

GUIDELINES ON RED FLAG WARNINGS AND WATCH-OUTS FOR FIRE CREWS OPERATING IN RUGGED LANDSCAPES



ARISING FROM
RECENT RESEARCH INTO
FIRE BEHAVIOUR
IN THE HIGH COUNTRY.

The photo, by a member of the public, and looking northwest from Urambi Hills in Canberra's southwest, shows fire moving onto Mt Stromlo from the west. Three smoke columns are visible, and the winds are from the west. The middle column is moving to the south, indicating a channelling event. A severe thunderstorm has formed overhead, in the convection column, which is part of a plume-driven fire.

PREAMBLE

Most fire crews in Australia already have a list of watch-outs close-to-hand when they are on a job. Through training they are familiarised with these and, hopefully, will be vigilant when a potentially dangerous situation develops.

Through the Bushfire Cooperative Research Centre's HighFire Risk Project, we now have a vastly improved knowledge of the key drivers of dangerous fire behaviour in rugged landscapes. Very little of this new understanding was available when past watch-out lists were developed.

Most of the wildfire suppression industry in southeast Australia is founded on the McArthur meter system and its derivatives. What these are based on is a weather continuum, and a fire danger index that reflects that weather. As the weather – temperature, relative humidity, wind speed and drought – changes, so too does the fire behaviour, in a predictable manner.

We now know that most of the catastrophic fire events in the high country of southeast Australia have been driven by discrete events that are not part of the weather continuum. They therefore are not picked-up by the fire danger indices.

We also suspect that these same events have been involved in many fire crew fatalities both here and overseas.

Thunderstorms and wind changes are well-known examples of discrete weather events, for which fire crews are *already* well briefed. They are included here to make a more complete list.

It is thus essential that we work to make fire crews vigilant for these events and able to immediately react in the prescribed safe manner. It is important that no-one delays the required actions because they were unfamiliar with the exotic concepts of channelling, foehn winds or whatever else nature throws at us.

In the US they have a system of Red Flag Warnings: “A Red Flag Warning is a forecast warning issued by the United States National Weather Service to inform area firefighting and land management agencies that conditions are ideal for wildland fire ignition and propagation.” We need to go beyond that system, as the events now known to be dangerous in southeast Australia are often not detected in the Australian weather observation network. We need to rely as much of the observational skill of fire service staff, and on a diverse range of internet resources.

To further aid this cause, a series of watch-outs are also provided to give some guidance as to what things might look like. Further detail is available through the HighFire Risk web site.

Just to repeat for clarity:

- Watch-outs are based on observing things happening.
- Red Flags warnings are signals that incident management objectives need to be reviewed, if not altered, on the basis of threats to safety.

This list is intended to AUGMENT, not replace, any existing lists of watch-outs or safety alerts.

| RED FLAG CONDITIONS | | |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Cause¹ | Implications | Recommended reactions² |
| 1) Plume-driven fire observed or detected. | Extremely dangerous spread, based on upper winds. | [A] Immediately set incident objectives to saving life and, if safe to do so, property. |
| 2) Conditions conducive to plume-driven fire forecast. | Possibility of plume-driven fire forming. | [C] Ensure safety focus on all sectors. Set up observation capability. Develop fall-back IAP. |
| 3) Passage of dry slot over fire forecast or detected. | Potential for violent escalation of fire. | [C] Ensure safety focus on all sectors. Set up observation capability. Develop fall-back IAP. |
| 4) Thunder-storm observed, detected, or forecast. | Possibility of erratic fire behaviour with downbursts, etc. | [B] Immediately withdraw all resources from relevant sectors. Review incident objectives. |
| 5) Wind change forecast, detected or observed | Wind changes can turn a flank into – longer – headfire, endangering crews working on direct suppression. | [B] Immediately withdraw all resources from relevant sectors. Review incident objectives. |
| 6) Channelling event detected or forecast. | Dangerous fire behaviour around and downwind. | [B] Immediately withdraw all resources from relevant sectors. Review incident objectives. |
| 7) Dew point depression event detected, observed or forecast. | Dangerous fire behaviour in areas affected. | [C] Review IAP, based on escalation of FFDI. |
| 8) Foehn wind forecast or detected. | Localised dangerous conditions may occur. | [C] Ensure safety focus on all sectors. Develop fall-back IAP. |
| 9) Unusual combustion observed. | Localised dangerous conditions may occur. | [C] Ensure safety focus on all sectors. Develop fall-back IAP. |
| 10) Intense spotting observed. | Likelihood of a channelling event underway. | [B] Immediately withdraw all resources from relevant sectors. Review incident objectives. |

¹ Observed = seen by field or aerial observer (these need to be tasked to record weather, fire and convective patterns);
Detected = noticed in remote sensing, such as WeatherWatch radar, weather satellite imagery (Vis, IR & WV), MODIS/AVHRR imagery or lightning detection systems;
Forecast = indicated as likely by a fire weather forecaster or forecast product.

² These reactions fall into three priorities:
[A] absolute priority, abandon all other actions;
[B] highest priority, review urgency by sector and act immediately if required;
[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis.

DETAILS

| Cause | Detection requirements | Required reaction ³ |
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| <p>1) Plume-driven fire observed or detected.</p> | <ul style="list-style-type: none"> • Observers on ground in either cross-wind quadrant, >5km from fire, tasked to look for cloud formation before mixing starts within plume, and make a report to Situation Unit if a development occurs. • Aerial observers tasked to assess and make a report to Situation Unit on plume dynamics every half hour. • Situation Unit staff monitoring BoM radar for active returns above fire ground. • A violent pyro-convection watchout is received from the field. | <p>[A] absolute priority, abandon all other actions Situation Unit staff advising Planning Officer of <i>potential</i> Red Flag situation and seeking a second source of intel as confirmation before advising on <i>actual</i> Red Flag situation. PO to immediately discuss with IMT. On confirmation the PO is to immediately meet with the IMT and declare the current IAP suspended and switch the Incident Objective to protecting life and, if it is safe to do so, property. It is essential that no backburns be lit, as these add to the event.</p> |
| <p>2) Conditions conducive to plume-driven fire forecast.</p> | <ul style="list-style-type: none"> • A Special Fire Weather Forecast advising of weather conducive to a plume-driven fire. • Situation Unit discussion with duty fire weather forecaster suggests weather conducive to a plume-driven fire. | <p>[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis. Situation Unit staff are to advise Planning Officer of the need to factor the <i>potential</i> Red Flag situation into current and next IAPs.</p> |
| <p>3) Passage of dry slot over fire forecast or detected.</p> | <ul style="list-style-type: none"> • A Special Fire Weather Forecast advising of an approaching dry slot. • Situation Unit staff monitoring of water vapor imagery suggests a need to discuss the potential with the duty fire weather forecaster. • Scheduled Situation Unit discussion with duty fire weather forecaster suggests approach of a dry slot is a concern. | <p>[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis. Situation Unit staff are to immediately advise the Planning Officer of an <i>actual or imminent</i> Red Flag situation and the potential rapid escalation of the fire when the dry slot arrives. Situation Unit is to establish a suitable observation capability, tasked to look out for escalation. Operations Officer is to ensure a heightened emphasis on safety in all sectors. Planning Officer to meet</p> |

³ In terms of type of Red Flag situation, ACTUAL = an event is occurring; IMMINENT = an event is expected and is likely to occur; POSSIBLE = an event may (or may not) occur.

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| | | with IMT to develop fall-back IAP. |
| 4) Thunder-storm observed, detected, or forecast. | <ul style="list-style-type: none"> • A Severe Weather Warning advises of thunderstorm development. • Situation Unit staff monitoring of weather radar and stability models suggests a need to discuss the potential with the duty fire weather forecaster. • Scheduled Situation Unit discussion with duty fire weather forecaster suggests thunderstorm formation is a concern. • Possibility of safety issues arising from storm phenomena: downbursts creating erratic fire behaviour; lightning; flash flooding; strong winds bring down trees; loss of air operations. | [B] highest priority, review urgency by sector and act immediately if required. Situation Unit staff are to immediately advise the Planning Officer of an <i>actual or imminent</i> Red Flag situation. Planning Officer is to assess affected sectors and work with Operation Officer to ensure safety of all crews in those sectors until the storm threat has abated. Planning Officer to meet with IMT to review incident objectives. |
| 5) Wind change forecast, detected or observed | <ul style="list-style-type: none"> • Duty fire weather forecaster forecasts a wind change. • Field observers, air observers, sector leaders or crew leaders report a significant change in the direction of overall movement of the smoke plume. • Meteorological measurements indicate an unforecast wind change moving across the region towards the fire. | [B] highest priority, review urgency by sector and act immediately if required. Staff are to immediately advise the Planning Officer of an <i>actual or imminent</i> Red Flag situation. Planning Officer is to assess affected sectors and work with Operation Officer to ensure safety of all crews in those sectors until the weather settles. Planning Officer to meet with IMT to review incident objectives. |
| 6) Channelling event detected. | <ul style="list-style-type: none"> • A fire is burning or has been recently contained in a part of the landscape that is conducive to channelling under the weather conditions current or forecast. • An aerial observer, or other field officer, observes a watch-out situation for channelling driving a fire. | [B] highest priority, review urgency by sector and act immediately if required. Situation Unit staff are to immediately advise the Planning Officer of an <i>actual or imminent</i> Red Flag situation. Planning Officer is to assess affected sectors and work with Operation Officer to ensure safe evacuation of all crews in those sectors until conditions abate. Planning Officer to meet with IMT to review current and next IAPs. |

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| <p>7) Dew point depression event detected, observed or forecast.</p> | <ul style="list-style-type: none"> • Where a fire is burning over a range of elevations generally crossing the 1500m ASL contour, weather observations must be obtainable from BoM, deployed field observers or real-time data-feed portable automatic weather stations. The reporting should be to a minimum repeat rate of half-hourly. The goal is to detect weather patterns that differ from extrapolations from forecast and observed weather at the nearby reference station[s]. | <p>[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis.</p> <p>If Situation Unit staff detect a consistent trend to depressed dew points (over three or observing sites or over one hours duration) they are to immediately advise the Planning Officer of an <i>actual</i> Red Flag situation.</p> <p>The Planning Officer is meet with the IMT to review incident strategies.</p> |
| <p>8) Foehn wind forecast or detected.</p> | <ul style="list-style-type: none"> • A special fire weather forecast or a discussion with the duty fire weather forecaster advising of the potential for a foehn wind to develop. • Situation Unit staff monitoring weather data and satellite imagery on the internet, detecting the features of a foehn event forming in the region. This should be followed by a discussion with the duty fire weather forecaster. • Field staff report a Foehn Wind Watchout Situation. | <p>[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis.</p> <p>Situation Unit staff must immediately advise the Planning Officer of an <i>actual or imminent</i> Red Flag situation.</p> <p>Planning Officer to meet with IMT to review current and next IAPs.</p> |
| <p>9) Unusual combustion observed.</p> | <ul style="list-style-type: none"> • Sector leaders, field observers and aerial observers need to report back any observations of extreme or inexplicable fire behaviour (fire balls, sheets of flame, fire whirls, etc). • Field staff report an unusual combustion Watchout Situation. | <p>[C] high priority for review of safety in all sectors, and ensuring IAP options are developed on a just-in-case basis.</p> <p>Situation Unit staff must immediately advise the Planning Officer of an <i>actual</i> Red Flag situation.</p> <p>Planning Officer is to assess affected sectors and work with Operation Officer to ensure safe evacuation of all crews in those sectors until conditions abate.</p> <p>Planning Officer to meet with IMT to review current and next IAPs.</p> |
| <p>10) Intense spotting observed.</p> | <ul style="list-style-type: none"> • Aerial observers need to be tasked to report the onset of intense spotting extending over an area of at least 1sq.km. | <p>[B] highest priority, review urgency by sector and act immediately if required.</p> <p>Upon receipt of such reports, Situation unit staff need to verify if the terrain</p> |

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| | <ul style="list-style-type: none">• Sector leaders need to be tasked to report if their tactics have failed due to intense spotting. | immediately upwind is conducive to channelling. If so they must report an <i>actual</i> Red Flag situation to the Planning Officer. Planning Officer is to assess affected sectors and work with Operation Officer to ensure safe evacuation of all crews in those sectors until conditions abate. Planning Officer to meet with IMT to review current and next IAPs. |
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Note that (1) and (2) are written in a conservative form. In the alternative (1) could require obligatory suspension of the current IAP and (2) could be a reaction of type B.



The second most intense pyro-convection ever recorded. Only Red Flag warning number 8 would not have been applicable at the time. The highest reaction level prescribed would be A, to Red Flag warning 1.

WATCHOUT: LENTICULARIS CLOUDS

In a generally clear sky, the formation of lens-shaped clouds aligned with the main ranges is a sign of strengthening winds. The clouds show the crests of a wind wave caused by flow over the ranges, and there may be a series of additional wind waves further to the lee of the ranges. Where the troughs of these hit the ground there will be locally amplified winds.

In a FLIR image lenticularis clouds can be seen to reflect strongly from the sky the infrared output from a fire.

The Planning Officer must have an immediate discussion with the duty fire weather forecaster upon receiving a report of lenticularis developing near a fire, to consider unforecast wind speeds.

POTENTIAL RED FLAG WARNINGS:

- **Conditions conducive to plume-driven fire**



Figure 1. A screenshot from an airborne thermal video of fire at Thredbo in January 2003. In this image dark is cold, white is hot. The lowest white areas are the fires on the ground. Above them, but below image centre, is the thermal reflections off the bases of pyro-cu clouds forming above and slightly downwind of the fires. Near the image top is thermal reflection off a band of lenticularis clouds indicating a mountain wind wave. It is likely that these waves influenced fire activity. Note that lenticularis are very cold and are composed of ice crystals, which reflect thermal radiation from below. Imagery courtesy of Australian Government.

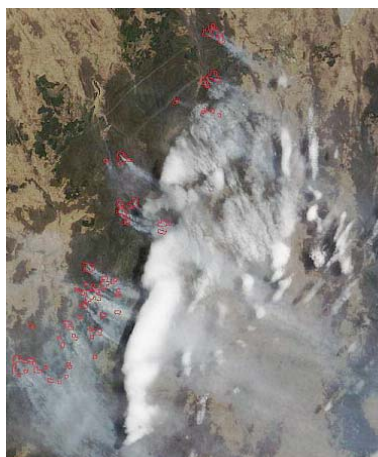


Figure 2. MODIS image of lenticularis clouds indicating intense mountain wind waves, ACT, 17 January 2003. Rectified imagery courtesy of NASA Goddard Space Flight Centre.

WATCHOUT: FOEHN WALL, FOEHN GAP & FOEHN ARCH

The particular pattern of clouds associated with a foehn wind can be seen from the ground, depending on where you are on the terrain. If two or more of these features are seen then it may indicate a pending deterioration of fire weather.

The Planning Officer must have an immediate discussion with the duty fire weather forecaster to assess whether any unforecast weather effects might occur.

AUTOMATIC RED FLAG WARNINGS:

- **Foehn wind**

POTENTIAL RED FLAG WARNINGS:

- **Wind change**
- **Dew Point depression event**

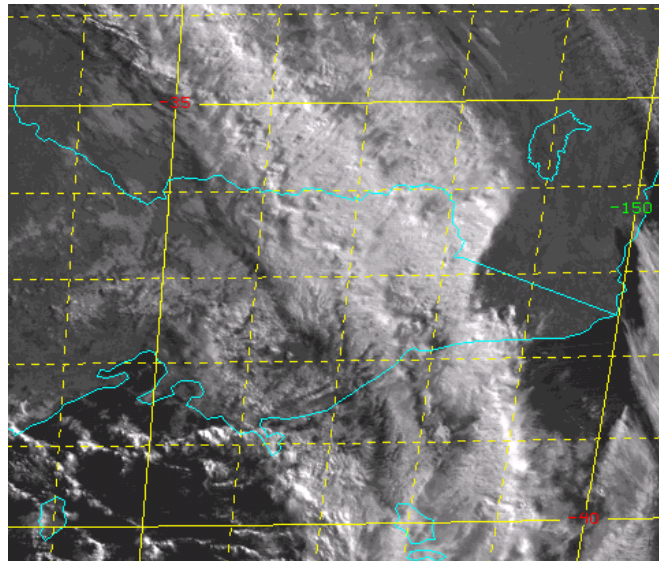


Figure 3. Satellite image of a foehn event over southeast Australia. A cold front is seen moving west to east, with rain clouds in a NW-SE band. Ahead of this more rain clouds are seen to the west of the Great Divide. The eastern edge of this is a Foehn Wall. A Foehn Gap is present over the Monaro region, and the upper clouds forming the Foehn Arch are seen just offshore. Note that the shadows from the Arch clouds are much longer than those off other clouds. Being high and cold the arch clouds are easy to see in infrared imagery. Cloud streakiness indicates strong winds ahead of the front. (Courtesy of BoM)



Figure 4. Moist air being partially blocked by the Liverpool Ranges near Muswellbrook. Note the downslope flow where clouds are overtopping the range. This is a Foehn wall.

WATCHOUT: CHANNELLING

There are a series of phenomena that may be observed that strongly indicate that channelling is occurring in a fire. Should this happen then a serious safety concern is indicated.

Firstly, an observer looking across the prevailing wind flow might see a valley aligned across the wind filled with smoke, and with the smoke reaching the top of the main slope in the windward direction, but with the top of the smoke being shorn off in the downwind direction. An eddy wind is taking the fire upslope to the windward, and is a component of fire channelling.

Secondly, an observer looking downwind at the rear of the fire, or of a fire run, over the top of a ridge aligned across the wind, might see a strengthening of the convection on one extreme of the smoke plume. This strengthening might take on an orange or tan colour. Further, this element of the smoke might be moving laterally, across the wind flow, but still lying in behind the ridgeline. The top of the plume will be blown downwind in all instances. This is the sign of the fire become intense within the eddy winds.

Thirdly, an observer downwind of the main fire activity may begin to see frequent, intense spotting, possibly preceded by dense ash or embers. Firstly that observer should leave immediately for their own safety, but secondly they must report the likely consequences of a channelling event occurring.

In all cases the entire part of the landscape where the channelling is occurring, either side of it and for some kilometres downwind is unsafe. Other parts of the fireground that are prone to channelling may also be unsafe. An immediate review of operations by the IMT is essential.

AUTOMATIC RED FLAG WARNINGS:

- **Channelling event**

POTENTIAL RED FLAG WARNINGS:

- **Conditions conducive to plume-driven fire**
- **Intense spotting**
- **Unusual combustion**



Figure 5. A mosaic from airborne video footage of a forced channelling event underway, northern Brindabella Ranges, 26 January 2003. Note colour of the smoke on the left, where the fire has moved into a gully and entered an eddy wind. Channelling is moving the fire towards the observer and at the same time igniting the countryside downwind (to the left). Note the wispy smoke from a new spotfire on the lefthand edge of the image.

WATCHOUT: VIOLENT PYRO-CONVECTION

As a general rule of thumb the plume off a fire will resist mixing with the surrounding air for a height of the same scale as the dimension of the flaming zone. Prior to the mixing kicking in the plume is vigorous enough to have an influence on the fire's behaviour.

An observer should note the height of the condensation level (or cloud base). Should the flaming zone achieve a size similar to the height, then moisture in the plume will condense and release up to triple the energy of the fire into the plume. This is a serious concern. This is not the same as a cloud forming in the plume, which will often happen after mixing has occurred.

The flaming zone can achieve that size through:

1. A wind change making the flank the new headfire.
2. Channelling
3. Massive forward rate of spread.

Any of these need to be considered.

Should an unmixed plume form a cloud, then a cauliflower-like appearance to that cloud is especially dangerous.

If any of this is observed, the entire fireground might be unsafe and the IMT needs to immediately review all actions.

AUTOMATIC RED FLAG WARNINGS:

- **Plume-driven fire**

POTENTIAL RED FLAG WARNINGS:

- **Passage of dry slot over fire**
- **Thunderstorm**



Figure 6. Another event showing many of the key features to watch for:

- **A thin lenticularis cap cloud, formed as air flows over the top of the plume**
- **The main plume is expanding backwards into the wind above the cloud base**
 - **An anvil forming and flowing away downwind**
 - **Much of the smoke being left behind at the cloud base**

Photograph, of the Mt Cooke Fire, WA, 10 Jan 2003, courtesy of ICS Group.

WATCHOUT: THERMAL BELT

Thermal belts can alter the expected gradient in fire behaviour with elevation across rugged landscapes. Decision to carry out night-time backburns may be unsafe if a thermal belt forms, but is not anticipated.

Likely prerequisites for a thermal belt to form are:

- A clear night
- Light winds overnight
- Rugged terrain
- Low relative humidity at low elevations at sunset.

Should crew leaders, field observers or Operations staff detect these conditions, then the strategy needs to be reviewed immediately. This watchout does not indicate a Red Flag warning.

It must be noted that knowledge of the formation of a thermal belt permits a better planned backburn to be implemented, and as such may be a benefit.



In rugged landforms, crews should think carefully when night-time backburns are unexpectedly intense.

WATCHOUT: UNUSUAL COMBUSTION

There is an extensive bushfire “folk lore” about unusual fire behaviour. Many large fires produce reports of fireballs or sheets of flame. Recent research has shown how these might be real events, and that they may tell us something about intense fires.



Some examples of unusual combustion. Top-left: anything close to the ground igniting, while trees are left intact; top-right: an ember storm blowing parallel to the ground; bottom-left: embers being generated from a mulch bed; bottom-right: spot fires merging into an intense localised fire.

Any deviation of fire behaviour from the standard “teachings” should be immediately reported up the line as a Watchout.

AUTOMATIC RED FLAG WARNINGS:

Unusual combustion.

MORE ON WATCH-OUTS

The rural firefighting industry has a standard training programme. This includes training on fireground safety, which covers watchouts. Using the ACT implementation as an example, it is useful to compare the standard material with the material in this report. To cite the “ACT ESA Basic Wildfire Awareness” Module... Remember the memory jogger WATCHOUT when on the fireground.

- Weather dominates fire behaviour, so stay informed
- Actions must be based on current and expected fire behaviour
- Try out at least two escape routes
- Communications maintained with your crew leader and adjoining crews
- Hazards to watch for are heavy fine fuels and steep slopes
- Observe changes in wind speed and direction, temperature, humidity and cloud
- Understand your instructions and make sure that you are understood
- Think clearly, be alert and act decisively before your situation becomes critical

It is apparent that the material in this report is covered by “Weather” and “Observe”.

The Module also lists 18 specific watchouts, of which some are relevant:

3. The wind changes speed or direction
4. The weather gets hotter or drier
8. Unfamiliar with weather and local fire behaviour
9. Frequent spot fires occur over your control line
17. The potential of the fire has not been assessed

It is clear that this material is oriented towards fire crews tasked to Operations Unit for suppression actions. The material in this report is oriented more towards the needs of the Situation Unit, and so has a more specific and more technical focus. However, the Events identified for Field Observers to look for are also relevant for all Operations crews. Thus it is recommended that crew leaders be given the opportunity to become familiar with this material.

Under “think” it is stated that you should “be alert and act decisively”. This is true of everything discussed in this report. The key is not to treat this report as prescriptive – it is guidance. If an Air Observer sees a fire crew in immediate threat from an Event, then it may be common sense to ensure that crew’s safety before making a report back to the IMT.