SUBMISSION TO THE INQUIRY INTO THE 2019-2020 BUSHFIRES.

Jonathan Sanders, B.Sc. (Hons)

Australian Fire Service Medal and Bar

This submission particularly focusses on issues of fuel management and fire behaviour, particularly with regard to fires in extreme seasons such as occurred in 2019-2020. It also briefly discusses issues of incident control systems, co-ordinated fire-fighting responses, community preparation and mentoring and training.

The Author:

I am a bushfire manager and fighter of over 3 decades of experience. Most importantly, I have worked at all levels of fire response, and in a wide range of roles. I am trained and experienced in Incident Control, and have worked as Deputy Incident Controller and in other senior roles in Incident Control Teams in declared Bushfire Emergencies on a large number of fires, usually under extreme conditions. I have worked as Planning Officer, and Situation Officer, in which capacity I have been responsible for observing and tracking fire behaviour and development, predicting future fire paths, and formulating the fire combat response, again usually in major bushfire emergencies. I have worked as Aerial Incendiary Operator, which involved slowing and steering wildfire through using incendiaries to remove fuel in the fire's path, without making the fire worse. I have extensive experience as a firefighter on the ground, from being in command of the burning and suppression operations, to being a Sector Boss or Crew Leader, and being a "grunt" on the fireline. I have worked as a trainer and mentor for firefighters, both in formal courses and during annual fire preparation days, and given talks to professional workshops, schools, communities and other groups on fire-related issues. Finally, I am a trained plant ecologist, and have many years of experience in fire ecological research in Australian native vegetation starting with the Govetts Ridge Fire near Cowan in 1983.

This breadth and detail of experience is important, as has allowed me to witness and gain an understanding of the behaviour of big fires under extreme conditions that many firefighters do not get, due to usually being assigned to a fire truck, and focussed on a limited task on any one shift. This means that most firefighters get a detailed look at only a very limited part of the fireground. In addition, a phenomenon as impressive as wildfire necessarily generates its own stories and explanations, and people seeing a large fire in action often fit what they are seeing into these pre-loaded frameworks, rather than actually watching and observing what are often new phenomena.

The submission includes discussion of some information and concepts that may be seen as fairly basic, but it is important to understand how these basic concepts cease to work expected ways in extreme fire conditions.

The 2019-20 Fire Season in Context

The recent 2019-20 fire season was certainly the most widespread and intense season that I have witnessed, and almost certainly the biggest season since European settlement in Australia in terms of fire-fighting efforts and the scale of threat to life and property. It is difficult to accurately judge the relative size and scale compared to past fires, as until the 1960-70s fires in remote areas were not generally mapped and followed closely in NSW, but were dealt with when they emerged from wilderness areas and threatened assets or settlements, and so attempting to reconstruct a detailed fire history and mapping involves a bit of guess-work. There was more area burnt in the 1974-75 season, but this was mostly remote country in western NSW with relatively few assets threatened.

Fire seasons with similar overwhelming devastation have occurred in NSW on a number of occasions, including (to name a few) 1938-39, 1974-75, and 1993-94, which was my first introduction to large intense fires and their extreme behaviour (referred to as "big" fires from here on)). Like 2019-20, the !993-94 season came after a long drought, and so fuels were very dry (including large fuel like logs and dead trees) and extinguishing these fires became a major challenge. It should be noted that very few people in 1993-94 had any experience of fighting a large intense fire under these conditions, and many (honest) mistakes were made as a result. There have been several big fires and notable fire seasons since, but up until 2019-20, none had approached the intensity of the 1993-94 season in my 3 decades of experience. A very high proportion of the firefighters who fought the 1993-94 fires had retired by 2019-20, especially the senior command staff from that season. However, there has been some success in passing down those 1993-94 lessons, and especially the instigation of the Incident Control System, which was first used at Bulga in December 1993 in the Singleton fires and is now standard practice.

It is almost certain that even bigger and more intense fire seasons have occurred in the pre-European times in eastern Australia, with "one-in-1-million" fire seasons having by definition occurred in the long-term past, and shaped Australia's landscape (e.g. the present restriction of the Wollemi Pine to remote refugia). It is not the intensity or the extent of the recent fires which is most concerning, therefore, as such fires have happened before and will happen again. It is the likelihood that fires of this intensity will become more frequent, rather than be separated by the 25 year gap which occurred between 1993-94 and 2019-20, and the similar-sized gaps which have historically separated intense fire seasons. The clear trend of increasing global temperatures makes this increased frequency more likely, as temperature increase directly correlates with more extreme fire behaviour. The projected general decline in rainfall, and increase in drought years makes similar intense fire seasons much more likely.

This is exacerbated by the increased development of areas closer to bushland, placing more assets and lives in the path of potential fire runs and ember attack. It is important to note that 2019-20 again demonstrated that houses do not need to be adjoining, or even very close to bushland to be at great risk of being ignited.

The Big Picture: Fuel and Fires

All firefighting trainees (but not many other people) learn about the "Fire Triangle" – fire requires three things to ignite and sustain itself, namely Heat, Oxygen and Fuel. Removing any one of these completely will extinguish the fire. Increasing the amounts of any one of these has the potential to increase the intensity of the fire (intensity can be understood as the heat energy being given off per metre of fire per second, and is often described at a fire in terms of flame height, rate of spread, spotting behaviour, etc.). Any piece of fuel has a given amount of energy stored in it, all of which is potentially available for release by combustion. The rate at which this combustion occurs is limited by the initial heat of the fire, and the availability of oxygen, and how much energy is required to heat the fuel to combustion temperature.

Oxygen availability can be blocked or limited by applying a covering such as a saucepan lid for a pan fire, or a blanket, or fire-fighting foam, or by immersion in water, but this only works for relatively small fires or in enclosed environments. For larger fires, oxygen cannot be removed.

Heat is generally removed by the application of water, which has great thermal inertia i.e. it takes a relatively large amount of energy to heat water up and in doing so the heat is absorbed. This makes water the preferred fire-fighting agent wherever it is available in sufficient quantities. However, water is not easily available in most situations away from development, and may be in short supply under drought conditions, even in developed areas. This means that removal of fuel is the remaining viable option, and is generally the major tactic for combatting fires, as well as the major focus of bushfire risk mitigation and of debates about bushfire management.

Fuel removal is done (i) by constructing permanent or temporary firebreaks (e.g. cleared zones adjoining development, or bulldozed lines cleared of vegetation through the bush), (ii) by lowering fuel levels across a larger area through mechanical thinning or (iii) through 'hazard-reduction' burning in times of lower fire danger, or (iv) by back-burning during fire suppression operations, which is lighting a burn that travels back to meet the oncoming fire, literally fighting fire with fire.

Historically, the major emphasis in fire management has been on fuel management through hazard reduction burning, as it is seen as a means of taking landscape- or community-scale action to protect many individual assets, properties and people through doing one or two burns, which protection would be much more difficult to organise if action was down to individual property owners/managers. Large-scale hazard-reduction burning is typically done through government-funded or organised action as part of a planned and co-ordinated program. As has occurred in previous big fire seasons, many people have immediately focussed on the assumed inadequacies of this hazard reduction program as a significant cause of loss of life and property in 2019-20.

This submission discusses fuel and fuel dynamics in terms of a typical native forest or woodland with shrubs in the understorey, as this was probably the most typical vegetation structure burnt during the bushfires. The same general concepts apply to grassy woodlands and shrublands, with some important distinctions. Grassland is a significant and separate vegetation type as far as fuel and fire behaviour is concerned, and I will make some points about this, but grasslands were generally not a major feature in these devastating bushfires. Grasses are nevertheless an important component of fuel in most native forests, even if they are not prominent in the vegetation structure, due to the unique role they play in propagating fire.

The basic fuel that most bushfires run on is the layer of leaf-litter and fallen branches on the forest floor. This is traditionally measured in tonnes (of fuel) per hectare (t/ha). If a forest is completely burnt out, with all fine components of vegetation consumed, then it would generally be considered that the fuel load is at or near 0 t/ha. As the forest grows back, leaves sprout, live for some months or even a year or two on the tree, and then die. As the leaf ages, it gets less efficient and the plant "retires" the leaf by withdrawing moisture and nutrients from it, after which the tissue joining the leaf petiole to the tree weakens and the leaf drops to the ground. Leaves are also lost by trees involuntarily, for example by being pinched off by a flock of cockatoos, or when branches are snapped off in high winds. These leaves arrive on the forest floor as green leaves, which then dry out and separate from the fallen branches. Over time, the leaves accumulate in a layer of overlapping debris, which eventually covers the ground and can eventually reach several centimetres thick. As this accumulation occurs, the t/ha of fuel increases.

It is important to note that one of the features of typical Australian *Eucalyptus*- or *Acacia*-dominated forest is that the leaves may take a relatively long time to break down. Australian soils are relatively poor in nutrients such as Phosphorous and Nitrogen (i.e. compared to other continents), which means that many Australian plants must build their leaves (and branches) with relatively little of the organic compounds containing these nutrients. They compensate by using a high proportion of woody compounds to build leaves, with a resulting predominance of woody compounds such as lignin over cellulose. This means that leaf litter derived from these "sclerophyll" (=hard-leaved) forests burns relatively well, takes a relatively long time to break down, and may persist on the forest floor for several years, which allows the leaf litter to accumulate.

So all of this gives us the simple conceptual model for bushfire hazard-reduction by burning, namely that

1. Fuel (Leaf litter) is reduced to zero, or near-zero t/ha by a fire.
2. As the time since the fire increases, the amount of litter accumulates, and the fuel t/ha increases, until it finally reaches an amount that will generate high or extreme fire behaviour.
3. Removing or reducing this accumulated fuel by burning it will render the forest “safe” again.

There is therefore generally considered to be a “safe” period in the first few years after a burn when not enough fuel will have accumulated to support a bushfire, and nearby properties will be safe. Conversely, when lives or properties are threatened by a fire, one of the first conclusions reached by many people is that this is because not enough hazard-reduction burning has been done, as has been loudly proclaimed by some poorly-informed people during and after this last fire season.

All of this is of course based upon the straight-forward concept that more fuel (more t/ha) directly results in more extreme or uncontrollable fire behaviour in a fairly simple and direct relationship.

Fuels Ain’t Fuels

It is important to understand the basic process that has to happen for a piece of fuel to start burning. The actual compounds (e.g. in a piece of wood) have to both be in contact with oxygen, and be heated to around 300 degrees Celsius. If these two conditions are met, the fuel <u>will</u> combust. It is important to note that <u>no contact with an existing flame is required</u>, and this is one of the misconceptions that colours observers understanding of fire phenomena they have witnessed. There are many accounts of trees ‘bursting into flame’, or even ‘tree crowns exploding’ without any prior flame being observed, as if this was a hellish miracle. If the heat coming off a fire is intense enough to heat a tree crown to over 300 degrees, it will start burning, and the same applies to wooden verandahs, doormats, curtains etc.., in fact, to <u>almost all plant-derived materials</u>.

It is important to understand the process by which this ignition occurs in a bit more detail. Firstly, ignition, and combustion take place at the surface of the fuel. This is partly because generally only fuel at the surface of a dense material such as a piece of hardwood will be in contact with oxygen. The interior of a piece of 4x2 wood may well reach a temperature of over 300 degrees (e.g. in an oven), but combustion will only occur in the surface layers of the wood until the interior comes into contact with oxygen, usually through the layers of wood on the outside burning away. By contrast, just about all of a typical leaf is in contact with oxygen, because all of the internal part of the leaf is close to an external surface which is in contact with the atmosphere, and the leaf itself contains significant air spaces.

Not understanding these processes is the cause of one of the major misconceptions about fuel and bushfires. When we light a fire, e.g. to keep warm, we look for large pieces of timber such as logs, as these will provide a lot of heat over an extended period when they burn. However, in a bushfire, these large pieces of timber are usually among the last to ignite, and generally play a minor role in the initial bushfire spread. Nevertheless, many people (including experienced firefighters) consider large logs on the ground (coarse woody debris) to be very hazardous fuel. The fact that coarse woody debris will burn for a long time means that they are a major focus of efforts to extinguish a bushfire after the fire front has passed, but they play much less significant part during the periods of most intense fire behaviour.

Instead, it is the fine fuels (leaves, and sticks with a diameter at, or less than, a little finger) which are the major fuel components in fire ignition and spread. This is not just because of the easy contact with atmospheric oxygen (as outlined above) but also because of heat transfer.

For fuel to ignite, a part of it must achieve the required heat (~300 C). This requires heat to be transferred into the fuel.

There are three ways that heat can be transferred: by **conduction** (e.g. through the bottom of a metal saucepan), by **radiation** (e.g. from standing next to a campfire) or by **convection** (e.g. hot air coming out of a heater). In nature, conduction is relatively rare as most organic materials such as wood are poor heat conductors. (However, heat conduction can cause issues and lead to burns when metal in man-made structures comes in contact with fires).

Radiation is very important in bushfires spreading, as it heats up any fuel immediately adjacent to the fire, sometimes to the point of causing ignition. However, radiation travels in straight lines (like light) and lessens exponentially as distance from the fire increases. For most bushfires, radiation is only a hazard to property or people when the fire is in close proximity, and in line-of-sight.

Convection is therefore the most influential heat transfer processes in bushfires. Air coming off a fire can be superheated, and a large 'blob' of superheated air can then heat up fuels after travelling some considerable distance from the fire. This superheated air can kill people, and is responsible for forming the giant smoke plumes generated by large wildfires, which can carry burning fuel for considerable distances downwind of the fire before dropping it.

The transfer of heat to fuel is usually not enough to guarantee ignition. Many fuels require heating for a considerable period before they will finally ignite, and even then combustion may be a process that spreads only slowly through the fuel. This is because many fuels resist heating due to their water content.

Water is present in the atmosphere as humidity across most of (non-desert) Australia. Live vegetation is full of water, which drives the processes of transpiration and photosynthesis. Since plant structures includes a myriad of pipes and vessels, these spaces continue to be capable of holding water after the actual death of the vegetation. Fine fuels (leaves and small sticks) generally have a moisture content which reflects the prevailing humidity. On a day when humidity is 80%, leaf litter will generally have a moisture content of 80%. If the moisture content drops to 30%, the moisture content of the fine fuel will generally also drop to 30 % within about 1 hour of the change. This is because of the relatively high surface area-to-volume of the fuel, with all internal parts of the fuel being close to an external surface, resulting in a quick rate of adjustment to the prevailing humidity.

Coarser fuels, such as sticks and logs, take much longer to respond to humidity changes. A large log may take several years to dry out after falling to the forest floor, and once dry, will similarly not re-hydrate rapidly after rain. The moisture content of large fuel therefore reflects the general climatic trends rather than daily and weekly variation, becoming drier in drought years and wetter in rainy years, and this scale of variability is reflected in the Keech-Byram Drought Index (KBDI) which can therefore be used by fire managers to predict fire behaviour as it informs about the likely underlying moisture content of coarser fuels.

As previously mentioned, water has a high thermal inertia, which means that it takes considerable energy to heat it up. A piece of fuel containing water (e.g. in conditions of over 40% humidity) cannot reach the temperature of ignition while that water is present. The fuel initially heats up to around 100C, at which point the water content starts to vaporise into steam, and as the water is driven out of the fuel, the fuel can then heat up to the necessary 300C required for ignition. This process has been seen by anyone who has started a campfire, with the initial smoke from the fire including lots of white smoke, much of which is water vapour. As the fuel dries out, there is less water vapour and the white smoke diminishes markedly, until it eventually becomes a fire of burning coals which gives off very little visible smoke (but lots of hot convective and radiant heat).

Understanding the requirement for bushfire fuel to be pre-heated to remove moisture before combustion is central to any understanding of fuel and its role in bushfire behaviour. It is also vital to understanding the risk of inaccuracy from traditional fuel measures of tonnes/hectare, when big intense fires are burning, as I explain below:

When a fire starts in a forest, there will be a given load of fuel present ('x' tonnes/ha). That fuel will have a current moisture content (e.g. 40%) which will change up or down in the fine fuel during the next hours as environmental humidity changes, after a short delay of around one hour. The fuel has to reach a moisture content of 30% or less to become easily flammable, and at 5% or 10%, it is very readily ignited. The coarser fuel and logs will have a moisture content which more closely reflects the longer-term climate – perhaps 60% in a wetter period, and as little as 20% or less after a long period of drought.

As the fire approaches at any piece of fuel, it has to transmit enough heat into the fuel to drive out the remaining moisture before that piece can reach combustion temperature. This heat will be transmitted first through convective heat (hot gases rising off the fire or being blown downwind from the fire) and then as the fire gets very close, usually within metres, as radiant heat hitting the surface of the fuel. The water in the heated fuel will start to expand, and as it reaches boiling point, vaporise and escape from the fuel. This is often visible as bubbling at the end of sticks. When part or all of the fuel has dried out, this dry fuel is then available for ignition and combustion, provided it can reach around 300C. It is quite normal in most bushfires, and in successful hazard reduction burns, for the majority of the leaf-litter to be burnt, but for the heat of the fire to also dry out and kill a large number of green leaves without burning them. These leaves then fall on the ground and form a new ground-fuel layer of leaves within a week or two.

In any fire, the amount of fuel that will actually dry out sufficiently to combust is dependent upon the starting moisture content of the fuel, and the amount of heat energy transmitted to the fuel to dry it out. The amount of heat energy transmitted to the fuel depends upon the actual heat generated each second by the fire, and the number of seconds during which the fuel is exposed to this heat. A bushfire can easily generate 100kWatts of radiant heat per metre of fire front, but the actual total heat transmitted depends upon the residence time of the burn, i.e. how long the fire is transmitting that heat in a particular spot. In really large burns, such as those of January 1994, or 2019-20, the hot dry winds coming off a fire can work to dry out fuels downwind of the fire for several days before the fire front actually arrives.

While the traditional measure of forest fuel concentrated on measuring the ground-litter layer, more recent fuel measure methodologies take into account the nature and structure of the shrub layer, the tree bark and canopy. This is a more accurate measure, but it still suffers from the difficulty of knowing what proportion of the dead and living vegetation will actually be brought into play in any particular fire.

In most bushfires in the real world, it is unusual for all of the fine fuel to be consumed, and it is not uncommon for only a portion of that fuel to be consumed in some areas, even in an extreme fire, and I have seen examples of this from the recent South Coast fires. On the other hand, in the same recent South Coast bushfires, there were also many examples of local areas where not only all of the leaf litter was consumed, but also almost all of the (living) shrub layer and all of the tree canopy including the smaller branches. This was green living vegetation before the fire, but the heat generated by the fire in these particular locations was sufficient to dry out all but the larger branches, thereby converting them into fuel. It was notable that many trees were already carrying leaves in their canopies that had dried out and died before the fire arrived due to the drought conditions.

As shown by these occurrences, the heat generated in an extreme bushfire can be so great that even the moisture content of green vegetation will not inhibit heating and combustion, and even green leaves are almost instantly vaporised and burnt.

I have personally witnessed a number of fires where areas have burnt more than once in the same season, or even in the same fire. This is because the first fire burnt only the already dry (or near-dry) fuel, but also dried and killed (without consuming) a lot of green leaves which then fell and became fuel for the next wave of fire. In one instance on the Boree Trail in Yengo National Park in the early 2000's, a ridge-top area burnt 3 times within 5-6 weeks within the same fire as each successive fire-front burnt a proportion of the fuel, but also dried out new fuel for the subsequent fire. The first two fires were quite extreme, and it was considered that none of the three fires would have been survivable for a person or a vehicle on the fireground at that location.

A relatively low level of fuel may be no protection, if the fire weather conditions mean that all of that fuel is brought into play in a short time. In the northwest Sydney fires in 2001-2, some houses north of Glenorie were threatened by fires burning across mown lawns. The extremely hot and dry conditions meant that the lawns had completely dried out, and with a following north-westerly wind, generated a flame front of 30-50cm height. While this was not hard to combat with water, it was also sufficient to cause a threat to life and property where water wasn't available, and several structures were ignited and damaged or destroyed by these 'lawn fires'.

The big variable influencing fire behaviour in these situations is usually the wind. The wind not only pre-dries fuel if it is low-humidity air, but also transmits convective heat thereby pre-heating the fuel. Once combustion starts, the wind influences the supply of oxygen to the fuel. A strong wind acts like a bellows in a blast furnace, with the result that the fuel is burnt more rapidly, the flames and heat given off are greater, and more of the fuel is likely to be burnt. The degree of exposure to the effects of wind is a major factor affecting fire behaviour, and especially the rate of spread of the fire. The degree of exposure to the wind can often be far more important that the total amount of fuel present (as discussed further below).

Exposure to the wind is mediated by the landscape. In the hilly ridges and mountain landscapes that typified much of the areas burnt in 2019-20, the wind can be funnelled to blow up valleys and slopes, and over ridges, so that some areas receive an increased wind pressure, and some areas are sheltered from the wind. The landscape also greatly affects the fuel type and its moisture content, as slopes and ridges facing north and north-westerly receive greater insolation from the sun, compared to slopes and ridges facing south and south-easterly. The hottest and driest winds also typically come from the north and north-west, so slopes and ridges with these aspects get the maximum drying and pre-heating effects. By contrast, not only does the fuel stay moister for longer in the more sheltered areas of the landscape, but the vegetation types often include many rainforest species which are not very flammable. Many rainforest gullies stood out in the landscape after the fire as the only vegetated areas that were still mostly unburnt. A notable feature of the 2019-20 fire season is that a relatively large area of rainforest across the eastern States did actually get burnt, which is unprecedented in European knowledge, and has the potential to change the landscape.

The 'structure' of the vegetation, and therefore of the fuel, is an important variable in all of this. Structure refers to the density, height and continuity of the different layers of vegetation. If plants are widely-spaced, then the heat from a burning plant is less likely to be transmitted to surrounding unburnt plants, and conversely, dense vegetation is more likely to burn as a whole. Fuel that is not in contact with the fire burning through the ground litter has to be close enough to it horizontally or vertically to be dried (if necessary) and heated to ignition temperature. The relative predominance of fine fuel, and especially grasses, in the groundstorey is a major determining factor in this spread. The grasses and fine fuel can ignite almost instantly, generating a short burst of intense heat that can more readily bring surrounding fuels into combustion. Vegetation close to the ground can therefore be ignited relatively easy by a ground fire, compared to vegetation some distance above the ground. If there is a dense layer of shrubs with relatively fine leaves, then these can ignite and form a "ladder" that carries the fire into the canopy of the forest. The presence of a dense shrub layer is therefore often seen as a particular risk factor in bushfire behaviour and controllability, and breaking up this shrub layer structure is often an aim of hazard reduction burning.

On the other hand, a dense shrub layer can often greatly reduce the wind speed and intensity under the canopy of the forest, by acting as a windbreak. This greatly reduces drying and heating effects of the wind, and can mean that the ground fuels also dry out less, both from the wind shelter and from shading by the overhead vegetation. This leads to the perverse reality that a fire in a forest with a relatively denser understorey may burn less intensely and travel much more slowly than a fire in forest with relatively more open understorey. The dense structure may lead to a fairly complete consumption of fuel, but at a much slower rate than would occur if the understorey was fully exposed to the prevailing wind.

Again, the traditional understanding of fires and fuel is that forests with a dense understorey are likely to develop canopy fires, while forests with an open grassy understorey are likely to only develop ground fires. The extraordinary conditions of drought and extreme fire weather experienced in 2019-20 negated these 'rules' (as had also been observed in 1993-94). In a number of places, including at Bilpin in the Blue Mountains, fires burning in grazed paddocks with very low levels of grassy fuels "jumped" into eucalypts and ignited canopy fires, to the astonishment of experienced firefighters watching on. The general rules using fuel to predict fire behaviour that can be relied upon in most circumstances, are rendered seriously unreliable by a combination of drought and extreme weather, and especially low humidity and hot dry winds. If every bit of plant material is available to be burnt, and burnt rapidly, then an apparently small amount of fuel can still generate a significant amount of heat.

The fire that burnt along Bells Line of Road from Bell down to Bilpin burnt through a large amount of country that had been relatively recently burnt in the State Mine Fire in 2013, but there was little evidence of this recent fire significantly slowing the 2019-20 fire. The State Mine Fire was a much more effective fuel reduction burn than any planned burn could have achieved, but any reduction in fuel was outweighed by the weather conditions..

Total fuel, in terms of tonnes per ha, therefore generally tells us the total potential energy (heat) that can be released if all of the dead vegetation material in the forest is burnt, but it doesn't tell us how quickly that heat will be released, or how much of the fuel will actually burn in any particular fire. If that heat is released in 10 minutes, then it will be a very different fire intensity to if the heat is released over 40 minutes. More importantly, it doesn't tell us how much of the existing green vegetation will be converted to fuel in the heat of the fire.

In summary, when all of this is taken into consideration, we need to adjust our definition of "bushfire fuel" with the understanding that virtually any product of photosynthesis, living or dead, is potentially flammable, given sufficient low humidity and heat for it to dry out and reach combustion temperature. Under very extreme conditions, and especially if accompanied by a long drought, virtually all above ground vegetation can become fuel, as has demonstrably occurred in many areas in the recent fire season. Relying upon fuel reduction to minimise fire risk in these extreme conditions would require large swathes of existing vegetation to be cleared to mineral earth or paved with concrete, as any sclerophyll vegetation or even cleared paddocks can form a significant danger if it is burnt intensely under extreme conditions.

Changes in Vegetation and Fuel following a Burn:

Any fire in Australian bushland resets a wide range of biological and physical characteristics and processes, which then change as the time since the last burn increases. Understanding these changes is essential to understanding how fuel management can reduce (or increase) bushfire risk.

A forest following a fire will generally still have large canopy trees, and some of the larger shrubs and small trees that have survived the fire, as well as some of the ground-cover species such a grass tussocks. These will quickly re-sprout from buds in trunks, larger branches and in root systems. Other species are typically killed by fire, but start a whole new generation from seeds stored in the ground or on the parent plant (e.g. Banksias). In general, most species will have a very large number of seedlings, leading to dense regrowth of young plants, which are then gradually thinned out from desiccation, grazing, competition for resources and other processes. The populations of many species of animals including invertebrates will have been reduced by the fire, especially those living predominantly in or above the litter layer, while those living underground such as ants will be less affected.

Leaf litter will start accumulating on the forest floor straight after the fire, from the leaves that were scorched but not consumed in the fire. This initial layer will generally be fairly scattered and discontinuous, and get deeper in lower areas and small depressions as it is moved about by rain and by animals. There will fairly quickly be dense growth of seedlings, but these will not be very visible for some months until they start achieving some height. In the first year or two after a fire, the ground fuel is generally low, the shrub layer is pretty scattered and discontinuous, and there may be significant gaps in the canopy if it was affected by the fire. There will be a lot of light reaching the forest floor, and due to the exposure to the sun and the lack of ground litter to trap run-off, the soil will generally be relatively dry. A number of species will flower and fruit very quickly after the fire, with some species re-sprouting and immediately flowering, sometimes within days of the fire, to establish the next generation as quickly as possible.

Around the third or fourth year, the leaf litter will usually be continuous enough to carry a fire through it, provided it is dry enough. The canopy will usually be approaching its pre-fire continuity, since the branches that give the tree canopy its structure generally survive relatively intact apart from the smaller branches. The ground layer will start to be shaded by the canopy and by the developing shrub layer. By this time the invertebrates living in or on the litter have built up in numbers, and will be chewing up and processing the leaf litter in increasing amounts. While the leaf litter continues to accumulate, the lower layers of the litter close to the soil are now being broken down by fungi, bacteria and other micro-organisms as well as invertebrates. The speed and extent of these composting processes is very much increased by more relative moisture in the ground litter.

By around the 5th to the 8th years, the shrub layer will generally be fairly dense, and often approaching pre-fire levels of density and size, depending upon the species. Species such as *Acacia suaveolens* will have flowered and fruited several times by now, and the post-fire generation will be approaching the end of their life-spans. Other species will only just have reached sexual maturity, and a fire before this occurs will risk local extinction by killing the adults before the next generation has been produced. By this stage fuel accumulation will often be considered to be reaching levels that pose a bushfire risk. The leaf litter layer will be starting to reach 1-3 centimetres in depth in places, but the lowest layers of litter are also more likely to be damp due to shading by vegetation and protection from drying by the litter layers above.

These general processes will continue as time since the last fire increases. The shrub species will grow larger and a bit denser, but many of them will also begin reaching the end of their lifespans, and around 20 years post-fire a numbers of shrub species will start to die of old age, leading to a gradual thinning of the understorey over the next 5-15 years. Some species will be reduced to only a few individual plants above-ground, with the rest existing as a large population of seeds awaiting the next fire.

By around 20 years post-fire, the litter layers will be much deeper, but below the surface layer they will be largely composting, with large amounts of fungal hyphae ('roots') growing through them. At this stage, water run-off will be greatly reduced, with a lot more moisture retained by the vegetation and litter. A measurement of total fuel at his stage will show alarming levels, but much of this may be too moist and compacted to burn, even under very hot conditions. In the Govett Ridge fire of 1983, which burnt extremely hot, ground litter on mid-to-lower slopes after the fire was 5 cm and even more thick, with generally only the top 5mm to 1 cm having been burnt, due to the moist, composted nature of the litter, and I have observed similar situations on a number of occasions since. Inspection of areas on the South Coast around Mogo-Batemans Bay showed that this characteristic of the full depth of the ground litter only burning patchily also occurred in places in 2019-20.

In areas where rainforest adjoins Eucalyptus forest, then rainforest species will tend to grow up in the understorey as the sclerophyll species senesce and die. If the between-fire interval continues for a long time, then the vegetation will gradually become dominated by these rainforest species and transform into rainforest proper, becoming less flammable in the process. If fires occur too frequently and/or they are too intense, then the rainforest margins will retreat as the Eucalypt forest expands into them, in a process of waxing and waning of boundaries that has been going on for many millions of years.

An extra significant issue is that the 're-setting' of vegetation dynamics that happens with a fire also re-sets weed populations. The increased light and nutrients after a fire stimulates germination of weed species, and provides an opportunity for weeds to flourish. The reduction of vegetation cover also makes it easier for feral predators to find and kill native animals, and introduced grazing animals such as deer and goats can do a disproportionate amount of damage by eating the new shoots and seedlings that sprout after the fire. Any burn can thus increase the vulnerability of native species to damage by introduced species, and this is an extra environmental impact that needs to be considered in both hazard reduction burning, and in recovery from wildfires. Conversely, burns provide a significant opportunity to target feral species for control, and it is a major weakness of land management today that fire management tends to be a separate program from pest and weed species management.

The general 'traditional' view which is still widespread in the general community has been that a fire will remove the hazard caused by too high a fuel load, and that repeated burning after that in intervals of 7-10 years will prevent the fuel load returning to dangerous levels. Even assuming this were correct, there are still numerous problems with this view, not least being the logistical difficulties of actually burning the very large areas of bushland that would be necessary to achieve this burning prescription across forested NSW. Over my decades as a fire manager, hazard-reduction burning technology and resources have improved greatly, but it is still rarely possible to burn anywhere near the area designated and planned for burning each season. The planning process for doing a hazard-reduction burn has definitely become more involved and a little more time-consuming, but the support and resources for doing this planning have similarly increased, and planning is not the major problem.

The major issue is getting suitable weather conditions to do a HR burn. While a wildfire burns whenever it starts, a HR or controlled burn has to be done under conditions where it will not itself cause a risk to life and property, but will still consume enough fuel to reduce the long-term bushfire risk. This can be a major difficulty in itself, as some vegetation will burn very willingly and intensely under hot summer conditions (<20% humidity, >30C temperature, and a medium wind) but will be very difficult to even light in conditions just a little cooler and damper than this. Fire managers are then faced with having to do burns that will be unlikely to achieve much fuel reduction, but will stay under control, or to light up a burn under conditions that run the risk of the burn becoming uncontrollable. The Cumberland Plain forest with a *Bursaria*-dominated shrub layer can generally only be successfully hazard-reduced in dry conditions with temperatures over 30 degrees, humidity around 20%, and a following wind of 10-15 km/hour – conditions that cause extreme fire behaviour in the nearby sandstone-based vegetation communities.

It is a great credit to fire managers that so many burns are successfully initiated and largely achieve their aims.

Over the past three decades, the climate has visibly changed. The fire season around Sydney now starts earlier, in late August-September, which used to be more typical of the NSW coast and ranges further north. In quite a few seasons over the past decade, the fire season has started by looking quite threatening, but then by Christmas has reverted to regular rain episodes from east coast low-pressure systems, which come much further south down the coast from Queensland than used to be the case. These generally moister climate periods have made getting suitable conditions for HR burning even harder to obtain. Away from the moist coastal influence, the increased temperatures have still seen large fires in the Wollemi and Blue Mountains wildernesses, which have still required major efforts to combat.

In those years where the rain doesn't arrive, the increased temperatures have had a major effect on fires, as happened in 2019-20. Any fire manager knows that temperature is one of the critical inputs determining fire behaviour and intensity, and an increase of even one or two degrees when a fire is burning will cause a significant increase in fire risk. When these increased temperatures occur over a prolonged period, coupled with drought conditions, then the fuel will become much drier than would otherwise be the case, and a proportion of leaves and even whole plants will die and be added to the fuel load. Under these conditions, you can 'hear the fire risk' as the leaf litter becomes loudly crunchy underfoot. There is no doubt that the wildfire season in terms of warmer temperature is much longer than it used to be.

There are other significant issues with relying predominantly upon broad-area hazard-reduction to manage bushfire risk.

Firstly, as outlined above, a hazard-reduction burn will generally only reduce fuel to ‘safe’ levels for a period of around 5-7 years post-burn at most, and usually even less. At this point, another burn becomes necessary, but burning with these short fire intervals risks send many native species extinct, due to there being insufficient time between fires for the next generations to establish.

At the same time, there are a number of shrub and groundcover species that respond readily to more frequent burning, and regenerate in large numbers following a burn. This includes the hard-seeded species such as wattles and native peas. Where more frequent burning has occurred, it is quite common to see an increased density of the understorey shrub layer post-fire due to one or several species of shrubs being favoured by this fire regime. In these cases the more frequent burning can actually have the opposite effect to that intended of increasing the potential fuel load within a few years by encouraging dense shrub growth. In the same way, more frequent burning can slow down the decomposition of leaf litter by drying out the understorey due to increased exposure to sun and the drying effects of wind. Again, this can have a perverse effect on fuel loads and subsequent fire behaviour.

A focus of much recent discussion has been indigenous burning, and the idea that Aboriginal people managed fire risk by lighting frequent low-intensity fires, thereby preventing large-scale conflagrations.

There is no doubt that many areas of Australia were subject to far more intensive land management by Aboriginal people than has been previously acknowledged, and that burning regimes were a particular part of this management (and still are in northern Australia and increasingly elsewhere). It is very likely that much of this burning was done to achieve particular outcomes, such as clearing grass swards to allow food plants such as Yam Daisy, Orchids and Lilies to thrive before harvesting, or to attract grazing animals with green pick from the post-fire re-sprouting. The areas where these ‘firestick farming’ practices are most likely to have occurred are generally vegetation with a predominance of grasses in the understorey, such as the grassy box woodlands that are characteristic of much of the more fertile soils on either side of the east coast ranges (e.g. major river valleys such as the Bega Valley or the Cumberland Plain). Most of these areas have been partially or fully cleared during the 19th and early 20th centuries, and are now rural landscapes which are not generally a focus for hazard reduction.

When the large remnant Eucalypt-dominated forested areas along the coastal escarpment are considered, relatively little of these landscapes were very fertile, and although undoubtedly being very important in their culture and mythology, they would not have supported large densities of Aboriginal people or rewarded intensive land management. Specific burning for cultural reasons (e.g. to clear a ceremonial site, or to care for the land) would still have occurred, but probably not so widely across the landscape. The vegetation in these areas includes many sclerophyll species, which were generally of lesser relative value in dietary terms, although not unimportant. The species that are characteristic of these vegetation types include many species that are adversely affected by frequent burning, and would have been unlikely to survive if there was widespread burning at intervals of 2-5 years over an extended period. Their current presence can be taken as indirect evidence that such frequent burning was not a constant in the past. More importantly, there is little evidence that frequent burning in such landscapes would have provided any particular benefit for Aboriginal people, and Aboriginal land management practices generally demonstrate an economy of effort that is focussed on results, rather than non-productive ‘habits’.

It is not possible for me to accurately ascribe motives to Aboriginal burning practices, beyond some of the obvious practical outcomes outlined above, but 'hazard reduction' is unlikely to have been one of them. Aboriginal people generally did not have large areas of major fire-vulnerable assets to protect, and moving out of the way of a fire was a relatively simple strategy to avoid danger, rather than any need to stay and defend land in the fire's path, or to plan and implement widespread fuel reduction to avoid wildfires (although this may have occurred in particularly valuable areas of the landscape). The revival of indigenous burning practices for cultural reasons is extremely worthwhile in itself, and is certainly an important part of the fire management picture in the future, but recommending "indigenous burning" as a solution for fire and hazard management is unrealistic, and is a distortion of its purpose. It should certainly be actively pursued as a part of applying fire across the landscape, but is not the cure-all panacea that is being portrayed in some circles.

One of the most significant problems with an over-reliance on hazard-reduction burning is the social effect on community preparedness and resilience. The number of people who are now living within close proximity to bushland in NSW has increased dramatically over the past 25 years. In this same period there have been major and significant improvements in fire combat capability with better command and co-ordination and access to very large waterbombers and modern equipment. This has led to there being more people living near bushland who have relatively little knowledge or experience of bushfire, but have an increased and widespread expectation that fire risk can be managed by the fire management authorities, and is therefore something that is 'external' to the ordinary householder's concerns or responsibilities.

It was very evident that a large proportion of the people affected by the 2019-20 fires did not anticipate or plan for such an event, and more importantly, did not believe that it would actually involve them personally and their property. There was also a fairly widespread lack of understanding of their own personal roles in minimising their own risks, especially where their houses were in areas that were largely separated from bushland. A significant number of the properties lost in both Cobargo and Mogo would not have appeared at risk to the average person since they were not adjacent to bushland, but they appear to have been ignited (at least initially) by ember attack nevertheless.

The fires that burnt around Cobargo travelled in grass along roadsides, and across drought-affected paddocks, which would be considered to have a low fuel load in any but the most extreme conditions. No amount of widespread prior hazard-reduction burning would have protected those properties once the huge fires and their downwind ember showers began. The only effective property protection would have been on-site at each property, through the pre-fire management of fine fuels and ember-admitting gaps around the property, the provision of property protection mechanisms such as sprinkler systems, and through preparedness and training of the residents.

Hazard-reduction burning is an extremely important tool for managing bushfire risk, and helps create areas where a fire may slow down, and be safer to combat. In "normal" years, hazard-reduced areas can be quite effective in helping to contain a fire. Reduction of fuel in areas immediately around development is important for protection of lives and property, but this can be done as effectively by mechanical fuel removal (thinning of shrubs, slashing and grazing) rather than necessarily being achieved by burning. Alternatives to hazard reduction burning have the advantage of being possible under a range of weather conditions, and not necessarily stimulating a large regrowth and re-generation of the very vegetation that is the target of the fuel reduction.

By contrast, fire-proofing houses at risk has a permanent improvement on reducing the risk to lives and property, and one which does not wax and wane as the time since the last fire increases.

'Big Fire' Behaviour – What changes?

The intense fires of 1993-94, 2019-20 and of some other fire seasons have some significant differences to 'normal' bushfires, which require a significant change to fire combat approaches. I use the term 'combat' rather than suppression, because an essential characteristic of these intense fires is that it is very, very difficult to stop their spread, let alone extinguish them.

Bushfire spread is normally halted by backburning, to deny fuel to the fire. In these intense seasons, backburns become very difficult to light safely and to control. A backburn is normally controlled by being lit very 'gently' as small low-intensity fires that gradually coalesce as they burn back into the wind and the wildfire. The increased temperatures experienced in these intense seasons, coupled with the prevalence of hot winds and low humidity, means that any small fire is very likely to become a bigger fire very quickly, and the backburn itself can rapidly become the main danger. This occurred on the Mount Wilson Road in 2019-20, when a backburn to slow the fire approaching from the Newnes area immediately jumped from the west side to the east side of the road, and it was this backburn which subsequently burnt the Grose Valley and threatened the upper Blue Mountains and Mt Tomah and Bilpin to the east. The main fire was still some large distance away when this burn was put in.

It is a concern that exactly the same situation occurred in 1993-94, when a backburn was lit in the same area and escaped in the same way. This demonstrates that the time lapse between the two events has allowed the local knowledge of this significant risk to have been lost as personnel have moved and retired.

When backburning becomes difficult, then doing the backburn at night when temperatures are lower and humidities higher is the next fallback. In most fire seasons, this is a highly effective strategy, although some fire managers dislike it due to the inability to fly aircraft in support at night. However, in intense seasons the underlying fuel moisture is very low, and temperatures may be kept higher by heat coming off the fireground upwind. In both 1993-94 and 2019-20, firefighters often found that even backburns lit at night behaved erratically and were difficult to control, often spotting over the control line. Furthermore, these backburns were often themselves difficult to contain the following day when conditions again got hot. This is because the coarse fuel (logs, dead branches, stags) had a very low moisture content due to the extended drought. If they ignite, then they will readily continue to smoulder, and take a concerted effort to extinguish. A hot wind blowing onto this smouldering timber will readily dislodge embers, which can then blow downwind for up to 50 metres across the control line, and start a new, uncontained fire. In 1993-94, fire combat was characterised by a long series of many control lines established by backburns, which were then breached 1 or 2 days later, necessitating retreat to establish a new control line.

The difficulty of establishing control lines by backburning in intense seasons is exacerbated by the fact that access into bushland areas is generally by tracks along ridgetops. These tracks are logistically the best locations for control lines, as there is vehicle access and a ready-made control line using the road. However, these tracks are on ridgetops which are generally exposed to the highest winds, and the most sunlight. There were no examples of a ridge-top track being successfully used as a control line during the intense fire period in 1993-94that I or my peers are aware of, and it appears that it proved similarly difficult in 2019-20.

The trajectory of a big fire generally starts with a small ignition, and most likely through a lightning strike. These strikes usually hit a tree, and start a smouldering fire in the tree which spreads to the surrounding ground. Quite often the initial fire does not start spreading straight away, but may exist as a small fire until a 'blow-up' day, when high temperature and winds and low humidity combine to cause the fire to flare up and grow.

The lightning strikes are mapped remotely, which gives authorities map locations that can be investigated by air and where possible extinguished by small crews of remote-area firefighters dropped in by helicopters. These small fires can also be temporarily contained by water-bombing, but long years of experience have shown that water-bombing without some on-ground presence to do the detailed black-out is often unsuccessful. Similarly, support from dedicated water-bombing helicopters greatly improves the safety and success of the on-ground firefighters. The increased use of highly-skilled Remote Area Fire Teams (RAFT Teams) dedicated solely to this task, especially by NPWS, has made a major difference to number and severity of wildfires in the past two decades. However, 2019-20 was characterised by a very large number of dry lightning strikes, and the underlying drought meant that these strikes had a higher than normal chance of turning into a full-blown fire despite the RAFT teams' efforts. Under these circumstances, there were insufficient RAFT teams to get to all the fires in time.

Fire growth is an exponential process, since fires generally grow along their boundaries, and as they grow, their boundaries become longer, providing more sites for the fire to spread. As it gets larger, it also generates more heat, and this means that more fuel dries out and becomes available for combustion. The critical point is often when this heat becomes enough to ignite the forest canopy. The combustible oils in the eucalyptus leaves vaporise and ignite as hot gases, and the heat and convective wind generated can tear burning pieces of the canopy off and carry them downwind to unburnt areas.

On a landscape scale, this usually involves burning fuel being blown from a ridge onto the next ridge downwind. This burning fuel usually lands on the windward slope, and then ignites a fire which commences burning uphill with the wind. The preheating of upslope fuel from the convective heat means that this fire will grow very quickly, and then become a new canopy fire and generate a rain of burning material to the next ridge downwind. The initial spread when the fire takes off in this fashion is very quick, resulting in a linear pattern of burning ridges. I have personally seen and measured this spread happening at around 20 kilometres in 30 minutes. Combating fire which is moving at this speed is near-impossible, as control lines are all too quickly overrun or out-flanked. It is the equivalent of the "blitzkrieg" of the Second World War, the fire's progress quickly out-runs and out-flanks any defences.

The initial run of an intense fire produces a large and very confused fireground. The fire at this time consists of a large number of spot fires, each of which is spreading locally, and producing a huge amount of smoke. Flying in proximity to the fireground becomes difficult as the existing high winds are joined by very poor visibility and massive updrafts of hot air which can throw aircraft around. On-ground intelligence is also difficult to obtain due to the smoke, the difficulties and dangers of moving around, and the fact that most observers are disoriented and confused by the size and scale of the fires. In Christmas 2001, I witnessed fire units repeatedly dispatched to properties around Eastern Creek that were in "imminent danger of being over-run" only to find no flames in the area – the fire was still 12 km upwind to the west. However, on an intense day, a blow-up fire looks much closer and more immediate than it actually is – a good rule-of-thumb is that it is 5 times bigger and 10 times further away than it appears.

By this time, the fire has a very large overall perimeter, but there are many internal fires burning, and much unburnt land within this perimeter. This makes it very hard for firefighting authorities, as there may be many properties which are now surrounded by fire on several sides, but still unburnt, and getting help to these properties is difficult in terms of intelligence (non-local crews may not know where they are) and operational danger. Travelling within a fireground which has unburnt areas and active fire burning is extremely hazardous, and has been a regular cause of death when fire crews have found themselves caught between two fire fronts.

The second day of a massive fire run may see a second run, but this is usually smaller than on the first day. This is because the fireground is now a very large area of burning country – the fine fuel is consumed in the initial fire spots from the run, but the coarse woody fuel is still burning actively, and the individual spot firess are now spreading out within the fireground and burning down slopes and into gullies. This means that there is still a lot of smoke, and especially, there is a large mass of hot air still rising off the firegound. The smoke shades the fireground, and an appreciable area downwind, and this can reduce insolation by the sun so much that it can drop the temperature on the fireground by several degrees.

The most significant effect is from the column of rising hot air over the fireground. This forms a solid block to the prevailing winds, such that the prevailing winds are channelled around the hot air mass and around the fireground. This effect is well-documented, but not always well-understood and brought into calculations by the incident controllers who only rarely face these situations. The result is that the very active fire-front becomes much more slow-moving after the first couple of days, unless there is a wind change. The upwind side of the fire is still subject to full insolation and prevailing winds, and the flanks are particularly vulnerable, since the prevailing winds are being pushed around and along the flanks. A common mistake made at this stage of managing a big fire is to start control lines with backburns at some position on the flank of the fire. The increased flank winds make these backburns almost impossible to contain, and many have failed over the years and caused property losses.

The fire strategy instead needs to be to halt the fire front where possible (while the smoke and hot air provide a limited 'respite') and try to keep the shape of the fire as compact as possible. Any areas of fire sticking out from the major fireground will be subject to the full effects of wind and sun, and are likely to be the source of the next runs. This pattern was again visible in 2019-20, where new fire runs tended to occur in parallel to the original run, along its flanks.

As previously stated, backburns from ridgetop trails are very difficult to control under extreme conditions, and have a relatively poor record of success in stopping these fires. One method that does have a good record of success is using aerial incendiaries to "steer" the fire into a natural control line, such as a wet gully. This is done by burning the ridges that will support spotting runs in front (downwind) of the fire. The incendiary work is done in the late afternoon/early evening by lighting the tops of the ridges, and then bringing the fire gradually downhill, so that no large uphill runs occur. If this fuel-reducing fire can be brought downhill into a wet gully, then it has a good chance of going out by itself overnight.

This method was used successfully in 1993-94, and the incendiary burn down into Sandy Creek in Yengo National Park was the only place where any of the intense Wollemi-Yengo bushfires were successfully stopped during the big runs. It was used successfully again in the Goulburn River fires of 1997, and at other places and times. In 2019-20, it was used to halt the Gospers Mountain fire complex around Spencer, by burning out the ridges in south-west Dharug National Park and thereby robbing the fire of its ridgetop fuel, and as a consequence, its capacity to spot.

Using incendiaries in front of an intense fire threatening houses is not without risk, and quite a few incident controllers shy away from the risk of being seen to light the fire that burnt houses. (They are usually less reluctant to light a conventional backburn from a firetrail, sometimes with property-damaging consequences). The other major issue is that Operations Officers are often unwilling to make a helicopter available for this work, keeping them in waterbombing and ground support roles instead. As mentioned below, this could be solved by reserving at least one helicopter under the Planning section at all major fires for strategic and tactical intelligence gathering, and for aerial incendiary work.

When a big, intense fire takes off, it all happens at a scale and a speed which is almost impossible to envisage until you are there. When a big fire takes off, 'normal' firefighting becomes irrelevant. The size and scale of the combustion process is far more than all of the available firefighting resources could ever control. This is not a situation that can just be solved by getting twice as many tankers, or helicopters, or super waterbombers. On a big day, when a fire takes off in intense ("catastrophic") conditions, normal firefighting techniques will no longer work, and the fire will travel to where the weather takes it, largely regardless of previous fuel reduction or any efforts to stop it. The sole realistic aim becomes saving lives and property (and many properties will be inherently un-saveable if fire or embers approach), and where possible, 'steering' the fire path to reduce the damage.

This is the central problem in fire management during intense seasons such as 2019-20. As a society, we are very successful at changing and controlling the world around us. We can change watercourses, dam rivers, irrigate dry country, clear forests, build large cities, drain and fill swamps, and generally shape the world to our plans. We therefore start with an expectation that all bushfires can be managed, and their risks mitigated, if only we could have better technology or do things better (fuel reduction, co-ordination, water-bombing, better tankers, calling in the army, etc.). Of course it is important to improve all of these things and more, and they will potentially lessen the damage and save more lives. There is no doubt that the improvements between 1993-94 and 2019-20 meant that many more lives and properties were saved than would have been the case if we had been using 1993-94 equipment and practices.

HOWEVER, the size and scale of bushfires in an intense season like 2019-20 (and more seasons that will follow with increasing frequency as the climate heats) are many orders of magnitude greater than anything that can physically be controlled by human agency. Understanding and accepting this, and framing fire management agendas to take this into account, is an essential requirement for reducing the impacts. This also means ensuring all people who live anywhere near bushland understand that the firefighting authorities cannot be relied upon to save their property, and may not even be able to save their lives, unless they have seriously understood and addressed the risks that they and their property face.

Incident Control Systems

The overall command and control of firefighting operations has improved dramatically between January 1994 and the 2019-20 season. A major factor has been the introduction and standardisation of the incident control system (ICS), which is based upon military command structures and emphasises the setting of strategic, tactical and local objectives and actions with clearly defined tasks, roles and responsibilities. The incident control team itself involves a range of different specialists providing intelligence and strategy (Planning) logistical support and co-ordination (Logistics) and the detailed operational command and control of the fire-fighting units on the fireground (Operations), with the Incident Controller and their Deputies making the overall command decisions. A major improvement has been the quality of intelligence provided to the ICS team, with newer technology such as remote infrared sensing, and the integration of information from GPS locating systems into computerised data and mapping software producing higher quality intelligence for decision-making and for operations on the ground.

When big intense fires start to run, however, the quality of the intelligence can be rapidly compromised, due to the speed with which the fire moves, and the huge amounts of smoke obscuring a clear view of the fireground. It also becomes a major challenge providing adequate mapping and planning information to each operational shift of firefighters that is prompt and accurate. Inadequate mapping and planning information is a major risk for firefighters, and has been implicated in many of the fireground fatalities in the past 25 years.

A significant error that often occurs under these circumstances is the diversion of all aircraft, and particularly helicopters, to operational fire combat and property protection (water-bombing), which then severely retards the flow of information to the planning section. This can have major flow-on impacts on the quality of the operational plans for the next 12-hour shift, as well as leading to fire-fighting units being dispatched to the wrong areas due to inaccurate information.

For any major fire, there should be at least one aircraft, preferably a helicopter, reserved for fire monitoring, mapping and intelligence-gathering at all times. This needs to be a clearly-stated policy, rather than left up to the individual incident controllers, as the pressure to put all available resources into immediate property protection under intense conditions can be overwhelming. However, the consequences of failing to continue to get the best intelligence on a rapidly changing situation are often failures of operational planning due to inaccurate information, and this leads to major risks and increased likelihood of fatalities.

Fire-Fighting Agencies and Co-ordinated Fire-fighting Responses

One fact that is not well understood by politicians or the wider community is the separate roles and expertise of the different fire-fighting agencies in NSW, namely Fire & Rescue NSW (F&R), the Rural Fire Service (RFS), NSW National Parks & Wildlife (NPWS), and NSW Forestry Corporation (FC). Most publicity goes to the RFS as the primary co-ordinating agency, and it is only fitting that the volunteers get a large share of the public credit for firefighting as they are contributing without financial reward. However, many people who do not understand the nature of the close co-operation between the agencies have tried to highlight the merits of one agency compared to another, and these differences have been used for short-term political gain to try and apportion blame, especially towards NPWS, (but localised rivalries between F&R and RFS should not be underestimated either). In 1994, non-RFS fire-fighters were often greeted by RFS crews with hostility, and there were instances where RFS crews disobeyed fire-fighting instructions because they perceived that it had come from another agency.

Thankfully, the recent tenure of Shane Fitzsimmons has dispelled much of the rivalry and hostility at higher levels, but there are still many pockets of cross-agency misunderstanding and distrust, and this is a dangerous thing when a major fire is being fought in confusing conditions.

As a general explanation of how it works on the ground, F&R crews have particular expertise in structural fires, and their firefighting starts in the street and goes to the back fence and sometimes a little beyond. They have a few crews who are trained and equipped to fight fires in the bush, but their vehicles are mostly limited to formed roads and work best off hydrant supply.

The RFS start in the backyard, and work into the bush on formed trails. They have some expertise in structural fires, but the majority of their fleet is all-wheel drive tankers, that can work a considerable distance from developed areas. They have some specialist crews who can do remote fire-fighting, however, most of their crews are trained to work off a tanker, and will generally be comfortable going several hose-lengths into the bush and no more. Their level of fitness and training is also quite variable, with some who are among the fittest and best-trained crews in NSW, but also a considerable number who have not had the time or inclination to do a lot more than basic training, and work from their experience, as you would expect with a volunteer force. The RFS provides the majority of the muscle to do the heavy lifting at fires, and especially property protection.

NPWS starts behind the back fence and works into the bush, often beyond the RFS sectors, and NPWS has a relatively high number of crew who are trained and experienced in working fully remote – without vehicles, inserted either by helicopter or on foot, and often working either without water (dry fire-fighting) or using remote water techniques such as buoywalls (mobile dams) or with support from precision helicopter bucketing. NPWS vehicles are generally smaller, and can go onto tracks that the large RFS tankers cannot negotiate (the RFS also has a few of these smaller tankers). NPWS are generally highly trained, and must pass stringent annual fitness tests, and they generally have a relatively high level of experience since the majority of the hazard reduction burning in NSW is on NPWS-managed land. In the incident control teams, NPWS staff usually fill the Planning and strategic/intelligence roles, both because they know the National Park land, and because they are trained and experienced in mapping, geographical information systems, and modelling fire behaviour.

FC crews are similar to NPWS, in that they generally work from smaller vehicles in more remote situations, but in recent years the Corporation has lost a fair bit of manpower and expertise with downsizing. FC do not do the same degree of RAFT work as NPWS, but also uses small tankers, and often has bulldozers with expert drivers to contribute.

There are other significant agencies such as the NSW Police, who manage traffic and evacuations, Soil Conservation Service who provide expert dozer drivers, and local government staff (amongst others).

There needs to be much better education about the integrated nature of fire-fighting in NSW, and the essential role played by all agencies in the total effort, to both politicians and the community. In recent years, NPWS has often been managed by senior managers and executives who have no experience in firefighting, and worse still, had no understanding of the vital role played by NPWS in the overall scheme of things. This caused some significant issues for a while, and could only come to pass because of the general ignorance in government about the nature of the co-operative fire-fighting arrangements. If there is wider understanding of what each agency brings to the overall effort, then perhaps the highly-distracting and destructive media comments that erupt during most significant fires may lessen, and the level of inter-agency co-operation and trust between crews may improve even further.

A major issue in dealing with the next significant season is an increase in the capacity to attack lightning strikes at the earliest possible stage, and I note with gladness that there has already been a promise of funding for increased RAFT capacity for this purpose.

Community Preparation and Awareness

There is still a very significant issue with community preparation and understanding of how a very intense fire will impact their own property and lives. The public education effort has increased a great amount since 1993-94, and building standards for bushfire-prone areas have also greatly increased. However, having a well-constructed building will not prevent it burning down if a high level of maintenance and protection is not provided, and many of the buildings that did burn in 2019-20 would not by any stretch of the imagination have been mapped as being in a fire-prone area (and certainly nowhere near the flame zone).

As mentioned previously, the factors that determine whether a house will survive are not only the major issues like design and materials, but also the fine detail, such as whether a coconut fibre door mat has been left outside a doorway, or whether air vents admit embers, or whether cypress pines have been planted close to the house (etc. etc.). These details are very unlikely to be addressed unless the occupants have been given a detailed inspection and run-down of what they need to address. Such education puts the occupants far more in charge of their own destiny, and will give them a better idea of whether they wish to stay and defend (i.e., whether they will be capable of staying and defending).

Sprinklers, an independent water source and an independently-powered pump are hugely important resources for increasing a house's chance of survival, but there is little understanding of this in the general community, and it seems like a complicated and expensive thing to install (which it does not have to be). It would be very cost-effective for insurance companies and/or the government to have an active program of rolling out sprinklers to those house that can retrofit them, encouraged by grants or insurance discounts.

There is an issue with the fact that the RFS is the responsible authority for community education. This is not because they are doing anything but an excellent job at community education, but because the task is huge, and the professional staff of the RFS are limited in number, and have to cover huge numbers of houses. Some of the RFS volunteers provide assistance with community education, and do a good job, but the volunteers join the RFS to fight fires and defend their community, not to critically appraise their neighbour's fuel management around their buildings. Again, there is likely to be large savings in buildings damaged or lost if local and State governments support a more vigorous and much better-supported program of community visits to educate people about how to reduce their fire risk on their own property. Quite a few of the burnt properties that I have personally seen from 2019-20 were clearly lost solely because there was combustible material near the house waiting to receive embers.

It is now quite clear from the experience of the 2019-20 season that in this heating climate human resources and technology can be completely overwhelmed by large intense fires for an extended period. The sooner that this is understood and acknowledged, the sooner we can have fire management planning and actions that clearly address these catastrophic situations and the altered fire response actions that they require. We can also have everyone across the community from politicians and public servants to ordinary householders aware of and willing to address the issues that arise in such a fire season. It will also underline the absolutely vital importance of taking prompt and comprehensive action in Australia to reduce our contribution to global warming, especially as it is likely that we Australians are far more likely to suffer significant environmental and economic damage than many other countries with milder climates.

I consider that it is vitally important that this Inquiry stresses the contribution of increased temperatures and drier conditions to the fire season of 2019-20, and also points out the increased likelihood of such seasons occurring more frequently as the climate heats up.

Continuity, Mentoring and Training.

As previously mentioned, the incident team in charge of the Central Coast section of the Gospers Mountain fire successfully used aerial incendiaries to stop the fire west of lower Mangrove Creek (and prevent it jumping the Hawkesbury as it did in 1993-94). I believe that this was possible in no small part due to the presence of at least one highly-experienced (but now retired) former firefighter, who had prior detailed experience with this technique dating from the 1993-94 fires, and used it regularly since. On the other hand, the backburn that was lit and lost off the Mount Wilson Road in an exact repeat of events in 1993-94 was very likely because of a contrasting loss of organisational memory. Both of these examples show the importance of continuity in fire-fighting. Going to 200 hazard reduction burns and wildfires under mild to fairly rough conditions will still in no way prepare you for the sheer size, scale, intensity and confusion of a series of big intense fires such as we experienced in 2019-20. Crews who went through the 1993-94 wildfires never forget it, just as crews will not forget this year's experiences. However, if we go another ten years without a huge season, then much of this experience may have retired, or gone to other occupations, without there being a strategy to ensure that experience is passed on to newer firefighters and the community.

Mentoring is also hugely important. Passing a firefighting course does not make you a safe fire-fighter (although it gives you a start), and being taught the on-ground appraisal skills that are necessary for safety on the fireground requires a fair bit of mentoring. This is currently a bit hit-or-miss, as some brigades and services do it well, while others lack the skills or the motivation, or the time. This can be a particular issue for rural brigades, as country people and especially farmers rarely have much time spare for extra activities, and their time at the brigade may be more likely to focus on fire response and work like hazard reduction, rather than a mentoring program or training courses.

Training has improved immeasurably since 1993-94, and the introduction of nationally-accredited training standards has been a major step forward. There is also a wider range of training, and more specialised courses. I believe that this improvement in training shows in the amazingly low death toll and loss of property, compared to the size and scale of the fire season.

Training is generally limited to a small proportion of the population, and of the emergency responders. Police often have a vital role to play, but rarely have any training in fire response. It would be a very worthwhile step to ensure that all Police officers working in areas likely to be affected by fire have done the equivalent of Basic Fire Modules training, perhaps with modifications to emphasise their own role. This would give them much better understanding of the situation that they are dealing with, and risks they (and the community) are facing.

There is a similar argument for at least some military personnel to be given fire training. In 2019-20, as in 1993-94, military resources were called in for support, and in both cases there was a fair bit of initial confusion and some wasted effort trying to co-ordinate a potentially effective resource which did not have a template for how to fit in to the fire-fighting structure. I realise that this is more the subject of the Federal inquiry, but undoubtedly the military will be called in again in the future, and if measures aren't taken to train and integrate them into the fire-fighting structure before the next time, then similar amounts of time will be lost and effort wasted before they slot into gear as a highly-valuable resource.

SUMMARY REMARKS:

The 2019-20 fire season was an exceptionally intense season, such as had not been seen in eastern NSW for 25 years since 1993-94, and it exceeded 1993-94 in extent and duration by a considerable margin (although there have been quite a few seasons with several big intense fires in-between these two seasons).

The size and scale of many of the fires experienced in 2019-20 was a very great distance beyond anything that could be controlled by human agency. This fact was not well understood by the community or by many politicians. These fires were also well beyond anything that could be controlled by previous hazard reduction programs, (except occasionally in a very localised, minor way).

Global heating makes the recurrence of such an intense fire season more likely, and it is absolutely essential that we understand that these are the real consequences of a heating planet affecting us in a hugely-detrimental way right now, not in 2050 or at any other future deadline. Minimising our impact on the climate is an absolutely essential action for future fire management in NSW and Australia.

Interception of fire ignitions at an early stage, and especially extinguishing lightning strikes in remote areas, is often the only realistic chance of stopping the development of a runaway intense fire in such climatic conditions.

When an intense fire goes for a run, firefighting teams and the general community need to understand that the rules of the game have completely changed, and that defence of life and property is often the only practicable response. While the efforts to communicate this were exceptional, particularly through the up-to-date mapping on the RFS website (Fires Near Me), it is also clear that the message did not get through to many people, and we had much public angst about what had 'gone wrong', rather than understanding and appreciation of exactly how much had been done well under impossible circumstances.

All firefighters need to understand that tactics that may work under 'normal' extreme conditions will no longer work in the catastrophic conditions experienced this season. Backburns, especially from ridgetops, become incredibly difficult to light and control, while conversely lighting large areas with incendiaries may be the best way of halting the fire's progress, if done by skilled operators under the right conditions.

The emphasis in fire protection and mitigation needs to shift greatly onto the importance and responsibilities of individual landowners, rather than relying on hazard reduction burns done by firefighting authorities. These hazard reduction burns are still important, but often far less so than risk management action on individual properties. The impacts of hazard reduction, and the mixed benefits of more frequent burning in some vegetation types also needs to be more widely understood, both by land managers and by the community.

Until it is widely understood that hazard reduction burning is not the magic bullet that would have stopped these fires or similar 'big' fires to come, then people will continue to externalise responsibility for their own safety, rather than do the many possible actions that can greatly lower their risk.

A major appraisal and support program for fuel and risk management on individual properties is very sorely needed. This needs to involve more resources and organisations than just the RFS (who already have a great deal on their plate) and be done in a supportive and non-judgemental manner by skilled appraisers, with an emphasis on the actions that will improve safety.

This inquiry, as well as individual organisational reviews of the fire season, need to draw out lessons about what worked and what failed during 2019-20, (both in fire-fighting and in the wider community) and ensure that these lessons are made widely available and passed on to people who didn't experience them.

The lessons and experience from 2019-20 must be used to mentor less-experienced firefighters over coming seasons, and much improved efforts to ensure continuity and passing-on of knowledge must be made to ensure this experience is not lost again.

Environmental recovery efforts are essential when such a high proportion of the bushland habitat has been burnt. A much greater integration of weed management with fire programs is sorely needed, especially as many of the weeds in question may increase the fire risk if they are allowed to proliferate after the fire (such as African Love Grass).

Seen through the lens of 1993-94, and the seasons since, the firefighting efforts in 2019-20 were very good, and greatly improved from 25 years ago. Whilst there are undoubtedly further improvements that can and will be made, I believe that 2019-20 has demonstrated clearly that the best firefighting response capability in the world will still not be able to control intense runaway fires under such conditions, any more than a tornado can be stopped. Future efforts need to focus on preventing these conditions getting worse, through minimising further global heating, and on adjusting to the reality of uncontrollable fires coming at people and assets, and the on-ground protective measures that can be taken in detail at individual properties to lessen the threat that these fires will pose.

Thank you for considering this submission.

Sincerely

Jonathan Sanders