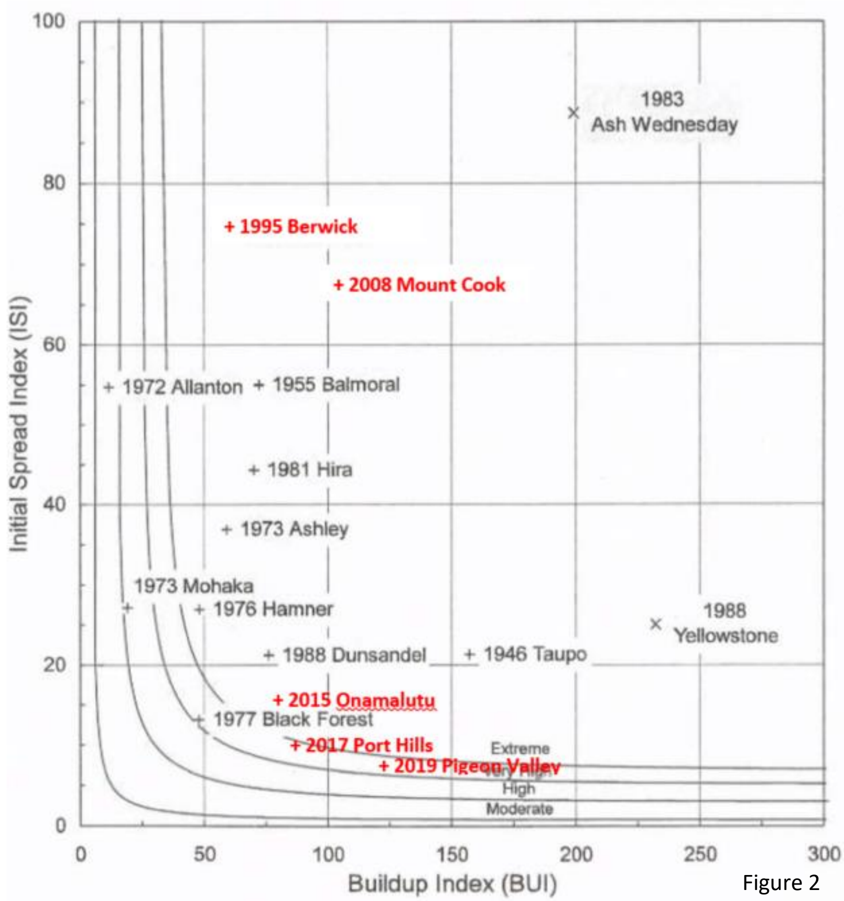


Figure 2

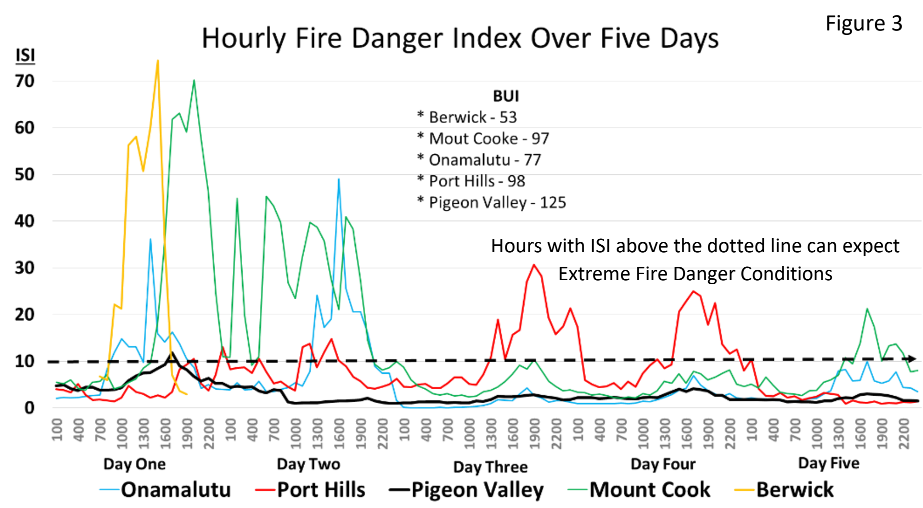
The fire danger conditions associated with time of ignition for the Berwick, Mount Cook, Onamalutu, Port Hills and Pigeon Valley fires compared with other New Zealand and overseas forest fires (adapted from Pearce and Alexander 1994, amended by Dudfield 2019)

Alexander then assumed that since the ISI represents only a few days of weather history after rain (via the FFMC), the BUI (which represents the increasing amount of fuel available for combustion as a dry spell lengthens) is therefore presumed to have at least some effect on the rate of fire spread as well (Van Wagner 1973b, 1989). Using the Alexander findings and applying this to the Pigeon Valley fire ISI and BUI on each of the seven days, commencing 5$^{th}$ February 2019, it provides the following results of fire spread in forested lands:

| Date | **BUI** | **ISI** | **Estimated Forward Rate of Spread** |
|---|---|---|---|
| 5$^{th}$ Feb | 125 | 11.6 | 400 m/hr |
| 6$^{th}$ Feb | 126 | 2.9 | 10 m/hr |
| 7$^{th}$ Feb | 129 | 4.7 | 70 m/hr |
| 8$^{th}$ Feb | 131 | 4.9 | 75 m/hr |

| | | | |
|---|---|---|---|
| 9th Feb | 133 | 4.2 | 70 m/hr |
| 10th Feb | 135 | 5.4 | 90 m/hr |
| 11th Feb | 138 | 5.9 | 100 m/hr |

Figure 3, outlines the fire intensity for the Pigeon Valley wildfire and how it compares with the Onamalutu, Port Hills, Mount Cook and Berwick forest fires. This shows the points of difference over a five day period for each wildfire.




The graph shows the Pigeon Valley fire danger conditions following the first day were low to moderate.

## 5) New Zealand Plantation Wildfires Case Studies

From a number of plantation wildfires over the past thirty years, a fire environment comparison between five wildfires (which burnt areas of plantation greater than 100 Hectares) makes for an interesting appraisal. The forest fires were;

a) Berwick Forest Fire – 26th February 1995;
b) Mount Cook Forest Fire – 16th January 2008;
c) Onamalutu Forest Fire – 4th February 2015;
d) Port Hills Fire – 13 February 2017; and
e) Pigeon Valley Forest Fire - 5th February 2019.

### (a) Berwick Forest Fire – 26th February 1995

The Berwick forest is located 36 km south west of Dunedin, located not far from Waipori Falls. The 26 February 1995 Berwick forest fire burnt a total area of 255 hectares, including 181 ha of stocked plantation forest, and 74 ha of scrub and recent cutover. This fire exhibited extreme and uncontrollable fire behaviour, with frontal spread being halted only when the fire reached pastoral lands.

Figure 4 shows that fire danger conditions, from a relative humidity perspective, were as bad as, or worse, than those encountered in many other New Zealand and overseas wildfires. Spread rates of the major fire runs were 850-2,780 metres/hour, and fire intensities ranged between 12,750 and 41,650 kW/m. Changes in wind direction, fuel types and terrain significantly altered the fire behavior, making suppression difficult and dangerous. Extreme burning conditions prevailed from 1100 - 1830 hours on the first day. Within 6 hours a theoretical *free burning* fire on flat ground, in continuous plantation of mature and mix-rotation conifer, would be expected to spread more than 17 km, have a perimeter length exceeding 30 km, and burn an area greater than 4,500 hectares[5]. The Berwick fire burnt a much smaller forest area (255 ha) and this is entirely due to the head fire running out of continuous forest fuels when it reached pastoral lands.

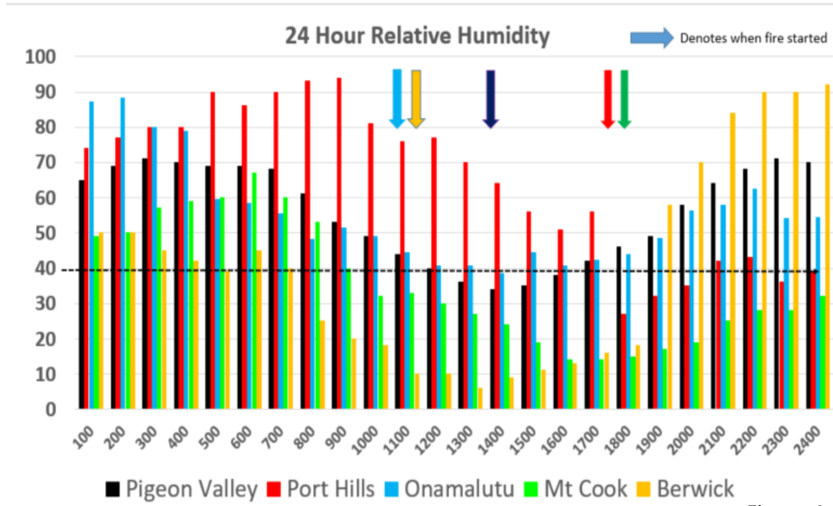


Figure 4

On the first day for a period of 10 hours from 0900 - 1800 hours the fire environment experience crossover effects where the RH values were lower than the Temperature values. For the two-hour period from 1300 - 1500 hours, the RH was less than 10 percent. With the lack of water vapor in the atmosphere this provided for a very dry environment that produced extreme fire behavior involving spot fires. Wind speeds from 1100 - 1600 hours varied between 24 - 33 km/hour.

These conditions are the most extreme of any recorded for a plantation wildfire in New Zealand.

**b) Mount Cook Forest Fire – 16th January 2008**

On the afternoon of Wednesday 16th January 2008, a fire was ignited on farmland on the eastern side of Lake Pukaki in South Canterbury. This fire escaped initial attempts at containment and went on to burn an area of 756 hectares of mainly forested lands. The fire burnt actively for the first two days, during which periods of extreme fire behavior were witnessed due to hot, dry windy conditions and heavy fuel loadings. The change in weather and fuel types allowed the fire to be contained on the third day.

On the first day, for a period of 7 hours from 1400 - 2000 hours, the fire environment experience crossover effects where the RH values were lower than the Temperature values. For the six-hour period from 1500 -2000 hours, the RH was less than 20 percent providing for a dry environment. Wind strengths from 1600 - 2300 hours varied between 34 km and 43 km/hour. During the second day there was also a second period of a crossover of Temperature and RH effects for four hours with RH less than 20 percent for three of those hours.

c) **Onamalutu Forest Fire – 4th February 2015**

The 4th February 2015 Onamalutu Forest Fire burnt close to 600 Ha, the biggest fire to impact the Marlborough region since the Boxing Day fires of 2000. It devastated forest and pastoral lands between the Onamalutu and Okaramio Valleys.

On the first day the fire environment experienced RH values greater than 40 percent. Wind strengths from 900 - 2100 hours varied between 23 - 38 km/hour.

On the second day the fire environment became elevated. For a 9-hour period between 800 and 1600 hours the fire experienced RH values between 28 to 40 percent. With these hourly RH levels, and the wind strength during this period between 6 - 43 km/hour, this would have seen spotting fires during this period. On day three the fire environment was greatly reduced as the RH levels only went below 40 percent for a three hour period in the late afternoon with light winds. On day four the RH did not go below 43 percent.

**d) Port Hills Fire – 13 February 2017**

On Monday 13th February 2017, two fires broke out in the Port Hills area of Canterbury at (a) Early Valley Road at 1745 hours, and (b) Marleys Hill at 1900 hours. The two Port Hills fires merged into one wildfire and covered an area of 1,661 ha, with a perimeter of 61 km, and resulted in the loss of nine dwellings with a further five suffering fire damage. The fire area also included 595 ha of forested lands.

The decision made on Monday night to manage both the Early Valley Road and Marleys Hill fires as one incident, under one Incident Management Team, was an appropriate one which proved insightful as both fires spread and eventually merged as one.

For the evening on the first day of the Port Hills fires the fire environment hourly temperatures were between 15 - 23 °C, RH of between 27 and 56 percent, and wind speed between 12 and 36 km/hour. On the second day the fire environment remained in extreme conditions with a crossover of RH and temperatures for an hour from 1400 - 1500 hours. In addition, for the sixteen hour period from 800 to 100 hours entering the third day, RH was less than 40 percent. Within the period the RH went below 30 percent for ten hours during that period. Wind strengths over this three day period involved 9 hours of wind greater than 30 km/hour. Given these conditions spot fires would have become a concern for the Incident Management Team on the first three days of this fire.

e) **Pigeon Valley Forest Fire 5 February 2019**.

At approximately 1400 hours on Tuesday 5th January 2019, a wildfire was reported in Pigeon Valley near Wakefield, about 30 kilometers southwest of Nelson. Given the elevated fire danger conditions at the time, this wildfire quickly spread from farmland into forested lands, covering more than 1,200 hectares by the end of the first day. This also included the destruction of one dwelling. The second day saw this wildfire continue to slowly spread covering a further 400 hectares. By day three the wildfire was finally contained to an area involving 2,300 hectares.

The majority of the area burnt was planted forest. This forest is owned by a number of corporate and smaller private forest owners. The area involved a range of different aged forest plantings from recently cut-over logging slash, newly planted trees with scrub understory, to intermediate and mature forest stands.

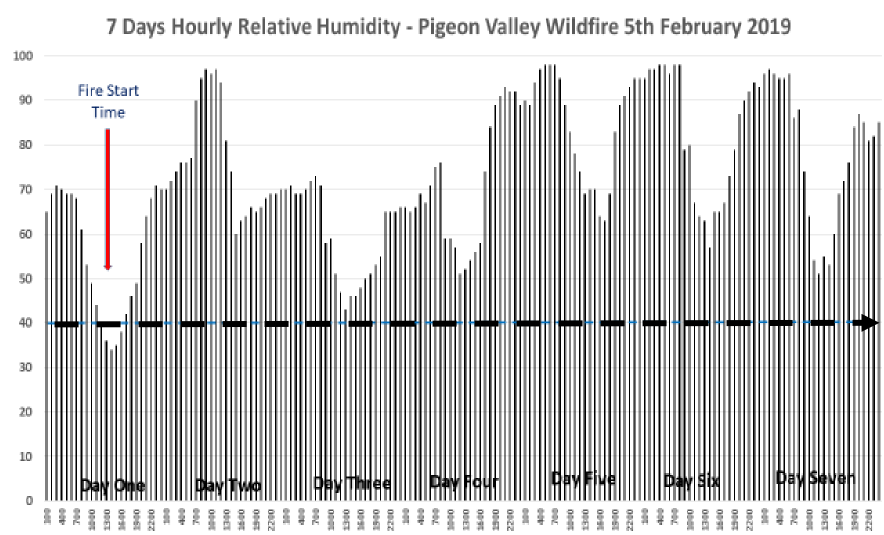



Figure 5

A heavy commitment of aircraft resources, firefighters and overhead personnel was deployed to this fire. The final cost involved in the management of the Pigeon Valley wildfire is estimated to be at least $17 million[6]. Forest industry estimates for firefighting and evacuation costs have been as high a $50 million[7]. This will be the highest cost incurred for any single wildfire in New Zealand history.

For the afternoon on the first day of the Pigeon Valley fire hourly weather information taken from the Dovedale remote automatic weather stations (RAWS) showed the fire environment hourly temperatures ranged between 10 - 24 °C, RH between 34 - 70 percent, and wind speed between 10 - 24 km/hour. On the second to the seventh day the fire environment for RH was no lower than 40 percent, Figure 5, and temperatures no higher than 25 °C.

At the Nelson airport RAWS, 22 km from the Pigeon Valley fire site, it recorded a comparable fire environment to the Dovedale RAWS, with hourly temperatures which ranged between 18 - 30 °C , RH between 34 - 68 percent, and wind speed between 11 - 26 km/hour. On the third day of this fire the fire environment for RH was no lower than 45 percent and temperatures no higher than 24 °C. This produced a benign fire environment for the second day of this fire. At no time during the first two days was there a crossover period of RH and temperatures at the Nelson Airport or Dovedale weather stations.

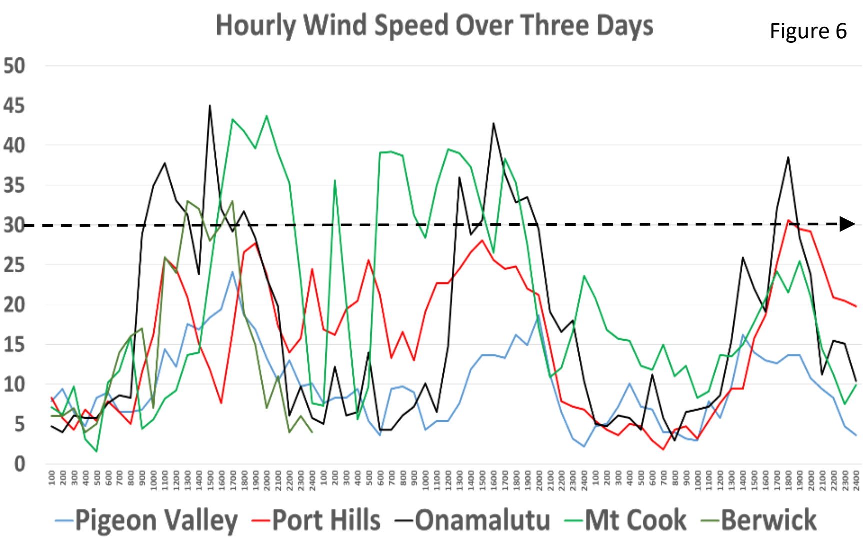



Figure 6

From the second to the seventh day of the Pigeon Valley wildfire, the probability of spot fires was less than 4 percent given the lowest daily RH values and wind speed, which are outlined in the following table:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **6th Feb** | RH 60% | **7th Feb** | RH 43% | **8TH Feb** | RH 50% | **9th Feb** | RH 58% | **10th Feb** | RH 57% | **11th Feb** | RH 48% |
| | 18.7kph | | 16.9kph | | 18.7kph | | 19.1kph | | 21.2kph | | 19.4kph |

Given the points made above, the transportation of live embers beyond the fire ground boundary was highly unlikely over following six day period. As further information Figure 6 provides an overview of wind speed for each of the five forest fire for the first three days.

## 6) Examination

An analysis of the weather forecasts provided to the Pigeon Valley fire Incident Management Team, has shown a strong correlation with the actual weather which followed. When you compare this actual weather with the Berwick, Mount Cook, Onamalutu and Port Hills fires there are a number of interesting observations. For the hourly recorded weather, Table 1 outlines the number of hours during the first two days for each of the forest wildfires. This compares the number of hours between each wildfire where the Relative Humidity and Wind were at levels which would have provided a fire environment conducive to elevated fire behavior conditions and the potential for spotting fires.

Also provided is the fire suppression cost per hectare for each of these wildfires. This shows a clear disproportional cost per hectare for the three fires in the past four years when compared with the Mount Cook and Berwick forest fires. Further work, at some future point, is required to identify why the cost per hectares is so much greater for the suppression of forest wildfires in 2019 compared to those in 1995 and 2008.

Table 1 also provides a detailed weather environment comparison between the five forest wildfires. This shows that the Pigeon Valley fire involved only four hours over the first day when RH was between 20 - 40 percent, and nil hours with wind speed greater than 30 km/hour. This is a lot less time in the extreme danger zone when compared with the Mount Cook or Berwick fires, which had 29 hours and 18 hours respectively of RH less than 40 percent, and RH values less than 20 percent, 8 hours and 10 hours respectively. Wind speed was also greater than 30 km/hour for Mount Cook fire, 19 hours and Berwick fire, 12 hours. Given these points of difference the Pigeon Valley fire environment following the first day was moderate when compared with the extreme conditions of the Port Hills, Onamalutu, Mount Cook and Berwick fires over the first two days.

| | No of hours with RH less than 40% over 1st two days (No hrs < 20%) | No of hours with wind greater than 30 km/hr over 1st two days | Number of hours in Crossover # | Area Burnt | Total Cost | Cost per Hectare |
|---|---|---|---|---|---|---|
| **Pigeon Valley Fire - 5 Feb 19** (Dovedale RAWS). | 4 hrs (0 hrs) | 0 hrs | 0 | 2,300 Ha | $17,000,000 | $7,400 |
| **Port Hills Fire - 13 Feb 17** (Motukarara RAWS) | 21 hrs (0 hrs) | 6 hr | 0 | 1,661 Ha * | $7,900,000 | $5,800 |
| **Onamalutu Forest Fire - 4 Feb 15** (Onamalutu RAWS) | 10 hr (0 hrs) | 10 Hrs | 0 | 600 Ha | $1,294,000 | $2,157 |
| **Mount Cook Station Fire - 16 Jan 08** (Tekapo RAWS) | 29 hrs (8 hrs) | 19 hrs | 11 | 756 Ha | $749,000 | $991 |
| **Berwick Fire - 26 Feb 95** (Dunedin Airport RAWS) | 18 hrs (10 hrs) | 12 hrs | 10 + | 255 Ha | $250,000 | $980 |

Table 1

* Denotes 594 Hectares of forest burnt
+ Denotes first day only
\# Crossover is the point at which the numerical value of the ambient relative humidity is less than, or equal to, the numerical value of the ambient air temperature

When also comparing the Mount Cook, Berwick and Port Hills wildfires with the Pigeon Valley wildfire, for the period during which there was elevated fire danger, the risk of spotting fires for Mount Cook Berwick and Port Hill (2nd Day) were extreme, whereas for Pigeon Valley, following the first day, the probability for spot fires from the second to the seventh day was less than four percent. In addition, for the Wakefield community on the southeast areas of the fire, to be impacted by this wildfire the fire had to breach the containment lines within the forest, burn downhill 1.5km through the remaining forested lands, travel 500 metres through pastoral grasslands, bridge a small river bed, and travel a further one kilometer before then presenting a threat to the community of Wakefield. Had the IMT had a strategy to preposition adequate resources on the eastern flank of this fire to respond quickly, should a ground fire exit the forest lands on to pastoral lands, this would have been adequate to cover the risk of a less than a four percent probability of spot fires. This proposition is supported as time has shown the fire did not spread from the forested lands on to pastoral lands on the southeast flank of this fire. Given this probability, and the landscape, the construction of firebreaks external to the forested land, and the evacuation of people from their homes, on the southeast flank of this wildfire, were not deemed necessary from a fire risk and management viewpoint.

## 7) Social Impacts

From overseas experience, evacuation from homes during a wildfire is inherently stressful because of the disruption to daily life and the uncertainty about what will happen (Cohn et al. 2006). Indeed, evacuees have cited a lack of current information about fire activity and fire impacts as one of the greatest challenges of evacuation (Kent et al. 2003, Sutton et al. 2008). Although individuals vary in their responses, evacuations often elicit strong negative emotions that can have a lasting impact (e.g., post-traumatic stress, anxiety, health problems, lack of trust) on both the individual and the community (Hodgson 2007).[8] Evacuation should be undertaken only when clear evidence confirms that homes will have a high risk of being impacted by the wildfire.

Scion researchers have assessed the social impacts of wildfires, but not necessarily evacuations. The NZ Forest Owners Association supported efforts to contact small forest owners after the Pigeon Valley fire to assist with forestry-related matters.

The 5th February 2019 Pigeon Valley fire affected the lives of those who owned lifestyle properties impacted by this wildfire on the northern edge of the forested lands on the first day. The residents of Wakefield and other surrounding villages and hamlets who had to evacuate their properties were also affected. The forest owners who lost forest were also greatly affected, particularly the contractors who lost their livelihood during the days of the declared Civil Defence emergency.

Fortunately, in the week which followed the first day of this fire the fire environment did not meet the same extreme levels present on the first day. This situation did not appear to have influenced the actions taken by the IMTs when evacuation of families from their homes were also undertaken in communities along the southeast area external to the forested lands, eg., Wakefield. A further point of concern was the need to construct the extended length of firebreaks external to the forested lands, and the damage to these lands which has resulted.

## 6) Conclusions and Recommendations

Lessons learnt from extended wildfire incidents in the past are critically important to review all aspects of the institutional, operational and financial implications of fire management. The comparison of the Pigeon Valley fire with similar fires in Berwick (1995), Mount Cook (2008), Onamalutu Forest (2015) and the Port Hills fire (2017) can provide important lessons for any operational review or independent inquiry evaluating the performance of the Pigeon Valley wildfire.

In summary:

- In comparison to the Port Hills, Onamalutu, Mount Cook and Berwick fires the Pigeon Valley fire did not have an elevated fire environment that produced the same extreme levels of high risk to spotting fires after the first day.

- As this analysis of the fire weather data (that was available to the Incident Management Team at the time) shows the risks that resulted in the ordering the evacuations and the major works to create firebreaks was low. It is unclear what additional or different information that the Incident Management Team leaders were considering when they made their decisions.

- There seems to be a lack of clarity with the Incident Management Team process when a wildfire incident becomes a Civil Defense Emergency.

- There is a lack of forest fire behavior specialists available to support fact-based decision-making for interpretation of risks in wildfire incidents in New Zealand that urgently requires attention.

- There has been a distinct change in the strategy and operational management of wildfires with the heavy deployment of aerial resources without adequate support from ground resources. This has had a major implications on effectiveness and the cost of fire management compared with the management and costs of past wildfires of a similar nature.

- It is recommended that an Independent Commission of Inquiry be undertaken for the Pigeon Valley wildfire to review the strategic, technical and administrative performance and lessons learned, including from previous forest wildfires, along the lines of past Independent Inquiries eg, Mount White 1973, Canterbury 1989.

28 July 2019

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[1] Members of the NZ Institute of Forestry Forest Fire Committee

[2] **Spot Fire**: A fire ignited outside the perimeter of the main fire by flying sparks or embers - USDA Forest Service glossary of wildfire terms

[3] **Prescribed fire** is a planned fire; it is also sometimes called a "controlled burn" or "prescribed burn," and is used to meet management objectives. A prescription is a set of conditions that considers the safety of the public and fire staff, weather, and probability of meeting the burn objectives – USA National Parks Service.

[4] Proposed Revision of Fire Danger Class Criteria for Forest and Rural Areas in New Zealand, Martin E. Alexander 2008.

[5] Fire behavior, suppression and lessons from the Berwick Forest Fire of 26 February 1995; L G Fogarty, A F Jackson, W T Lindsay

[6] $12.7m - OIA Request to FENZ, plus an estimate of$4+m for FENZ direct wages and overheads costs (Murray Dudfield).

[7] https://www.rnz.co.nz/news/national/393583/forestry-firm-hit-in-tasman-wildfires-wants-tougher-fire-prevention-rules

[8] Improving An Inherently Stressful Situation: The Role Of Communication During Wildfire Evacuations; Melanie Stidham; Eric Toman;Sarah M. McCaffrey; Bruce Schinder, 2011