BLACKWOOD DISTRICT FIRE 29
LEEUWIN NATURALISTE NATIONAL PARK
6 & 7 APRIL 2006

NARRATIVE

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Summary

On 6 April 2006 the Department of Conservation and Land Management (CALM) commenced a prescribed burn in 14 year old forest fuel in the southern part of the Leeuwin Naturaliste National Park. Burning operations proceeded without incident until late afternoon when spot fires from within the burn breached the north-western boundary and ignited coastal shrubland west of Caves Rd. Direct attack was not successful and spot fires merged to form a head fire that burnt to the coast by midnight under the influence of overnight easterly winds. Fire suppression operations were undertaken on 7 April to contain the fire west of Caves Rd and south of a management access track linking Caves Rd to the coast. This involved crews burning back (edging) from existing tracks to create a fuel reduced zone as a barrier to further spread of the fire. Wind direction and strength varied considerably over the fire ground during the day, although upper level winds remained easterly. By mid afternoon southerly winds had pushed several very intense head fire fronts towards the northern containment line which was breached in several places by spotting. At around 1700 hrs, two CALM personnel on a heavy duty 4x4 truck working to extinguish spot fires on the north side of the containment line were caught in a localised but very intense whirlwind. The hose operator on the back of the truck was exposed to severe heat and flying debris but avoided serious injury by seeking shelter between the cab and tank, and cooling his surroundings with water spray from a hose. The truck itself suffered substantial damage from flying debris and secondary damage from direct flame contact, although the driver was not injured. There is insufficient information to explain the mechanisms responsible for the development of this unusually strong whirlwind, but contributing factors could include complex wind patterns over the fire ground, the dense shrubland fuel type, and the use of line ignition techniques for edging. The severity of the fire whirl surprised even experienced personnel who work with fire on a regular basis, particularly as the burning conditions at the time were relatively mild. The fact that the personnel involved in the fire whirl incident were experienced and alert to the potential danger of the situation avoided more serious injury. This event provides a timely reminder that firefighters and incident management teams must remain alert to the possibility of unexpected fire behaviour, and highlights the importance of regular refresher training in basic fire safety procedures for all personnel venturing onto the fireground.

1. Introduction

On 6 April 2006 the Department of Conservation and Land Management (CALM) commenced a prescribed burn (BS_236) in 14 year old forest fuel in the southern part of the Leeuwin Naturaliste National Park. Prescribed burning was undertaken for the purposes of community protection and biodiversity management. During the late afternoon spot fires from within the burn breached the north-western boundary of the burn area and ignited dense coastal shrubland west of Caves Rd. This escaped fire subsequently burnt for several days and required the mobilisation of significant firefighting resources from CALM, the Forests Products Commission and local volunteer bush fire brigades. The fire resulted in temporary closure of some public roads and tracks and damage to facilities within the national park, including infrastructure associated with cave visitation. Two CALM personnel engaged in fire suppression operations were caught in a localised but very intense whirlwind that resulted in one person receiving superficial burns and damage to a truck.

This report describes events on 6 and 7 April with a focus on the implementation of the prescribed burn and fire suppression operations up to about 1700hrs on 7 April when the incident involving the two CALM personnel occurred. The purpose of the report is to provide a concise summary of the following issues:

- weather conditions influencing the prescribed burn and subsequent unplanned fire,
- predicted and observed fire behaviour,
- factors that may have contributed to the development of the unexpectedly severe whirlwind.

Information sources used to compile this report include burn prescription documents prepared by Blackwood District, the fire diary and associated records compiled by the Incident Management Team, personal fire diaries and interviews with firefighters. Personnel who provided information are listed in Appendix A.

2. Burn prescription documents

The objectives for prescribed burn BS_236 were:

Primary: Protection

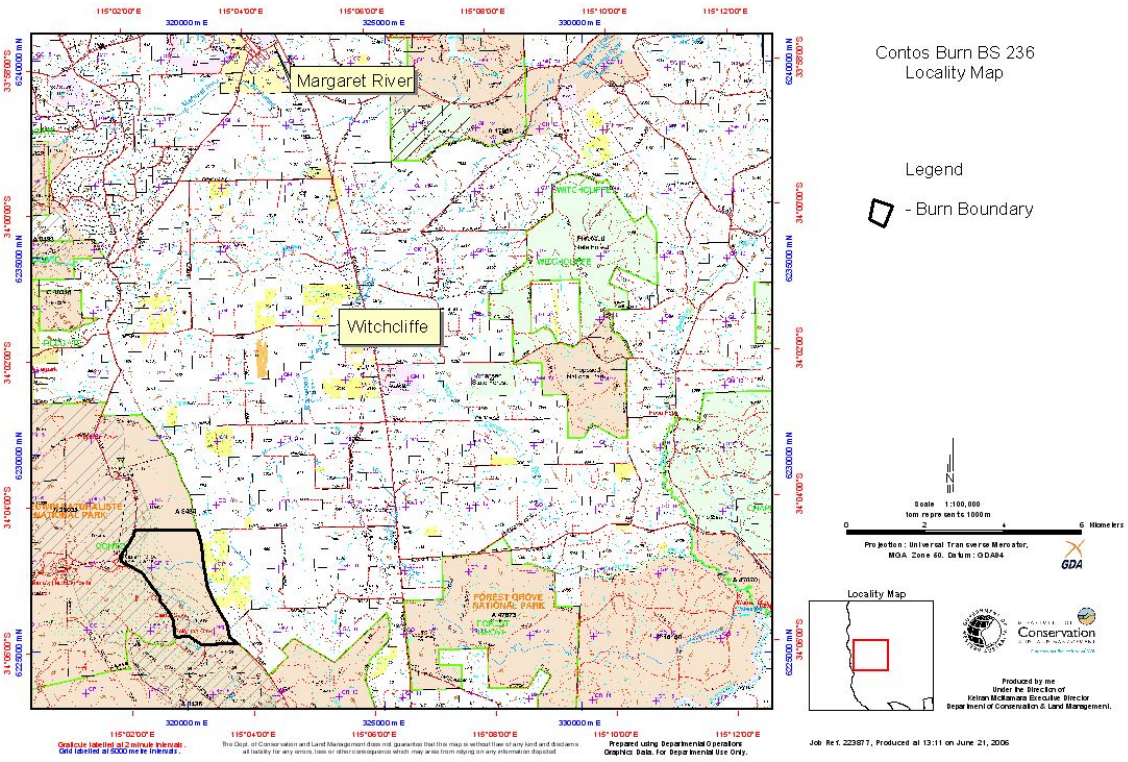
> *To minimise the potential size and intensity of wildfires and/or the risk of damage from wildfire to the caves, infrastructure, visitors, private property and nearby powerlines by the application of fire under prescribed conditions to reduce the quantity of combustible material.*

Secondary: Biodiversity Management

> *To protect, maintain and enhance biodiversity values and ecological processes within the precinct of Leeuwin Naturaliste National Park by applying fire under prescribed conditions to achieve a mosaic of fire intensities and burnt and unburnt areas at both a landscape and a local scale.*

The burn included 448 ha of the Leeuwin Naturaliste National Park in the locality known as Contos. This area forms part of an extensive karst landscape and is well known for its deep caves and other karst features. The boundaries of BS_236 are Caves Rd on the west and south, Forest Grove Rd on the north, and a management access track adjoining private property on the eastern side. Vegetation is predominantly open forest of karri (*Eucalyptus diversicolor*) up to 50 m tall mixed with marri (*Corymbia calophylla*) and jarrah (*Eucalyptus marginata*), with a section of heath and open woodland in the north east corner of the burn. The forest supports a dense understorey with *Agonis flexulosa*, *Banksia grandis* and *Xanthorrhoea preissii* as prominent taller species.

Map 1. Contos prescribed burn (BS_236) locality map



The prescription for BS_236 was based on a fuel assessment conducted using the standard techniques described in the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1998). Total fuel quantity ranged from 13-20 t/ha in jarrah-marri type forest and from 23-37 t/ha in karri forest. A Fire Danger Index (FDI) of 18–22 m/hr was prescribed for the core ignition in jarrah-marri forest, with an index of 26–30 m/hr for karri forest.

The Western Ringtail possum has been recorded in areas adjacent to the burn, and the prescription sought to achieve a low intensity mosaic burn within stands of peppermint (*Agonis flexuosa*) likely to provide food and shelter for possums. The burn area also contained two priority flora species *Acacia subracemosa* (P2) and *Bossiaea disticha* (P3). Both species are known to regenerate well following fire events at an interval greater than four years.

The burn area contains two recreational cave sites at Golgotha Cave and Giants Cave. Giants Cave contains infrastructure which was excluded from the burn with rake trails and edging. Both sites were closed prior to the burning operation commencing.

3. Weather conditions and predisposing factors

3.1 Seasonal dryness and fuel moisture content

The Bureau of Meteorology maintains an automatic weather station (AWS) at Witchcliffe 8 km north east of the burn area. Rainfall at Witchcliffe was 3.8 mm in February and 26.4 mm in March compared to monthly averages of 11 mm and 17 mm respectively. Rainfall of 3.4 mm was recorded on 3 April with a further 0.4 mm the following day. Rainfall records maintained by the landowner of Loc. 2703 which adjoins the southern boundary of the burn indicated a total of 42 mm during March and 3.3 in April prior to the commencement of the burn.

The Soil Dryness reading at Witchcliffe was 154 on 6 April, having declined by about 10 points from the maximum summer value.

Rainfall and temperature records from Witchcliffe were used to calculate the profile moisture content (PMC) using the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1998). The PMC represents the moisture content of the entire litter layer above mineral soil and is an indicator of potential fuel consumption and fire intensity. The PMC fell below 20 per cent during mid March but by 6 April had risen to 55 per cent as a result of several rainfall events. This is within the normal range for prescribed burning in karri fuel types. Experienced staff inspected fuel moisture conditions on several occasions prior to commencing the burn, although no samples were collected for oven dry moisture determination.

3.2 Forecast and actual weather conditions

The routine weather forecast for Witchcliffe on 6 April was for fine conditions with a maximum temperature of 23 degrees and minimum relative humidity of 38%. Wind speeds were forecast at 15 – 18 km/hr from the east in the morning and south east in the afternoon. Actual conditions matched the forecast (Table 1).

Table 1. Forecast and actual winds at Witchcliffe AWS for 6 April

Time	Forecast wind speed (km/h)	Actual wind speed (km/h)	Forecast wind direction	Actual wind direction
1000 - 1200	16	9	E	E
1200 - 1400	15	13	ESE	ESE
1400 - 1600	15	11	SE	E
1600 - 1800	18	17	SE	SSE
Overnight	15	10	E	SE

The Surface Moisture Content (SMC) represents the moisture content of the upper 10 mm of the leaf litter layer on the forest floor and provides a measure of the ease of

ignition and potential rate of spread of a fire. Litter samples taken from jarrah-marri forests on the morning of the 6 April and tested with a Wiltronics moisture meter had SMC's of 12–15% which is within the normal range for prescribed burning in forests. This moisture content range was used to determine an estimated fire rate of spread for the day of 18–23 m/hr using the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1998). This rate of spread was within the prescribed FDI range for the burn.

4. Implementation

4.1 Decision making prior to ignition

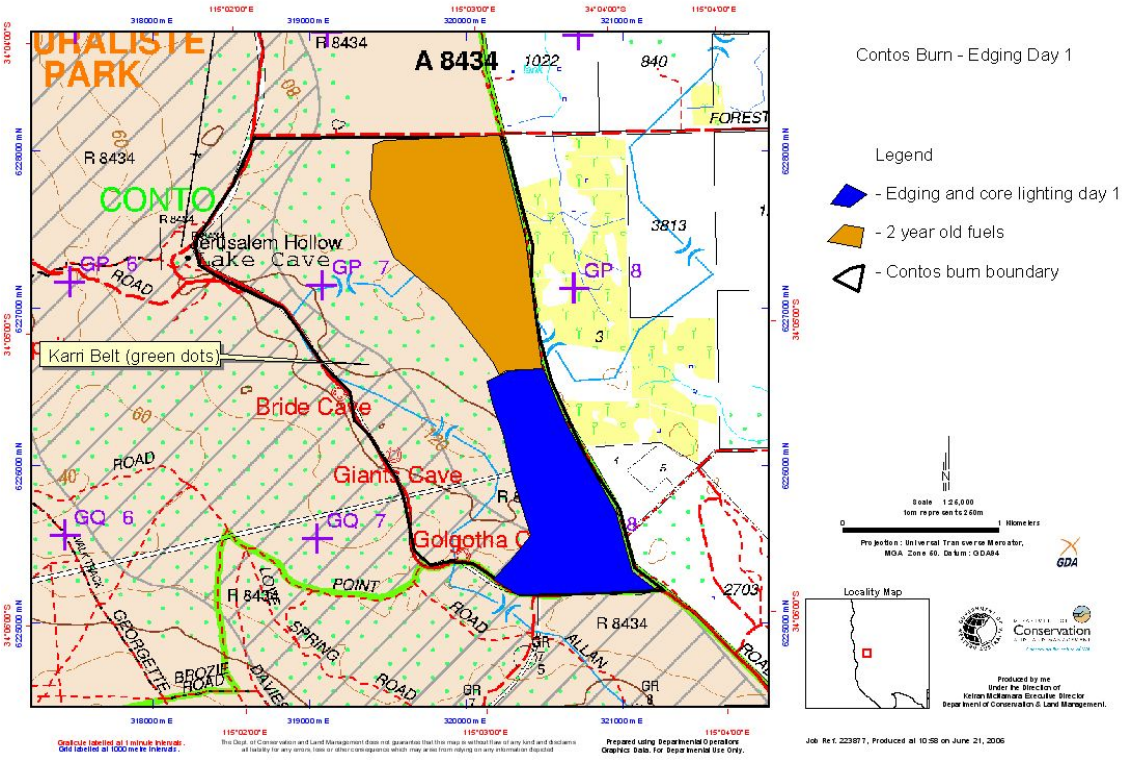
The burn was inspected twice by senior Blackwood District staff in the week leading up to the ignition. The purpose of these inspections (on 31 March and 4 April) was to determine whether the fuels within the burn area were drying out sufficiently to allow edge burning to commence. Inspections indicated that fuels would have suitable moisture contents for burning from 6 April onwards provided that the weather remained dry. Field measurements on 4 April indicated an SMC of 18-20% in jarrah-marri forest, with the PMC in karri forest too high to sustain fire.

Senior District and Regional staff reviewed the situation on 5 April. Forecast weather and fuel moisture conditions were within prescribed limits and south easterly winds were favourable for dispersing smoke away from private property, including several vineyards located to the east and north of the burn boundary.

Based on the 0800hr forecast for 6 April District Fire Coordinator Rob Turner, Regional Fire Coordinator John Tillman and District Manager Greg Mair decided to commence edging jarrah-marri fuels on the southern and eastern boundary. Karri vegetation types would be ignited later as drying progressed. The intent of the operation on 6 April was to restrict fire activity to the jarrah and marri forest in the south east corner of the burn using a moisture differential against karri vegetation on the western and northern boundaries and 2 year old fuels to the north.

Two gang units, two sector commanders and one operations officer were assigned to the burning operation. Resources were reduced from the prescribed number because the intended work for the day did not involve complete edging or core ignition of the burn.

Map 2. Contos prescribed burn – edging and core lighting on 6 April



4.2 Ignition

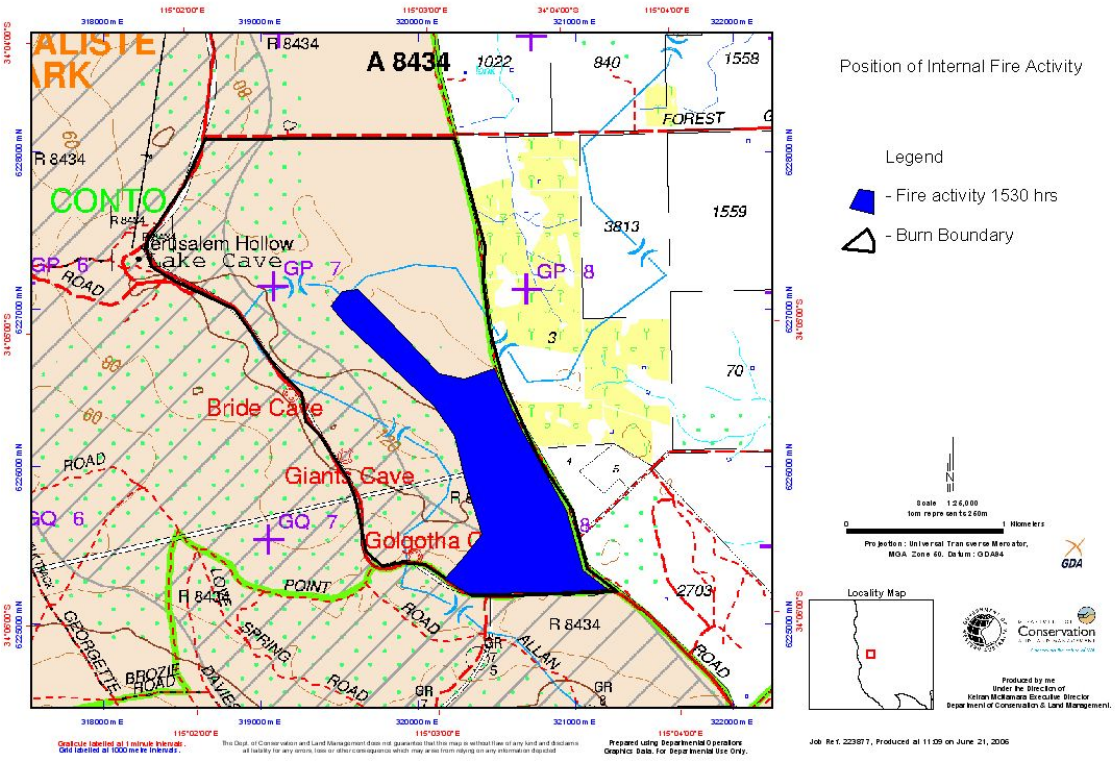
At 1130hrs a test fire was ignited in heavy fuels 30 m in from the eastern boundary, with resulting flame height of 0.5–1.0 m and 50 m/hr rate of spread on the head fire. The Operations Officer (Rob Turner) and Incident Controller (Greg Mair) noted that the intensity of the test fire was at the upper limits of the prescribed range, but based on their experience felt that that the overall intensity would drop to within prescribed range as the fire spread into the moister and lighter fuels typical of the core areas of the burn.

Wind direction at the burn was stable with light easterlies and a forecast change to south easterlies in the afternoon. Because of expected wind direction it was decided that edging operations would proceed on the southern boundary and, once established, a helicopter would be used to fly two internal lines adjacent to a band of karri forest running parallel to the western boundary. This would allow fire to backburn out to the eastern boundary. The fuels on the southern boundary were moister and lighter than on the eastern boundary and the fire behaviour under a south easterly wind blowing across this boundary was expected to be within the prescribed range.

The burn strategy was implemented and edging commenced on the southern boundary at 1245hrs. Edging and lighting of the two internal lines was completed by 1455hrs. Fire behaviour on the southern boundary was active with average flame heights of 1.5 m. Reports from the aircraft indicated that the fire behaviour was normal but at the upper limits of the prescribed ranges with flame heights of 1.5-2 m. More intense fire behaviour was associated with elevated fuels in areas of dense *X. preissii*.

At 1530hrs the Operations Officer reported a narrow head fire burning on the eastern side of the karri forest towards the northern end of the burn area (blue zone on map 3). Smoke from this fire indicated that the fire behaviour was mild but the activity was reported to the Incident Controller as a potential threat to the north western boundary. The Operations Officer considered that the northern boundary might need to be edged to contain this fire within the boundaries of the burn. It was agreed to monitor the activity of this head fire for the remainder of the afternoon as a basis for deciding on the lighting pattern for the following day. About this time a wildfire (Blackwood fire 28) was reported at Ballan Block in the southern Sunklands and all available District resources were called on to suppress this fire. No crews were withdrawn from BS_236 to respond to the wildfire. The northern head fire was checked on at least three occasions between 1530hrs and 1715hrs.

Map 3. Fire shape at 1530hrs on 6 April

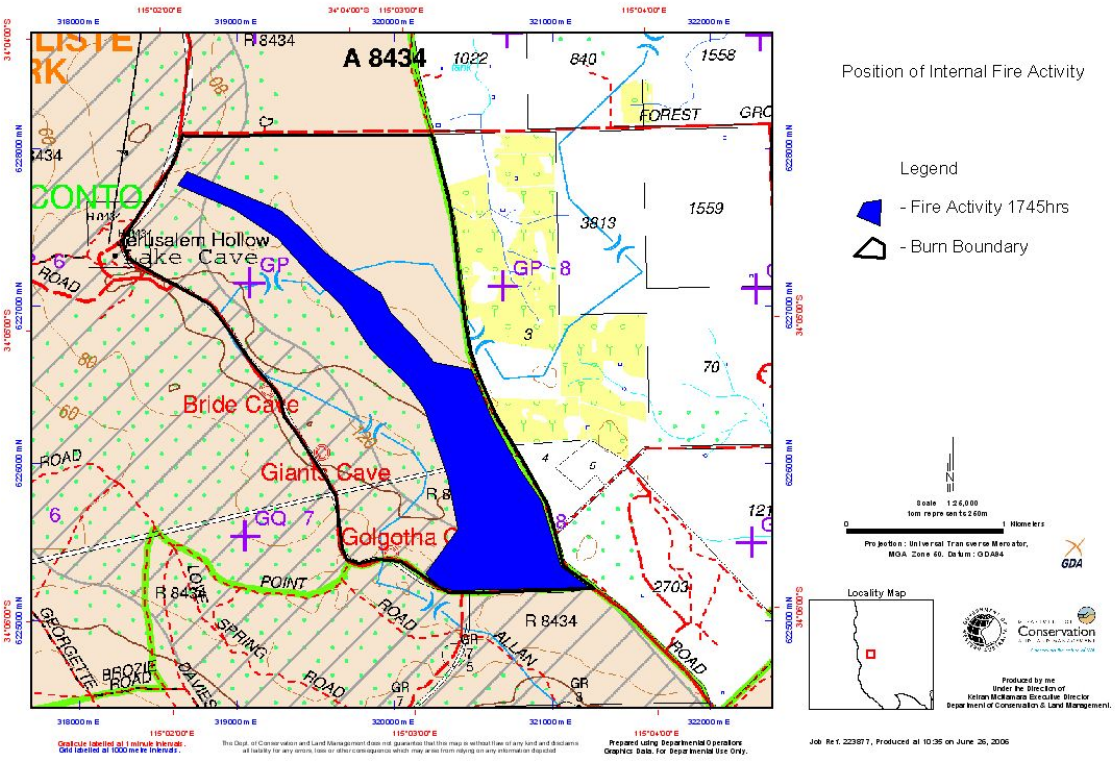


At 1715hrs the Operations Officer noted that the tongue of fire had extended to within approximately 500 m of the north western boundary of the burn. This was reported to the Incident Controller, together with the observation that fire intensity appeared to be declining and that the moister karri fuels would prevent fire from reaching the northern or western boundaries of the burn under the prevailing weather conditions. The Operations Officer did note a narrow (200m wide) zone of more open karri forest that extended to the western boundary on Caves Road about 400 m south of the junction with Forest Grove Road. The understorey of this more open forest had a substantial component of *X. preissii.* The view of the Operations Officer at this time was that there was no imminent danger of fire reaching the western boundary.

4.3 Fire suppression operations

At 1745hrs fire activity was detected within 200 m of the western boundary in the open Karri forest south of Forest Grove Road (Map 4). The head fire was 200 m wide with flame heights of 3–6m and was spotting ahead 20-30 m.

Map 4. Fire shape at 1745hrs on 6 April



Crews were immediately despatched from the southern boundary to the point where fire was threatening to cross Caves Road taking about 10 minutes to reach the north west corner of the burn. Simultaneously, fire fighting appliances were requested from Shire of Augusta Margaret River Chief Fire Control Officer Gordon Temby. Crews were initially instructed to attempt a direct attack on the head fire and any spot fires on the western side of Caves road.

At around 1815hrs it became evident that spot fires were escalating too quickly in the coastal heath for successful direct attack. Spots on the western side of Caves Road rapidly joined up to form a solid head fire spreading to the west. The option of containing the fire to a power line running north-south 250 m west of Caves Road was considered, but became redundant when the fire crossed this line at 1845hrs. Fig. 1 illustrates coastal shrubland representative of the vegetation west of Caves Rd.

By 1900hrs the intense fire behaviour in 15–24 year old coastal heath and the limitations placed on machinery movement by the cave risk in the terrain dictated that an indirect attack strategy was required. The Incident Management Team set an objective to control fire at the following roads shown on Map 5:

West of Caves Road (Fire Ground)
Southern boundary – Contos Road
Eastern boundary – Caves Road
Northern boundary – Mammoth Cave Road
Western boundary – Ocean

East of Caves Road
All boundaries as per original burn

A unnamed track running north-south approximately 1.4 km west of Caves Road and Bobs Hollow Road were briefly considered as containment lines to hold fire to a smaller area but following ground inspections these options were discarded as vehicle movement would have been extremely slow and difficult due to limestone outcropping on the tracks.

For the remainder of Shift 1 (overnight) the priority was to protect infrastructure at Lake Cave and to edge the southern containment line west of Caves Road, given that east north east winds were forecast the following morning (see appendix F). It should be noted that north side winds were not indicated in the morning forecast on 7 April, although they did eventuate (Table 2).

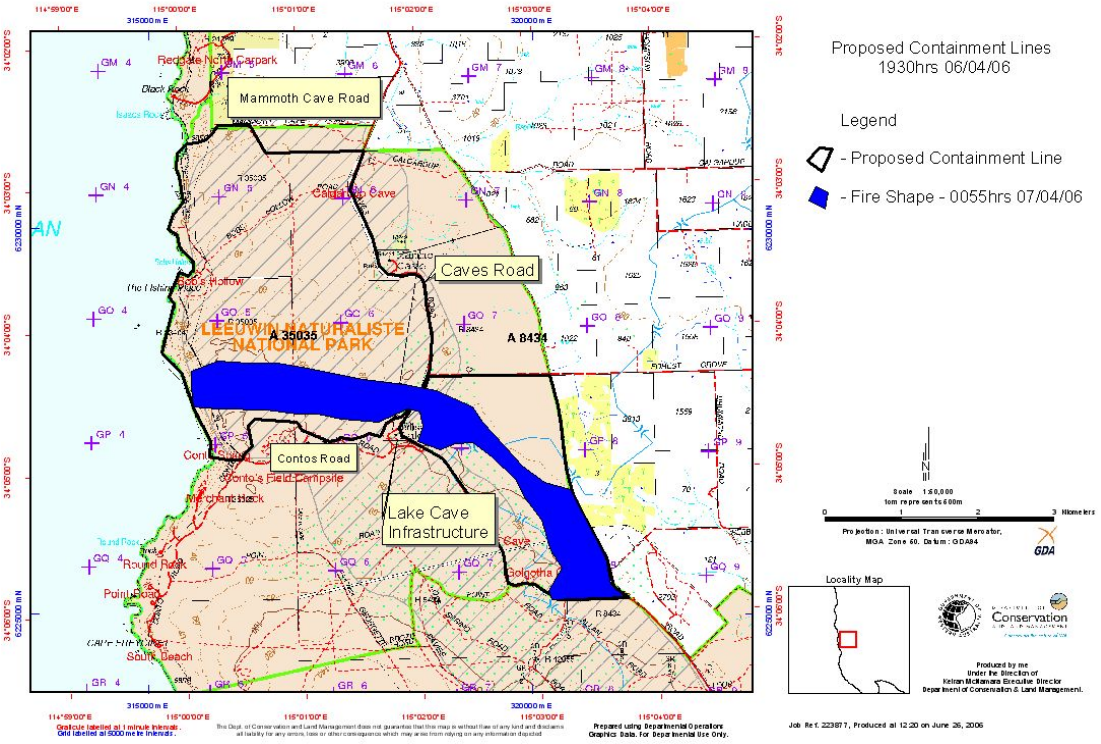
Overnight on Shift 1 a small area of fire became active near Caves Road south of Contos Road. However fire behaviour was mild and the fire was readily controlled.
Work also commenced on establishing a final fire boundary west of Caves Road. At daybreak on 7 April it was realized that a track parallel to and south of Mammoth Cave Road had been upgraded, instead of Mammoth Cave Road. The incoming Operations Officer for Shift 2 was advised of this at the hand over and agreed to use this unnamed track as the northern boundary. Mammoth Cave road was also upgraded as a fall back position in case of an escape to the north.

By the end of Shift 1 edging had been completed along 95% of Contos Road which formed the southern boundary. The main head fire spread parallel with Contos Road and reached the coast at approximately 0055hrs on the 7 April, having travelled 2.5 km in 6.5 hours (rate of spread 385 m/h). All infrastructure at Lake Cave and Contos camp ground was protected and considered safe by the end of Shift 1.

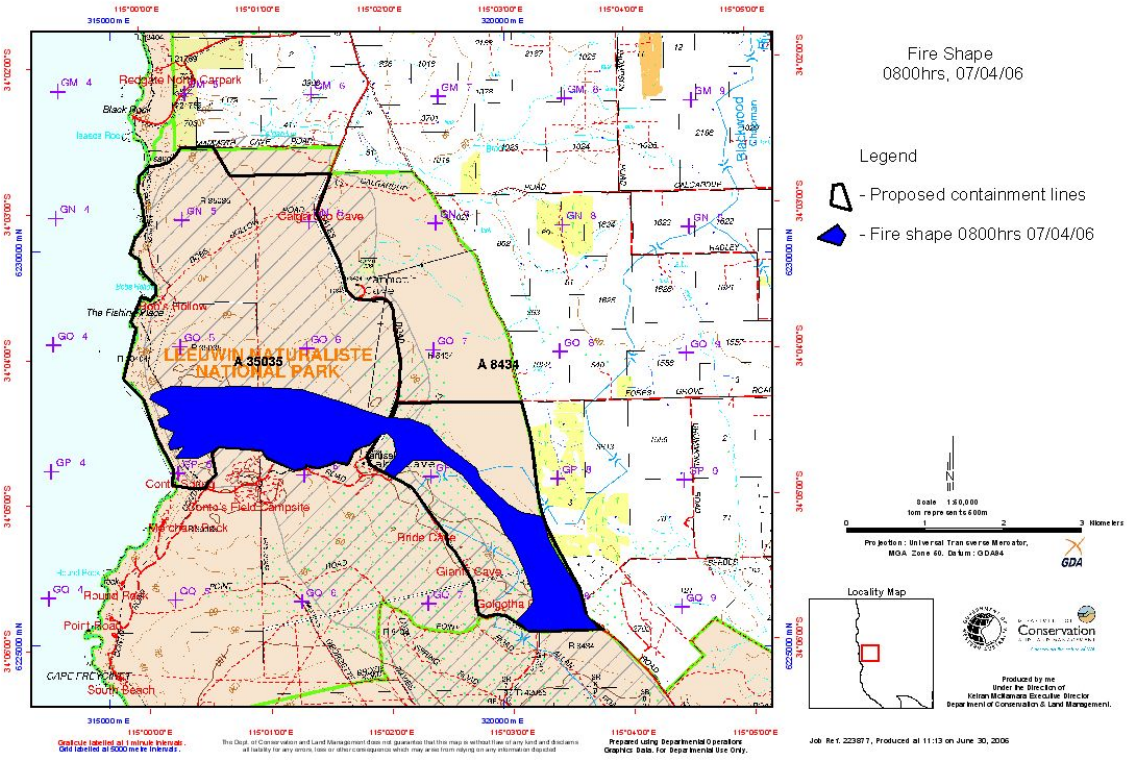
North easterly winds began to influencing the fire ground by 0900hrs on 7 April. Edging work on the southern boundary of the fire ground proved to be crucial in preventing an escape to the south during the morning.

Fig. 1. Coastal shrubland west of Caves Rd typical of the vegetation burnt overnight on 6 April and on the following day.

Map 5. Initial containment lines and fire shape at 0055hrs on 7 April



Map 6. Fire shape at 0800hrs on 7 April.



South easterly winds were forecast for the afternoon of 7 April. Therefore the first task for the day was to secure the northern containment line of the fire west of Caves Road and the northern boundary of the original BS_236 burn. Progress with edging on the northern containment line of the fire was slow with approximately 1 km completed from the west by 1400hrs. Edging progress was initially delayed due to the need for control line construction by hand through sand dunes prior to edging on the northwest corner of the containment area. It was also difficult to achieve satisfactory ignition in the coastal heath vegetation prior to 1100 hours on the morning of the 7th of April due to high relative humidity counts (see appendix B). Edging was unsuccessful on the northern boundary of the Contos burn (Forest Grove road) as fuel moisture contents were too high.

Table 2. Forecast and actual winds at Witchcliffe AWS for 7 April

Time	Forecast wind speed Km/h	Actual wind speed Km/h	Forecast wind direction	Actual wind direction
1000 - 1200	20	15	E	NNE
1200 - 1400	16	9	E	NE
1400 - 1600	15	18	ESE	SSW
1600 - 1800	8	13	SE	SSW
Overnight	13	9	E	S

At approximately 1435hrs a shallow west south westerly sea breeze began to influence the western and northern flanks of the fire, although the upper level winds remained from the north east (Fig. 2). The northern flank of the fire became active and began to spread towards Caves Road.

Fig. 2. Fire behaviour at 1435hrs on 7 April looking south towards Contos Road.

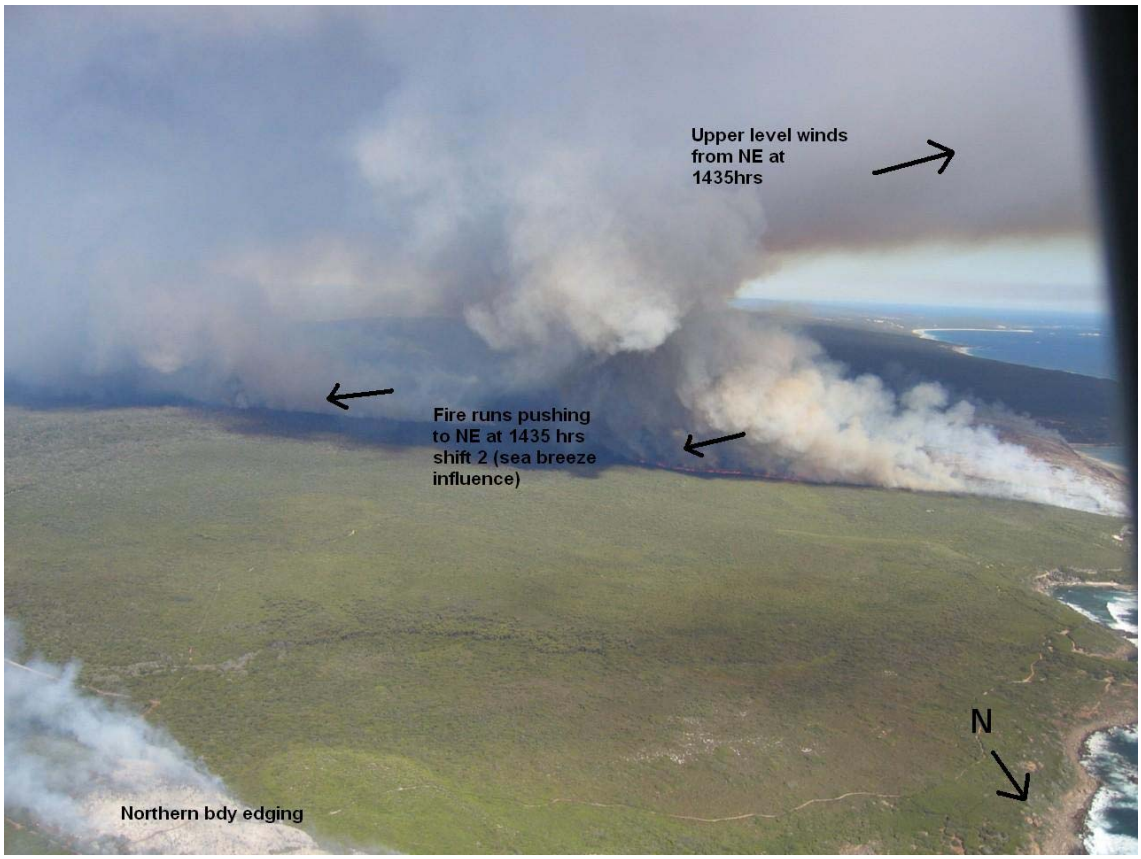


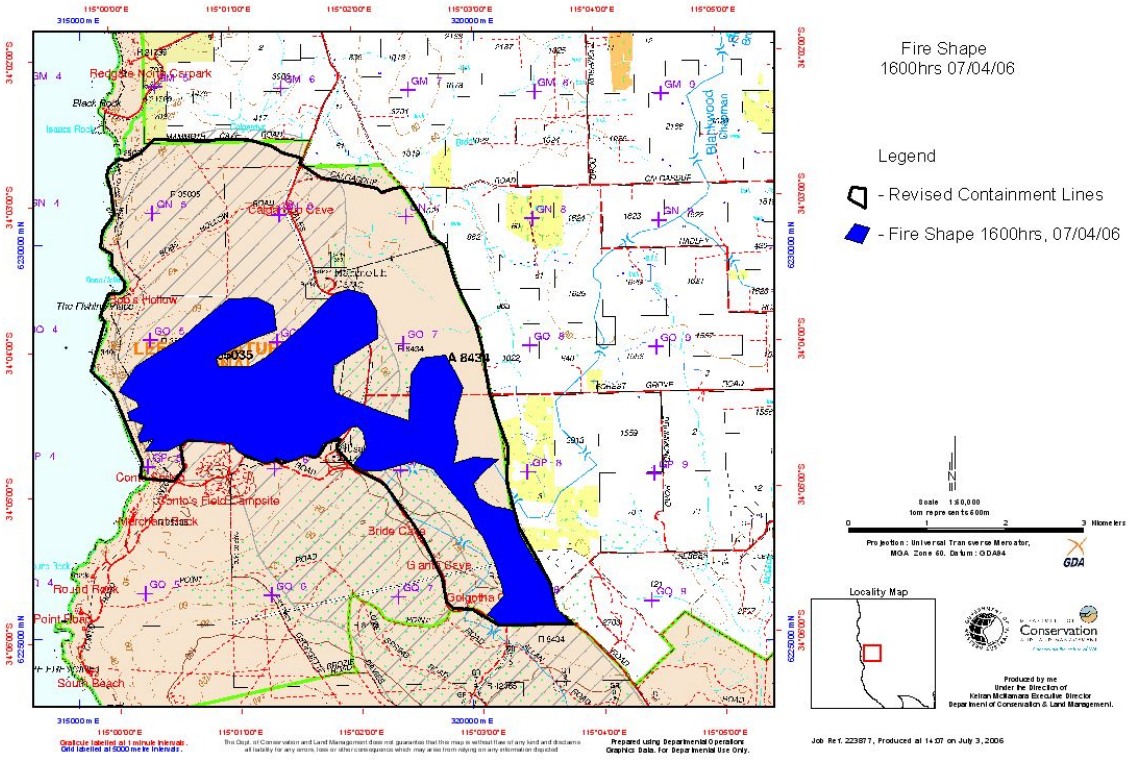
Photo courtesy of Tim Firth

At approximately the same time fire behaviour increased significantly within the original burn area and began pushing north across Forest Grove Road.

At approximately 1600hrs the fire crossed to the east of Caves Road in several places and to the north of Forest Grove Road. Direct attack on these head fires was not possible due to intense fire behaviour and crews withdrew to Mammoth Cave road to the north and the eastern boundary of the National Park boundary adjoining private property. The main fire front crossed Caves Road at the Mammoth Cave turn off and 400 m south of this point. The objective and containment lines were revised to take account of the changed situation as follows (Map 7):

Southern boundary – Contos Road and caves road
Eastern boundary – Interface of National Park and private property
Northern boundary – Mammoth Cave Road and Calgardup Road
Western boundary – Ocean and Caves road

Map 7. Revised containment lines and fire shape at 1600hrs on 7 April



No crews were present at the Mammoth cave infrastructure when the fire reached this area. An inspection conducted after the fire had passed revealed damage to approximately 25% of the board walks and steps leading into and out of the cave system. The main structure which includes a pay station and office was not damaged. Most of the vegetation, predominantly karri forest at the site was burnt under mild conditions overnight on Shift 3.

From 1620hrs crews concentrated on edging the northern boundary to the west and east of Caves Road and on the eastern boundary from Forest Grove Road northwards towards Calgardup Road.. Some spot fires ignited in private property on the eastern boundary south of Forest Grove Road but were rapidly suppressed with water bomber aircraft and ground crews.

At approximately 1630hrs a southerly wind began to influence the fire ground. The northern flank of the fire began spreading rapidly towards the northern containment line with very intense fire behaviour west of Caves Road (Fig. 3).

Fig. 3. Fire behaviour at 1705hrs on 7 April looking north east towards Mammoth Cave Road and Caves Road.

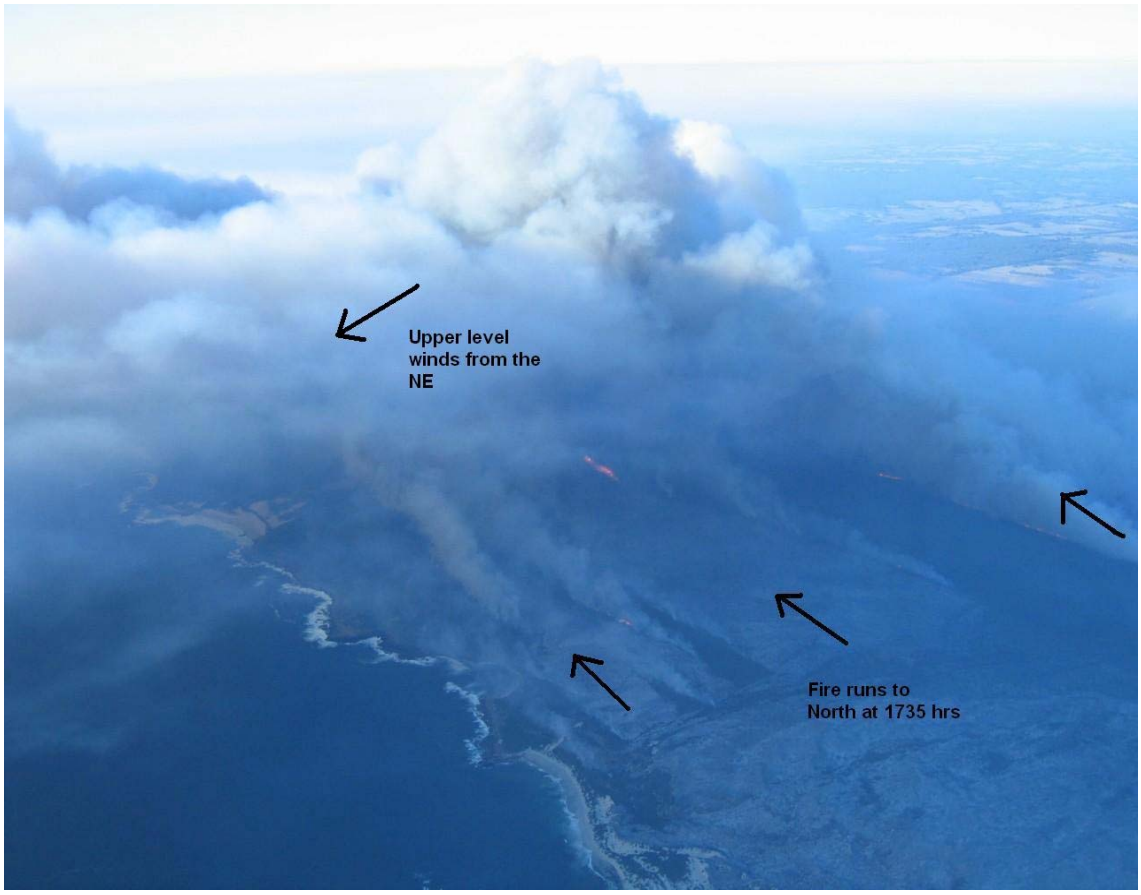
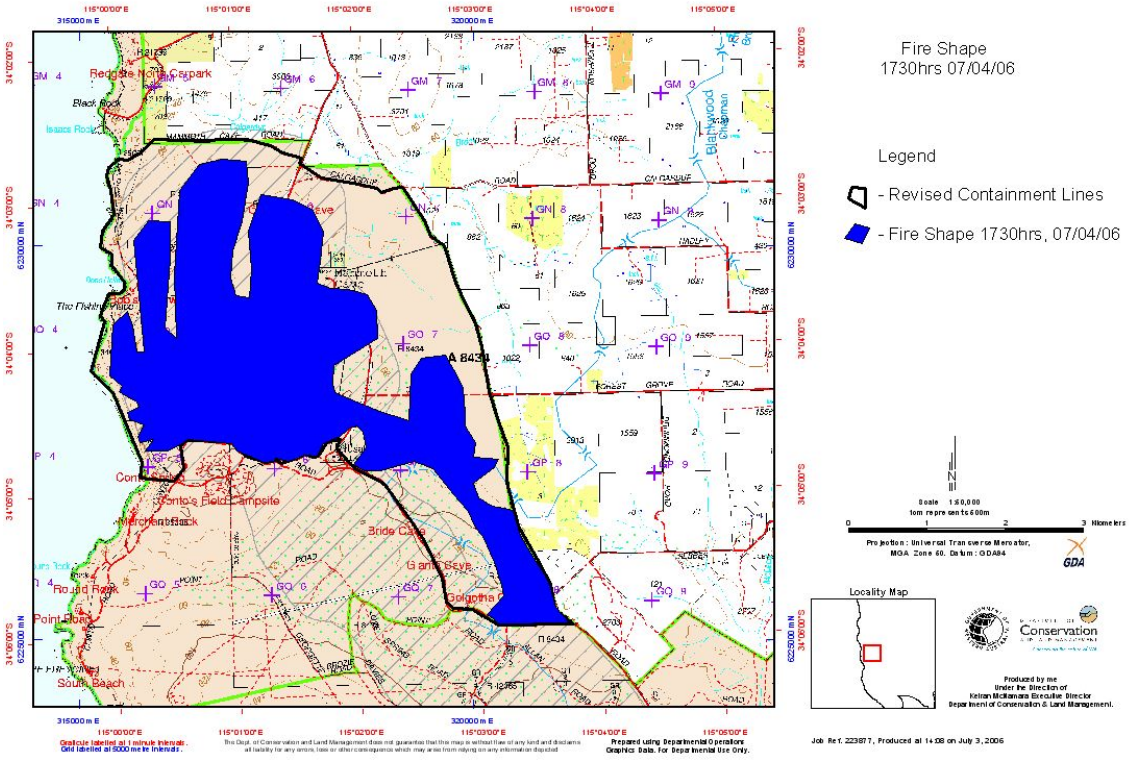


Photo courtesy of Tim Firth

Two significant fire runs occurred under the southerly winds. The first pushed across Caves Road at approximately 1650hrs on a fire front from the Calgardup Cave turn off to a point on Caves Road 500 m to the south of the turnoff. An infrastructure protection sprinkler systems at the Calgardup Cave office and pay station was turned on 1 hour prior to arrival of the head fire and prevented any damage to the buildings at this site. No fire fighting appliances were present when the fire burnt through this site. CALM Officer Neil Taylor photographed the fire as it burnt through this area (Appendix E).

The second fire run crossed the northern containment track 700m west of Caves Road. at approximately 1700hrs. Fire fighters attempted direct attack on hop overs on the northern side of the containment line but were unsuccessful and fell back to Mammoth Cave Road where the fire was eventually held. The final containment line is shown in Map 8.

Map 8. Fire shape as at 1735hrs on 7 April.



5. Fire whirl incident

5.1 Description of events

At approximately 1700hrs on 7 April an intense fire front approaching the northern containment line triggered a fire whirl that resulted in minor injuries to CALM employee Eddie McIntyre and damage to a Departmental heavy duty fire appliance. This incident took place about 700 m west of Caves Road (CALM grid ref. GN0573).

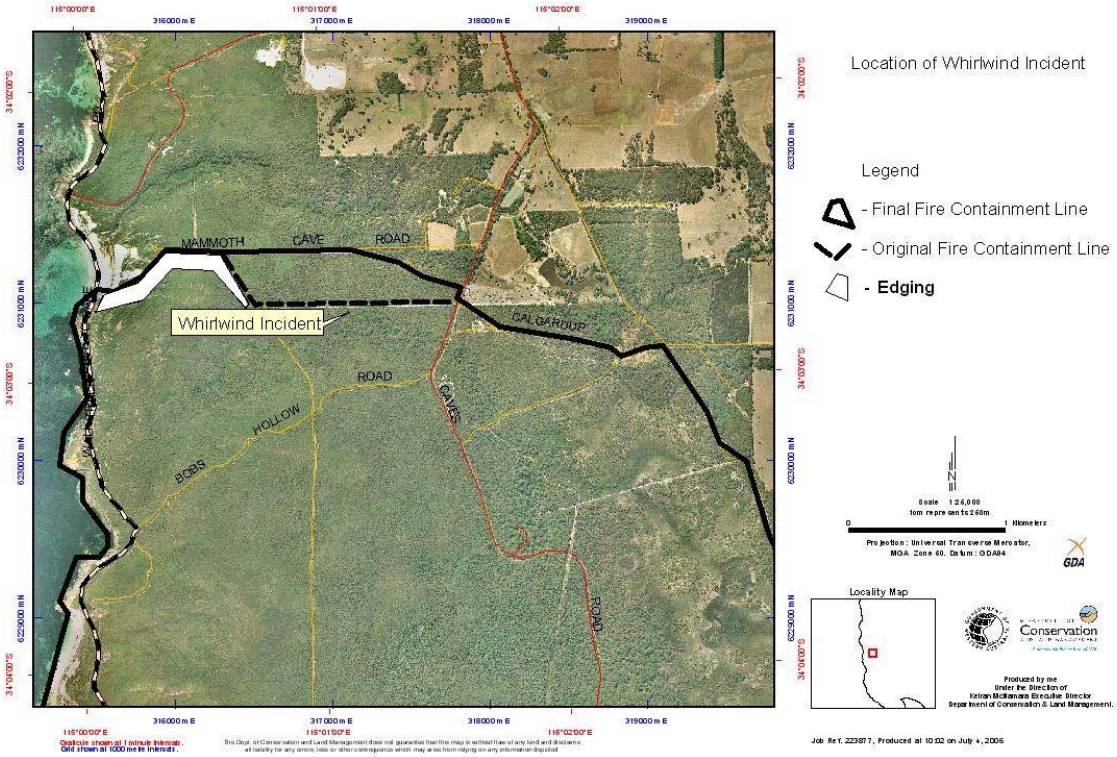
At the time of the incident the northern containment line had been edged from the coast for a distance of 1.3 km towards Caves Road. Crews had also started edging westwards from Caves Road. As the intense fire front approached the northern boundary spotting ignited numerous fires on the north side of the boundary. Crews were tasked to suppress the spot fires, including heavy duty Wellington 41 with Eddie McIntyre working as hose operator from the back of this truck. The truck was facing west and was parked on the northern edge of the fireline to minimise exposure to radiant heat from the edging and the approaching head fire. The fireline was up to 10 m wide in this area and had been upgraded with a front end loader as part of the fire suppression operations.

The fireline was located in a mid-slope position with a south-west to southerly aspect, and slopes of up to 3° south from the fireline. Vegetation either side of the fireline was dense coastal shrubland with an overstorey of melaleuca and hakea up to 10 m tall (Figs. 4 & 5). The area was last burnt in 1981 and carried 25 year old fuel. There was no obvious pattern of surface water drainage because the area is situated on limestone karst terrain.

Fig. 4. View westwards along the northern containment fireline near the scene of the fire whirl incident.

Fig. 5. View southwards from the site of the incident. Note the relatively mild slopes south of the fireline and the defoliated overstorey.

Map 9. Location of the fire whirl incident on the northern containment line



Personnel on the fireline were initially alerted to a change in fire behaviour when the edging fires increased in intensity and began to spread southwards towards the approaching headfire, which at that stage was still at least 100 m south of the fireline. Increased wind movement in tree tops and flying sparks provided further indications of escalating fire behaviour. Within less than a minute, the section of fireline where Wellington 41 had parked was engulfed in a localized severe whirlwind. Flames and strong swirling winds impacted on the southern (passenger) side of the truck, warping plastic exterior fittings and embedding hot embers into the plastic components on the side of the truck. In a post-incident de-brief Eddie McIntrye spoke of long tongues of flame spreading underneath the truck and rising up on the northern (drivers) side. He was standing in the hose operators position at the front of the tray between the tank and the rear of the truck cab. This area is relatively well shielded from heat by the tank and cab, and by heavy aluminium panels on each side of the truck tray. Rapidly realising the danger in this situation, Eddie dropped to the floor of the truck tray and used the hose to direct a dense mist spray over this head and upper body to minimize exposure to radiant heat and flames. In dropping to the floor his safety helmet came off, but his safety goggles stayed on. Eddie McIntyre received minor burns to his head, and his protective Proban overalls had several small holes burnt in them.

In addition to severe heat exposure on the southern side of the truck, the northern (drivers) side was blasted with ash and flying debris. Live tree branches up to 10 cm in diameter were torn from nearby trees and showered down on Wellington 41 (Fig. 6). A large branch hit the front drivers side roof pillar of the truck, bending the pillar and breaking the windscreen. Live shrubs stems up to 4 cm in diameter were also broken by the force of the wind (Fig. 7). The driver of Wellington 41 Terry Wheighell sheltered in the cab of the truck during the incident and was not harmed by flying debris or heat.

Fig. 6. Branches of up to 10 cm broken from the crown of a live tree on the south side of the fireline.

Fig. 7 Stems of live shrubs broken by the wind. The pattern of charring indicates that the stem was fractured before the fire arrived.

Once the wind abated Wellington 41, accompanied by Wellington 44, immediately moved off the sector onto Caves Road where Eddie McIntyre received first aid treatment from CALM personnel. An Ambulance was called and he was transported to Busselton Hospital, being later discharged at 2130hrs.

5.2. Possible contributing factors

The pattern of fire behaviour described by CALM personnel present at the incident and the nature of damage sustained by Wellington 41 indicate that a localised but severe fire whirl developed at this location on the northern containment line. Fire whirls have been linked to a number of significant fire escapes and safety incidents in Western Australia and elsewhere, although their very nature makes them difficult to observe and understand. Billing and Rawson (1981) documented a fire tornado in western Victoria that cut a swathe up to 50 m wide over a distance of 1 km in mallee vegetation. Similar severe events have been documented in the United States, and Countryman (1971) refers to the notable example of the Polo fire near Santa Barbara California where a fire whirl moved out of the fireground, demolishing two houses, damaging several other buildings, and driving a piece of 6 mm plywood up to 75 mm into a live oak tree. This fire was burning in chaparral shrubland not unlike the coastal heathland at Contos.

Factors that may contribute to the formation of fire whirls have been examined by Haines and Updike (1971) and include:

- a fire of sufficient area and size to produce convective heating necessary for formation of vortices,
- neutral or unstable atmospheric conditions that will encourage warm air to continue to rise,
- light winds at ground level,
- clear skies and therefore the potential for strong heating at the ground surface.

Conditions at Contos on 7 April met a number of these requirements including a large expanse of recently burnt fire ground retaining substantial heat, an intense and actively spreading headfire, and relatively light winds. The closest measurements of atmospheric stability are made at Perth and Albany and cannot be assumed to necessarily represent conditions over the fire ground. Smoke plumes shown in Figs. 1 and 2 show some tendency for convective development, although the dispersal of the smoke plume appears dominated by the upper level winds from the north east while ground winds were from the south west. The complex vertical structure in the atmosphere above the fire ground may have been favourable for formation of a fire whirl. Countryman (1971) observed that moving air masses that differ in temperature, speed or direction do not readily mix and where they come in contact a zone of shear stress may form. This can cause segments of air in the boundary area to rotate and form eddies.

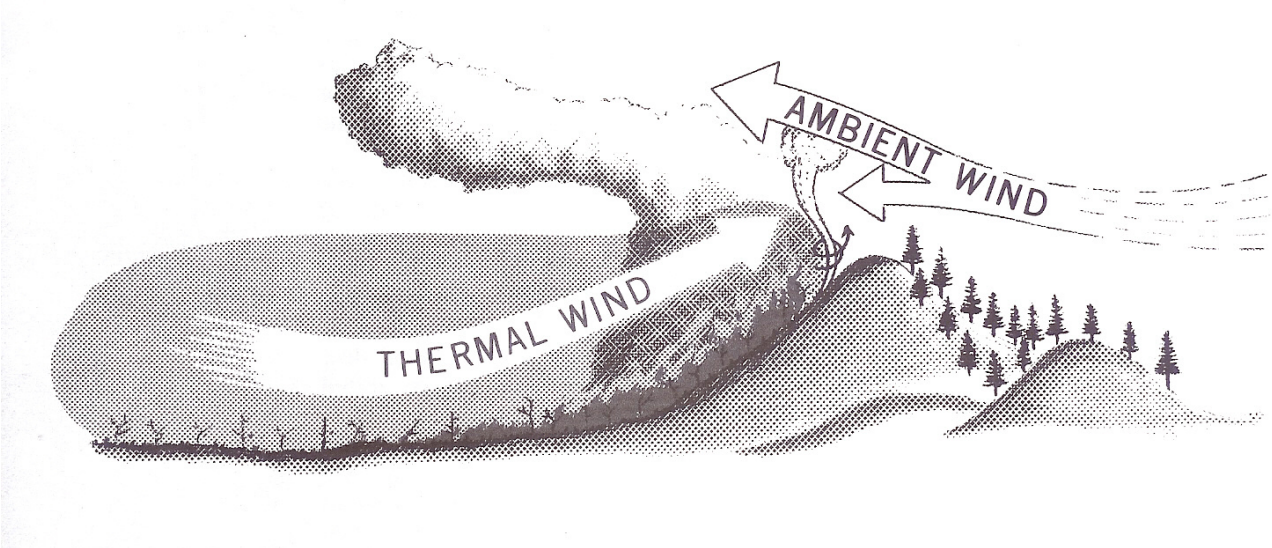
Terrain is also an important factor contributing to formation of whirls. Countryman (1971) noted that fire whirls often form when a fire is burning on the lee side of a ridge (Fig. 8) and attributed this to several factors:

- the mechanical obstruction of the ridge causes eddies to form naturally on the lee side,

- the flow of hot gases from the fire will be upslope, creating wind shear where it meets the cool opposing wind and intensifying the eddying action.

The combined blocking effect of the ridge and the fire causes hot and cool air to mix and establishes locally unstable conditions conducive to fire whirl formation.

Fig. 8 Schematic diagram illustrating fire whirl formation in the lee of a ridge (from Countryman 1971)



The situation of the fire whirl on the northern containment fireline at Contos has some similarities with the Countryman's (1971) schematic example illustrated in Fig. 8, notably the formation of a whirl in a mid-slope position in front of an advancing intense headfire. How well this example reflects the situation at Conto's depends on the direction of the ambient wind. Hourly weather observations from the Witchcliffe AWS indicate south westerly winds at 1700hrs which would have resulted in the ambient wind and the thermal wind acting in the same direction. If, however, there was a tendency for north easterly winds to persist along the ridge adjacent to Mammoth Cave Road then the southern slopes would have been in the lee of the ambient wind. The fact that dew point and relative humidity were lower at 1700hrs than at 1600hrs suggests that drier north-easterly winds may have continued to influence conditions at ground level during the latter part of the afternoon.

Interaction between the advancing headfire and the edging fire lit along the northern containment line may also have contributed to an escalation in fire intensity, particularly if the edging was lit as a continuous line of fire rather than independent spot fires. Line fires can interact strongly resulting in a sudden and violent increase in fire behaviour (Burrows 1984). However, establishing a well burnt edge in shrubland fuels using spot ignition can be difficult if the litter layer on the ground is sparse or discontinuous. In this situation firefighters may have to resort to a more risky line ignition technique to establish an edge of sufficient depth before the headfire arrives.

The severity of the fire whirl surprised even experienced personnel who work with fire on a regular basis, particularly as the burning conditions at the time were relatively mild. The fact that the personnel involved in the fire whirl incident were experienced and alert to the potential danger of the situation avoided more serious injury.

This event provides a timely reminder that firefighters and incident management teams must remain alert to the possibility of unexpected fire behaviour, and highlights the importance of regular refresher training in basic fire safety procedures for all personnel venturing onto the fireground.

6. References

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Appendix A

The following personnel provided information to this report:

Greg Mair – Blackwood District Manager
John Tillman – Southwest Regional Fire Coordinator
Brad Commins – Blackwood District Operations Manager
Rob Turner – Blackwood District Fire Coordinator
Paul Mammone – FPC, Roading Officer
Tim Firth – Swan Region Fire Operations Officer
Richard Hartwell – FPC, Softwood Plantation Officer
Neil Taylor – Acting Marine

Information about the fire whirl incident was drawn from an initial report prepared on 8 April by Ian Rotheram (FPC, Bunbury) and Keith Mungham (FPC, Bunbury) and from direct discussions with Eddie Mcintyre and Terry Wheighell (Wellington 41), Chris Roberts and Erin Davis (Wellington 44) and Overseer Ron Winfield of Wellington District at Collie on 10 April.

Appendix B
Hourly Weather Observations at Witchcliffe AWS on 07 April

Time	Temp	Dew Point	RH %	Wind Direction	Strength KM	Gust KM
07 19:00	16.9	11.2	69	S	9	11
07 18:00	18.7	10.0	57	S	11	17
07 17:00	20.9	9.8	49	SSW	13	17
07 16:00	20.7	11.4	55	SW	13	17
07 15:00	22.2	10.0	46	SSW	18	22
07 14:00	24.3	8.7	37	ENE	9	13
07 13:00	24.2	9.4	39	NE	9	17
07 12:00	23.3	10.4	44	N	17	24
07 11:00	21.8	10.4	48	NNE	11	17
07 10:00	18.7	10.8	60	NE	13	22
07 09:00	14.5	12.6	88	E	9	13
07 08:00	10.3	9.6	95	ESE	7	17
07 07:00	7.5	6.6	94	SE	7	11
07 06:00	7.8	6.8	93	SE	7	11

Appendix C

Aerial Photo Mosaic of Fire Ground taken 21 May 2006

Appendix D

Time Line of Events at Contos Prescribed Burn BS236 and subsequent Blackwood Fire 29

Collated by Rob Turner and Brad Commins 21/04/06

Date / Time	
27/03/06	**Liaison prior to burn** Letters sent to immediate neighbours of Contos burn on the 27/3/06, 8/12/05, 11/11/05, 4/10/05, 6/5/05, 31/3/05, 15/11/04, 15/10/04, 16/4/04, 6/10/03, 8/9/03.
25/03/06	**Rain Recordings** 22.2 mm of rain recorded at Witchcliffe AWS over the previous month. 3.8 mm recorded on the 3rd and 4th of April. Approximately 15mm more rain recorded at Borannup community over the same month period.
31/03/06	**First Burn Inspection** Regional Fire Coordinator, John Tillman and District Fire Coordinator Rob Turner check burn area to determine readiness of burn for first ignition within Jarrah and Marri fuel types. Fuels are wet but drying out sufficiently to consider another field check early the following week.
04/04/06	**Second Burn Inspection** Brad Commins and Rob Turner inspect burn area and decide that fuels are drying out nicely and that the burn will require one more day of drying. PMC was estimated at 70% plus in Karri and 18 - 20% in Jarrah Marri.
05/04/06	**Deliberations leading upto burn** Discuss burn with JT, BC and GM. Look at forecast in morning but all looks good for ignition within J/M fuels the following day. Discussed forecast conditions which suited the dispersal of smoke away from vineyards. This contributed to the decision to go ahead with the burn
05/04/06 1530	**Liaison prior to burn** Rob Turner contacts Boranup Gallery, Lake Cave, Calgardup Cave, Explorus (adventure guides) and Gordan Temby. Discussed burn and all were happy with burn proceeding. Discussed wind direction with Boranup Gallery and stated that winds will push smoke away from them so inconvenience should be minimal.
06/04/06 0800	**Deliberations leading upto burn** Discussion on forecast conditions with JT, GM, RT. Conditions were forecast to remain stable with an easterly trend. Time available for mop-up prior to the Easter holiday break was also considered. Decision to go with burn was made. Conditions were within prescribed parameters and winds would push smoke away from grape growers and into Karri Vegetation occurrences within the burn area. Karri holding a moisture differential. Greg Mair – IC, Rob Turner – Ops
06/04/06 0900	**Liaison prior to burn** Contacted caves operators at Cave Works, Calgardup Cave and confirmed that it was CALM's intention to proceed with burn today.
06/04/06 1130	**Test fire deliberations** First test fire placed in on eastern edge, fire behaviour was strong and at the upper

	range limit. Decided to place another test fire further in off edge away from edge effect. Fire behaviour normal on this spot with 0.5 – 1 m flame height and 50 m/hr rate of spread. Extinguished test fire to allow further deliberations. Decided to go with burn with edging starting on caves road and moving around the eastern boundary where we would run fire into Karri belt. It was decided that aerial ignition would be used to light burn internally to allow fire to back burn out to eastern boundary.
06/04/06 1245	Lighting commenced on Caves Road – fire behaviour normal with no activity within Karri vegetation type.
06/04/06 1455	Edging on Caves Road and internal lighting completed. Helicopter reports fire behaviour normal with flame height of 1.5 – 2m, fire shape round.
06/04/06 1515	**Fire 29 detected at Ballan Block**
06/04/06 1530	Report to IC from Ops that fire behaviour is pushing to the north which could cause an issue with northern boundary having to be edged. Monitoring situation at this time as fire behaviour looks normal and is at least 1 km from Northern boundary.
06/04/06 1645	One Heavy Duty requested for the Ballan Block fire 29, but not sent.
06/04/06 1715	Ops rechecked northern boundary and caves road to the north and all OK however fire behaviour has closed to around 500 m of these boundaries but activity is dying as it hits the Karri belt to the north. Intention was to continue to monitor however there was no direct concern with Karri not burning and holding fire away from both roads. All other fire behaviour normal with very good result off Caves Road.
06/04/06 1745	**First activity reported on Caves Road north** First activity reported close to Caves Road approximately 400m south of Forest Grove Road. Marginal Karri Belt approximately 200m wide where fire is pushing out to Caves Road.
06/04/06 1800	All crews moved to Forest Grove Road to hold fire to within burn area
06/04/06 1815	Addition crews requested from brigades
06/04/06 1830	**Burn escaped over Caves Road** Attempt to hold fire on caves road has failed and looking to fall back to powerline to the west as containment line. Fire 29 declared.
06/04/06 1845	Attempt to hold fire to powerline failed and thus moved resources to concentrate on southern flank to protect Lake Cave Infrastructure and Contos camp ground.
06/04/06 1915	Working hard to hold southern flank as it burns along powerline and Old Contos Road to north of lake cave infrastructure.
06/04/06 1930	**Initial objective and strategies for Fire 29, shift 1** Objective set by IMT – which is to hold fire to following containment lines- Contos road – south Caves road – east Ocean – west Mammoth Cave road – north First nights tasks are to edge and secure southern boundary and commence upgrade of northern boundary. This was in light of a northerly influence forecasted for the morning of the 07/04/06 and easterly trends throughout the day. Shift 2 would establish the northern edge and follow this up with edging eastern edge along caves road.

07/04/06 0500	Shift change imminent. Southern edge secured with work 40% complete on Northern break. A parallel track 500m south of Mammoth Cave road was upgraded by mistake in the early hours of shift 1. It was decided that this break was good if not better then the Mammoth Cave track therefore alteration of intended containment line to north was approved by IMT.
07/04/06 0700	**Strategies to meet objectives during shift 2** Strategies for the containment of the fire during this shift was to establish an edge by back burning on Mammoth Cave road and Caves road south from Mammoth cave road to Forest Grove road.
07/04/06 1030	Back burning operation commenced at the NW corner of the final fire area. A control line through the sand dunes was established by slashing and foam trail to lock the northern boundary into the sand dunes. The water bombers were used to reinforce the security of the northern edge. The forecast for the day was for NE winds going ESE in the PM. The implementation of the edge establishment was to move from the north west corner of the fire east to Caves road and then south to Forest Grove road. This was the safe progression of the edge given the forecast winds for the day. Some attempts at edging Forest Grove road were made to strengthen the edge but the Karri fuel would not burn.
07/04/06 1330	Operations Officer went up in the helicopter to inspect the edging progress on Mammoth Cave road and position of running fire within the fire. Two areas of activity were observed. One at GP0568 west of Caves road and one at GP0724 South of Forest Grove road. NE wind was still prevailing over the fire
07/04/06 1420	Paul Mammone went up in the helicopter to observe the fire from overhead. He returned to the control point and reported that a SW wind influence has come in and was affecting the two areas of running fire. This potentially would give control problems. Radio contact with the edging crew on the northern boundary indicated that they were still under a NE influence. It was not possible to commence edging Caves road with the risk of fire running through the northern boundary and affecting the crews backburning.
07/04/06 1445	Two fire runs began to become evident originating from GP0568 under a WSW wind influence. The wind was very localized as the NE wind persisted on the N boundary and conditions away from the fire were calm.
07/04/06 1530	The edging on the northern boundary was progressing well under a NE wind
07/04/06 1615	**Escape over Caves Road north of Forest Grove Road** The fire fronts running west of Caves Road had built up momentum and were obviously going to breach the eastern control line. Resources were shifted around to Caves Road to suppress the oncoming fires. The two fronts were going to hit Caves Road at Mammoth Cave and about 400 metres further south.
07/04/06 1645	Resources were moved from Caves Road for reasons of safety as an entrapment situation was developing. The fire would cross Caves Road and enter 5 year old fuel. Resources were moved to the northern boundary and east boundary north of Forest Grove Road
07/04/06 1700	Edging commenced on the northern boundary east of Caves Road to establish a control line CALM. Brigades commenced edging eastern boundary north of Forest Grove Road. Some spotting into bluegums south of Forest Grove Road on eastern boundary. Suppressed by water bombers.
07/04/06	**Accident on Northern boundary**

1730	Report from northern boundary west of Caves Road that a Conservation Employee had been injured in fire willy willy. Called ambulance. Employee taken to hospital. Several hop overs, dealt with
07/04/06 App 1800	**Escape over Northern Boundary west of Caves Road** Several hop overs in the bush between Mammoth Cave road and the internal break. Decided to drop back to the Mammoth Cave road as the control line. This worked OK
07/04/06 App 1900	All control line establishment is progressing well. Fire behaviour is dropping off. Significant impacts to Calgardup and Mammoth Caves complexes. Infrastructure is OK but forest severely scorched. Caves Road remains closed.
07/04/06 App 2000	Crew changes commencing. Will be staggered. Night shift should be OK. Forecast favorable. Some Karri ignited up within the burn area during the day. Small pockets adjoining jarrah areas.

Appendix E

Photos taken by Neil Taylor at Calgardup cave when fire front moved through area at 1650hrs on the 07/04/06.

Sprinklers wet down the infrastructure and surrounding vegetation.

Sprinklers located on buildings.

Fire front approaching car park from the south.

Fire activity adjacent to board walk which leads tourists to cave entrance from cave office.

Fire run approaching from west.

Vegetation immediately following fire passing through area.

Fire Weather for C.A.L.M.
from the Weather Bureau, Perth

Issued at 1545 WST on Thursday the 6th of April 2006

LOCATION	FORECAST FOR FRIDAY	AM Dir/Spd PM Dir/Spd	OUTLOOK FOR SATURDAY	OUTLOOK FOR SUNDAY	OUTLOOK FOR MONDAY
PEARCE	FINE.	T 28 DP 6 RH 25 km/hr ENE 30 ESE 20	FINE. W 15 MID/LATE PM.	T 31 NE 25 N 15 SHOWER OR TWO.	T 25 VRB 10 WSW 18 FINE.	T 26 SSE 22 S 20
BICKLEY	FINE.	T 25 DP 6 RH 30 km/hr ENE 30 E 18	FINE. WNW 15 MID/LATE PM.	T 28 NE 25 N 15 SHOWER OR TWO.	T 23 VRB 10 WSW 15 FINE.	T 23 SSE 18 S 22
DWELLINGUP	FINE.	T 25 DP 7 RH 32 km/hr ENE 25 ESE 16	FINE. WNW 15 MID/LATE PM.	T 28 NE 25 N 15 CHANCE OF A SHOWER.	T 23 VRB 10 WSW 15 FINE.	T 23 SE 12 SSW 20
BRIDGETOWN	FINE.	T 25 DP 7 RH 32 km/hr ENE 18 E 15	FINE.	T 27 NNE 20 NW 15 CHANCE OF A SHOWER.	T 24 VRB 10 SW 15 SHOWER OR TWO.	T 23 W 10 SW 22
WITCHCLIFFE	FINE.	T 25 DP 10 RH 39 km/hr ENE 20 ESE 15	FINE. SW 16 MID PM.	T 25 NNE 20 NW 18 SHOWER OR TWO.	T 22 SSW 18 SW 20 SHOWER OR TWO.	T 22 WSW 16 SW 26
PEMBERTON	FINE.	T 24 DP 10 RH 41 km/hr ENE 18 ENE 15	FINE. WSW 14 MID/LATE PM.	T 26 NNE 15 NW 12 SHOWER OR TWO.	T 21 SW 10 SW 12 SHOWER OR TWO.	T 21 W 18 WSW 26
WALPOLE	FINE.	T 23 DP 10 RH 44 km/hr ENE 18 ESE 15	FINE. WIND W 16 LATE PM.	T 27 NNE 25 NW 18 SHOWER OR TWO.	T 20 SSW 15 SW 20 SHOWER OR TWO.	T 19 W 20 WSW 26
ROCKY GULLY	FINE.	T 23 DP 8 RH 38 km/hr ENE 20 ENE 15	FINE.	T 27 NNE 25 NW 18 SHOWER OR TWO.	T 23 SW 12 SW 18 SHOWER OR TWO.	T 20 WNW 16 WSW 24
COMMENTS:						