


TASMANIAN WILDFIRES JANUARY-FEBRUARY 2013: FORCETT-DUNALLEY, REPULSE, BICHENO, GIBLIN RIVER, MONTUMANA, MOLESWORTH AND GRETNA

REPORT PREPARED FOR THE TASMANIA FIRE SERVICE

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Cover: At left, the Forcett–Dunalley fire approaching Dunalley on 4 January 2013. Photo by Andrew Skelly, Tasmania Fire Service.
At right, smoke-filled valleys during the Giblin River fire.
Photo by Jon Marsden-Smedley

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Summary

This report provides information on the areas burnt and fire behaviour of some of the fires that occurred during the 2012–13 Tasmanian fire season. The fires covered are: Forcett–Dunalley, Repulse, Bicheno, Giblin River, Montumana, Molesworth and Gretna. In total, the fires covered in this report burnt about 90 175 ha (out of the nearly 120 000 ha that was burnt during the 2012–13 Tasmanian fire season).

The period January to March 2013 featured well above normal Fire Danger and atmospheric instability. This resulted in the 2012–13 Tasmanian fire season being the worst since February 1967, with about 128 wildfires being recorded that burnt about 119 267 ha (about double the yearly average for the preceding 10 years). Over the summer, more than 200 houses were destroyed.

Detailed weather, fuel, site and fire behaviour data has been collated for a total of 12 fire runs. Five of these fire runs were burning with extreme levels of fire behaviour, four were burning with very high levels of fire behaviour, two were burning with high levels of fire behaviour and one had moderate levels of fire behaviour.

The observed rates of fire spread for the fires were compared against predictions made by the McArthur Forest Fire Danger meter, Project Vesta, Phoenix RapidFire, Buttongrass Moorland and CSIRO Grassland fire models. The McArthur model provided very poor predictions, under-predicting fire spread rate by an average of 73%. The Project Vesta, Phoenix RapidFire and Buttongrass Moorland models provided good predictions of head fire spread rate, with the average predicted versus observed head fire spread rates being about -4%, 14% and 13% respectively. The CSIRO grassland fire model over-predicted the head fire spread rate by nearly 75%. Phoenix RapidFire also provided predictions of flank fire spread rate, with the predicted versus observed flank fire spread rates being about 43%. None of the McArthur Forest Fire Danger meter, Project Vesta, CSIRO Grassland or Buttongrass Moorland fire models predict flank fire spread rate. In dry eucalypt forest, the Project Vesta provided the best predictions of head fire spread rate.

The main driver of the extreme levels of fire behaviour observed during these fires was a combination of surface weather conditions and atmospheric instability. During the time periods when the fires were making their major runs, both of these factors were at very high levels. This means that in order to predict the likely fire behaviour during these conditions, measures of both of these factors are required. This can be done using a combination of the Fire Danger Rating to give an estimate of the conditions prevailing at the ground surface and the C-Haines Index for a measure of atmospheric instability.

During each of the Forcett–Dunalley, Repulse, Bicheno and Giblin River fires, high-intensity fires burnt into recently burnt areas. In each of these situations, the head fire's spread rate, intensity and spotting were stopped or greatly reduced, indicating the value of low-fuel-hazard areas for reducing the level of fire risk.

This report also identifies the importance of early response with adequate resources, effective mop-up and patrol, and the importance of identifying the conditions where effective suppression is not feasible so that fire crews can pull back and all resources can be applied to protecting life and property. For example, when the fire danger rating is high or above and the C-Haines Index is above 8 (and especially when it is above 10), fire suppression operations are often ineffective and fire-management agencies need to concentrate on protecting life and property.

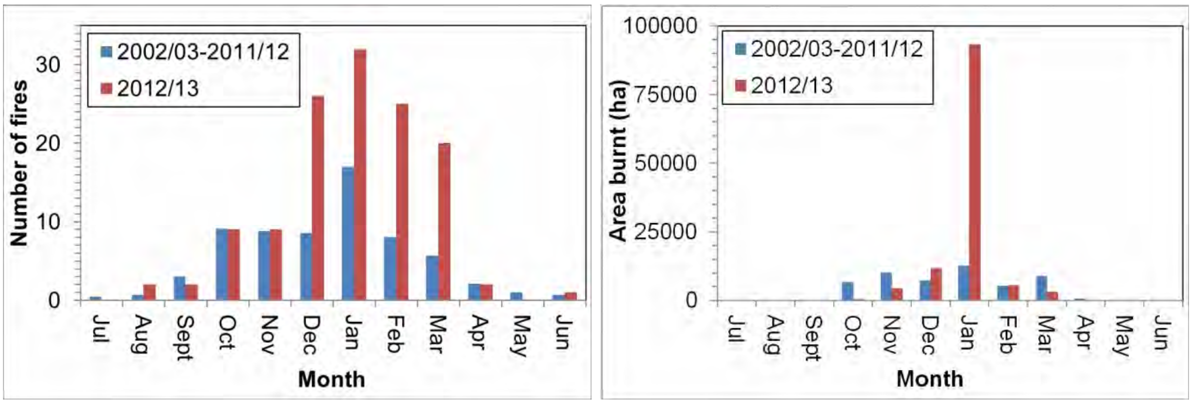
1. Introduction and aims

This report describes the fire behaviour of the major wildfires that occurred during the 2012–13 Tasmanian summer and is primarily intended to be a data collection and description project with only limited analysis of the data collected. The report includes detailed descriptions of the weather, fuel, fire behaviour and area burnt, maps of burnt areas and field data collected, and discusses some of the major effects and characteristics of these fires. This report also includes a review of the influences of weather, fuel and site conditions on fire behaviour, seasonal conditions prevailing during the 2012–13 summer and data used.

The annual number of and area burnt by wildfires in Tasmania tend to be highly variable. Most fire seasons consist of relatively few fires burning only moderate areas. However, periodically in Tasmania, the number of fires and area burnt greatly increase.

The worst fire season recorded since European settlement in Tasmania occurred during the 1897–98 fire season, when about 2 000 000 ha was burnt (or about a third of the state). The second-worse recorded fire season occurred in the 1933–34 fire season when about 1 000 000 ha was burnt. The third worst recorded fire season occurred in 1966–67 (most of which occurred on 7 February 1967), when 62 people were killed, about 1400 buildings destroyed and about 250 000 ha was burnt (see Luke and McArthur 1978; Marsden-Smedley 1998; Johnson and Marsden-Smedley 2001).

During the 2012–13 fire season, 128 wildfires burning 119 267 ha were recorded in Tasmania. This compares with an average over the preceding 10 years of 65 wildfires burning 51 920 ha per year (Figure 1).



a) Number of fires b) Area burnt

Figure 1. Average number of fires and area burnt for 2002–03 to 2011–12 versus 2012–13. Data sources: Tasmania Fire Service, Parks and Wildlife Service and Forestry Tasmania unpublished fire history databases.

During the 2012–13 fire season, over 200 houses were destroyed, mostly by the Forcett–Dunalley fire, with most of these houses being burnt on 04/01/13. No lives were lost when the fires were burning with high spread rates and intensities (although one life was lost during the mop-up phase of the fires).

2. Background information

2.1 Influences on fire behaviour

The main factors influencing fire spread rate are wind speed, slope, fuel characteristics and fuel moisture, while the main influences on fire intensity are the rate of fire spread, fuel height and fuel load.

The relative importance of wind speed, fuel characteristics and fuel moisture on fire behaviour varies with different wind speeds. At low to moderate wind speeds (i.e. <25 km/h), wind speed and fuel characteristics have similar levels of influence on fire behaviour in moorlands (Marsden-Smedley and Catchpole 1995b) and dry eucalypt forests (Cheney et al. 2012). At higher wind speeds, (i.e. >25 km/h), wind speed becomes the dominant influence on fire behaviour. Overall, wind speed accounts for about half of the observed variation in fire spread rate.

When assessing fire behaviour, it is important to consider both the conditions prevailing at the ground surface (e.g. wind speed, fuels being burnt, humidity and site slope) and the degree of atmospheric instability (see Mills and McCaw 2010). Under highly unstable atmospheric conditions, fires have a higher probability of forming large convection columns, which act to increase the fire's ventilation rate with resultant increases in wind speed and decreases in humidity. This means that if fires occur under highly unstable atmospheric conditions, then it is much more likely that they will burn with enhanced levels of fire behaviour.

The most important fuel factor influencing fire behaviour is the percentage of dead fuel, followed by fuel structure, which in turn is more important than the fuel load (see Marsden-Smedley and Catchpole 1995a, 1995b; DEH 2008; Hines et al. 2010; Cheney et al. 2012; Gould et al. 2007a, 2007b). In order to address this issue, fuel hazard assessment systems have been developed that incorporate the different influences of different fuel factors into easily utilised ratings.

When fuel hazards are assessed, the level of fuel hazard is based on a combination of the surface, near-surface, elevated and bark fuel strata (Figure A1.1). Each of these strata is assessed on a five-point scale between low and extreme (DEH 2008; Hines et al. 2010).

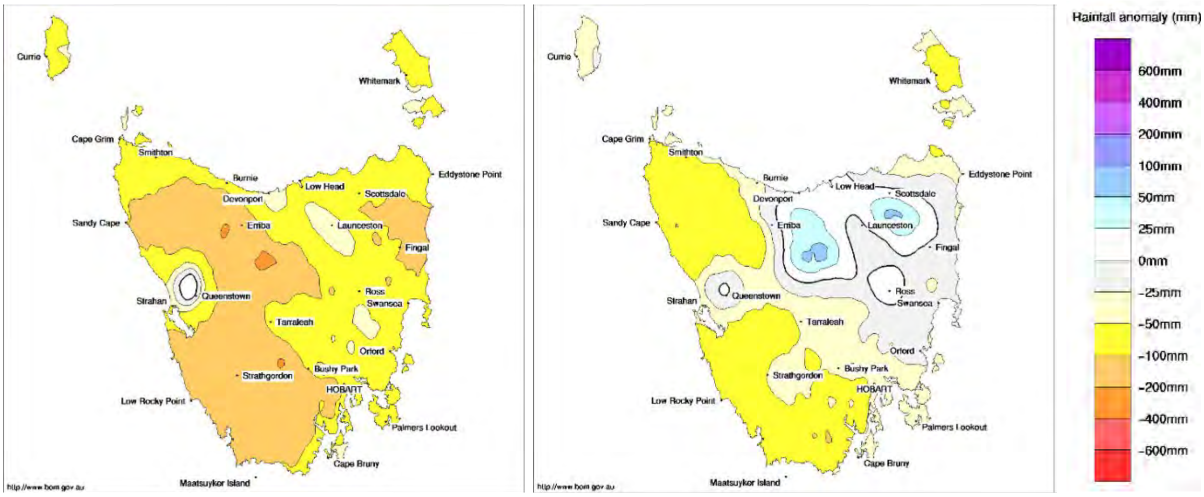
For fire management purposes, the term fuel moisture is the fuel moisture content of dead fuel that has a diameter of less than 6 mm. Fuel moisture is calculated as the percentage weight of water in the fuel to its oven-dry weight. The most important factors influencing fuel moisture are humidity, dew-point temperature, solar radiation (which is in turn influenced by the cloud cover, season, slope and aspect) and recent rainfall.

By itself, temperature only has very minor influences on fuel moisture and, hence, fire behaviour. Temperature does, however, strongly influence fire crew fatigue and their ability to manage fires.

The influences on fire behaviour are reviewed in more detail in Appendix 1.

2.2 Seasonal outlook: summer 2012–13

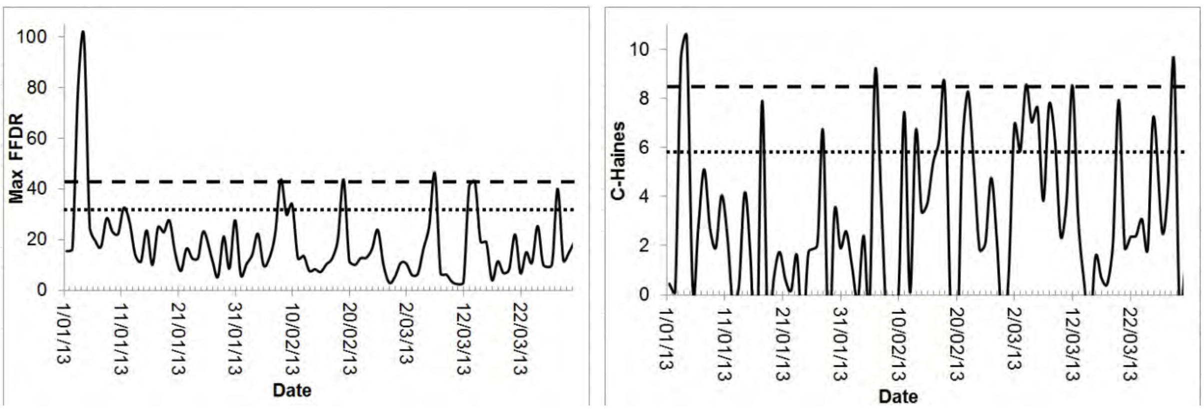
The last quarter of 2012 was drier than average across most of Tasmania, resulting in very dry soils and vegetation leading into January 2013 (Figure 2). In January itself, rainfall was again well below average in most areas.



a) October to December 2012 b) January to March 2013

Figure 2. Rainfall anomalies in Tasmania between October 2012 and March 2013.
Source: Bureau of Meteorology.

A feature of the 2012–13 summer was the elevated levels of fire danger that prevailed through January to March 2013 (Figure 3). For example, at Hobart Airport over the 7 years between 1998 and 2005, the January to March 95th percentile for the daily maximum Forest Fire Danger Rating was about 31 (Bureau of Meteorology data), with the corresponding figure for January to March 2013 being 43. For the C-Haines Index (measure of atmospheric instability; see Mills and McCaw 2010) at Hobart Airport, the 95th percentile for the period 2000 to 2007 was about 5.8 (Mills and McCaw 2010) with the corresponding figure for January to March 2013 being about 8.5.



a) maximum FFDR b) C-Haines Index

Figure 3. Maximum Forest Fire Danger Rating (FFDR) and C-Haines recorded at Hobart Airport.
Note: maximum Forest Fire Danger Rating recorded each day, C-Haines recorded at 11:00 Eastern Daylight Saving Time (EDST) each day; dotted lines indicate the 95th percentiles: ········ average from 7 years' data, – – – data recorded Jan to Mar 2013.
Data sources: Forest Fire Danger Rating: Bureau of Meteorology; C-Haines: Mills and McCaw (2010).

The most severe fire danger days during the 2012–13 fire season occurred on 3 and 4 January 2013. On 3 January, there were increasing fresh to strong and gusty north to northwesterly winds, which combined with high temperatures and low humidities to produce widespread areas of severe fire danger. On 4 January, temperatures in eastern and southeastern Tasmania rose into the low 40s as a high-pressure system over the Tasman Sea combined with an approaching low-pressure trough and cold front to direct a very hot northerly airflow over the state. This airflow was also associated with extreme levels of atmospheric instability (Figure 3). For a more detailed review of the weather prevailing during the 2012–13 summer, see BoM 2013.

2.3 Fires assessed

The locations of the fires reviewed in this assessment are shown in Figure 4 with the fire names and corresponding incident numbers listed in

Table 1.

Table 1. Wildfires assessed in this review.

Inala Road, Forcett–Dunalley	201651	Dawson Road, Lake Repulse	201635
Apsley River, Bicheno	201693	Giblin River	201666
Speedwell Road, Montumana	201830	Glen Dhu Road, Molesworth	203055
Marked Tree Road, Gretna	203548		

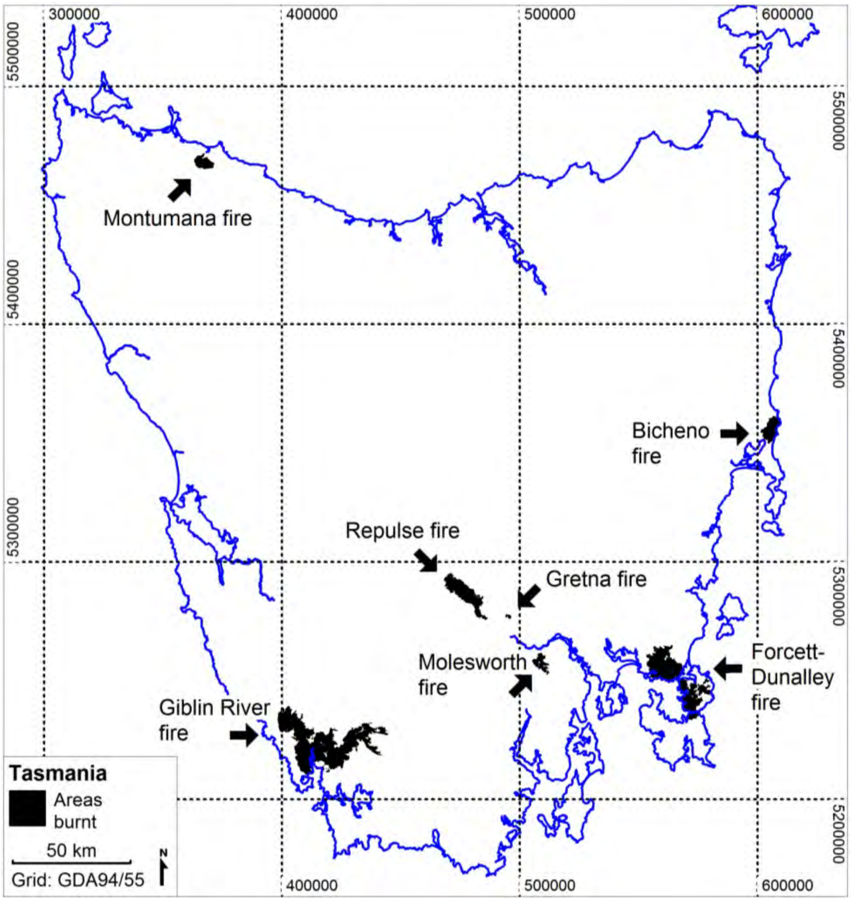


Figure 4. Location of the fires reviewed.

2.4 Fire behaviour prediction

In forest vegetation types (Forcett–Dunalley, Repulse, Bicheno, Montumana and Molesworth fires), the fire behaviour of the fires assessed has been compared against the predictions made by the McArthur Forest Fire Danger Meter (McArthur 1967, 1973) and the Project Vesta fuel hazard rating model (Cheney et al. 2012). The fuel hazard rating inputs required to make predictions using this model were obtained from the fuel hazard rating prediction models developed by Marsden-Smedley and Anderson (2011, note that these models have been updated as part of the preparation of papers for publication in a refereed journal with the updated models being included included in Appendix 1). When forest fire behaviour was predicted in damp and wet forests, the in-forest wind speed was adjusted using a formula that was derived from McArthur 1967. This formula is shown in Appendix 1.

In grassland vegetation (Gretna fire only), fire behaviour has been predicted using the natural grassland model of Cheney et al. (1998).

In buttongrass moorland and scrub vegetation types respectively (Giblin River and Montumana fires), fire behaviour was compared against the outputs of the models detailed in Marsden-Smedley et al. (1999) and Catchpole et al. (1998).

Forest and Grassland Fire Danger Ratings were predicted using systems developed by McArthur (1966, 1967, 1973) with the numerical values being calculated using the equations detailed in Noble et al. (1980).

The fuel moisture prediction models that form part of the fire behaviour prediction models were used to make predictions of dead fuel moisture prevailing during the major fire runs.

Fire spread predictions made during the time periods that the major fires were burning were also compared against the fire behaviour data collected by the present project. These fire predictions were made using the Phoenix RapidFire fire model (developed from the Phoenix fire prediction system developed by Tolhurst et al. 2008).

The performance of the different fire prediction models at predicting fire behaviour was assessed using the system proposed by Cruz (2013). This involved comparing the observed rates of fire spread against the predictions made by the Project Vesta, Phoenix RapidFire and McArthur fire behaviour models. For each of the models, the predicted mean absolute errors (MAE), mean absolute percentage errors (MAPE) and bias (see Janssen and Heuberger 1995) was calculated.

2.5 Site data collection

At each of the fire sites, digital photographs were taken, along with information on aspect, topographic position (eg lower slope, mid slope, ridge top or flat) and grid reference. All grid references were GPS located using the GDA94/55 datum. The slope (degrees) in the direction of fire travel was also recorded. This means that if fires were burning across a slope, the value recorded was the slope in the direction of fire travel. Note that this slope value was often less than the value looking straight up or down the slope. Where fires were burning up-slope, the slope was recorded as positive and negative for fires burning down-slope.

The methodology used to collect the field data and the data collected are summarised in Appendix 2.

2.6 Fire and fuel data

Information has mainly been collated from Situation Reports, maps made during the fires, interviews with fire management personnel and observations of post-fire dynamics, with some additional information being obtained from Incident Action Plans. This information was then geo-referenced and correlated against data on fuels, weather and site characteristics.

Wherever possible during the post-fire assessments, the likely level of fuel hazard at the time of the fires was estimated. However, in most sites, only minimal information on fuel hazards was obtainable owing to the very dry conditions that occurred during the fires resulting in most fine fuel being consumed. Where data on fuels was recorded, the fuel hazard rating system developed by Hines et al. (2010) for the Department of Sustainability and Environment (DSE) was used.

In dry forest, the fuel hazard prediction models developed by Marsden-Smedley and Anderson (2011; see also Marsden-Smedley and Anderson unpublished; Marsden-Smedley et al. unpublished) was used to predict the level of surface, near-surface and overall fuel hazard and the total fuel load at the time of the fires (see Section 2.1, Appendix 1).

In each site where post-fire assessments were conducted, the identity of the dominant tree species and (where appropriate) the co-dominant or sub-dominant tree species was estimated along with their height, canopy cover, bark type, likely amount of bark and degree of bark charring. In each of these sites, the direction of fire travel (degrees) and fire intensity class were also recorded. Fire intensities were recorded on a six-point scale, as shown in Table 2.

Table 2. Fire intensity classes

1	unburnt	4	burnt with 75 to 100% crown scorch
2	burnt with minimal scorch	5	partial crown fire
3	burnt with 25 to 50% crown scorch	6	full crown fire

When the fires detailed in this report have been described, the distance travelled has been estimated in kilometres (km), rate of spread (ROS) in metres per minute (m/min), fire intensity has been based on Byram's Intensity (Byram 1959) in kilowatts per metre of fireline (kW/m), area burnt in hectares (ha) and fire perimeter in kilometres (km). Eastern Daylight Saving Time (EDST) has been used for all fires.

2.7 Fire mapping

Maps have been generated for each fire for as many time periods as practical between the fire's ignition and when it was reported to be contained. This resulted in several maps being developed per day during the time periods when the fires were making major fire runs, and the time period between maps increasing once fires had done their major runs and the fire suppression was in the control and mop-up phase.

The fire maps generated for each time period show the location of the fire's head, flank and back fire boundaries. In addition, while the fires were making major fire runs, there would have been spotfires outside the areas that have been mapped. The maps generated for each of the time periods that the fires have been mapped are in Appendix 4.

The data as part of this project and the sources used to map the fires are summarised in Appendix 2.

All mapping was performed in MapInfo using the GDA94/55 datum.

2.8 Weather data

Weather data collected by the Bureau of Meteorology automatic weather stations (AWS) detailed in Table 3 has been summarised.

Table 3. Bureau of Meteorology automatic weather station names and identification numbers

Wynyard Airport	91107	Luncheon Hill	91259	Smithton Aerodrome	91292
Friendly Beaches	92114	Maria Island	92124	Hobart Airport	94008
Hobart	94029	Mt Wellington	94087	Tasman Island	94155
Campania	94212	Dunalley	94254	Bushy Park	95003
Ouse	95048	Butlers Gorge	96003	Liawenee	96033
Low Rocky Point	97080	Scotts Peak	97083	Cape Sorell	97000
Maatsuyker Island	94041				

Data for the Forest Fire Danger Rating and C-Haines at Hobart Airport at 23:00 and 11:00 EDST for the period 01/01/2013 to 31/03/2013 have been summarised (see Figure 3).

For the period 00:00 01 January to 23:50 31 March 2013, the weather data factors shown in Table 4 have been summarised at 10-min intervals (see Appendix 3).

Table 4. Weather data parameters from Bureau of Meteorology automatic weather stations

Temperature	°C	Dew-point temperature	°C	Relative humidity	%
Wind speed	km/h	Maximum wind gust	km/h	Wind direction	degrees

Owing to the size of the automatic weather station data files, the full data was not included in this report. The automatic weather station data for temperature, relative humidity and wind speed are summarised in Appendix 3.

3. Fire descriptions

3.1 Forcett–Dunalley fire

Forcett–Dunalley fire from White Beach at about 15:55 04/01/13. Photo: Janice James

3.1.1 Forcett–Dunalley fire summary

Fire identifier:	201651 – Forcett–Dunalley
Cause:	re-ignition from a campfire
Ignition location:	555195 5260448 ± ~25 m
Ignition time:	14:00 03/01/13
Containment:	18/01/13
Final area:	23 960 ha
Final perimeter:	310 km
Fire maps:	Appendix 4.1

3.1.2 Forcett–Dunalley fire description

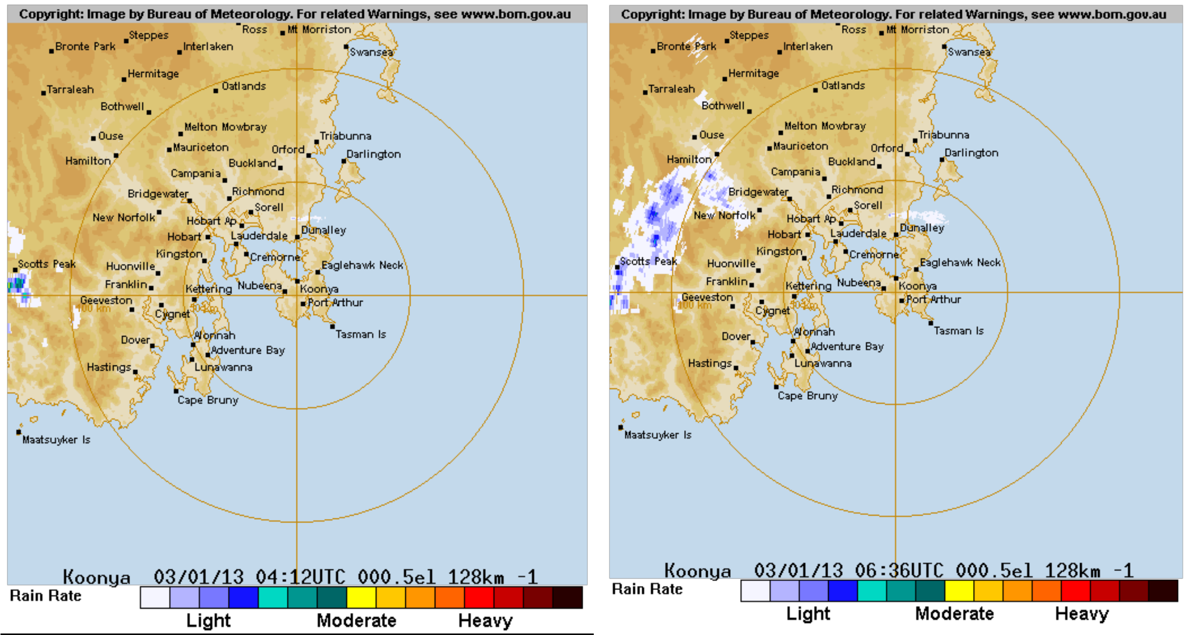
The closest AWSs to the Forcett–Dunalley fireground are at Hobart Airport and Stroud Point, Dunalley. For the period 14:00 03/01/13 to 18:00 04/01/13, data on the prevailing weather was obtained from the Hobart Airport AWS. The Hobart Airport AWS was used for this time period owing to the weather data from the Stroud Point AWS being influenced by the fire between about 16:00 and 18:10 04/01/13. Research published by Gould et al. (2007a) indicates that fires influence local weather conditions from shortly before the fires hit through to about an hour later. The Stroud Point AWS was then used for the time period from 18:00 04/01/13 through to when the fire was contained on 18/01/13 except for a short period when data from Hobart Airport was used owing to the Stroud Point AWS being off-line.

The Forcett–Dunalley fire started at about 14:00 03/01/13 in the vicinity of 242 White Hills Road, Forcett. The cause of the fire was probably re-ignition from a campfire that had been lit in an old stump on 28/12/12 (TFS 2013b).

Between about 14:00 and 15:00 03/01/13, the fire spread southeast down an approximately –5° slope on a westerly wind as a head fire at an average speed of about 6 to 8 m/min. During this time period, the fire is estimated to have increased in size to about 2.5 ha, its perimeter to about 0.7 km, flame height to about 5 m, intensity to about 2500 kW/m and with a spotting distance beyond the area mapped of about 1.5 to 2.5 km.

During the time period between 14:30 when Tasmania Fire Service (TFS) fire crews arrived at the fireground and about 15:00 03/01/13, it is probable that the fire crews would have been able to perform effective fire suppression on the fire's northern flank along White Hills Road. However, the fire crews would have been unable to access and hence suppress the fire's head and southern flank. By about 15:00, the fire had grown to a size and intensity where, under the prevailing weather, site and access conditions, effective suppression would not have been feasible given the available resources. At 15:00 03/01/13, the C-Haines Index would have been about 10.5, the mean wind speed about 40 km/h, gusting to 55 km/h, and the relative humidity about 14%, with a Forest Fire Danger Rating of about 47.

The fire first becomes visible on the Bureau of Meteorology Mt Koonya radar at 15:06 03/01/13. By 15:12, increased amounts of smoke can be seen streaming away from the fire's location under the influence of the prevailing westerly wind (Figure 5a).



a) 15:12 03/01/2013 b) 17:36 03/01/2013

Figure 5. Bureau of Meteorology Mt Koonya radar at 15:12 and 17:36 EDST 03/01/2013.
Note: smoke streaming east just north of Dunalley.

Between about 15:00 and 16:00 03/01/13, the fire moved east with a rate of spread of about 30 m/min and with a predicted intensity of about 9175 kW/m.

After 16:00 03/01/13, the fire burnt towards Mother Browns Bonnet with a spread rate of about 43 m/min and a predicted intensity of about 18 500 kW/m.

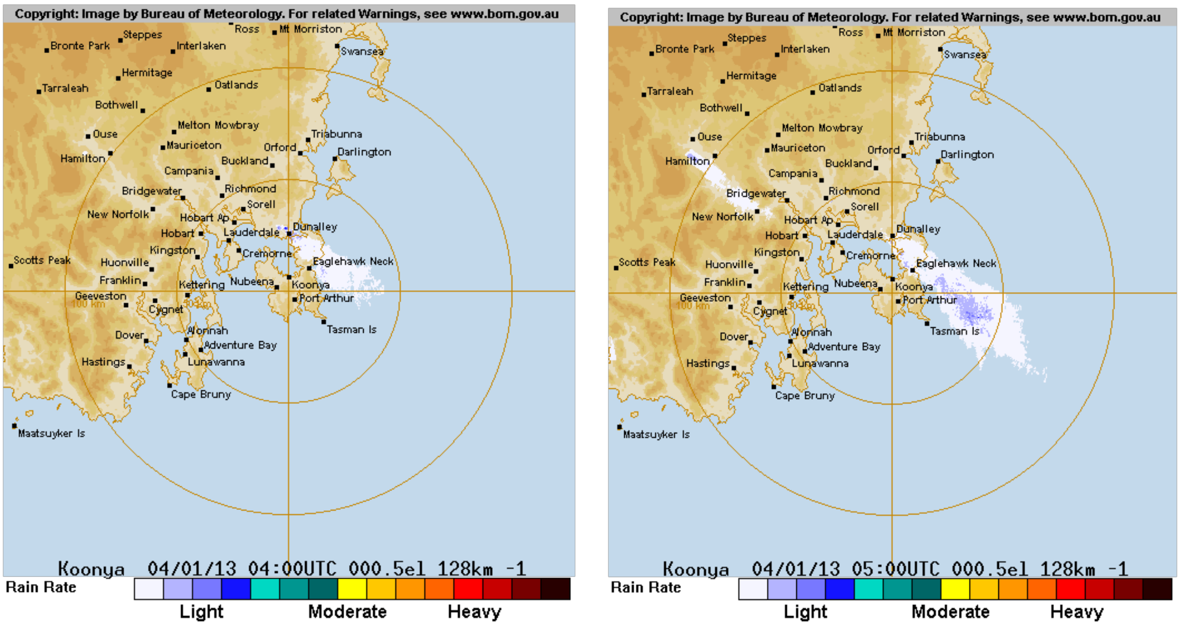
The fire was mapped by the TFS at about 17:35 03/01/13. By this time, the fire had travelled about 5.9 km, was about 506 ha, with a perimeter of about 14.0 km. The fire had also spotted across to a hill adjacent to Wettenhall Flat.

The level of fire behaviour then decreased overnight. The fire continued to burn south to southeast in rough country with an average overnight rate of spread of about 2 m/min and an intensity of about 1000 kW/m. During this time, the fire's uncontained southern and eastern boundary was about 12 km in length.

By 06:45 04/01/13, the fire had increased in size to about 973 ha with a perimeter of about 19.6 km. At this time, the fire was burning slowly south, in the vicinity of Gangells Road and the southern slopes of Gunns Hill.

After 06:45 04/01/13, the fire then steadily increased its spread rate and intensity, crossing the Arthur Highway in several locations between Sugarloaf Road and Blue Hills Road between 12:00 and 12:30 (A Skelly, personal communication[1]). At 12:30, the fire was about 1586 ha with a perimeter of about 21.7 km.

The fire then spread rapidly, mostly as a crown fire, towards the southeast at an average spread rate of about 58.3 m/min and a predicted intensity of about 25 000 to 30 000 kW/m. By 14:30, the fire had increased to about 5819 ha with a perimeter of about 42.8 km. From 15:00 on, smoke can be seen streaming towards the southeast on the Bureau of Meteorology Mt Koonya radar (Figure 6).



a) 15:00 04/01/2013 b) 16:00 04/01/2013

Figure 6. Bureau of Meteorology Mt Koonya radar at 15:00 and 16:00 04/01/2013.

Note: smoke streaming southeast from the Dunalley and Repulse fires.

The fire reached Dunalley at about 15:25 (Figure 7). At this time, the rate of fire spread would have been between about 45 and 50 m/min with a predicted intensity of between 22 500 and 25 000 kW/m.

Observations of the fire as it impacted on Dunalley indicate that its arrival was associated with large numbers of embers, resulting in spotfires throughout the town (A Skelly, personal communication; see also Figure 7b). This issue will be discussed further in Section 4.2.

After 15:25 04/01/13, the fire continued to burn towards the southeast (Figure 8). During this time period, the fire's rate of spread averaged about 50.6 m/min with a predicted intensity of about 24 000 kW/m. The level of fire activity can also clearly be seen on the Mt Koonya radar images taken at 15:00 and 16:00 (Figure 6).

[1] Andrew Skelly, Tasmania Fire Service, Cambridge, Tasmania.

a) 15:19 04/01/2013
from MacGregor fire tower

b) 15:24 04/01/2013
taken from a helicopter

Figure 7. Forcett–Dunalley fire about to impact on Dunalley at 15:24 04/01/2013.
Photo 7a: Forestry Tasmania; photo 7b: Mike Goldsmith, Tasmania Fire Service.

a) 15:44 04/01/2013

b) 16:06 04/01/2013

Figure 8. Forcett–Dunalley fire from MacGregor fire tower between 15:44 and 16:06 04/01/13.
Photos: Forestry Tasmania.

At 17:30 04/01/13, the fire was burning past the township of Murdunna and was about 9623 ha with a perimeter of about 93.6 km. As the fire passed Murdunna, there was probably a minor wind change from northwesterly to north-northwesterly that acted to steer the fire from burning in a southeast direction to a south-southeast direction (S Lennox, personal communication[2]). This change in wind direction in combination with the dry forest immediately to the east and northeast of the town having been hazard-reduced about a year previously explains why there was lower proportion of house losses in Murdunna compared with Dunalley. Note that the dry forest immediately to the east and northeast of Murdunna did re-burn in this fire, but it did so as a very low-intensity fire (S Lennox, personal communication).

Between about 15:25 and 20:00, the southwest flank of the fire spread towards Connellys Marsh and Primrose Sands, with an average rate of spread of about 20 m/min and with an intensity of about 10 000 kW/m.

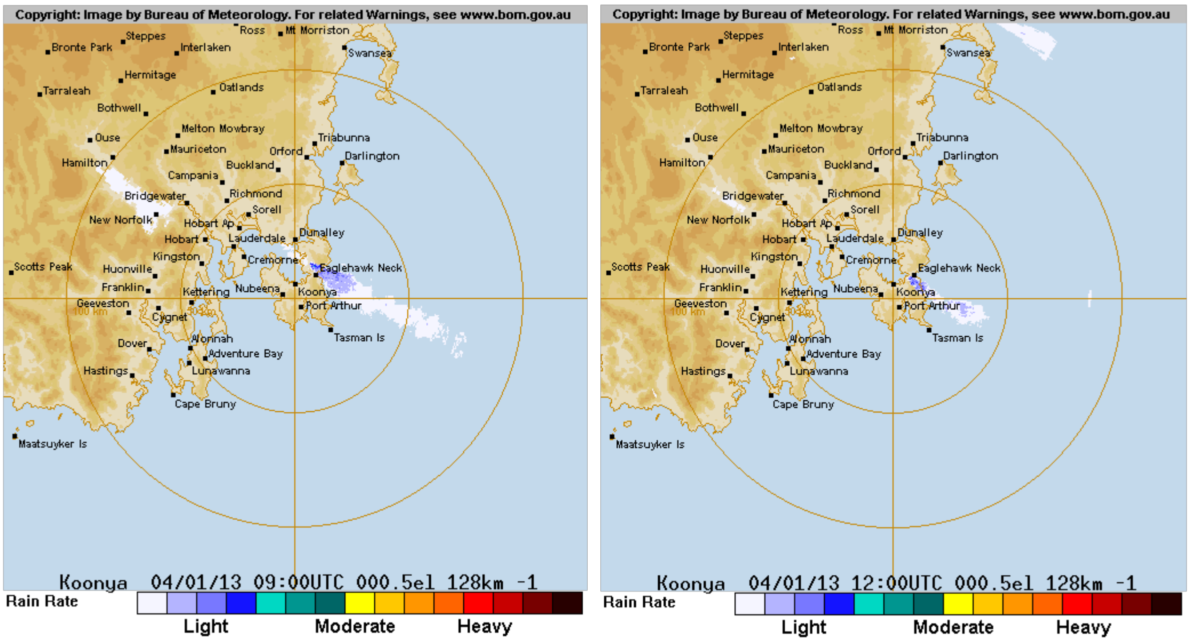
The fire then continued to burn towards the south-southeast, with its location being line-scanned by the Victorian DSE at 19:56 04/01/13. Between 17:30 and 20:00, the

[2] Mr S Lennox, Arthur Highway, Murdunna, Tasmania.

fire had an average spread rate of about 32.4 m/min and a predicted intensity of about 15 500 kW/m. At 20:00, the fire had an area of about 13 277 ha and a perimeter of about 146.8 km.

Between 20:00 and 23:00 04/01/13, the fire continued to move towards the south-southeast (Figure 9) at an average spread rate of about 17.4 m/min and a predicted intensity of about 8700 kW/m.

By 23:00, the Bureau of Meteorology Mt Koonya radar indicates that the fire had probably reached Eaglehawk Bay (Figure 9b), with the smoke trace on the radar rapidly decreasing after this time. The Sentinel Hotspot[3] data for 00:00 05/01/13 (Figure 10) also indicates that the fire had reached Eaglehawk Bay and spotted across the bay onto the hill west of Cashs Lookout. At this time, the fire was about 15 322 ha in size with a perimeter of about 166.9 km.



a) 20:00 04/01/2013 b) 23:00 04/01/2013

Figure 9. Bureau of Meteorology Mt Koonya radar at 20:00 and 23:00 04/01/2013.
Note: smoke streaming southeast from Dunalley and Repulse fires.

Between about 01:00 and 02:00 05/01/13, a south to southwest wind change moved through the fireground, resulting in the fire stopping its rapid spread towards the south-southeast and causing it to spread towards the east-northeast.

The fire was scanned by DSE again at 20:30 05/01/13, at which time it was about 19 692 ha in size and had a perimeter of about 246.6 km.

Large-scale back-burning to take the fire out to safe boundaries commenced on 06/01/13, mainly in the fire's northern sector, north of Forcett.[4] The Sentinel Hotspots data for 06/01/13 also indicates that on the Forestier Peninsula, the fire was burning actively in the area north of Hylands Road and that back-burning was being conducted on Bangor. The fire was scanned by DSE again at 21:00 06/01/13, at which time it was about 20 981 ha in size and had a perimeter of about 269.1 km.

3 Sentinel Hotspots, Geoscience Australia, Canberra, ACT. See: http://sentinel1.ga.gov.au/Sentinel/imf.jsp
4 Forcett–Dunalley Fire Situation Reports 7 and 8.

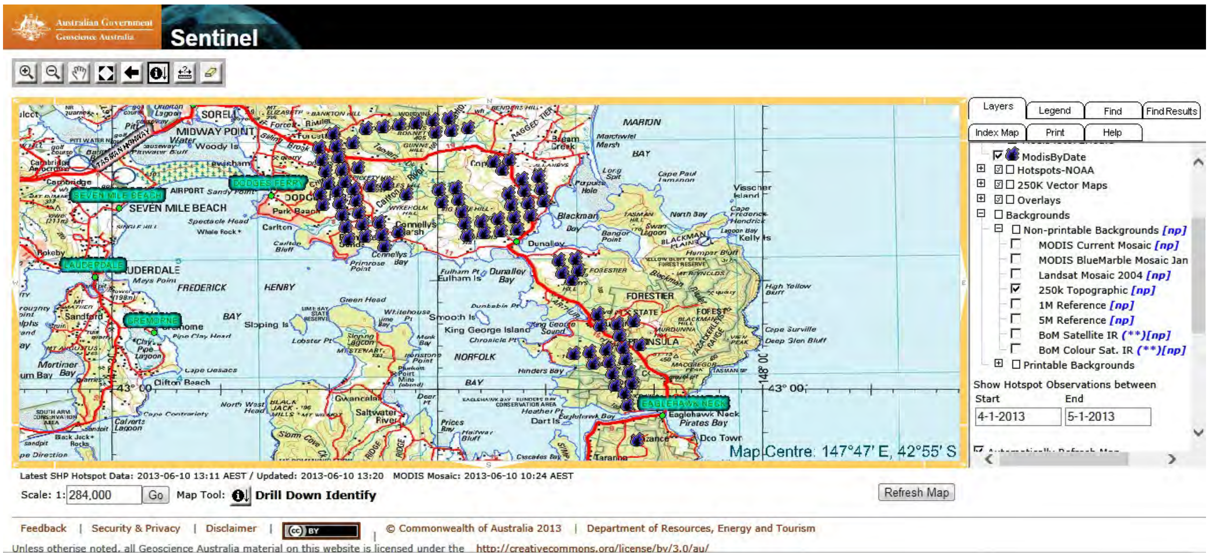


Figure 10. Sentinel Hotspot data for the Forcett–Dunalley fire at 00:00 05/01/13.
Source: Geoscience Australia, Canberra, ACT.

With the exception of the eastern half of the Forestier Peninsula, the fire was largely contained by 07/01/13. On the Forestier Peninsula, between 07/01/13 and 18/01/13, the fire spread progressively east, with the area south of Hylands Road being burnt by 16/01/13 and the area north of Dungeon Gully being burnt by 18/01/13.[5]

The Forcett–Dunalley fire was contained on 18/01/13, at which time it had burnt a total of about 23 960 ha and had a perimeter of about 309.9 km.

The fire's final boundary is shown in Figure 11, and maps of the areas burnt at different time periods are given in Appendix 4.1.

[5] Sentinel Hotspots 07/01/13, 10/01/13, 12/01/13, 14/01/13; Forcett–Dunalley Fire Situation Reports 9 to 34.

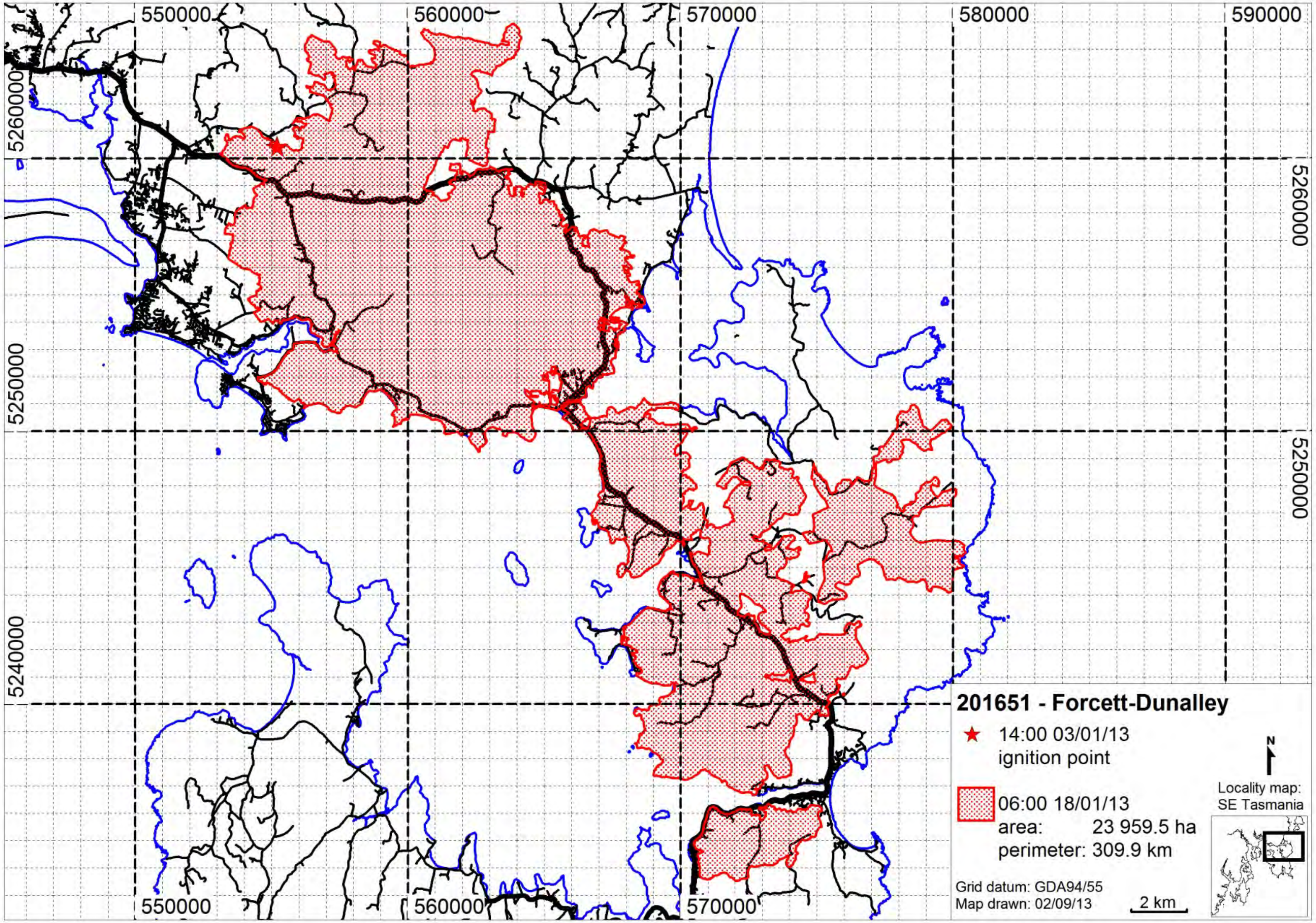


Figure 11. Final boundary of the Forcett–Dunalley fire on 18/01/13. See Appendix 4.1 for all mapped fire boundaries.

3.2 Repulse fire

Repulse fire burning south out of the Repulse River at 15:19 EDST 04/01/2013.
Photo: Bernard Plumpton, Forestry Tasmania

3.2.1 Repulse fire summary

Fire identifier:	201635 – Dawson Road, Lake Repulse
Cause:	escaped campfire
Ignition location:	469888 5294576 ± ~100 m
Ignition time:	11:30 03/01/13
Containment:	18/02/13
Final area:	10 637 ha
Final perimeter:	121.5 km
Fire maps:	Appendix 4.2

3.2.2 Repulse fire description

The weather conditions at the Repulse fireground have been estimated by averaging the data from the Ouse and Bushy Park AWS data. When the data for temperature was used, the temperature at the fireground was corrected for the effects of variation in altitude, with the relative humidity being calculated using the altitude-corrected temperature and the dew-point temperature.

The Repulse fire started from an escaped campfire on the shores of Lake Repulse at about 11:30 03/01/2013. In the vicinity where the fire started, several campfires had been lit the previous evening (02/01/13), at which time a Total Fire Ban was in force (TFS 2013e).

At the time of the campfire's re-ignition, the weather conditions at the fireground were a temperature of about 28°C, a relative humidity of about 22% and a wind speed of about 21 km/h, resulting in a Forest Fire Danger Rating of about 15. The C-Haines Index was about 10.5. The wind direction was from the northwest, at about 310°.

The fire initially spread from its ignition point towards the southeast as a flank fire and had spotted across to the eastern side of Lake Repulse prior to 14:45 03/01/13. Between 11:30 and 14:45, the fire travelled about 600 m as a flank fire with a rate of spread of about 3.1 m/min (equivalent to a head fire spread rate of about 7.7 m/min) and a predicted intensity of about 1500 kW/m. By 14:45, the fire was about 24 ha in size and had a perimeter of about 3.0 km.

By 14:45 03/01/13, a combination of the wind changing from west-northwest to northwest and the fire burning past the Repulse Dam resulted in the fire changing from mainly burning as a flank fire to mainly burning as a head fire which was moving towards the southeast.

Between 14:45 and 20:00 03/01/13, the fire travelled about 3.3 km at an average rate of spread of 9.6 m/min and a predicted intensity of about 2900 kW/m. By 20:00, the fire was about 311 ha in size with a perimeter of about 17.6 km.

Between 20:00 03/01/13 and 15:45 04/01/13, the fire's spread rate was slowed by poorly stocked eucalypt plantations in the vicinity of the Repulse and Broad Rivers.[6] Once the fire had travelled south of this zone and crossed into native dry forest on the State Forest, its rate of spread and intensity markedly increased (Figure 12). The build-up in fire behaviour can also be seen on the Bureau of Meteorology Mt Koonya radar between 15:00 and 15:30 04/01/2013 (Figure 13a and 13b).

a) 15:47 04/01/2013 b) 15:58 04/01/2013

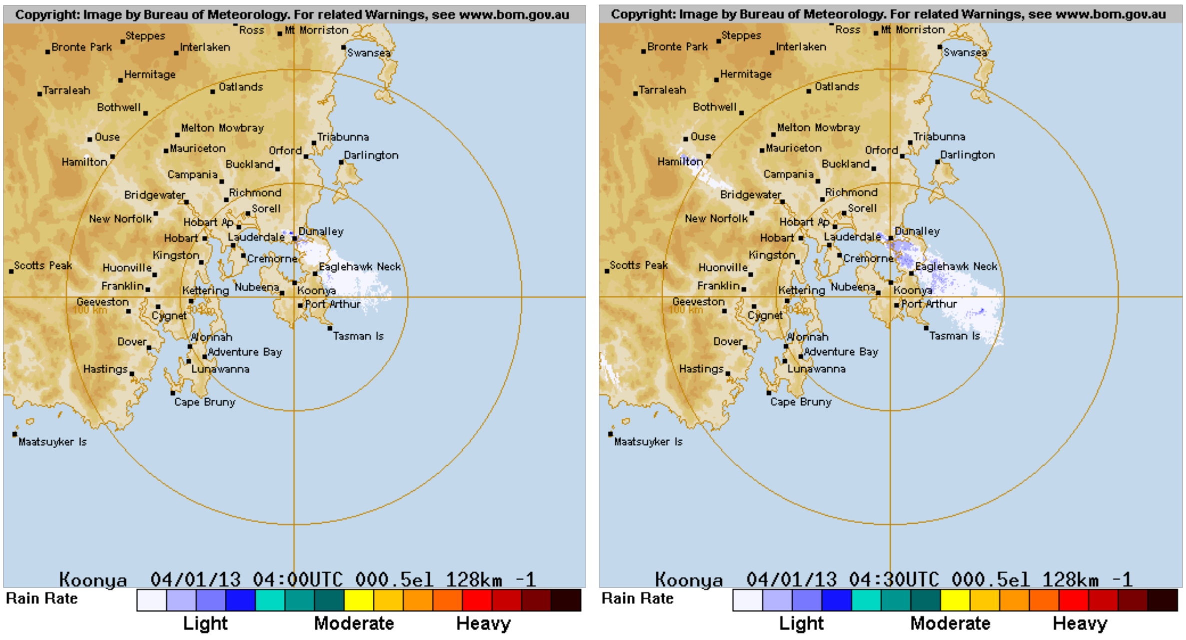
Figure 12. Repulse fire burning up out of the Broad River towards the Dunrobin pine plantation.
Photos: Bernard Plumpton, Forestry Tasmania

By 15:45 04/01/13, the fire had an area of about 877 ha and a perimeter of about 26.9 km.

The fire then spread very rapidly as a crown fire towards the southeast. The fire's location was mapped by a DSE linescan at 18:50. Between 15:45 and 18:50 04/01/13, its average rate of spread was about 59.5 m/min with a predicted intensity of about 30 000 kW/m.

By 18:50, the fire had an area of about 4109 ha and a perimeter of about 67.9 km.

6 Michael Phillips, Bernard Plumpton, Forestry Tasmania, Hobart, Tasmania.



a) 15:00 04/01/2013 b) 15:30 04/01/2013

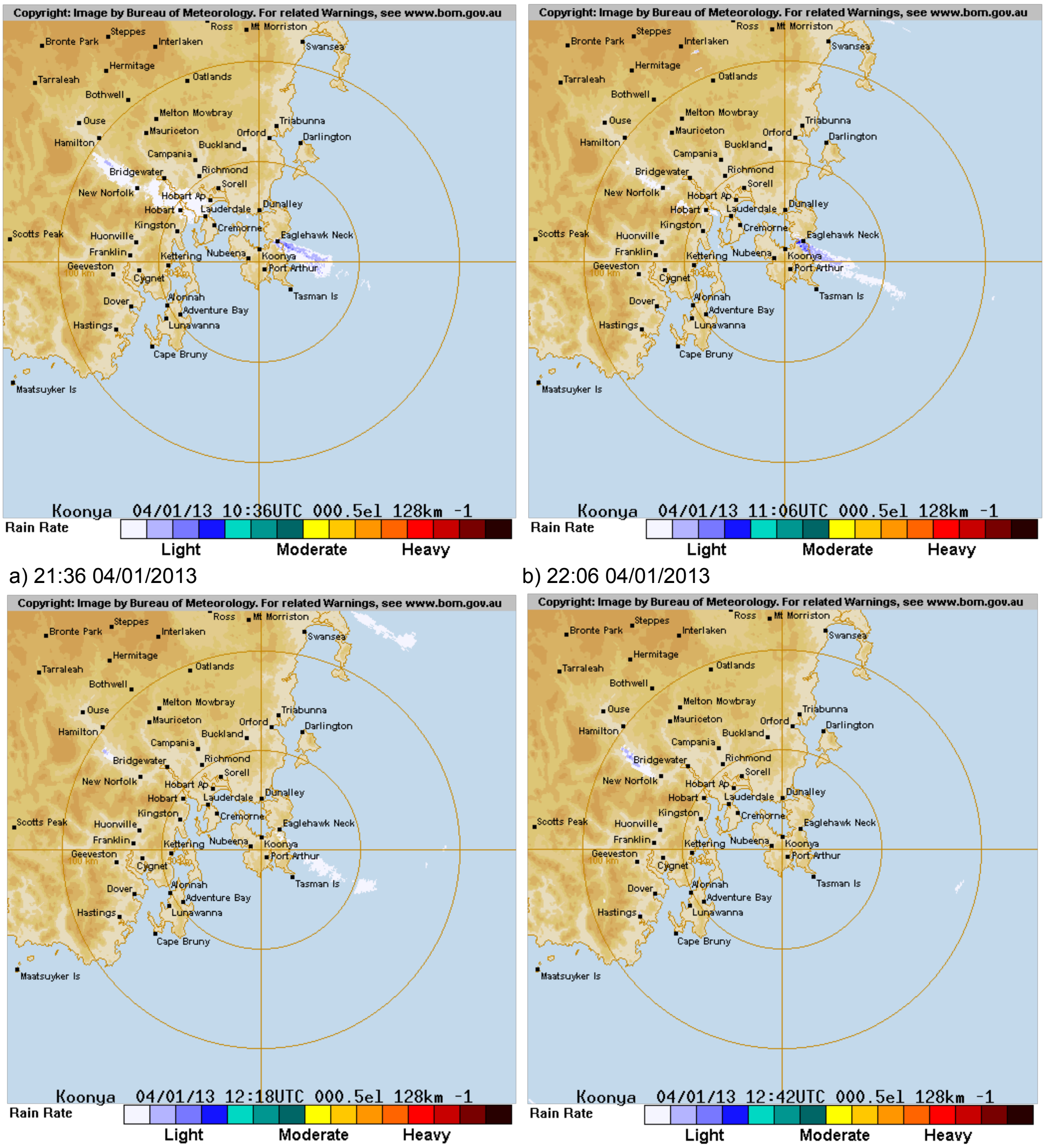
Figure 13. Bureau of Meteorology Mt Koonya radar at 15:00 and 15:30 04/01/2013.

After 18:50 04/01/13, the fire continued to spread rapidly towards the southeast (Figure 14). The Bureau of Meteorology Mt Koonya radar data and observations by Forestry Tasmania fire crews indicate that the fire dropped in intensity at about 22:00 04/01/13 (Figure 15b and 15c) when it ran into areas burnt by the 2012 Meadowbank fire. This resulted in the majority of the fire's front being extinguished, with the exception of the fire's southeastern corner which burnt around the end of the area burnt by the Meadowbank fire.

Figure 14. Repulse fire taken from Hamilton at 20:41 04/01/13.
Source: Toni Fish: http://www.flickr.com/photos/the_smileyfish/8352064853

This reduction in fire behaviour of the main part of the head fire can be seen on the Bureau of Meteorology Mt Koonya radar between 21:36 and 22:06 (Figure 15a and

15b). After 22:42, the fire then increased in intensity again in its southeast corner before this section of the fire also ran into areas burnt by the 2012 Meadowbank fire by about 23:48 (Figure 15c and 15d).



a) 21:36 04/01/2013

b) 22:06 04/01/2013

c) 23:18 04/01/2013

d) 23:42 04/01/2013

Figure 15. Bureau of Meteorology Mt Koonya radar at 21:36, 22:06, 23:18 and 23:42 04/01/2013.

The Sentinel Hotspot data also indicates that the fire had reached the area burnt in the Meadowbank fire by 00:00 05/01/13 (Figure 16).

During the time period between 18:50 and 22:06 04/01/13, the fire had an average spread rate of about 44.23 m/min and a predicted intensity of about 22 000 kW/m.

By 23:00 04/01/13, the fire had an area of about 9008 ha and a perimeter of about 101.8 km.

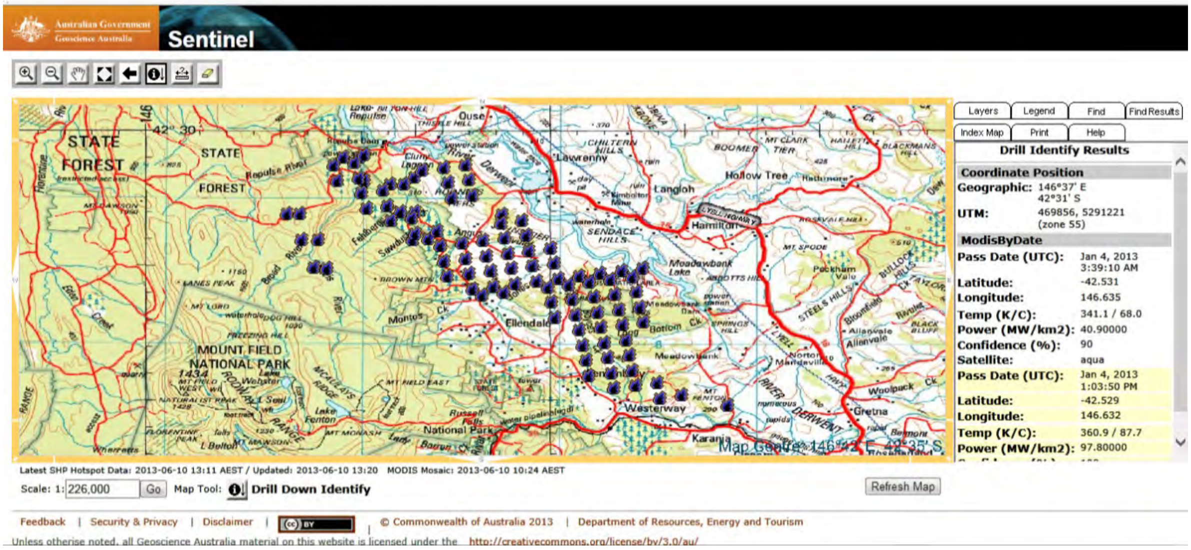


Figure 16. Sentinel Hotspot data for the Repulse fire at 00:00 05/01/13.
Source: Geoscience Australia, Canberra, ACT.

The level of fire behaviour of the Repulse fire then decreased.

By 19:40 05/01/13, the fire had increased to about 9101 ha with a perimeter of 102.0 km; by 20:30 06/01/13, it was about 9545 ha with a perimeter of about 108.8 km; and by 19:00 07/01/13, it was about 10 345 ha with a perimeter of 120.0 km. The fire had a final size of about 10 489 ha with a perimeter of about 124.1 km when it was contained on 18/01/13.

The fire’s final boundary is shown in Figure 17, and maps of the areas burnt at different time periods are given in Appendix 4.2.

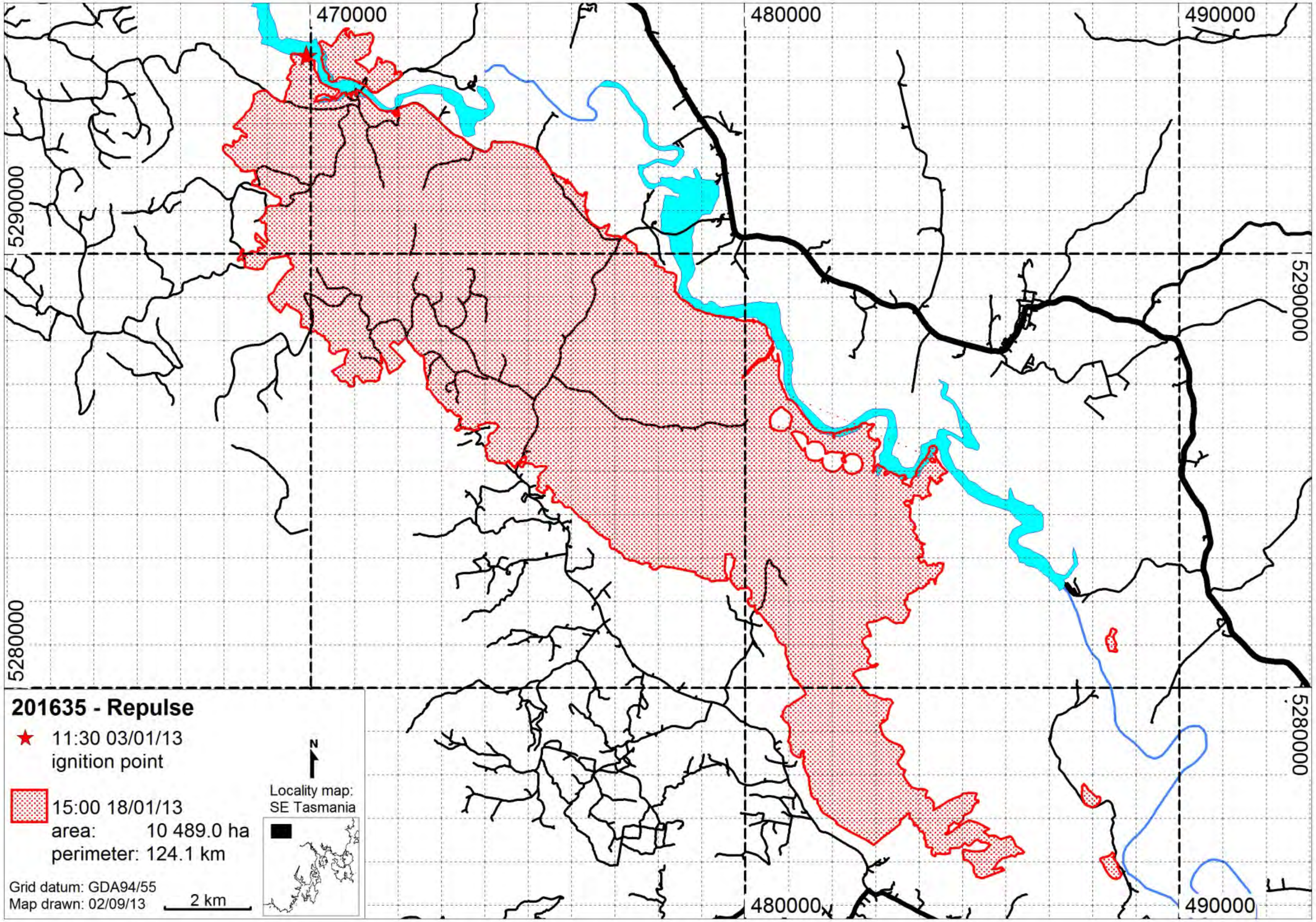


Figure 17. Final boundary of the Repulse fire on 18/01/13. See Appendix 4.2 for all mapped fire boundaries.

3.3 Bicheno fire

Ridgeline near Courland Bay burnt by crown fire during Bicheno fire.

3.3.1 Bicheno, Butlers Hill and Freshwater Lagoon fire summaries

	Bicheno
Fire identifiers:	201693
Cause:	lightning
Ignition locations:	604701 5360285
Ignition time:	20:00 to 20:20 03/01/13
Containment:	09/01/13
Final area:	4939 ha
Final perimeter:	41.3 km
Fire maps:	Appendix 4.3

3.3.2 Bicheno fire descriptions

Weather data for the Bicheno fire has been estimated from data from the Friendly Beaches AWS, which is located just south of the fireground.

The lightning storms that passed through the Bicheno area on the evening of 03/01/13 started at least four fires, three of which will be discussed in this report. The Bicheno fire was started between 20:00 and 20:20 03/01/13 adjacent to the Apsley River (TFS 2013c). The lightning storm also started the Butlers Hill fire (identifier: 201706) at about 20:01 03/01/13 and the Freshwater Lagoon fire (identifier: 201717) adjacent to Neville's Track in Freycinet National Park at about 20:30 03/01/13 (PWS 2013a, 2013b).

Both the Butlers Hill and Freshwater Lagoon fires were dozer-tracked early on 04/01/13 and fire-suppression crews performed comprehensive mop-up and patrol operations. Neither of these fires broke their containment lines and they were held to less than 1.5 ha in size. However, when the Bicheno fire escaped, it burnt over the Butlers Hill fireground. These fires will be discussed further in Section 4.6 of this report.

The Bicheno fire was dozer-tracked late on 03/01/13 and at that time had an area of about 3.2 ha and a perimeter of about 0.8 km.

At about 15:15 04/01/13, the Bicheno fire flared up and escaped (J Duggan, personal communication[7]).

[7] John Duggan, Fire Crew Supervisor, Parks and Wildlife Service.

The fire then spread rapidly towards the southeast (Figure 18), mostly as a crown fire, and reached Courland Bay (where most of the shacks that were burnt were located) by about 17:30 (Figure 19) and Butlers Point by 18:00 (Figure 20).

Figure 18. Bicheno fire ignition site at about 15:35 04/01/13.
Photo sourced from video taken by Nick Talbot, Tasmanian Helicopters.

a) Burnt forest 500 m inland of Courland Bay b) Burnt house behind the dunes at Courland Bay

Figure 19. Bicheno fire at Courland Bay at about 18:05 04/01/13.
Photos sourced from video taken by Nick Talbot, Tasmanian Helicopters.

Figure 20. Bicheno fire burning onto Butlers Point at 18:01 04/01/2013.
Photo taken by Nick Talbot, Tasmanian Helicopters.

During the time period between 15:15 and 18:00 04/01/13, the fire had an average rate of spread of about 36.4 m/min and a predicted intensity of about 16 000 kW/m. At 18:00, the fire was about 732 ha in size with a perimeter of about 15.3 km.

The fire then continued to spread south and was line-scanned by DSE at 22:00 04/01/13. At this time, the fire was about 2112 ha with a perimeter of about 29.0 km.

By about 00:00 05/01/13, the Sentinel Hotspot data (Figure 21) indicates that the fire had burnt up to the area burnt by the 30/03/11 Isaac Point planned burn (planned burn: FRENP013P[8]). At this time, the fire was about 2746 ha in size with a perimeter of about 29.5 km.

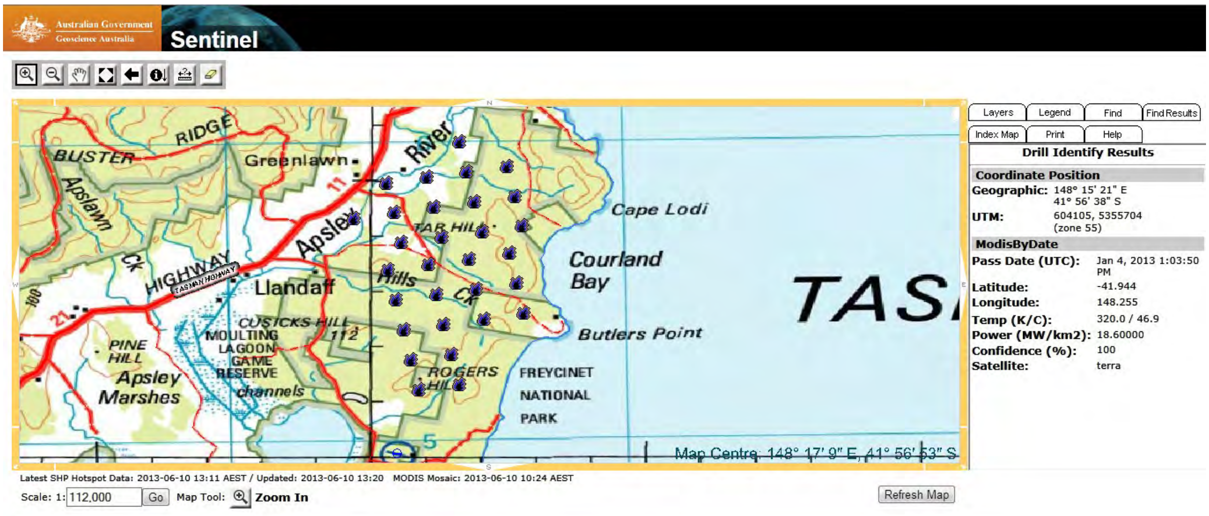


Figure 21. Sentinel Hotspot data for the Bicheno fire at 00:00 05/01/13.
Source: Geoscience Australia, Canberra, ACT.

8 Unpublished fire history database: Parks and Wildlife Service, Hobart, Tasmania.

Between 00:00 and 19:00 05/01/13, the fire spread to the west, crossing the Coles Bay Road between 13:00 and 14:00[9] under the influence of easterly to southeasterly winds.[10] Back-burning was also performed on the fire's northern and northeastern boundaries in order to bring the fire out to safe edges. The fire was line-scanned by DSE at 19:00, at which time it had an area of about 3573 ha and a perimeter of 47.7 km.

Between the evening of 05/01/13 and 09/01/13 when the fire was contained, extensive back-burning was performed on the fire's northern, western and southwestern flanks to bring the fire out to safe edges[11].

The fire's final boundary is shown in Figure **22**, and maps of the areas burnt at different time periods are given in Appendix 4.3.

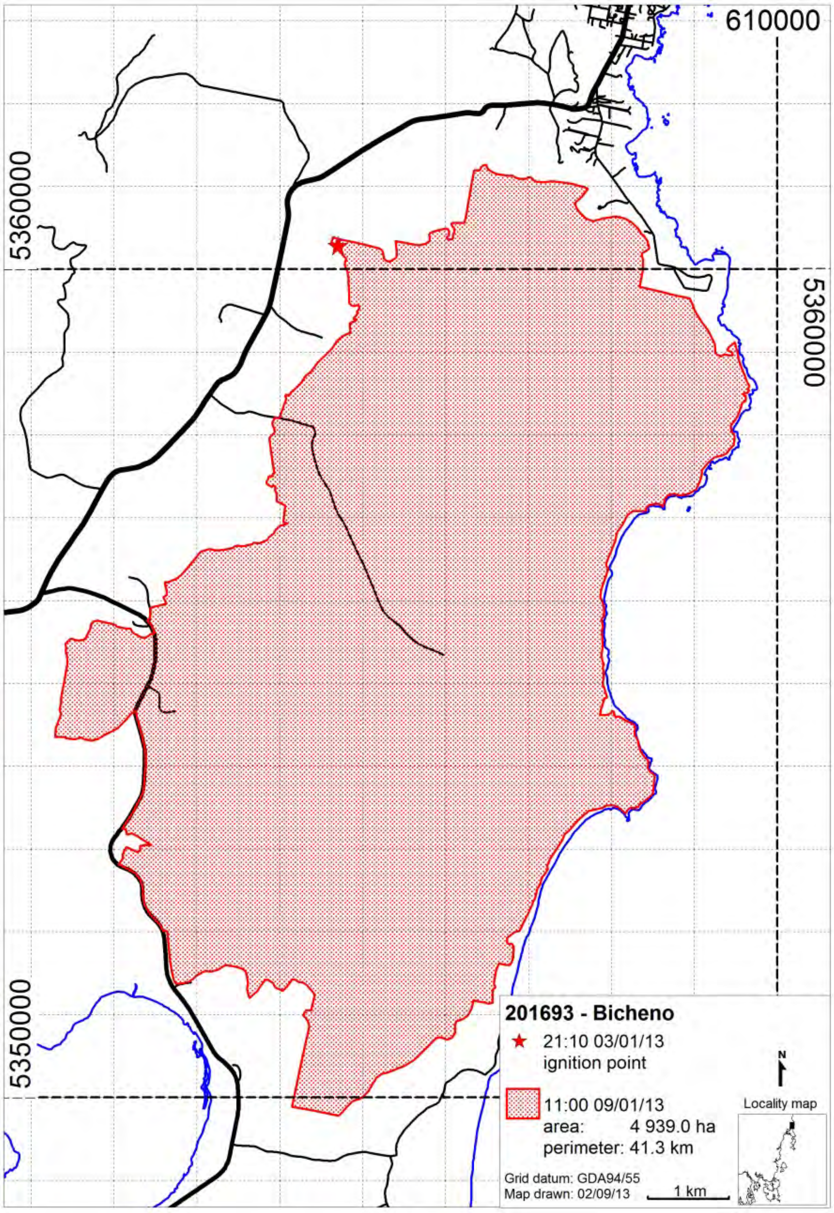


Figure 22**. Final boundary of the Bicheno fire on 09/01/13.**
See Appendix 4.3 for all mapped fire boundaries.

9 Steve Everts, Freycinet Field Centre, Parks and Wildlife Service.
10 Bureau of Meteorology Friendly Beaches AWS.
11 Bicheno Fire Situation Reports 6 to 15.

3.4 Giblin River fire

Smoke-filled valleys during the Giblin River fire.
Photo taken at 09:09 07/01/13 from the Propsting Range by Jon Marsden-Smedley

3.4.1 Giblin River fire summary

Fire identifier:	201666
Fire name:	Giblin River fire
Cause:	lightning
Ignition location:	approx. 401950 5,237070 ± ~2 km (GDA94/55)
Ignition time:	early afternoon 03/01/2013
Containment:	22/01/13
Final area:	45 124 ha
Final perimeter:	387 km
Fire maps:	Appendix 4.4

3.4.2 Giblin River fire description

Weather data for the Giblin River fire has been estimated from the Low Rocky Point and Scotts Peak AWS data. For the time period from the fire's ignition up until 24:00 04/01/13, the Low Rocky Point AWS was used, and the Scotts Peak AWS was used after this time.

The Giblin River fire was started by lightning early-afternoon on 03/01/13. During this storm, it is probable that about 0.6 mm of rain fell over the fireground. The fire was first reported mid-afternoon on 03/01/13 and at about 15:00 was reported to be 1 to 2 ha in size and burning slowly.[12] No attempts were made to suppress the fire at this time owing to the fire's remoteness, the difficulty of performing effective suppression, the lack of fire suppression resources due to other fires and the very low probability of fire suppression operations being effective.

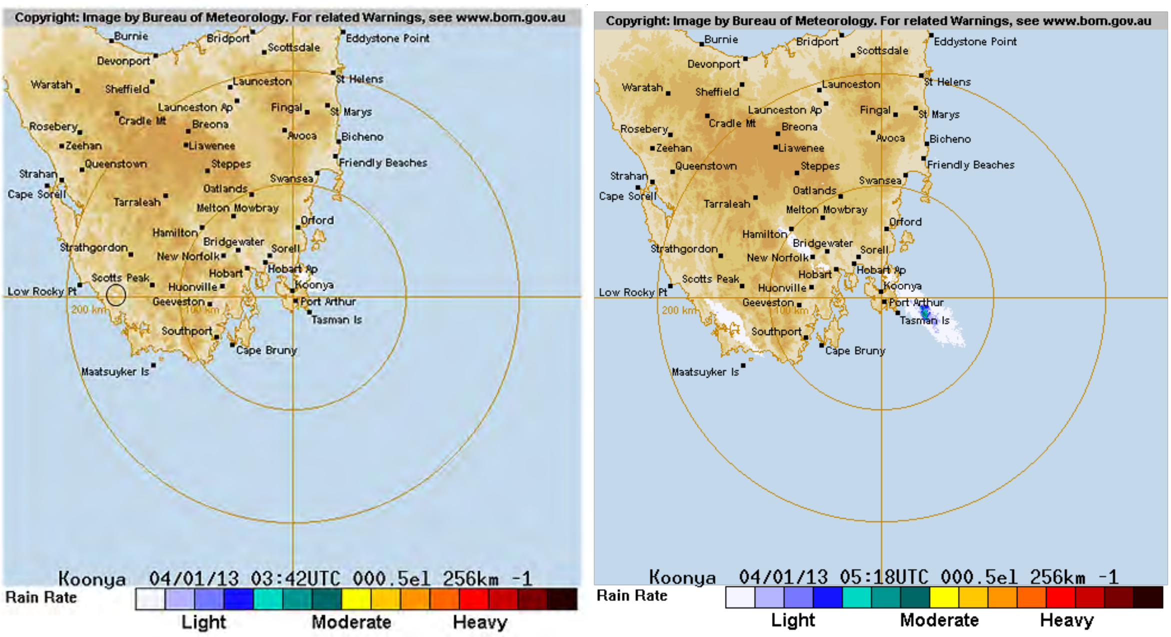
[12] Report from Osborne Aviation helicopter pilot.

Between 06:30 and 10:00 04/01/13, a fire spotter flight assessed the region for lightning fires. At about 08:00, when the fire spotter flight was about 20 km to the southeast, they reported that no smoke was visible from the Giblin River fire. This indicates that at this time fire was burning slowly in relatively sparse buttongrass moorland. The fire’s probable size at this time would have been about 25 to 30 ha.

The Giblin River fire probably increased its rate of spread and intensity from about 09:00 04/01/13. Between 09:00 and 16:15, the fire spread rapidly towards the southeast, averaging about 37.5 m/min.

At 13:25 04/01/13, smoke was reported by a flight on its way into Melaleuca, about 35 km to the southeast. By 14:00, the fire’s smoke column was visible from Strahan, about 125 km to the northwest.

First becomes visible on the Mt Koonya radar at 14:42 04/01/13 (small circled area next to the west coast on Figure 23a). By 16:18, the Mt Koonya radar was recording a marked increase in the amount of smoke (Figure 23b). At this time, the fire was burning through mixed buttongrass moorland, wet scrub and wet eucalypt forest in the vicinity of Castle Hill.



a) 14:42 04/01/2013. Circle indicates smoke location b) 16:18 04/01/2013

Figure 23. Bureau of Meteorology Mt Koonya radar at 14:42 and 16:18 04/01/2013.

By about 16:15 04/01/13, the Sentinel Hotspot data (Figure 24) indicates that the fire had run about 16.5 km towards the southeast from its ignition point and had a size and perimeter of about 8843 ha and 67.6 km respectively.

The fire continued to spread rapidly towards the southeast at an average speed of about 33.8 m/min, spotting across the Davey River at about 17:00 04/01/13 and then continuing to burn across the northern side of Settlement Point. The fire then crossed the Lost World Plateau and burnt towards Bakers Ridge. By about 24:00, the Sentinel Hotspot data (Figure 24) indicates that the fire had run an additional 15.2 km or so towards the southeast. At this time, the fire had a size and perimeter of about 21 995 ha and 177.9 km respectively.

The southeast movement of the Giblin River fire was checked by a recent planned burn (Gunfight Creek planned burn performed April 2011) on its southern boundary and wet forest and rainforest on its southeast boundary. The fire then continued to burn up the Spring and Crossing River valleys towards the northeast, mostly as a flank fire.

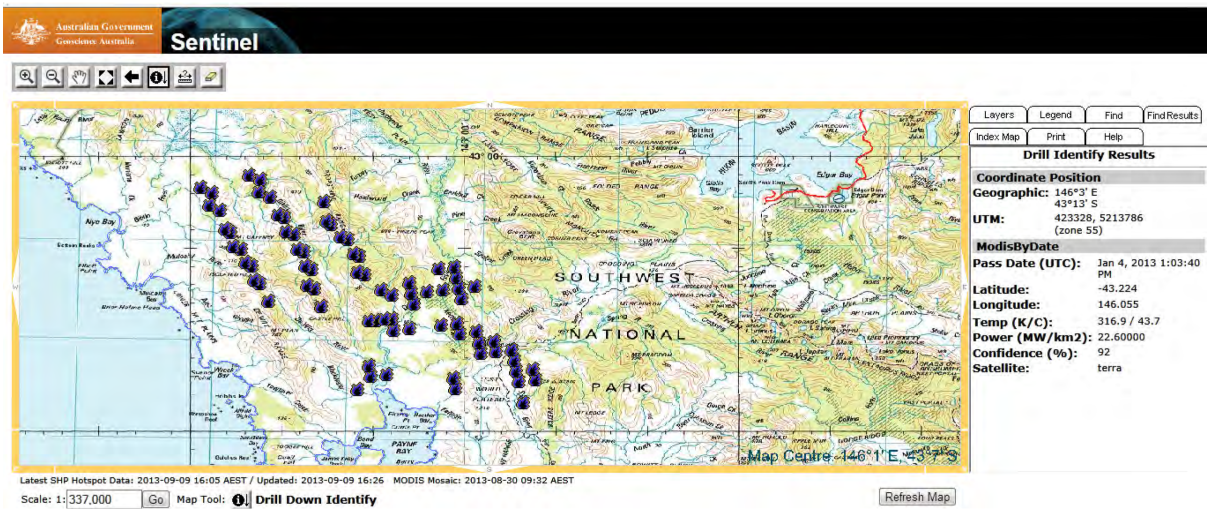


Figure 24. Sentinel Hotspot data for the Giblin River fire at 24:00 04/01/13.
Source: Geoscience Australia, Canberra, ACT.

The fire was mapped by a DSE linescan at 23:00 05/01/13, at which time it had travelled about 10.3 km up the Spring and Crossing River valleys towards the northeast and had a size and perimeter of about 27 545 ha and 199.6 km respectively.

The fire was mapped by the Parks and Wildlife Service (PWS) at 08:00 07/01/13, at which time it had a size and perimeter of about 33 956 ha and 255.4 km respectively, and was burning up onto the western end of the Western Arthur Range (Figure 25a).

The fire was mapped again by PWS at 16:30 08/01/13, with the fire having an area and perimeter of about 43 408 ha and 356.6 km respectively. At this time, the fire was burning up onto the southern slopes of the Western Arthur Range and up the Crossing River valley (Figure 25b).

The fire then continued to burn slowly until it was contained on 22/01/13, when it had a final size and perimeter of about 45 124 ha and 386.7 km respectively.

a) Burning up to Lake Fortuna in the Western Arthur Range. Photo: Chris Arthur, PWS.

b) Burning up the southern slopes of Mt Sirius in the Western Arthur Range. Photo: Jon Marsden-Smedley.

Figure 25. Giblin River fire burning up onto the Western Arthur Range at 10:37 08/01/13.

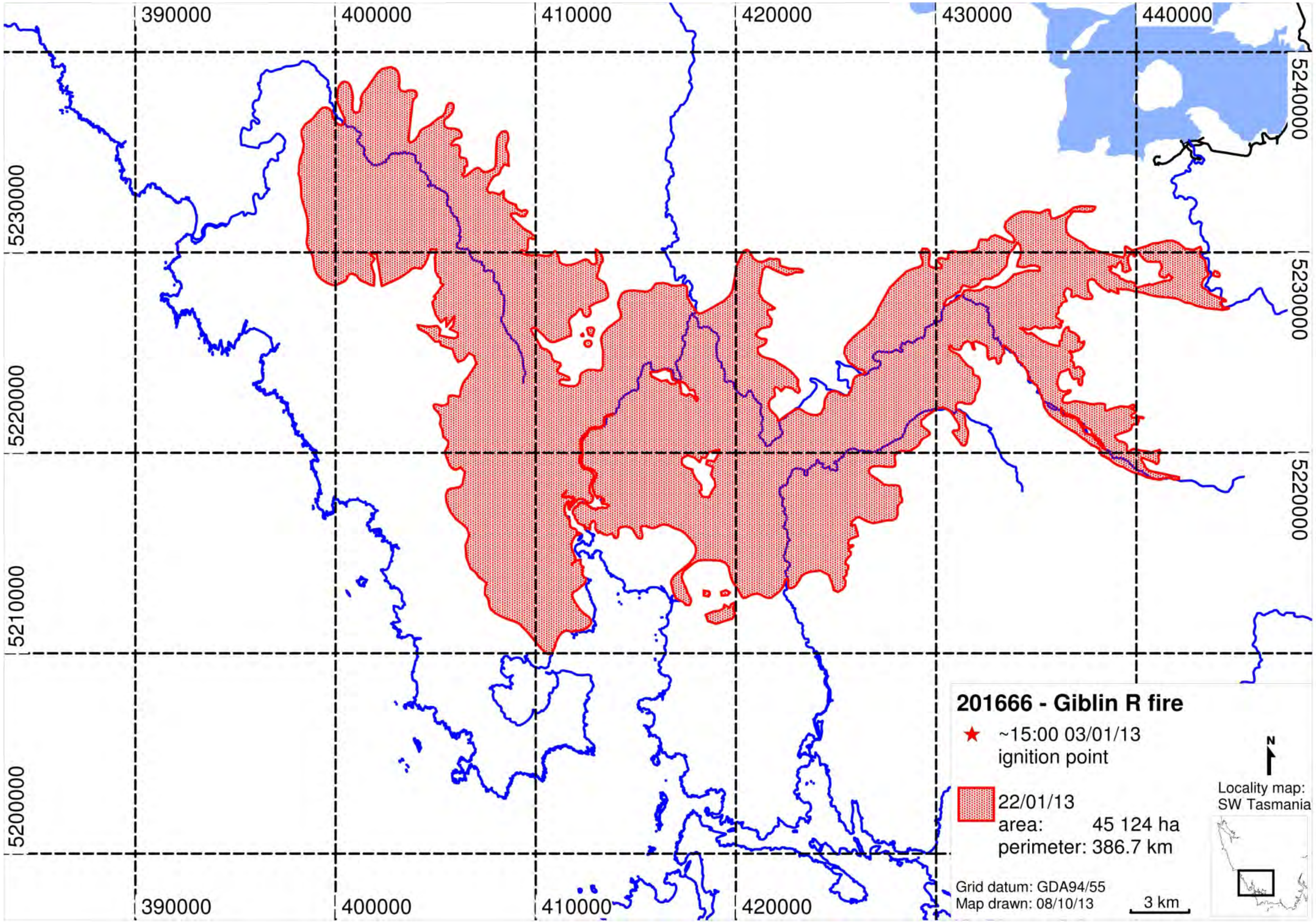


Figure 26. Final boundary of the Giblin River fire on 22/01/13. See Appendix 4.5 for all mapped fire boundaries.

3.5 Montumana fire

Montumana fire at 14:45 05/01/13. Photo by Murchison District, Forestry Tasmania.

3.5.1 Montumana fire summary

Fire identifier:	201830
Fire name:	Speedwell Road, Montumana
Cause:	lightning
Ignition location:	approx 366900 5469200 ± ~250m (GDA94/55)
Ignition time:	between 07:52 and 08:52 05/01/2013
Containment:	20/01/13
Final area:	3158 ha
Final perimeter:	28.5 km
Fire maps:	Appendix 4.5

3.5.2 Montumana fire description

The weather conditions at the Montumana fireground have been estimated from the Wynyard airport, Smithton aerodrome and Luncheon Hill AWS data (the fire was located approximately equal distances from each of these AWS). When the data for temperature was used, the temperature at the fireground was corrected for the effects of variation in altitude, with the relative humidity being calculated using the altitude-corrected and the dew-point temperatures. A major issue with the Montumana fire was the frequent changes in wind direction, which resulted in all of the fire’s boundaries becoming head fires at different times.

The fire was ignited by lightning between 07:52 and 08:52 05/01/13. The fire Incident Action Plan for 06/01/13 states that the fire started on State Forest south of Loosemores Spur 1 between Blackfish and Hook Creeks. The Global Position and Tracking Systems (GPATS) lightning data[13] indicates that relative to the fire's assumed ignition point, there were cloud-to-ground strikes recorded about 1.1 km to the east, about 1.1 km to the southwest and about 2.1 km to the north-northeast. There were also an additional 12 cloud-to-ground strikes recorded between 3 and 5 km from the fire's assumed ignition point (Figure 27).

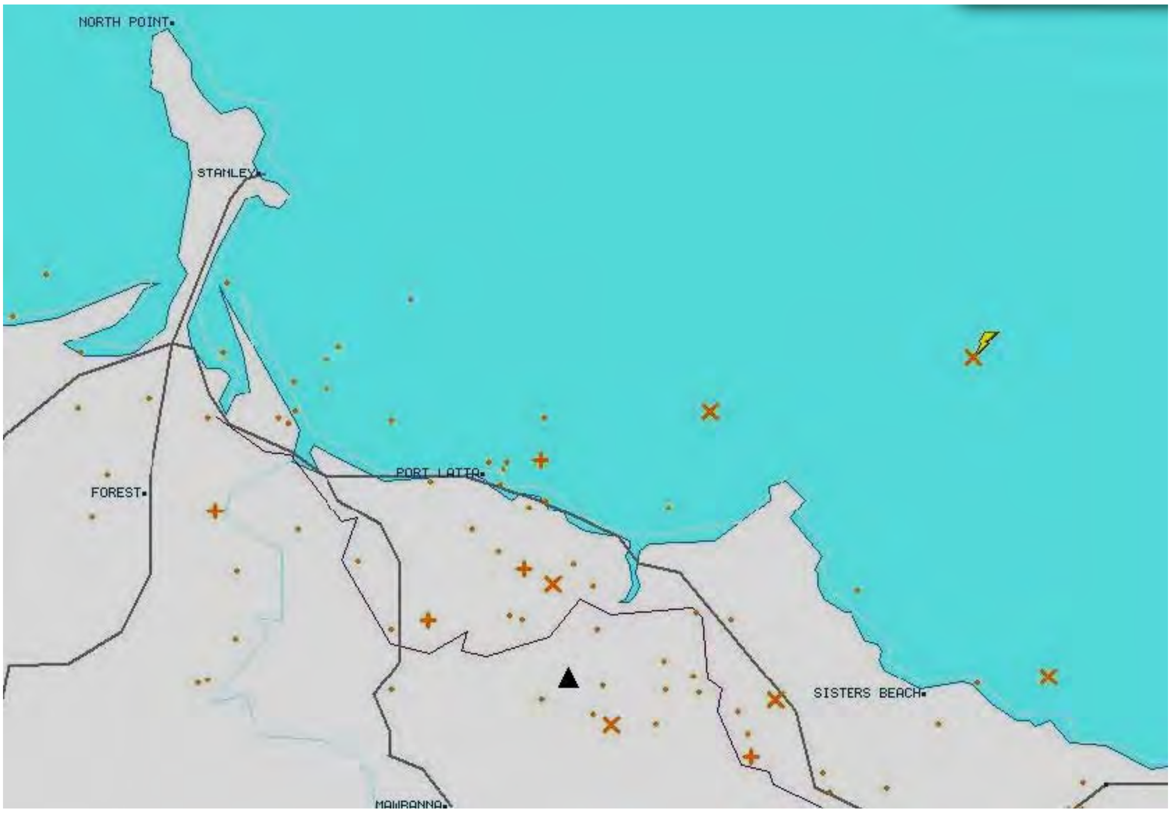


Figure 27. GPATS data for the Montumana fire between 07:52 and 08:52 05/01/2013.
Note: ▲: fire ignition point; x: cloud-to-cloud strikes; + and •: cloud-to-ground strikes.

The fire was aerial-mapped at about 12:58 05/01/13. At this time, the fire was moving primarily towards the northeast[14] and had an area and perimeter of about 77 ha and 4.2 km respectively.

Between 13:00 and 18:00 05/01/13, the fire moved towards the southwest, south-southeast and northeast (Figure 28), burning damp forest, wet scrub and buttongrass moorland. During this time period, the fire's average spread rate towards the southwest was about 5.3 m/min.

At 18:00 05/01/13, the fire had an area of about 329 ha and a perimeter of about 9.0 km.

13 Global Position And Tracking Systems: Sydney, New South Wales, Australia.
14 Montumana Fire Situation Report 1.

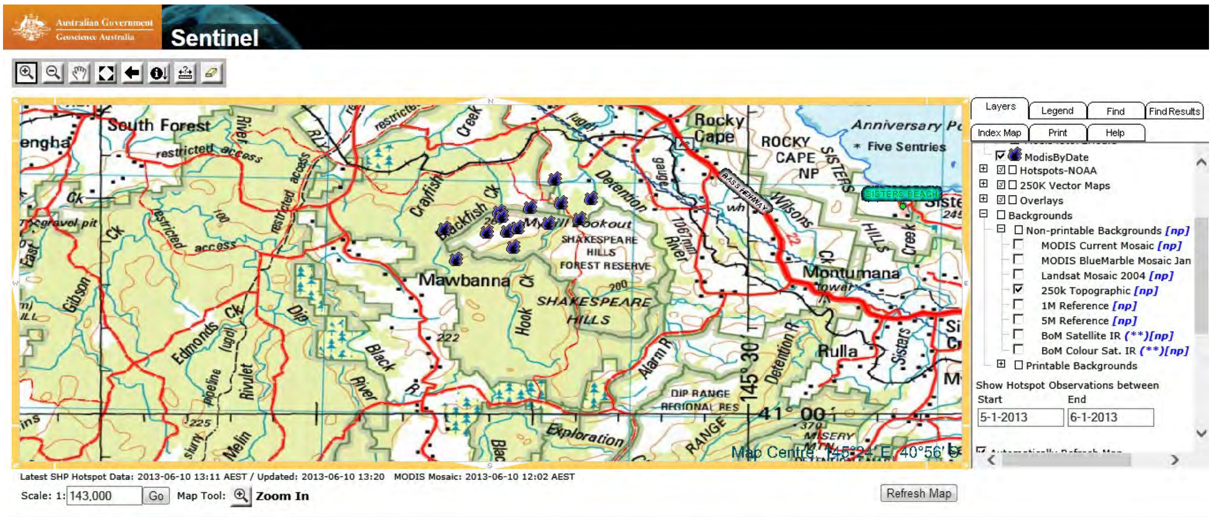


Figure 28 Sentinel Hotspot data for the Montumana fire between 15:22 05/01/13 and 00:47 06/01/13.
Source: Geoscience Australia. Canberra, ACT.

The fire was mapped at 08:35 06/01/13, at which time it had travelled a further 1.6 km towards the southwest at an average spread rate of about 2.5 m/min and had an area of about 545 ha and a perimeter of about 13.4 km.

Between 08:35 and 17:13 06/01/13, the fire moved about 600 m, primarily towards the southeast (Figure 29), at an average spread rate of about 1 m/min.

At 17:13 06/01/13, the fire had an area of about 817 ha and a perimeter of about 16.8 km.

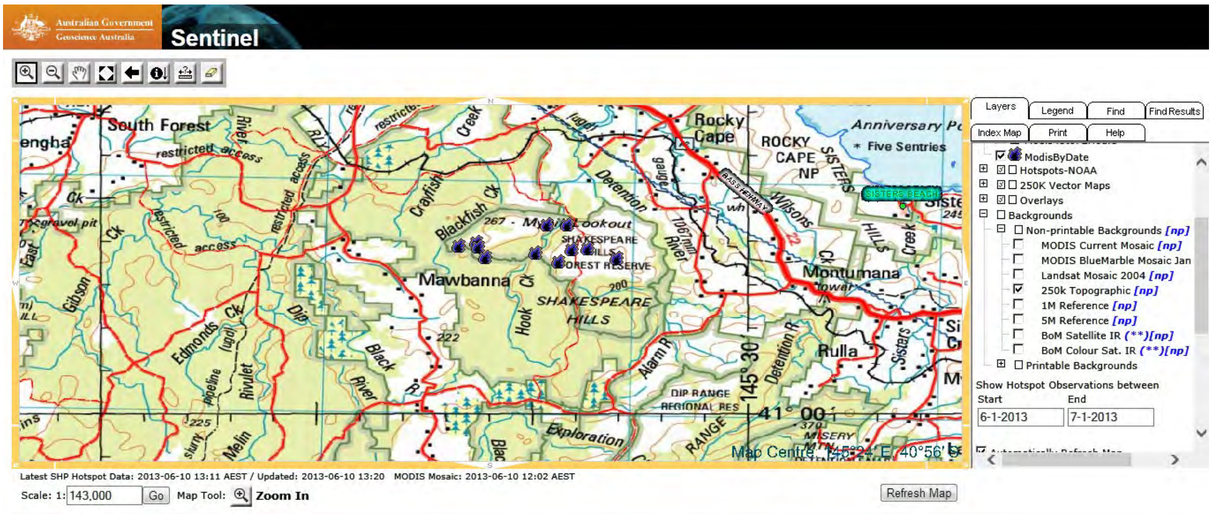


Figure 29. Sentinel Hotspot data for the Montumana fire at 16:05 06/01/13.
Source: Geoscience Australia, Canberra, ACT.

Between 17:13 06/01/13 and 09:00 07/01/13, the fire continued to move primarily towards the southeast and the Shakespeare Hills.

At 09:00 07/01/13, the fire had an area of about 1069 ha and a perimeter of about 19.5 km.

Between 09:00 07/01/13 and 07:00 08/01/13, the fire did a run towards the south and southeast, mostly burning in buttongrass moorland, wet scrub and eucalypt forest (Figure 30 and Figure 31).

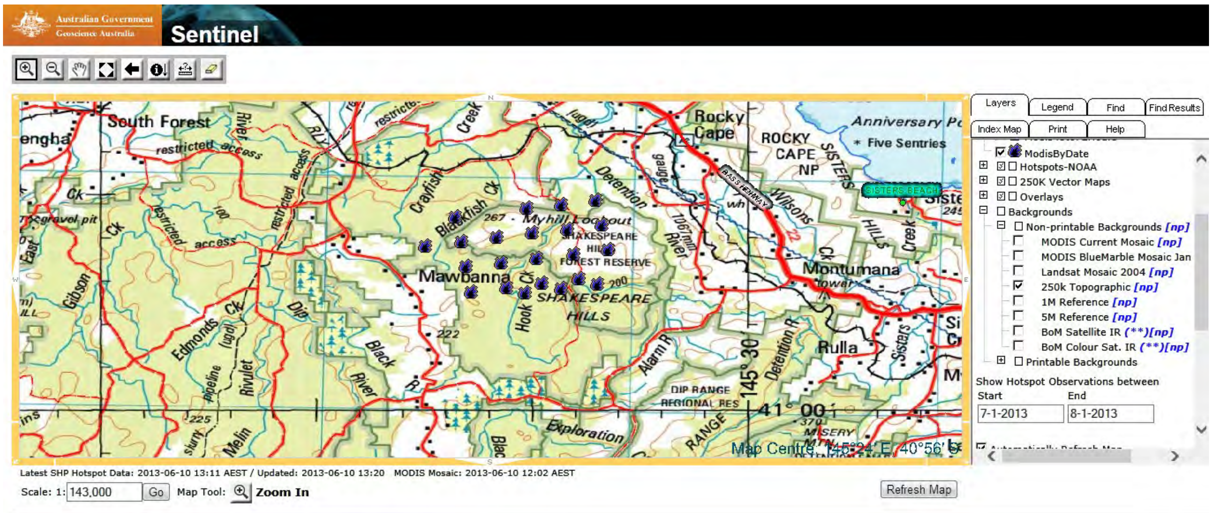


Figure 30. Sentinel Hotspot data for the Montumana fire at 15:10 07/01/13.
Source: Geoscience Australia, Canberra, ACT.

Figure 31. Montumana fire at 11:17 07/01/13.
Photo: Murchison District, Forestry Tasmania.

At 07:00 08/01/13, the fire had an area of about 1880 ha and a perimeter of about 22.0 km.

During 08/01/13, a southwest change moved through the fireground,[15] resulting in the fire doing a run of about 3 to 4 km on the fire's northwest flank and a run of about 2 km on the fire's southeast flank (Figure 32).

15 Montumana Fire Situation Reports 8 to 10.

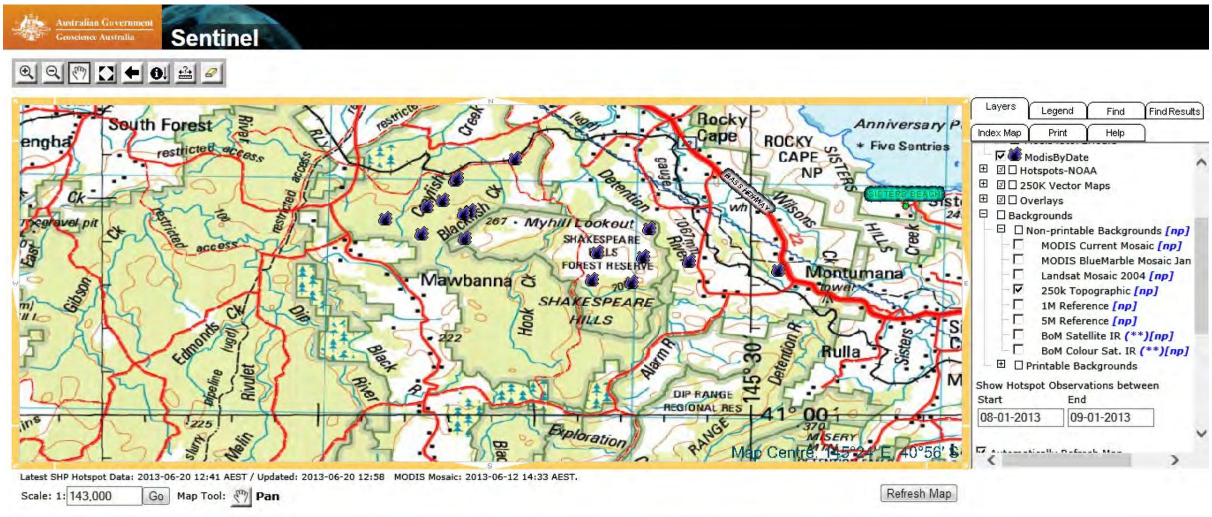


Figure 32. Sentinel Hotspot data for the Montumana fire at 11:40 08/01/13.
Source: Geoscience Australia, Canberra, ACT.

By 17:30 08/01/13, the fire had an area of about 2916 ha and a perimeter of about 28.6 km.

The fire then slowed its rate of expansion with most of the fire's increase in area coming from back-burning to bring the fire out to safe boundaries.[16]

By 19/01/13, the fire had an area of about 2983 ha and a perimeter of about 29.1 km.

Back-burning in the fire's southeast corner was performed on 19/01/13 to contain the fire. By 20/01/13, the fire had an area of about 3158 ha and a perimeter of about 28.5 km.

The fire's final boundary is shown in Figure 33, and maps of the areas burnt at different time periods are given in Appendix 4.5.

16 Montumana Fire Situation Reports 11 to 37.

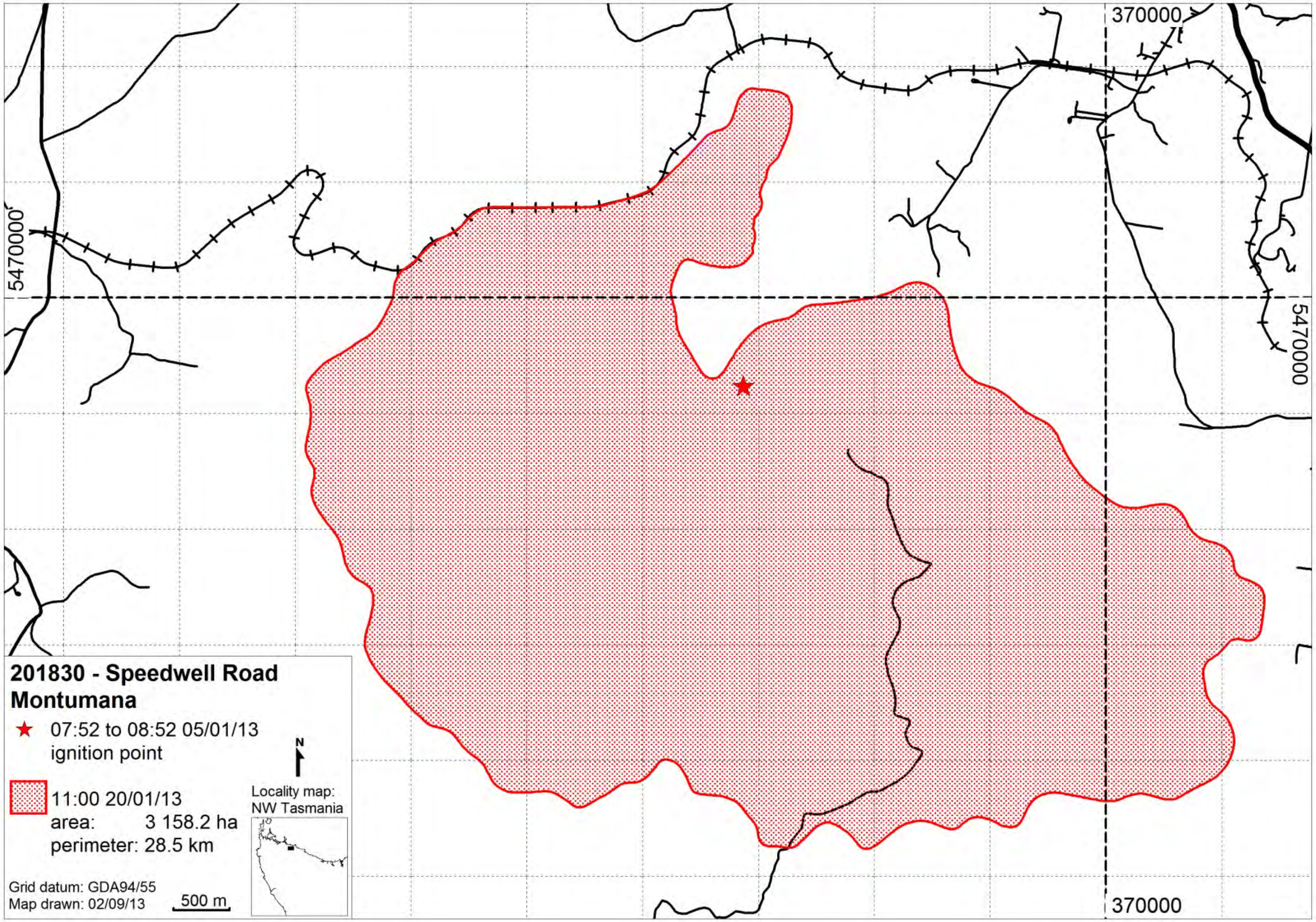


Figure 33. Final boundary of the Montumana fire on 20/01/13. See Appendix 4.5 for all mapped fire boundaries.

3.6 Molesworth fire

Collins Cap and Molesworth fire from near Collins Bonnet. Photo: Jon Marsden-Smedley

3.6.1 Molesworth fire summary

Fire identifier:	203055
Fire name:	Glen Dhu Road, Molesworth
Cause:	unknown
Ignition location:	508854 5259892 (GDA94/55)
Ignition time:	~13:00 06/02/13
Containment:	18/02/13
Final area:	2582 ha
Final perimeter:	54.4 km
Fire maps:	Appendix 4.6

3.6.2 Molesworth fire description

The weather conditions prevailing at the Molesworth fireground have been estimated from the Bushy Park and Mt Wellington AWS data. When the data for temperature was used, the temperature at the fireground was corrected for the effects of variation in altitude, with the relative humidity being calculated using the altitude-corrected and the dew-point temperatures.

The Glen Dhu Road, Molesworth, fire started adjacent to piles of cut vegetation at about 13:00 06/02/13 (TFS 2013a). The fire initially spread up a steep hill towards the east.[17]

By 18:00 06/02/13, the fire had an area of about 239 ha and a perimeter of about 6.8 km (Figure 34).

By 07:00 07/02/13, the fire had spread to both sides of Glen Dhu Road and the fire had an area of about 387 ha and a perimeter of about 10.4 km.

On 07/02/13, the fire made runs west up onto the Backbone and to the southeast up Silver Falls Creek.

By 15:00 07/02/13, the fire had an area of about 711 ha and a perimeter of about 13.6 km, increasing to an area of about 952 ha and a perimeter of about 17.6 km by 18:34 07/02/13 (Figure 35).

[17] Molesworth Fire Situation Report 1.

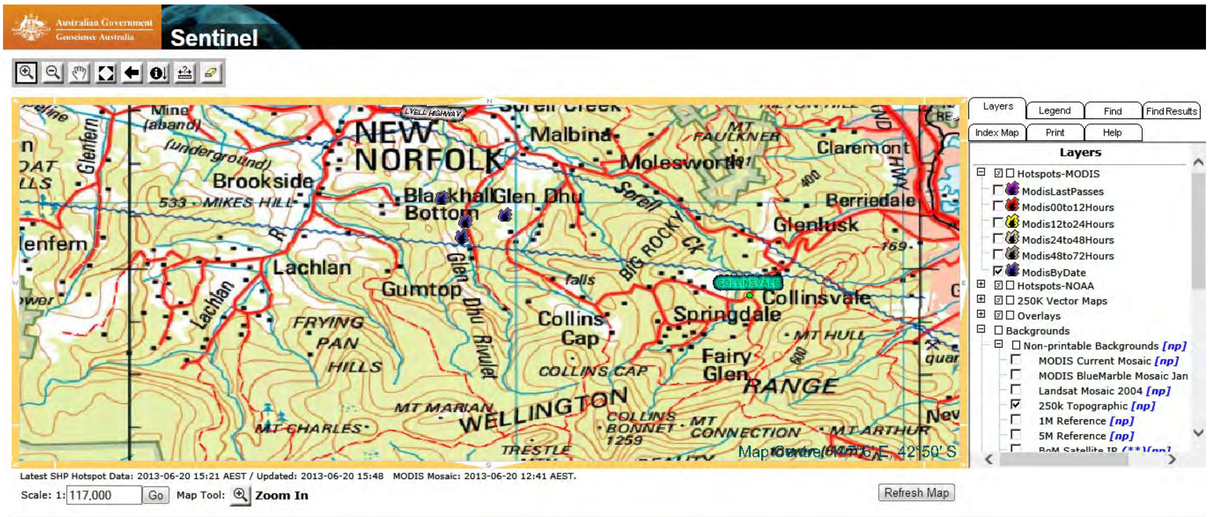


Figure 34. Sentinel Hotspot data for the Molesworth fire 06/02/13.
Source: Geoscience Australia, Canberra, ACT.

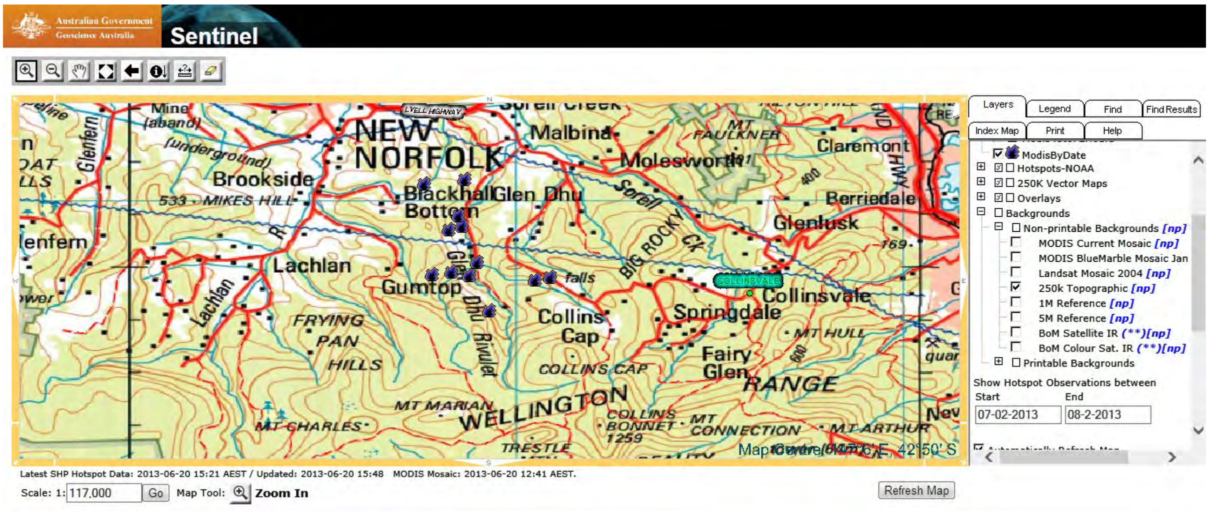


Figure 35. Sentinel Hotspot data for the Molesworth fire 07/02/13.
Source: Geoscience Australia, Canberra, ACT.

By 08:00 08/02/13, the fire had expanded out to an area of about 1087 ha with a perimeter of about 20.8 km.

On 08/02/13, the fire did a run towards the southeast and Suhrs Road.[18] By 19:00 08/02/13, the fire had an area of about 1432 ha and a perimeter of about 36.5 km.

On 09/02/13, the fire did major runs towards the south under the influence of strong northerly winds.

By 17:30 09/02/13, the fire had burnt up onto Gum Top, the western slopes of Collins Cap, Suhrs Road and on to the top of the Wellington Range near Collins Bonnet. At this time, the fire had an area of about 1969 ha and a perimeter of about 50.9 km.

By 09:18 10/02/13, the fire had an area of about 2108 ha and a perimeter of 53.3 km.

The fire then continued to expand, mainly in the vicinity of Gum Top on the fire's western boundary (Figure 36).

18 Molesworth Fire Situation Reports 4 and 5.

Figure 36. Sentinel Hotspot data for the Molesworth fire on 10/02/13.
Source: Geoscience Australia, Canberra, ACT.

By 19:30 10/02/13, the fire had an area of about 2247 ha and a perimeter of about 54.9 km.

Between 10/02/13 and 18/02/13, back-burning, mainly on the fire's western and southwestern boundary, took the fire out to Ringwood fire trail.[19]

The fire was contained on 18/02/13, at which time it had an area of about 2582 ha and a perimeter of about 54.4 km.

The fire's final boundary is shown in Figure 37, and maps of the areas burnt at different time periods are given in Appendix 4.6.

[19] Molesworth Fire Situation Reports 8 to 17.

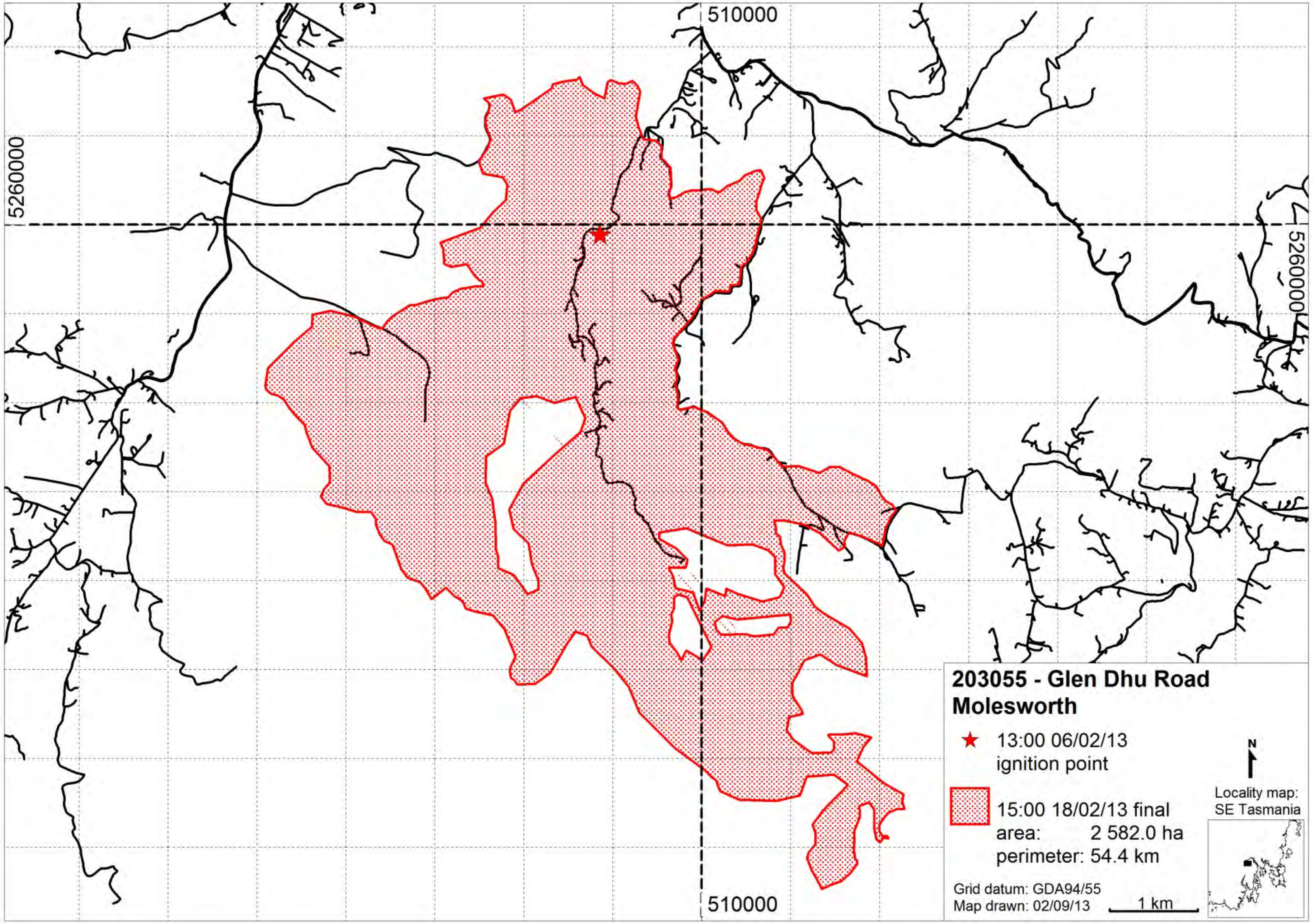


Figure 37. Final boundary of the Glen Dhu Road, Molesworth, fire on 18/02/13. See Appendix 4.6 for all mapped fire boundaries.

3.7 Gretna fire

Gretna fire at 16:56 18/02/2013. Photo: Mathew Smith, TFS.

3.7.1 Gretna fire summary

Fire identifier:	203548
Fire name:	Marked Tree Road, Gretna
Cause:	accident
Ignition location:	494397 5277932 (GDA94/55)
Ignition time:	15:57 18/02/13
Containment:	19:44 18/02/13
Final area:	221.6 ha
Final perimeter:	10.1 km
Fire maps:	Appendix 4.7

3.7.2 Gretna fire description

The weather conditions prevailing at the Gretna fireground have been estimated by averaging the weather data from the Bushy Park and Ouse AWS.

The Gretna fire burnt primarily in grass fuels and started from sparks resulting from a vehicle mechanical failure on the Lyell Highway at 15:57 18/02/13 (TFS 2013d). At this time, the temperature, relative humidity and wind speed were about 35°C, 20% and 28 km/h respectively, giving a Grassland Fire Danger Rating (GFDR; McArthur 1966) of about 35. The C-Haines Index was about 9.4. In addition, the grass fuels have been assumed to have been fully cured (i.e. the near-surface grass fuel was assumed to be 100% dead).

Predictions of potential fire spread for the Gretna fire were made at 16:50 18/02/13,[20] which indicated that the fire had the potential to impact on New Norfolk by about 00:00 19/02/13. As a result, all available fire crews and firefighting aircraft were deployed to the fire. The resources tasked to the fire were re-deployed from the Repulse and Molesworth fires, with aircraft arriving on site from about 17:00 18/02/13 (Figure 38).

The first locally based suppression crew arrived on site at 16:16, at which time the fire was about 0.5 ha in size. The first fire suppression task force was deployed at 16:17 with the crews being on site by 16:41.

Between 16:16 and 16:46 18/02/13, the fire travelled about 1.4 km at an average spread rate of 43.3 m/min and with a predicted intensity of about 7200 kW/m.

By 16:46 18/02/13, the fire had an area of about 70 ha and a perimeter of about 4.2 km.

Owing to the large number of resources available and since the fire was burning in open grassland, fire suppression crews were able to rapidly suppress the fire. The fire was contained by 18:11 18/02/13 and had a final area of about 222 ha and a perimeter of about 10.1 km (Figure 39).

Maps the areas burnt in different time periods are shown in Appendix 4.7.

Figure 38. Fire suppression on the Gretna fire at 17:18 18/02/2013.
Photo: Martin Piesse, Forestry Tasmania.

[20] Gretna incident 203548: fire prediction Feb 18 16:00 to 23:00. Parks and Wildlife Service.

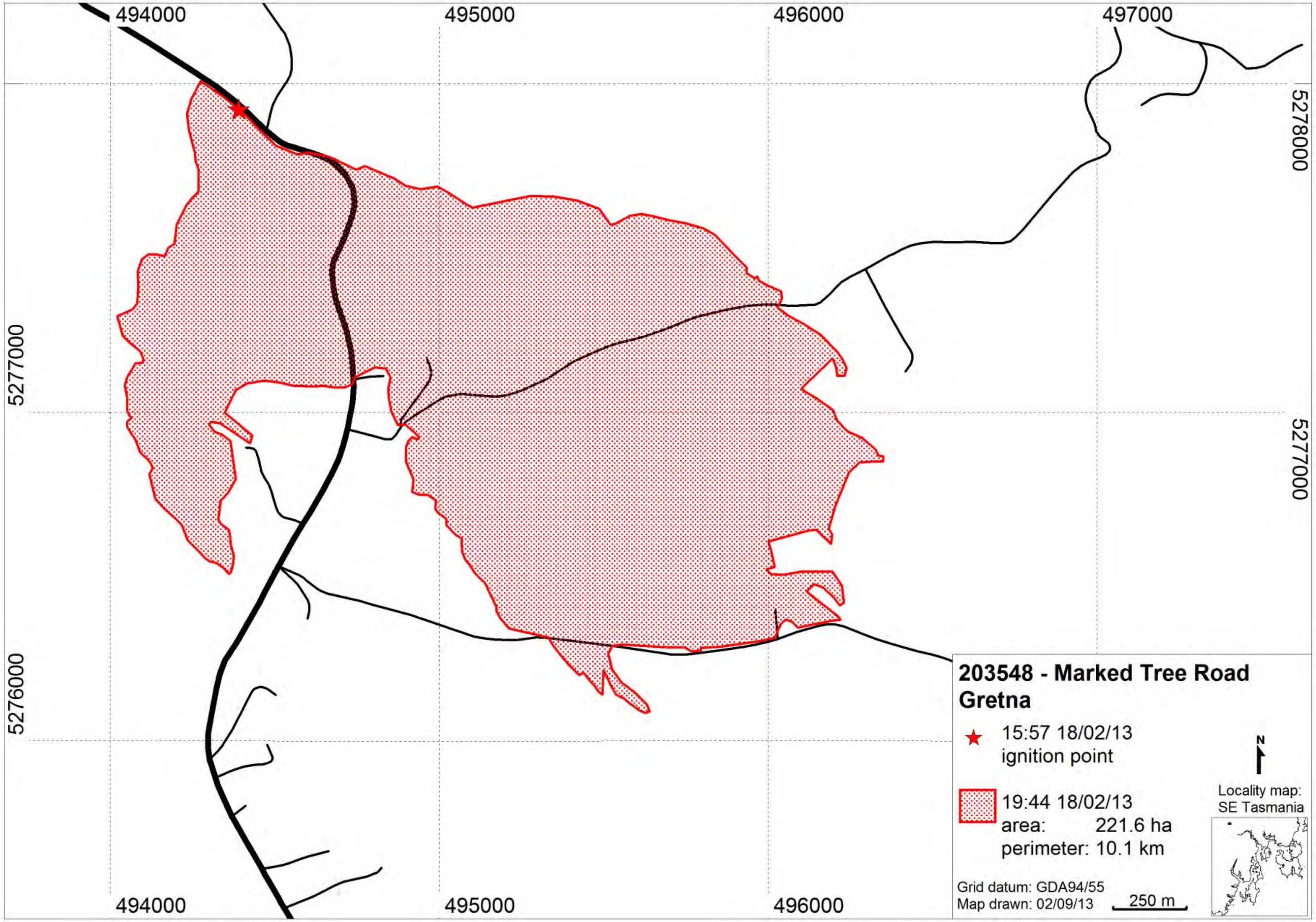


Figure 39. Final boundary of the Marked Tree Road, Gretna, fire on 18/02/13. See Appendix 4.7 for all mapped fire boundaries.

4. Report outcomes

4.1 Areas burnt by the fires

The seven fires covered in this report burnt about 90 175 ha with a total of 75 fire boundary locations being mapped (Table 5). All of the fires burnt the majority of their area in the first few days of the fire, after which the rate of increase in fire area slowed (with the exception of the Gretna fire, which was extinguished on the first day). Note that fire boundary maps are provided in Appendix 4 for all of the time periods shown in Table 5.

Table 5. Areas and perimeters at different times of the fires

Forcett–Dunalley		
Time and date	Area	Perimeter
1400 03/01/13	0.0	0.0
1500 03/01/13	2.5	0.7
1735 03/01/13	506.1	14.0
0647 04/01/13	972.5	19.6
1230 04/01/13	1585.5	21.7
1430 4/01/13	5818.0	42.8
1730 04/01/13	10215.8	93.9
1956 04/01/13	13276.7	146.8
2300 04/01/13	15322.4	166.9
2030 05/01/13	19692.2	246.6
2100 06/01/13	20981.0	269.1
1500 08/01/13	21737.1	259.8
1000 09/01/13	22128.3	273.0
1800 10/01/13	22469.5	280.1
0600 16/01/13	23507.9	296.5
0600 18/01/13	23959.5	309.9

Repulse		
Time and date	Area	Perimeter
1130 03/01/13	0.0	0.0
1445 03/01/13	23.9	3.0
2000 03/01/13	311.2	17.6
1200 04/01/13	464.6	21.2
1430 04/01/13	542.7	22.0
1545 04/01/13	876.5	26.9
1850 04/01/13	4108.7	67.6
2300 04/01/13	9008.2	101.8
1940 05/01/13	9101.0	102.0
2030 06/01/13	9544.9	108.8
1900 07/01/13	10344.5	120.0
1500 18/01/13	10489.0	124.1

Bicheno		
Time and date	Area	Perimeter
2110 03/01/13	0.0	0.0
1515 04/01/13	3.2	0.7
1801 04/01/13	732.1	15.3
2200 04/01/13	2112.4	29.0
0000 05/01/13	2745.7	29.5
1900 05/01/13	3573.2	47.7
1100 09/01/13	4939.0	41.3

Giblin River		
Time and date	Area	Perimeter
1500 03/01/13	0.0	0.0
0900 04/01/13	70.8	3.0
1615 04/01/13	8843.3	67.6
0000 05/01/13	21994.5	177.9
2300 05/01/13	27545.3	199.6
0800 07/01/13	33955.9	255.4
1630 08/01/13	43408.1	356.6
1435 22/01/13	45123.7	386.7

Gretna		
Time and date	Area	Perimeter
1557 18/02/13	0.0	0.0
1616 18/02/13	0.5	0.3
1646 18/02/13	70.1	4.2
1944 18/02/13	221.6	10.1

Montumana		
Time and date	Area	Perimeter
0752 05/01/13	0.0	0.0
1258 05/01/13	77.1	4.2
1800 05/01/13	328.8	8.9
0835 06/01/13	544.8	13.4
1713 06/01/13	816.5	16.8
0900 07/01/13	1068.6	19.5
0700 08/01/13	1880.1	22.0
1730 08/01/13	2916.3	28.6
1900 19/01/13	2983.5	29.1
1100 20/01/13	3158.2	28.5
0730 11/02/13	2302.4	54.0
1400 12/02/13	2459.9	55.2
1500 13/02/13	2486.5	55.6
1600 15/02/13	2521.4	56.4
1500 18/02/13	2582.1	54.4

Molesworth		
Time and date	Area	Perimeter
1300 06/02/13	0.0	0.0
1800 06/02/13	238.9	6.8
0700 07/02/13	387.6	10.4
1500 07/02/13	711.1	13.6
1834 07/02/13	956.5	17.6
0800 08/02/13	1087.3	20.8
1900 08/02/13	1432.5	36.1
1730 09/02/13	1968.9	50.4
0918 10/02/13	2108.0	52.8
1930 10/02/13	2246.9	54.5

Note: Area - hectares; perimeter = km.

In addition to the areas mapped listed in Table 5, while the fires were making major fire runs, there would have been spotfires outside the areas mapped.

4.2 Fire behaviour during the major fire runs

In total, this project has been able to identify and quantify weather, fuel and fire behaviour data for a total of 12 fire runs (Table 6). The weather, fuel and fire behaviour data has been collated as detailed in Section 2 of this report. The data collected from Bureau of Meteorology automatic weather stations is summarised in Appendix 3.

Five of these fire runs were burning with extreme levels of fire behaviour (i.e. >40 m/min: fires 2, 3, 5, 6 and 10 in Table 6), four fires were burning with very high levels of fire behaviour (i.e. 30 to 40 m/min: fires 1, 7, 11 and 12 in Table 6), three fires were burning with high levels of fire behaviour (i.e. 15 to 30 m/min: fires 4, 8 and 10 in Table 6) and one fire had moderate levels of fire behaviour (i.e. 5 to 15 m/min: fire 9 in Table 6).

A feature of the Forcett–Dunalley fire was the ember storm that impacted on the township of Dunalley, starting at about 15:24 04/01/13 (A Skelly, personal communication; see also Figure 7b). Similar ember storms have been documented during several other high-intensity wildfires that burnt under highly unstable atmospheric conditions (e.g. the Canberra suburb of Duffy in the ACT on 18/01/03 and around Kinglake during the Kilmore East fire in Victoria on 07/02/09).

While the exact mechanism driving this ember storm is uncertain, it probably results from the collapse of the fire's convection column and a reduction in the height to which and duration for which embers are lofted. This means that when a fire is burning as a high-intensity, fast-moving fire, its convection column would have been lofting material to in excess of 10 000 m (e.g. prior to hitting Dunalley, the fire's convection column was in excess of 15 000 m in height; BoM unpublished radar data; Figure 40). When the fire hits a low fuel hazard zone (e.g. as it burns into urban areas), the fire's energy release decreases, reducing the height to which embers are lofted. This reduction in ember lofting height would in turn act to reduce the time period that embers are airborne prior to returning to the ground surface, resulting in both ember transport distance and the number of embers self-extinguishing being reduced. This would greatly increase the number of short- to medium-range spotfires.

During the major fire run of the Giblin River fire on 04–05/01/13, the Soil Dryness Index (SDI) at the fireground was about 12. The relationships published in Marsden-Smedley et al. (1999) predict that at this level of SDI, only buttongrass moorland and wet scrub should be dry enough to carry fire. Post-fire assessment indicates that only very limited areas of eucalypt forest and no rainforest were burnt (Figure 41).

Table 6. Observed weather, fuel and head fire behaviour data for the major fire runs

		Weather data						Fuel data							Fire behaviour		
		Temp	RH	Wind	SDI	DF	C-				E hgt	Load	Fuel	Mf	ROS	IB	Data
Time period		°C	%	km/h			Haines	S	NS	E	m	t/ha	type	%	m/min	kW/m	qual.
Forcett–Dunalley																	
1	1500-1740 03/01/13	32.4	16	45.1	142	10	9.6	2.3	2.8	2.2	1.2	11.1	DSF	5.0	35.6	13188	H
2	1230-1530 04/01/13	38.5	13	37.4	143	10	10.5	3.0	3.4	2.4	1.5	14.4	DSF	4.2	54.0	25857	VH
3	1540-2000 04/01/13	38.3	15	34.9	143	10	10.5	3.0	3.4	2.4	1.5	14.4	DSF	4.6	48.5	23205	VH
4	2010-2300 04/01/13	34.1	24	22.3	143	10	10.5	3.0	3.4	2.4	1.5	14.4	DSF	6.1	18.8	9013	M
Repulse																	
5	1540-1850 04/01/13	37.1	16	33.3	148	10	10.5	3.3	3.5	2.4	1.5	15.0	DSF	4.8	55.0	27462	VH
6	1900-2200 04/01/13	32.0	23	20.4	148	10	10.5	3.3	3.5	2.4	1.5	15.0	DSF	6.1	44.2	22075	M
Bicheno																	
7	1515-1800 04/01/13	38.5	17	25.1	118	10	10.5	4.0	3.2	2.3	1.4	13.3	DSF	4.9	35.3	15609	VH
8	1810-2200 04/01/13	34.7	21	21.1	118	10	10.5	4.0	3.2	2.3	1.4	13.3	DSF	5.8	22.2	9807	VH
Montumana																	
9	0700-1730 08/01/13	17.3	66	14.5	59	8	2.7	4.2	3.5	2.4	1.5	15.0	WSF	13.9	7.0	3487	M
Gretna																	
10	1616-1646 18/02/13	34.9	22	27.2	169	10	9.4	-	-	-	-	5.0	GR	4.7	43.3	7217	VH
Giblin River																	
11	0900-1620 04/01/13	27.7	36	54.6	12	5	10.5	-	-	-	-	11.1	BG	10.2	37.5	13825	H
12	1630-2400 04/01/13	23.4	49	37.3	12	5	10.5	-	-	-	-	11.1	BG	5.8	33.8	12450	H

Note: time period = EDST; temp = dry bulb temperature; RH = relative humidity; Wind = 10-min average wind speed measured at 10 m above the ground surface; SDI = Soil Dryness Index; DF = Drought Factor; S = surface fuel hazard rating; NS = near-surface fuel hazard rating; E = elevated fuel hazard rating; E hgt = elevated fuel height; load = total fuel load; Fuel type: DSF = dry sclerophyll forest, WSF = wet sclerophyll forest, GR = grassland, BG = buttongrass moorland; Mf = predicted dead fuel moisture; ROS = rate of fire spread; IB = Byram’s Intensity; data qual = quality of the fire’s parameters: M = moderate, H = high, VH = very high.

Figure 40. Forcett–Dunalley fire, aerial photograph taken from the north at 16:01 04/01/13.
Source: Wikipedia - http://en.wikipedia.org/wiki/File:Copping_fire_4_Jan_2013.jpg

Figure 41. Unburnt rainforest patches within the area burnt by the Giblin River fire.
Photo taken from the Propsting Range looking southwest on 07/01/13 by J. Marsden-Smedley

4.3 Comparison between observed and predicted rates of fire spread

The weather and fuel data outlined in Table 6 has been used to make fire behaviour predictions using the McArthur Forest Fire behaviour model (McArthur 1967, 1973), Project Vesta fuel hazard rating model (Cheney et al. 2012), Buttongrass Moorland fire model (Marsden-Smedley and Catchpole 1995a, 1995b, 2001; Marsden-Smedley et al. 1999, 2001) and CSIRO natural grassland model (Cheney et al. 1998), and the data has been compared against the outputs from the Phoenix RapidFire model (Tolhurst et al. 2008), as shown in Table 7 and Figure 42 (see also Section 2.4 of this report).

The fit of the outputs from the McArthur Forest Fire, Project Vesta and Phoenix RapidFire prediction models to the observed head fire spread rate has been compared using the different models' mean absolute errors (MAE), mean absolute percentage errors (MAPE) and bias (see Janssen and Heuberger 1995), as shown in Table 8.

On average, the predicted versus observed head fire spread rates (ie bias) for the McArthur Forest Fire Danger meter, Project Vesta, Phoenix RapidFire and Buttongrass moorland fire models were -71%, -4%, 14% and 13% respectively. Overall, the Project Vesta fire model provided the most reliable predictions of head fire spread rate, as evidenced by its lower MAE, MAPE and bias (Table 8).

For eight of the nine fires predicted using the Project Vesta fire model (i.e. fires 1 to 5 and 7 to 9 in Table 7), there was an very close fit between the observed versus predicted fire spread rate (Figure 42). For the remaining fire predicted by the Project Vesta fire model (ie Repulse fire 6 in Table 7), the larger divergence between the observed versus predicted fire spread rate is possibly the result of night-time atmospheric de-coupling of wind speed at the Bushy Park and Ouse AWS sites resulting in these AWSs recording reduced wind speeds. This drop in wind speed was not recorded at the Mt Wellington AWS. At the Repulse fireground, the fire's energy release would have had the potential to prevent localised atmospheric de-coupling, and hence may have maintained higher wind speeds.

The Phoenix RapidFire model under-predicted flank fire spread rate, with its average predicted versus observed flank fire spread rate being 43% (Table 8). This under-prediction of flank fire spread is probably the result of the model's assumptions regarding fire shape. It is unlikely to be the result of the user selecting too narrow a starting width for the model run because the predicted fires maintained their long narrow shape over extensive distances and because the starting width for the Repulse fire approximated the observed width for that time period.

The Buttongrass Moorland model over-predicted the Giblin River fire run 11 (see Table 7). This over-prediction was probably due to the fire run being slowed between about 14:30 and 16:15 as the fire burnt through a zone of mixed vegetation types on the northern side of Castle Hill. Once the fire burnt through this zone and spotted across the Davey River, the observed versus predicted fire spread rates were very similar at 33.8 versus 35.1 m/min respectively (ie fire run 12 between about 16:30 and 24:00 04/01/13 in Table 7). The Giblin River fire then continued to burn as a flank fire in a northeast direction up the Spring and Crossing River valleys, with the fire travelling 10.3 km between 24:00 04/01/13 and when the fire was line-scanned by DSE at 23:00 05/01/13. Using the weather prevailing at Scotts Peak, the Buttongrass Moorland model predicts a head fire run over this time period of 37.0 km and a flank fire spread of 14.8 km (ie 40% of the head fire spread rate; see Marsden-Smedley et al. 1999), which is close to the observed distance.

Observations of unburnt grass fuels immediately adjacent to the areas burnt by the Gretna fire indicate that the CSIRO natural grassland model was a closer fit to the fire's fuel characteristics than the CSIRO eaten-out grassland fire model (see Cheney et al. 1998). However, this model gave poor predictions of head fire spread rate, over-predicting by an average of 73% (see Table 7; Figure 42).

Table 7. Observed versus predicted head fire rate of spread (m/min) for the major fire runs

		Observed fire		McArthur	Project	Phoenix-		Buttongrass	CSIRO
Time period		head	flank	head	head	head	flank	head	head
	Forcett-Dunalley								
1	1500-1740 03/01/13	35.6	3.8	10.0	36.5	-	-	-	-
2	1200-1530 04/01/13	54.0	13.3	14.1	50.8	52.5	7.2	-	-
3	1540-2000 04/01/13	48.5	10.0	11.9	43.0	-	-	-	-
4	2010-2300 04/01/13	18.8	13.6	5.1	18.5	28	5.7	-	-
	Repulse								
5	1540-1850 04/01/13	55.0	14.2	21.3	61.2	54.3	6.5	-	-
6	1900-2200 04/01/13	44.2	14.2	12.7	29.5	49.2	7.1	-	-
	Bicheno								
7	1515-1800 04/01/13	35.3	5.6	9.3	33.3	-	-	-	-
8	1810-2200 04/01/13	22.2	3.9	6.7	24.0	-	-	-	-
	Montumana								
9	0700-1730 08/01/13	7.0	1.0	2.0	7.3	-	-	-	-
	Gretna								
10	1616-1646 18/02/13	43.3	14	-	-	35.0	3.3	-	74.9
	Giblin River								
11	0900-1620 04/01/13	37.5	-	-	-	-	-	46.1	-
12	1630-2400 04/01/13	33.8	-	-	-	-	-	35.1	-

Note: see Table 6 for weather and fuel data; time period = EDST; Project Vesta: Cheney et al. (2012); Phoenix RapidFire: Tolhurst et al. (2008); Buttongrass moorland: Marsden-Smedley et al. (1999); CSIRO natural grassland: Cheney et al. (1998); head = head fire; flank = flank fire.

Table 8. Model fit for the McArthur, Project Vesta, Phoenix RapidFire and Buttongrass Moorland fire prediction models

Model		MAE	MAPE	Bias
McArthur Forest Fire	head fire	25.28	71.29	0.29
Project Vesta	head fire	3.88	9.33	0.96
Phoenix RapidFire	head fire	4.10	13.01	1.14
Phoenix RapidFire	flank fire	7.90	56.92	0.43
Buttongrass Moorland	head fire	4.95	13.39	1.13

Note: MAE = mean absolute error, MAPE = mean absolute percentage error.

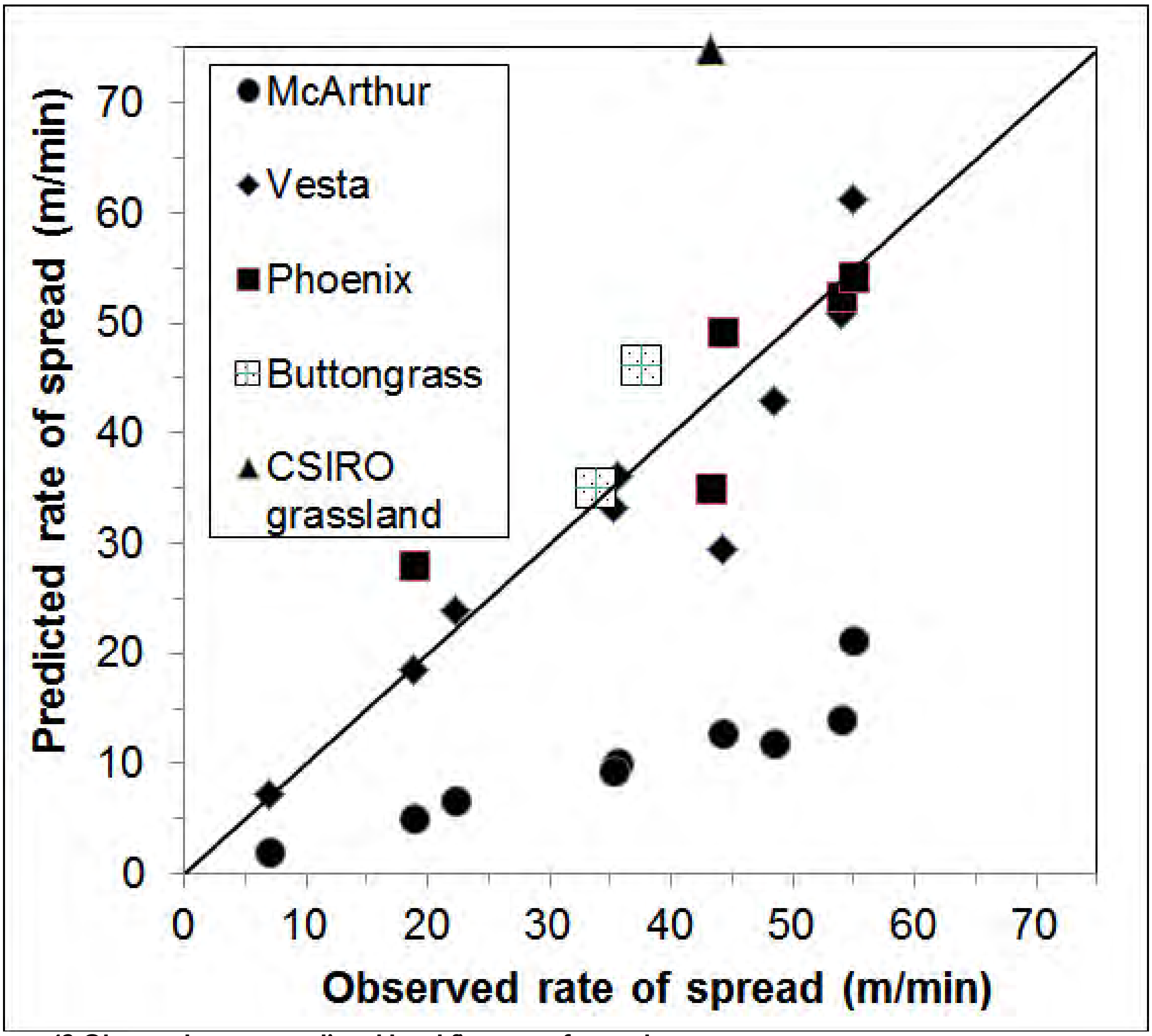


Figure 42 Observed versus predicted head fire rate of spread.
Note: data for fires 1 to 12 in Table 6 and Table 7 shown.

4.4 Weather influences on fire control and behaviour during the major fire runs

The weather conditions prevailing in Tasmania during the 2012–13 summer were notable for their extended periods of high fire danger. In many parts of state, new records were set and there were extended periods with elevated levels of fire danger (see BoM 2013; Figure 3). This was particularly the situation during the first week of January, where multiple new temperature records were made (BoM 2013).

As is discussed in Section 2.1 and Appendix 1, fire weather has two main components: weather conditions prevailing at the ground surface and the degree of atmospheric instability. In order to comprehensively assess the influence of weather on fire behaviour, it is necessary to incorporate both surface conditions and atmospheric instability (Bally 1995; Mills and McCaw 2010).

High levels of atmospheric instability are also associated with lower fuel moisture levels than would otherwise be expected from the prevailing humidity, wind speed and temperature conditions (Mills and McCaw 2010). These low fuel moistures have several important influences on fire behaviour and management. In particular, compared with what would normally be expected from the weather conditions prevailing at the surface, the likelihood of fire re-ignition is much higher, higher rates of fire spread and intensity normally occur, fire suppression is much harder and requires larger volumes of water to be effective, and spotfire number and distance travelled increase.

On 3 and 4 January 2013, the C-Haines Index recorded at Hobart Airport was 9.6 and 10.5 respectively compared with a maximum C-Haines Index of about 13. In addition, very high to catastrophic levels of fire danger were associated with these elevated levels of atmospheric instability (see BoM 2013, unpublished data in Appendix 3; see also Figure 3).

4.5 Effect of recently burnt areas on the fire behaviour of the major fire runs

During each of the Forcett–Dunalley, Repulse, Bicheno and Giblin River fires, very-high- to extreme-intensity fires impacted on recently burnt areas. In each of these situations, the head fire's spread rate, intensity and spotting were stopped or greatly reduced.

During the Forcett–Dunalley fire, at about 17:30 04/01/13, a very-high-intensity fire reached the township of Murdunna. At this time, the head fire spread rate was about 48.5 m/min (Table 6), with a predicted intensity and spotting distance of about 23 200 kW/m and 9.2 km respectively. At this time, the fire was burning on the Bangor property at the northeast boundary of Murdunna in an area that had been hazard-reduced about 1 year prior. The fire re-burnt the hazard-reduced area as a low-intensity ground fire[21] (in contrast to surrounding areas, which were burnt as a very-high-intensity crown fire). This reduction in fire intensity possibly accounts for the low number of burnt houses in the parts of Murdunna that are adjacent to the planned burn.

During the Repulse fire, at about 22:00 04/01/13, the fire's head ran into areas burnt by the February 2012 Meadowbank fire. Observational evidence indicates that the Repulse fire burnt into areas burnt by the Meadowbank fire about 200 to 400 m.

During the Bicheno fire, at about 00:00 05/01/13, the fire's head ran into areas burnt by the FRENP013P Isaac Point planned burn behind the Friendly Beaches. This planned burn had been carried out in late March 2011. At the time it was conducted, the Isaac Point planned burn had a coverage of about 65%,[22] which is at the lower end of the scale that is considered adequate for a successful planned burn. The Bicheno fire burnt into the area of the planned burn between 50 and 100 m (Figure 43).

[21] Mr S Lennox, Arthur Highway, Murdunna, Tasmania.
[22] Garth Bennett, Fire Operations Officer, Northern Region, Parks and Wildlife Service.

a) Area burnt by both fires

b) Area burnt by 2011 Isaac Point planned burn only

Figure 43. Areas burnt by the 2013 Bicheno fire and the 2011 Isaac Point planned burn.

The southeast spread of the Giblin River fire was stopped in the vicinity of Settlement Point and Heather Bay by a 2-year-old hazard-reduction burn (i.e. the Gunfight Creek HRB burnt April 2011; Figure 44). The fire went about 300 to 700 m into the area burnt by the planned burn. If this hazard reduction burn had not been conducted, under the conditions prevailing between 04 and 06/01/13 it is probable that the Giblin River fire would have burnt to Bathurst Channel and Mt Rugby, increasing the fire's size by 15 000 to 20 000 ha.

Figure 44. Areas burnt by the Giblin River wildfire and Gunfight Creek planned burn.
Note: red line indicates boundary between fires: foreground burnt 11/04/11 by the Gunfight Creek planned burn, background burnt 04/01/13 by the Giblin River fire. Photo: Chris Arthur

4.6 Effect of early response, access and effective mop-up on fire suppression

A feature of the major wildfires during the 2012–13 Tasmanian summer was the simultaneous combination of extreme levels of fire danger and atmospheric instability. These elevated levels of fire danger and atmospheric instability would have resulted in fire control being much harder than is normally the case and the likelihood of successful fire suppression being much lower. This meant that the likelihood of poorly extinguished campfires re-igniting and/or embers starting fires was much higher, while the ability of fire crews to suppress going fires was much lower. Hence, the inability of fire crews to suppress the Forcett–Dunalley, Repulse and Bicheno fires on 3 and 4 January 2013 is not unexpected.

The relationships in McCarthy et al. (2003) provide an indication of the resources that would have been required to suppress the Forcett–Dunalley, Repulse, Bicheno and Gretna fires during their initial phases.

The Forcett–Dunalley fire started from a campfire re-ignition and was first reported at 14:13 03/01/13, with first attack crews arriving on site at about 14:30 (TFS 2013b). At this time, the fire had an area and perimeter of about 2.5 ha and 0.7 km respectively. The weather conditions were a temperature, relative humidity, wind speed, Forest Fire Danger Rating and C-Haines Index of about 32°C, 16%, 45 km/h, 45 and 9.6 respectively (see Table 6). A major issue during the initial stages of the Forcett–Dunalley fire was poor access to the fire's head and southern flank, resulting in crews being only able to suppress the fire's northern flank along White Hills Road. Under these conditions, McCarthy et al. (2003) suggest that in order to have a realistic probability of first-attack success, the fire suppression resources required would be of the order of six to ten tankers (of which at least four needed to be heavy tankers), between 20 and 50 crew on hand tools and aerial support from at least four medium helicopters (or four to six light helicopters).

The Repulse fire started from a campfire re-ignition and was first reported at 11:33 03/01/13, with first-attack crews arriving on site at about 12:34 (TFS 2013e). At this time, the fire had an area and perimeter of about 8.5 ha and 1.2 km respectively. The weather conditions were a temperature, relative humidity, wind speed, Forest Fire Danger Rating and C-Haines of about 29°C, 21%, 24 km/h, 29 and 6.7 respectively (see Table 6). Under these conditions, McCarthy et al. (2003) suggest that in order to have a realistic probability of first-attack success, the fire suppression resources required would be of the order of six tankers (of which at least two need to be heavy tankers) and aerial support from at least two helicopters.

The Bicheno fire started from a lightning strike at about 21:10 03/01/13. The fire was dozer-tracked when it had an area and perimeter of about 3.2 ha and 0.8 km respectively. The fire flared up from sparks from a burning tree while the mop-up crews were refilling with water. McCarthy et al. (2003) suggest that the fire suppression resources required to patrol a fire of this type and size is at least one medium to heavy tanker.

It is also worth considering the fire suppression of the Butlers Hill and Freshwater Lagoon fires on 03/01/13 (see PWS 2013a, 2013b). The Butlers Hill fire started from a lightning strike at about 20:01 03/01/13. The fire was dozer-tracked and contained prior to 10:00 04/01/13 when it had an area and perimeter of 1.1 ha and 0.4 km respectively. McCarthy et al. (2003) suggest that the fire suppression resources required to control a fire of this type and size are of the order of one dozer and two tankers. When the Bicheno fire escaped, it burnt over the area burnt by this fire. The Freshwater Lagoon fire started from a lightning strike at about 20:30 03/01/13. The fire was dozer-tracked and contained prior to 10:00 04/01/13 when it had an area and perimeter of 1.5 ha and 0.5 km respectively. McCarthy et al. (2003) suggest that the fire suppression resources required to control a fire of this type and size are of the order of one dozer and three tankers.

The Gretna fire started from a vehicle mechanical failure at 15:57 on 18/02/13. The Forest Fire Danger Rating, Grassland Fire Danger Rating and C-Haines were about 10, 35 and 9.4 respectively. McCarthy et al. (2003) suggest that the fire suppression resources required to control a fire of this type and size are of the order of six to eight tankers supported by four to six helicopters. The actual resources deployed to the fire were six helicopters, one fixed-wing water bomber, 12 light tankers, three medium tankers, six heavy tankers, two dozers and a total of 60 personnel.[23] The fire was contained by 18:11 on 18/02/13.

The critical findings from this assessment of fire-suppression resource requirements relate to the importance of:

- early response with adequate resource levels,
- effective mop-up and patrol, and
- the identification of the conditions where suppression is not going to be effective.

This assessment indicates that where there are adequate resources available to suppress fires (e.g. as occurred during the Butlers Hill, Freshwater Lagoon and Gretna fires), effective suppression can be performed, even under adverse conditions. It also underlines the importance of effective mop-up and patrol following fire knockdown.

Another major finding is that under extreme fire conditions (i.e. high to very high levels of fire danger and extreme levels of C-Haines), effective suppression of running fires will frequently not be feasible, and fire management agencies need to be prepared to pull back and put all available resources into protecting life and property.

[23] Gretna Fire Situation Report 1.

5. Conclusion

This report provides information on the Forcett–Dunalley, Repulse, Bicheno, Giblin River, Montumana, Molesworth and Gretna fires that occurred during the 2012–13 Tasmanian fire season. The weather conditions, fuels, site conditions and corresponding fire boundaries and areas burnt have been mapped. Detailed weather, fuel, site and fire behaviour data has been collated for 12 fire runs burning with moderate to extreme rates of fire spread and intensity. The observed rates of fire spread for the fires were compared against predictions made by fire prediction models. The Project Vesta, Phoenix RapidFire and Buttongrass Moorland models provided good predictions of head fire spread rate while the McArthur Fire Behaviour model under-predicted head fire spread rate and the CSIRO Grassland fire model over-predicted the head fire spread. The Phoenix RapidFire model under-predicted flank fire spread rate. Overall, the Project Vesta fire model provided the best predictions of dry eucalypt forest head fire spread rate. The main driver of the extreme levels of fire behaviour observed during these fires was a combination of surface weather conditions and atmospheric instability, with these factors being in the extreme to catastrophic range when the fires were making their major fire runs. The Forcett–Dunalley, Repulse, Bicheno and Giblin River fires all burnt into recently burnt areas with correspondingly low fuel hazard levels, which were effective at reducing or stopping high-intensity fire behaviour. The importance of early response with adequate resources, effective mop-up and patrol and the importance of identifying the conditions where effective suppression is not feasible have also been identified in this report.

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Appendix 1. Influences on fire behaviour

The main factors influencing fire spread rate are wind speed, slope, fuel characteristics and fuel moisture while the main influences on fire intensity are the rate of fire spread, fuel height and fuel load.

The rate of fire spread is normally estimated as its quasi-steady state, which is the fire's spread rate once minor variation resulting from short-term changes in wind speed (e.g. gusts), fuel characteristics and/or slope have been accounted for.

The normal method of estimating a fire's intensity is to use Byram's Intensity, which is a measure of the energy output from the burning of fine fuels in the entire fire front (Byram 1959). In contrast, when a fire's intensity is estimated from its flame dimensions (normally flame height, with flame length being used less frequently), only the energy output at the leading edge of the fire front is considered, which ignores the energy output at the rear of the flaming zone. This means that while Byram's Intensity probably gives a better estimate of the fire's energy output than flame measurements, it is much harder to calculate and utilise owing to Byram's Intensity being measured in kW/m of fireline in contrast to flame size, which is normally measured in m.

The relative importance of wind speed, fuel characteristics and fuel moisture on fire behaviour varies with different wind speeds. At low to moderate wind speeds (i.e. <25 km/h), wind speed and fuel characteristics have similar levels of influence on fire behaviour in moorlands (Marsden-Smedley and Catchpole 1995b) and dry eucalypt forests (Cheney et al. 2012). At higher wind speeds (i.e. >25 km/h), wind speed becomes the dominant influence on fire behaviour. Overall, wind speed accounts for about half of the observed variation in fire spread rate.

Vegetation type, height and density strongly influence the wind speed prevailing at the fire front. This issue was addressed by McArthur (1967) and a formula has been developed from McArthur's relationships, as shown in Equation A1.1:

$$\text{In-forest wind} = (1.48 - 0.237 \times \text{veg type} + 0.00436 \times \text{wind}) \times \text{wind} \qquad \text{Equation A1.1}$$

where: wind = wind speed measured at 10 m, km/h;
veg type: dry woodland = 2;
dry forest = 3;
damp forest = 4;
wet forest = 5;
rainforest = 6.

When assessing fire behaviour, it is important to consider both the conditions prevailing at the ground surface (e.g. wind speed, fuels being burnt, humidity and site slope) and the degree of atmospheric instability (see Mills and McCaw 2010). Under highly unstable atmospheric conditions, fires have a higher probability of forming large convection columns, which act to increase the fire's ventilation rate with resultant increases in wind speed and decreases in humidity. This means that if fires occur under highly unstable atmospheric conditions, then it is much more likely that they will burn with enhanced levels of fire behaviour.

The most important fuel factor influencing fire behaviour is the percentage of dead fuel, followed by fuel structure, which in turn is more important than the fuel load (see Marsden-Smedley and Catchpole 1995a, 1995b; DEH 2008; Hines et al. 2010; Cheney et al. 2012; Gould et al. 2007a, 2007b). This is because, by itself, the fuel load only has very minor influences on fire spread rate. The fuel load does, however, have significant influences on the amount of energy available and hence, the fire's intensity. In order to address this issue, fuel hazard assessment systems have been developed that incorporate the different influences of different fuel factors into easily utilised ratings.

When fuel hazards are assessed, the level of fuel hazard is based on a combination of the surface , near-surface, elevated and bark fuel strata (Figure A1.1). Each of these strata is assessed on a five-point scale between low and extreme (DEH 2008; Hines et al. 2010).

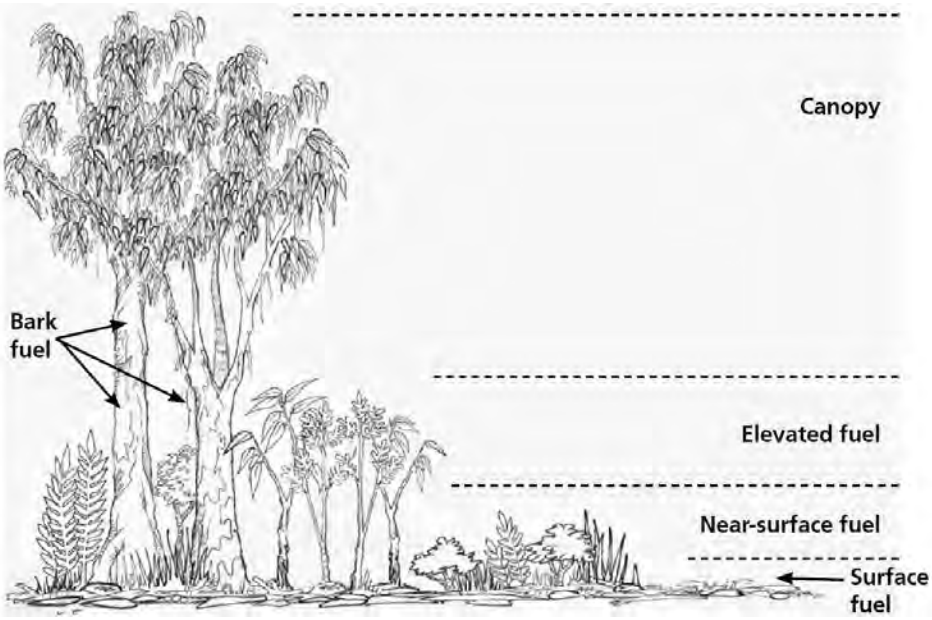


Figure A1.1. Fuel hazard stratums. Copied from figure 2.1 in Hines et al. (2010).

The surface fuel stratum is composed of: dead grass, leaves, bark and twigs, predominantly in a horizontal orientation and in contact or close to contact with the soil surface. Surface fuels often contain the majority of the fuel load and often have elevated fuel moistures and relatively low aeration. This results in these fuels having minor influences on rates of spread, but major influences on fire intensity.

The near-surface fuel stratum consists of live and dead fuels above the surface fuel stratum, and comprises both vertical and horizontal material. In some sites, the surface and near-surface fuel strata integrate with no clear break between them. Near-surface fuels are typically about 10 to 30 cm deep, but may be as high as 1 m in some situations. Owing to their proximity to the surface fuels, near-surface fuels will normally be burnt in a fire. Near-surface fuels consist of fine fuel including: suspended bark, leaf litter, low shrubs, bracken, tussock grasses, and sedges and rushes.

The elevated fuel stratum consists of shrubs, immature overstorey species and tall bracken. The fuels in this stratum are primarily vertical in their orientation and are typically about 1 to 2 m tall, but may be 8 to 10 m tall in wet eucalypt forests. This stratum has a major influence on flame height and the development of crown fires (Gould et al. 2007a; Cheney et al. 2012).

The main bark types affecting fire behaviour are: smooth or gum barks, platy bark, and stringybark (see Figure A1.2). Gum bark (also known as candle bark) consists of long, coiled bark strips, which may burn for extended periods and be lofted in the fire’s convection column, resulting in the potential for long-distance spotting (i.e. greater than 2 km). Platy bark (i.e. the bark tends to form small ‘plates’) from peppermints, ironbarks and pines is characterised by layers of dead bark that can flake off and cause short- to medium-range spotting (ie up to about 2 km). Stringybarks form fibrous wads that can be removed by fire and can result in extensive short- to medium-range spotting.

a) candle bark b) platy bark c) fibrous bark

Figure A1.2. Candle bark, platy bark and fibrous bark types.

Models for predicting fuel hazard rating and fuel load in Tasmanian dry forests have been developed by Marsden-Smedley and Anderson (2011; note that this report is currently being updated and prepared for publication).

These fuel hazard prediction models use the time since the last fire to predict:

a) surface fuel hazard;
b) near-surface fuel hazard;
c) combined surface and near-surface fuel hazard;
d) bark fuel hazard;
e) overall fuel hazard, and
f) total fuel load.

These models were developed from the fuel accumulation model developed by Olson (1963) with an adjustment for fuel left over from the previous burn (see Fensham 1992) and assume an asymptotic relationship between site age versus fuel hazard rating and fuel load.

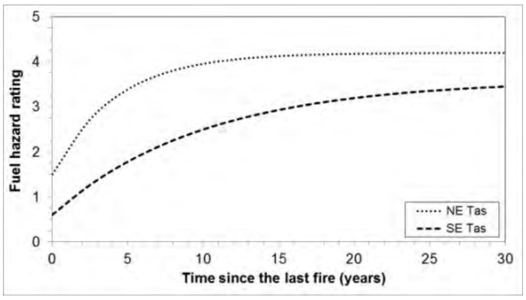
The fuel prediction equation used is shown below (Equation A1.2), the parameters for the equation are shown in Table A1.1 and predictions of fuel hazard rating and fuel load at different times since fire are shown in Figure A1.3.

$$\text{Fuel parameter} = \text{Max} \times (1 - \exp(-k \times \text{Age})) + \text{Residual} \times \exp(-k \times \text{Age}) \qquad \text{Eqn A1.2}$$

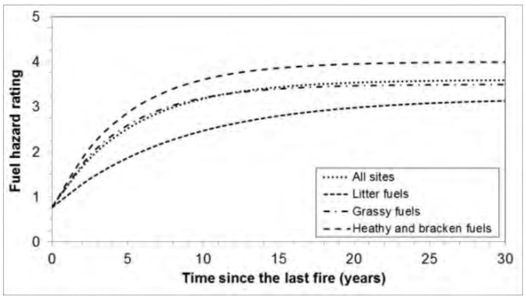
where: Max = equilibrium fuel hazard or fuel load under steady-state conditions;
k = equation parameter;
Age = time since the last fire, years;
Residual = fuel remaining following the previous fire.

Table A1.1. Fuel hazard and load parameters for Equation A1.2.

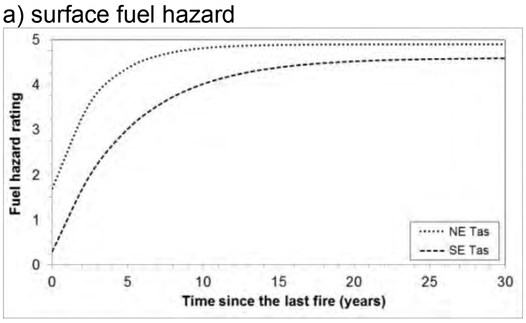
Grouping	Max	k	Residual
a) Surface fuel hazard rating			
NE Tas	4.2	0.26	1.4
SE Tas	3.6	0.11	0.6
b) Near-surface fuel hazard rating			
NE and SE Tas	3.6	0.18	0.9
Litter	3.2	0.13	0.5
Grass	3.5	0.23	0.5
Heath and bracken	4.1	0.2	1
c) Combined surface and near-surface fuel hazard rating			
NE Tas	4.9	0.37	1.6
SE Tas	4.3	0.19	0.5
d) Bark fuel hazard rating			
NE Tas	4.1	0.07	1.8
SE Tas	5	0.02	1.1
e) Overall hazard rating			
NE Tas	4.7	0.17	1.6
SE Tas	3.5	0.14	1.1
f) Fuel load (t/ha)			
NE Tas: E. amygdalina and E. sieberi	15.1	0.21	0.14
NE Tas: E. obliqua	12.8	0.23	2.75
SE Tas: E. globulus, E. viminalis, E. pulchella, heathy E. amygdalina,	15.4	0.1	1.47
SE Tas: grassy E. amygdalina	9.9	0.14	1.2
SE Tas: dry eucalypt forest	14.9	0.1	1.45



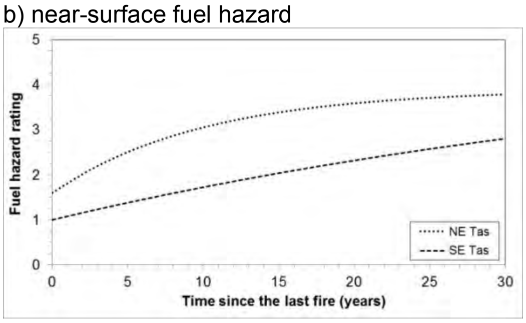
a) surface fuel hazard



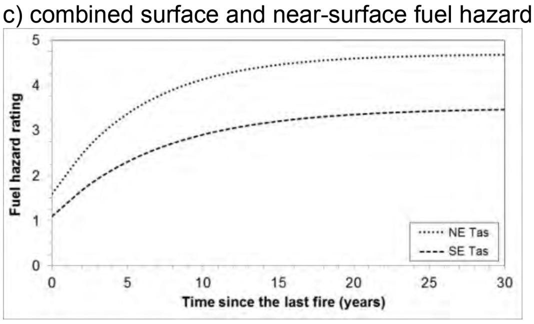
b) near-surface fuel hazard



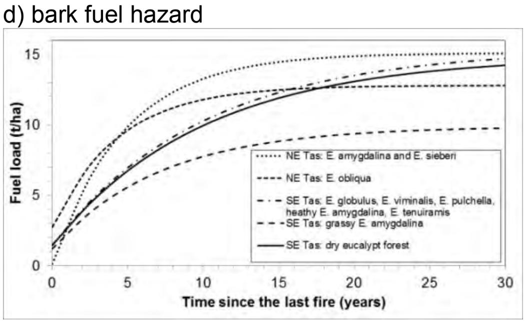
c) combined surface and near-surface fuel hazard



d) bark fuel hazard



e) overall fuel hazard



f) fuel load

Figure A1.3. Fuel hazard and load predicted from the time since the last fire in dry forests. Data predicted using Equation A1.2 and the parameters in Table A1.1. See Marsden-Smedley and Anderson (2011).

For fire management purposes, the term fuel moisture is the fuel moisture content of dead fuel that has a diameter of less than 6 mm. Fuel moisture is calculated as the percentage weight of water in the fuel to its oven-dry weight. The most important factors influencing fuel moisture are humidity, dew-point temperature, solar radiation (which is in turn influenced by cloud cover, season, slope and aspect) and recent rainfall.

By itself, temperature only has very minor influences on fuel moisture and, hence, fire behaviour. Temperature does, however, strongly influence fire crew fatigue and their ability to manage fires.

For more than 50 years, atmospheric stability has been recognised as a major influence on fire behaviour (e.g. Byram 1959; McArthur 1967; Luke and McArthur 1978; Bally 1995; Tolhurst and Chatto 1999; Mills and McCaw 2010). Fires burning under unstable atmospheric conditions have increased probabilities that large-scale fire convection columns will develop, which have the potential to result in enhanced surface wind speeds, the drawing-down of low-humidity air from aloft to the ground surface and the possibility of downdrafts causing abrupt changes in wind speed and fire behaviour.

Methods for quantifying the degree of atmospheric stability for fire management purposes were introduced to Australia by Bally (1995) who used the Haines Index (Haines 1988) in Tasmania to show that a large proportion of the area burnt occurred on days when the Haines Index was 5 or 6. The Haines Index (as used by Bally 1995) incorporates a stability term and a moisture term, each of which has a score between 1 and 3, with the two terms being added together so that the outputs range between a minimum of 2 and a maximum of 6.

However, subsequent research indicated that the Haines Index provides poor discrimination of the degree of atmospheric stability across the southern mainland of Australia. This led Mills and McCaw (2010) to extend the range of the Haines Index and in doing so, develop the Continuous Haines Index (normally referred to as the C-Haines). The C-Haines is very similar in concept to the Haines Index, except that it uses a linear extension of the bounds of the original Haines Index so that it ranges between a minimum of 0 and a theoretical maximum of about 13.

The main advantage of incorporating measures of atmospheric stability when predicting fire behaviour is that it overcomes a major shortcoming in all of the fire behaviour prediction models currently utilised. That is, these models only incorporate the influences of weather, fuel and topography at the ground surface and do not incorporate the influences of higher-altitude wind speed and humidity along with the likelihood that there will be vertical movement of air in the atmosphere. This means that it is not possible at the current time to make quantitative predictions of the increase in fire rate of spread and intensity expected when the atmosphere is unstable (and conversely, the decrease in the level of fire behaviour expected when the atmosphere is stable).

For example, when the atmosphere is highly stable, the level of fire behaviour is likely to be less than that predicted by fire behaviour models (i.e. lower rates of fire spread, intensity and spotting). Conversely, when the atmosphere is unstable, the level of fire behaviour is likely to be greater than that predicted by fire behaviour models (i.e.

higher rates of fire spread, intensity and, especially, a larger number of spotfires and greater spotfire distances).

Probably the easiest and most effective methodology for incorporating the influences of atmospheric stability into fire behaviour predictions is to use the fire behaviour prediction models (e.g. Project Vesta, Phoenix RapidFire, Forest Fire Danger Rating; see below) to predict the fire's potential spread rate. The C-Haines Index can then be used to estimate the likelihood that the fire will realise this potential spread rate. For example, the limited data available to date suggests that when the C-Haines Index is less than about 4, fires are unlikely to burn with the spread rates predicted by fire behaviour models; when the C-Haines Index is between about 4 and 8, fires typically burn at their predicted spread rate, while when the C-Haines exceeds about 8 (and especially when it exceeds about 10) fires normally burn with high spread rates, intensity and spotting, and may exceed the predictions made by fire models.

The direction in which a fire travels is dominated by two main factors: wind direction and terrain. Terrain mainly influences fire path through the direction in which the slope is pointing (i.e. the slope's aspect). These two factors, wind and slope, act to reduce the distance between flames and unburnt fuel and to carry burning embers forward to ignite unburnt fuel. For example, fires burning with the wind have their flames pushed down closer to the ground surface (rather than standing upright) while fires burning up slopes have their flames closer to unburnt fuel on their upslope side.

Fires are normally divided into three zones: head fires, flank fires and back fires. The head fire is the most intense part of the fire and burns in the same direction as the wind and/or up the slope. The flank fire is the section of the fire that is burning at 90° to the wind direction and/or across the slope. The back fire is the least intense part of the fire and burns back into the wind and/or down the slope.

If fires occur in areas with uniform vegetation and topography and under conditions of uniform wind direction, then the relationships between head versus flank and back fire spread rate and intensity will be dominated by the wind speed, with fires becoming longer and narrower as the wind speed increases. However, such uniform conditions very rarely occur in the field, with the normal situation being for fuel type, slope, aspect, wind speed and wind direction to all vary, often over small distances and short time periods. This variation acts to increase the spread rate of flank and back fires while decreasing the head fire spread rate.

This means that when wind speeds are low (e.g. below about 10 km/h) and/or when there is a high degree of variation in wind direction (e.g. as often occurs when fires are burning under turbulent conditions), fires may frequently switch between head, flank or back fires, resulting in a relatively wide burn shape. Conversely, where fires are burning under high wind-speed conditions (e.g. above about 40 km/h) and/or when there is little variation in wind direction, then fires may burn as longer and narrower fires due to their comparatively lower flank and back fire spread rates. As a result, under field conditions, when fires are burning with up to high head fire spread rates (i.e. up to about 30 m/min), flank fires normally average about 40% and 60% respectively of the head fire spread rate and intensity, with back fires normally averaging about 10% and 50% respectively of the head fire spread rate and intensity. However, when fires are burning with very high to extreme head fire spread rates (i.e. >30 m/min), the ratio of head to flank fire probably decreases and fires form longer and narrower burnt areas. For example, as the head fire spread rate increases from about 30 to about 60 m/min, the ratio between the fire's head and flank probably decreases from an average of about 40% to an average of about 25 to 30%.

The main factors influencing scorch height are fire intensity (i.e. flame height and Byram's Intensity), temperature and wind speed. Scorch normally averages about 6 to 8 times the flame height in spring, and 10 to 14 times the flame height in autumn owing to the typically drier fuels in autumn (DSE 2008).

Fire danger ratings aim to provide a description of fire suppression difficulty that integrates the influences of fuel, site factors and weather into a dimensionless index and a rating class. The concept was developed in Australia by Luke (1953) with further development by Douglas (1957) and Luke and McArthur (1978; see also Cheney 1988). The system has been recently updated by the Australasian Fire and Emergency Service Authorities Council to incorporate additional high-intensity categories. The fire danger rating classes are:

- low 0 to 5 fire control relatively easy;
- moderate 6 to 11 direct attack on fires possible if well resourced;
- high 12 to 24 fire control operations difficult and frequently fail;
- very high 25 to 49 fire control operations very difficult and normally unsuccessful;
- severe 50 to 74 fire control unlikely to be feasible or safe;
- extreme 75 to 99 fire control not feasible or safe, and
- catastrophic 100+ very high level threats to life and property.

In Tasmania, two systems are routinely used for estimating fire danger:

- Forest Fire Danger Rating (FFDR, McArthur 1973)
- Moorland Fire Danger Rating (MFDR, Marsden-Smedley et al. 1999)

Appendix 2. Data collection methodology

A2.1 Field data collection

A score sheet was developed for recording data in the field. The field data collected is summarised in Appendices 2.2 and 2.3.

When field data was collected, the aim was to estimate the likely pre-fire conditions and not the current post-fire conditions. However, in most sites, it was not possible to determine the pre-fire fuel hazard and load data owing to the very low fuel moistures that occurred during the fires removing most of the fine fuel. Where it is not possible to characterise the pre-fire data, the fields have been treated as missing values (ie not as zero). The values for dead fuel and cover were made as ocular estimates to the nearest 5% while values for height were estimated to the nearest metre (except for surface fuel depth, which was estimated to the nearest centimetre).

The following data attributes were recorded:

Site data	
Fire name and id	name and identifier used by fire-management agencies
Location	locality name close to plot site
Date	dd/mm/yr
GPS point	number or identifier used by GPS when data was collected
Easting	six-figure easting grid reference using the GDA94/55 grid datum
Northing	seven-figure northing grid reference using the GDA94/55 grid datum
Photographs	identification numbers of digital photographs taken at the site
Vegetation community	vegetation assemblage type: DSF = dry sclerophyll forest, WSF = wet sclerophyll forest, WS = wet scrub, BG = buttongrass, GR = grassland
Age	time in years since the previous fire
Altitude	height above sea level, m
Aspect	direction slope is pointing, degrees
Slope	slope in direction of fire travel, degrees
Topographic position	location of plot on slopes
Fuel data	
Surface fuel type	main component making up the surface fuel
Surface depth	average surface fuel depth, cm
Surface cover	surface fuel foliage projective cover, %
Surface continuity	based on the categories in the DSE fuel hazard guide (Hines et al. 2010)
Near-surface fuel type	main component making up the near-surface fuel
Near-surface dead fuel	ratio of dead fuel to the total fuel expressed as a percentage
Near-surface height	average height, m, estimated by looking across the fuel array
Near-surface cover	near-surface fuel foliage projective cover, %
Near-surface continuity	based on the categories in the DSE fuel hazard guide
Elevated dead fuel	ratio of dead fuel to the total fuel expressed as a percentage
Elevated height	average height, m, estimated by looking across the fuel array
Elevated cover	elevated fuel foliage projective cover, %
Elevated continuity	based on the categories in the DSE fuel hazard guide
Canopy height	height of the top of the canopy, m
Canopy cover	canopy foliage projective cover, %
Canopy species	identified using the 4–4 naming code: Acca deal = *Acacia dealbata*, Allo vert = *Allocasuarina verticillata*, Euca amyg = *Eucalyptus amygadalina*, Euca cocc = *E. coccifera* , Euca dele = *E. delegatensis*, Euca glob = *E. globulus*, Euca obli = *E. obliqua*, Euca nite = *E. nitens*, Euca niti = *E. nitida*, Euca pulc = *E. pulchella*, Euca tenu = *E. tenuiramis*, Euca vimi = *E. viminalis*, Lept scop = *Leptospermum scoparium*, Pine radi = *Pinus radiata*
Bark type	canopy species bark type: fibrous bark, candle bark, other bark types
Bark quantity	based on the categories in the DSE fuel hazard guide
Fire behaviour data	
Fire travel direction	direction fire is travelling in, degrees
Fire severity	degree of scorch and/or crown fire: unburnt, burnt with no scorch, partial crown scorch, full crown scorch, partial crown, fire, full crown fire

Appendix 2.2 Site and fire data

Plot	Fire	Veg type	Easting GDA94/55	Northing GDA94/55	Age years	Altitude m	Aspect deg	Slope deg	Topographic position	Fire deg	Fire severity
1	Forcett	damp forest	572910	5234799	–	185	235	8	Saddle	135	partial crown scorch
2	Forcett	damp forest	572912	5234839	–	185	70	13	Saddle	135	partial crown scorch
3	Forcett	wet forest regen	572616	5234120	–	155	215	–20	mid slope	135	full crown scorch
4	Forcett	wet forest	573921	5234085	–	400	5	–13	mid slope	–	crown unscorched
5	Forcett	wet forest regen	574015	5234757	–	420	250	–8	ridge top	60	partial crown fire
6	Forcett	wet forest regen	574238	5234942	–	410	flat	flat	ridge top	60	crown fire
7	Forcett	dry forest	574783	5235236	–	385	55	12	upper slope	115	crown unscorched
8	Forcett	dry forest	572610	5235514	–	120	300	20	mid slope	120	partial crown scorch
9	Forcett	dry forest	570754	5233663	–	55	260	–6	lower slope	320	partial crown scorch
16	Forcett	dry forest	572470	5236907	–	45	160	–17	lower slope	unknown	partial crown fire
17	Forcett	plantation: eucalypt	575184	5240494	–	175	250	10	lower slope	130	full crown scorch
18	Forcett	wet forest	575746	5240465	–	185	140	–7	lower slope	unburnt	unburnt
19	Forcett	wet forest	575207	5239982	–	175	320	15	lower slope	190	full crown scorch
20	Forcett	wet forest	574644	5240492	–	150	255	2	creek flat	unknown	partial crown scorch
21a	Forcett	wet forest	574346	5240361	–	150	340	2	lower slope	130	partial crown fire
21b	Forcett	wet forest regrowth	574360	5240288	–	150	340	2	lower slope	130	crown fire
22	Forcett	dry forest	573398	5238711	–	220	flat	flat	ridge top	–	unburnt
23	Forcett	dry forest	573276	5239064	29	190	315	–5	mid slope	100	crown unscorched
24a	Forcett	plantation: eucalypt	572613	5239928	–	120	150	6	mid slope	340	crown unscorched
24b	Forcett	damp forest	572616	5239868	30	120	150	6	mid slope	unknown	partial crown scorch
25	Forcett	wet forest regen	573447	5240357	–	115	150	4	flat	unburnt	unburnt
26	Forcett	damp forest	574258	5241414	–	145	260	3	lower slope	180	full crown scorch
27	Forcett	scrub	574488	5241712	30	130	300	4	flat	130	crown fire
28	Forcett	damp forest	575778	5241926	–	215	310	14	mid slope	170	crown unscorched
29	Forcett	dry forest	571802	5242122	–	110	355	6	upper slope	120	crown fire
30	Forcett	dry forest	570119	5239287	40	65	flat	flat	flat	200	crown fire
31	Forcett	dry forest	567924	5247647	–	45	200	8	lower slope	135	partial crown fire
32a	Forcett	plantation: eucalypt	558919	5258291	–	120	260	4	upper slope	90	partial crown fire

Plot	Fire	Veg type	Easting GDA94/55	Northing GDA94/55	Age years	Altitude m	Aspect deg	Slope deg	Topographic position	Fire deg	Fire severity
32b	Forcett	dry forest	558915	5257747	–	90	20	15	mid slope	135	partial crown fire
33	Forcett	plantation: pine	559442	5258078	–	160	flat	2	hill top	130	full crown scorch
34	Forcett	dry forest	559957	5258541	–	140	170	13	lower slope	80	partial crown scorch
35	Forcett	dry forest	560260	5258386	–	120	180	6	upper slope	110	partial crown fire
36a	Forcett	dry forest	562302	5258503	–	80	20	15	mid slope	120	crown fire
36b	Forcett	plantation: eucalypt	562064	5259089	–	40	flat	flat	flat	120	partial crown fire
37	Forcett	plantation: eucalypt	563394	5259297	–	60	260	4	lower slope	130	crown fire
38	Forcett	dry forest	563113	5258495	–	95	75	–4	lower slope	95	crown fire
39	Forcett	plantation: eucalypt	565767	5256834	–	105	180	4	mid slope	135	crown fire
40	Forcett	dry forest	567968	5255077	–	30	flat	flat	flat	130	crown unscorched
41	Forcett	dry forest	568443	5254875	–	20	flat	flat	flat	160	partial crown scorch
42a	Forcett	dry forest	566258	5252273	–	55	145	–6	lower slope	unknown	partial crown fire
42b	Forcett	dry forest	565756	5253712	–	220	70	18	mid slope	160	crown fire
43	Forcett	dry forest	566087	5252139	–	55	140	–6	lower slope	130	crown fire
44	Forcett	dry forest	572420	5245196	–	100	230	5	lower slope	95	partial crown fire
45	Forcett	dry forest	574758	5246325	–	215	340	4	ridge top	80	partial crown scorch
46	Forcett	dry forest	577512	5246069	–	80	flat	flat	flat	40	crown unscorched
49	Forcett	dry forest	570720	5244756	1	10	flat	flat	flat	220	crown unscorched
50	Forcett	dry woodland	567494	5247585	–	30	340	8	upper slope	160	crown fire
51	Forcett	dry forest	557748	5255598	–	130	225	0	mid slope	125	full crown scorch
52	Forcett	dry forest	555856	5257329	–	100	150	–9	lower slope	190	partial crown scorch
53	Forcett	dry forest	555389	5259284	–	145	120	–4	lower slope	65	full crown scorch
54	Forcett	dry forest	555668	5259499	–	135	40	6	lower slope	180	partial crown fire
55	Forcett	bracken	558087	5262343	–	225	170	7	mid slope	350	burnt
56	Forcett	plantation: eucalypt	558869	5263340	–	185	flat	flat	flat	20	partial crown scorch
68	Repulse	dry forest	476430	5290706	–	140	10	2	flat	120	partial crown scorch
69	Repulse	dry forest	473637	5292162	–	150	340	2	lower slope	90	full crown scorch
70	Repulse	plantation: eucalypt	472673	5293316	–	130	flat	flat	flat	130	partial crown fire
71	Repulse	grassy woodland	470814	5293671	–	140	20	3	mid slope	145	crown unscorched

Plot	Fire	Veg type	Easting GDA94/55	Northing GDA94/55	Age years	Altitude m	Aspect deg	Slope deg	Topographic position	Fire deg	Fire severity
72	Repulse	dry forest	470275	5293323	–	150	290	3	lower slope	50	partial crown scorch
73	Repulse	damp forest	470054	5293558	–	140	120	4	lower slope	110	crown unscorched
74	Repulse	dry forest	470773	5292620	–	205	50	6	mid slope	40	partial crown scorch
75	Repulse	plantation: eucalypt	469884	5291604	–	335	80	4	ridge top	140	full crown scorch
76a	Repulse	plantation: eucalypt	472498	5291195	–	230	255	15	mid slope	110	partial crown fire
76b	Repulse	dry forest	472579	5291190	–	230	255	15	mid slope	110	partial crown scorch
77	Repulse	wet forest	472270	5289949	–	240	280	5	lower slope	130	crown fire
78	Repulse	plantation: pine	472382	5289145	–	275	flat	flat	ridgeline	130	crown fire
79	Repulse	wet forest	469838	5289079	–	540	flat	flat	ridgeline	130	full crown scorch
80	Repulse	damp forest	473847	5287176	–	278	flat	flat	low ridge	100	partial crown fire
81	Repulse	dry forest	476401	5288759	–	280	15	5	saddle	100	partial crown fire
82a	Repulse	grassland	477774	5286160	–	150	60	2	valley	–	burnt
82b	Repulse	dry forest	478129	5286656	–	170	210	0	mid slope	140	partial crown fire
83a	Repulse	grassland	478992	5286052	–	120	40	7	valley	140	burnt
83b	Repulse	dry forest	478802	5286298	–	140	150	–9	lower slope	140	partial crown fire
85	Repulse	dry forest	480602	5283319	–	350	flat	flat	saddle	110	partial crown fire
86	Repulse	dry forest	481003	5283937	–	280	40	9	mid slope	125	full crown scorch
87a	Repulse	dry forest	482418	5282987	–	270	5	10	ridge top	100	full crown scorch
87b	Repulse	dry forest	483051	5282736	–	270	300	23	mid slope	100	crown fire
103	Bicheno	dry forest	602244	5355296	–	35	flat	flat	flat	80	crown unscorched
104	Bicheno	dry forest	601429	5354616	–	35	flat	flat	flat	40	crown unscorched
105	Bicheno	dry forest	602250	5354746	–	30	flat	flat	flat	210	crown unscorched
107	Bicheno	dry forest	607437	5360433	9	80	250	2	mid slope	140	crown unscorched
108	Bicheno	dry forest	607570	5358711	9	80	250	1	mid slope	115	crown fire
109a	Bicheno	dry forest	607137	5358182	9	75	flat	flat	valley	160	crown fire
109b	Bicheno	dry forest	606928	5357889	9	100	45	15	mid slope	160	crown fire
110	Bicheno	dry forest	606373	5357886	9	70	320	8	mid slope	120	crown fire
111	Bicheno	dry forest	607638	5357622	9	55	180	–2	mid slope	90	crown fire
112	Bicheno	dry forest	607625	5357147	9	35	90	–5	mid slope	90	crown fire

Plot	Fire	Veg type	Easting GDA94/55	Northing GDA94/55	Age years	Altitude m	Aspect deg	Slope deg	Topographic position	Fire deg	Fire severity
113	Bicheno	heathy low forest	607876	5356644	9	20	100	–2	lower slope	130	crown fire
114a	Bicheno	heath	607986	5356806	9	15	flat	flat	flat	120	crown fire
114b	Bicheno	dry forest	607481	5356741	9	100	45	15	mid slope	140	crown fire
115	Bicheno	heathy forest	608180	5357157	9	20	120	–2	lower slope	120	crown fire
116	Bicheno	dry forest	607636	5360644	–	90	260	–6	upper slope	170	partial crown scorch
117	Bicheno	dry forest	602589	5355348	–	30	flat	flat	flat	230	partial crown fire
118	Bicheno	dry forest	602875	5355003	–	25	flat	flat	flat	230	crown fire
119	Bicheno	gorse	604773	5360369	–	30	flat	flat	flat	120	crown fire
121	Bicheno	coastal heath	608208	5354522	–	5	flat	flat	flat	90	crown fire
122	Bicheno	dry forest	607020	5354813	–	80	320	5	mid slope	120	crown fire
124	Bicheno	dry forest	605266	5351099	–	75	280	2	ridgeline	80	partial crown scorch
125	Bicheno	dry forest	605345	5350351	–	50	flat	flat		–	unburnt
126	Bicheno	dry forest	605425	5350363	–	50	220	3	ridgeline	170	full crown scorch
127	Bicheno	dry forest	606191	5351142	–	100	160	–10	ridgeline	160	partial crown fire
128	Bicheno	dry forest	606153	5350987	–	60	120	–13	mid slope	120	partial crown scorch
106	Freshwater	dry forest	606162	5341574	–	150	flat	flat	hill top	–	crown unscorched
123	Butlers Hill	dry forest	605874	5355222	–	55	flat	flat	flat	–	full crown scorch
133	Montumana	wet forest	365972	5466300	–	130	flat	flat	ridgetop	200	crown fire
134	Montumana	wet scrub	366072	5465996	–	90	20	15	mid slope	200	crown fire
135	Montumana	wet forest	364797	5465863	–	160	flat	flat	ridge	230	partial crown scorch
140	Montumana	plantation: eucalypt	363909	5469140	–	90	flat	flat	flat	25	partial crown fire
141	Montumana	wet scrub	365185	5468796	–	140	10	8	mid slope	170	crown fire
142	Montumana	wet forest	365089	5469677	–	90	flat	flat	flat	30	partial crown fire
143	Montumana	plantation: eucalypt	366058	5469846	–	70	flat	flat	flat	50	partial crown fire
144a	Montumana	buttongrass	367043	5469228	–	60	flat	flat	flat	340	crown fire
144b	Montumana	wet forest	367043	5469228	–	60	200				crown fire
145	Montumana	wet forest	367405	5468937	46	50	flat	flat	flat	140	crown fire
146	Montumana	wet forest	367007	5468929	–	60	30	3	mid slope	230	partial crown fire
147	Montumana	coupe	365955	5470492	–	60	flat	flat	flat	unknown	crown unscorched

Plot	Fire	Veg type	Easting GDA94/55	Northing GDA94/55	Age years	Altitude m	Aspect deg	Slope deg	Topographic position	Fire deg	Fire severity
88	Molesworth	wet forest	512121	5256689	–	690	28	11	mid slope	100	crown unscorched
89	Molesworth	damp forest	511469	5256623	–	635	200	8	mid slope	100	crown unscorched
90	Molesworth	damp forest	511008	5257110	–	565	flat	flat	ridge top	100	partial crown scorch
91	Molesworth	damp forest	510595	5257507	–	525	260	16	mid slope	140	partial crown fire
92	Molesworth	dry forest	509529	5260754	–	145	275	–23	mid slope	unknown	crown unscorched
93	Molesworth	dry forest	508829	5258552	–	145	215	7	lower slope	150	partial crown scorch
94	Molesworth	dry forest	509260	5257006	22	320	175	10	mid slope	140	partial crown scorch
95	Molesworth	dry forest	508759	5259962	–	110	150	5	lower slope	280	crown unscorched
96	Molesworth	dry forest	508927	5261557	–	175	290	21	mid slope	90	partial crown scorch
97	Molesworth	dry forest	508648	5261599	–	185	240	6	ridge line	150	partial crown scorch
98	Molesworth	dry forest	506862	5257418	–	365	30	0	mid slope	110	crown unscorched
99	Molesworth	dry forest	506545	5256993	–	485	flat	flat	shelf	80	crown unscorched
100	Molesworth	wet forest	506858	5256029	–	685	flat	flat	shelf	90	full crown scorch
101	Molesworth	subalpine woodland	511707	5252767	–	995	295	15	upper slope	80	full crown scorch
102	Molesworth	subalpine heathland	512084	5253111	–	1095	260	22	upper slope	110	crown fire
59	Gretna	dry woodland	495759	5277478	–	150	145	–10	lower slope	90	crown fire
60	Gretna	grassland	495289	5277086	–	150	270	4	mid slope	95	burnt
65	Gretna	grassland	494694	5277302	–	115	210	0	mid slope	140	burnt
67	Gretna	grassland	494356	5277973	–	110	5	5	lower slope	120	burnt

See Appendix A2.1 for data descriptions.

Appendix 2.3 Site fuel data

		Surface				Near-surface					Elevated					Canopy			Bark		
			Dph	Cvr			Dead	Hgt	Cvr		Hgt	Dead	Cvr	horiz	vert	Hgt	Cvr	spp.	Type	Quan	Char
Plot	Fire	type	cm	%	cont.	type	%	m	%	cont.	m	%	%	cont.	cont.	m	%				%
1	Forcett	litter	–	–	–	bracken	–	1	–	–	3	–									
2	Forcett	litter	–	–	–	bracken	–	1	–	–	3	–	30	H	H	30	40	Euca obli	F	H	50
3	Forcett	litter	20	90	VH	cutting	60	1.5	75	VH	5	25	30	H	H	20	35	Euca obli	F	H	90
4	Forcett	litter	30	100	E	sag	–	1.5	70	VH	8	–	60	E	E	35	40	Euca obli	F	VH	60
5	Forcett	litter	–	–	–	shrub	–	–	–	–	2	–	60	E	E	35	40	Euca obli	F	E	50
6	Forcett	litter	–	–	–	bracken	–	1	–	–	2	–	20	H	H	12	30	Euca obli	F	H	80
7	Forcett	litter	10	40	M	sag	40	1	60	H	3	20	20	L	L	12	30	Euca obli	F	M	100
8	Forcett	litter	–	–	–	bracken	–	1	–	–	2.5	–	35	H	M	18	30	Euca vimi	C	M	10
9	Forcett	litter	10	60	H	sag	45	1	65	VH	1.75	–	25	H	M	20	20	Euca obli	F	M	40
16	Forcett	litter	–	–	–	sag	–	1	–	–	2	–	20	H	VH	12	25	Euca obli	F	H	95
17	Forcett	litter	–	–	–	cutting	–	–	–	–	none	–	10	L	L	26	30	Euca obli	F	M	30
18	Forcett	litter	20	40	VH	cutting	60	2	80	E	8	30	–	–	–	16	75	Euca nite	C	L	80
19	Forcett	litter	–	–	–	cutting	–	1	–	–	4	–	75	E	E	45	30	Euca obli	F	VH	un-
20	Forcett	litter	–	–	–	sag	–	–	–	–	4	–	50	E	VH	35	40	Euca obli	F	H	35
21a	Forcett	litter	–	–	–	bracken	–	–	–	–	4	–	15	M	L	25	40	Euca obli	F	VH	50
21b	Forcett	litter	–	–	–	bracken	–	–	–	–	6	–	15	M	L	45	35	Euca obli	F	VH	35
22	Forcett	litter	–	–	–	0	–	–	–	–	–	–	25	H	M	10	40	Euca obli	F	M	100
23	Forcett	litter	–	–	–	sag	–	–	–	–	2.5	–	–	–	–	–	–	Euca obli	F	M	0
24a	Forcett	litter	10	50	M	bracken	–	1	60	H	3	–	30	40	40	40	40	Euca obli	F	H	75
24b	Forcett	litter	–	–	–	bracken	–	1	–	–	6	–	40	M	L	15	40	Euca nite	C	L	10
25	Forcett	litter	5	30	M	cutting	25	1.5	40	VH	6	5	30	VH	H	35	40	Euca obli	F	VH	80
26	Forcett	litter	–	–	–	cutting	–	–	–	–	4	–	80	VH	M	8	25	Euca obli	F	L	–
27	Forcett	litter	–	–	–	teatree	–	3	80	VH	–	–	30	H	H	20	35	Euca obli	F	H	85
28	Forcett	litter	–	–	–	bracken	–	0.5	–	–	1.5	–	–	–	–	–	–	Lept scop	O	L	100
29	Forcett	litter	–	–	–	bracken	–	–	–	–	2	–	60	VH	H	30	40	Euca obli	F	VH	50
30	Forcett	litter	–	–	–	sag	–	–	–	–	2.5	–	–	–	–	22	30	Euca obli	F	H	95
31	Forcett	litter	–	–	–	sag	–	–	–	–	5	–	30	VH	H	25	30	Euca obli	F	H	100

		Surface				Near-surface					Elevated					Canopy			Bark		
Plot	Fire	type	Dph cm	Cvr %	cont.	type	Dead %	Hgt m	Cvr %	cont.	Hgt m	Dead %	Cvr %	horiz cont.	vert cont.	Hgt m	Cvr %	spp.	Type	Quan	Char %
32a	Forcett	grassy	–	–	–	none	–	–	–	–	none	–	25	VH	M	40	40	Euca vimi	C	L	50
32b	Forcett	litter	–	–	–	none	–	–	–	–	–	–	–	–	–	6	70	Euca nite	C	L	100
33	Forcett	needles	–	–	–	none	–	–	–	–	none	–	–	–	–	–	–	Euca pulc	C	M	75
34	Forcett	litter	–	–	–	bracken	–	–	–	–	2.5	–	–	–	–	18	70	Pine rada	O	H	20
35	Forcett	litter	–	–	–	sag	–	–	–	–	2	–	20	M	L	35	35	Euca obli	F	VH	60
36a	Forcett	litter	–	–	–	none	–	–	–	–	–	–	5	L	L	20	35	Euca	F	H	50
36b	Forcett	litter	–	–	–	none	–	–	–	–	–	–	–	–	–	20	30	Euca	F	M	100
37	Forcett	grass	–	–	–	none	–	–	–	–	none	–	–	–	–	0	0	Euca nite	C	L	80
38	Forcett	litter	–	–	–	bracken	–	–	–	–	1.5	–	–	–	–	8	80	Euca nite	C	L	100
39	Forcett	grassy	–	–	–	none	–	–	–	–	none	–	10	L	L	35	35	Euca	F	H	100
40	Forcett	litter	–	–	–	sag	–	–	–	–	1.5	–	–	–	–	8	60	Euca nite	C	L	100
41	Forcett	litter	–	–	–	bracken	–	–	–	–	3	–	50	VH	VH	20	60	Euca	F	VH	15
42a	Forcett	litter	–	–	–	sag	–	–	–	–	1.5	–	20	M	L	25	35	Euca vimi	C	M	25
42b	Forcett	litter	–	–	–	none	–	–	–	–	–	–	10	L	L	18	35	Euca vimi	C	H	60
43	Forcett	litter	–	–	–	sag, grass	–	–	–	–	1.5	–	–	–	–	25	35	Euca	F	M	100
44	Forcett	litter	–	–	–	bracken	–	–	–	–	1.5	–	10	L	L	7	50	Allo vert	O	L	100
45	Forcett	litter	–	–	–	bracken	–	–	–	–	3	–	10	L	L	7	40	Euca pulc	C	M	90
46	Forcett	litter	–	–	–	bracken	–	1	–	–	–	–	20	M	L	12	40	Euca obli	F	VH	60
49	Forcett	litter	–	–	–	bracken	–	–	–	–	–	–	–	–	–	35	40	Euca obli	F	VH	75
50	Forcett	litter	–	–	–	sag, grass	–	–	–	–	3	–	–	–	–	8	60	Allo vert	O	M	25
51	Forcett	litter	–	–	–	bracken	–	–	–	–	–	–	10	L	L	7	20	Allo vert	O	L	100
52	Forcett	litter	–	–	–	sag	–	–	–	–	–	–	–	–	–	25	35	Euca pulc	C	M	75
53	Forcett	litter	–	–	–	bracken	–	–	–	–	none	–	–	–	–	18	40	Euca pulc	C	L	30
54	Forcett	litter	–	–	–	bracken	–	–	–	–	–	–	–	–	–	25	35	Euca obli	F	H	95
55	Forcett	litter	–	–	–	bracken	–	1.5	100	E	none	–	–	–	–	18	35	Euca obli	F	VH	100
56	Forcett	litter	–	–	–	none	–	–	–	–	none	–	–	–	–	non	–	–	–	–	–
68	Repulse	litter	–	–	–	bracken	–	–	–	–	3	–	–	–	–	14	80	Euca nite	C	L	50
69	Repulse	litter	–	–	–	bracken	–	–	–	–	2.5	–	20	L	L	35	30	Euca	C	L	50

		Surface				Near-surface					Elevated					Canopy			Bark		
		Dph		Cvr			Dead	Hgt	Cvr		Hgt	Dead	Cvr	horiz	vert	Hgt	Cvr	spp.	Type	Quan	Char
Plot	Fire	type	cm	%	cont.	type	%	m	%	cont.	m	%	%	cont.	cont.	m	%				%
70	Repulse	litter	–	–	–	none	–	–	–	–	none	–	10	L	L	25	20	Euca tenu	C	M	35
71	Repulse	grass	–	–	–	grass, sag	–	–	–	–	2	–	–	–	–	12	80	Euca nite	C	L	100
72	Repulse	litter	–	–	–	bracken	–	–	–	–	none	–	15	L	L	18	5	Euca	C	H	10
73	Repulse	litter	–	–	–	bracken	–	–	–	–	3	–	–	–	–	30	25	Euca pulc	C	M	45
74	Repulse	grass	–	–	–	grass,	–	–	–	–	1.5	–	30	M	L	40	45	Euca vimi	C	L	10
75	Repulse	litter	–	–	–	none	–	–	–	–	none	–	40	M	L	25	30	Euca pulc	C	M	30
76a	Repulse	sag	–	–	–	sag	–	1	–	–	none	–	–	–	–	8	80	Euca nite	C	L	75
76b	Repulse	sag	–	–	–	bracken	–	1	–	–	3	–	–	–	–	12	60	Euca nite	–	L	100
77	Repulse	litter	–	–	–	bracken	–	1	–	–	3	–	10	L	L	35	20	Euca pulc	–	–	–
78	Repulse	litter	–	–	–	none	–	–	–	–	none	–	15	L	L	40	30	Euca dele	F	H	90
79	Repulse	litter	–	–	–	bracken	–	1	–	–	3	–	–	–	–	35	90	Pine rada	O	H	100
80	Repulse	litter	–	–	–	bracken	–	1	–	–	2	–	60	H	M	35	30	Euca dele	F	H	80
81	Repulse	litter	–	–	–	bracken	–	1	–	–	3	–	10	L	L	35	40	Euca dele	F	H	90
82a	Repulse	grass	–	–	–	none	–	–	–	–	none	–	20	L	L	25	35	Euca obli	F	H	90
82b	Repulse	litter	–	–	–	none	–	–	–	–	–	–	–	–	–	non	–	–	–	–	–
83a	Repulse	grass	–	–	–	none	–	–	–	–	none	–	–	–	–	30	30	Euca obli	F	VH	80
83b	Repulse	litter	–	–	–	none	–	–	–	–	–	–	–	–	–	non	–	–	–	–	–
85	Repulse	litter	–	–	–	bracken	–	–	–	–	1.5	–	–	–	–	30	30	Euca obli	F	VH	80
86	Repulse	litter	–	–	–	bracken	–	–	–	–	2.5	–	20	M	L	16	35	Euca	C	L	40
87a	Repulse	litter	–	–	–	bracken	–	1	–	–	none	–	30	M	L	30	40	Euca	C	L	20
87b	Repulse	0	–	–	–	litter	–	–	–	–	–	–	–	–	–	12	30	Euca tenu	C	L	30
103	Bicheno	litter	–	–	–	sedge	–	0.5	–	–	none	–	–	–	–	12	30	Euca tenu	C	L	50
104	Bicheno	litter	–	–	–	bracken	–	–	–	–	none	–	–	–	–	8	80	Allo vert	0	L	0
105	Bicheno	litter	–	–	–	shrub	–	–	–	–	1.5	–	–	–	–	12	50	Euca	F	M	60
107	Bicheno	litter	–	–	–	bracken	–	–	–	–	none	–	5	L	L	10	30	Euca	F	H	30
108	Bicheno	litter	–	–	–	bracken	–	–	–	–	1.5	–	–	–	–	22	35	Euca	F	H	50
109a	Bicheno	litter	–	–	–	bracken	–	–	–	–	none	–	5	L	L	25	35	Euca	F	H	90
109b	Bicheno	–	–	–	–	bracken	–	–	–	–	–	–	–	–	–	25	40	Euca	F	H	100

		Surface				Near-surface					Elevated					Canopy			Bark		
Plot	Fire	type	Dph cm	Cvr %	cont.	type	Dead %	Hgt m	Cvr %	cont.	Hgt m	Dead %	Cvr %	horiz cont.	vert cont.	Hgt m	Cvr %	spp.	Type	Quan	Char %
110	Bicheno	litter	–	–	–	bracken	–	1	–	–	none	–	–	–	–	–	–	Euca	F	–	–
111	Bicheno	litter	–	–	–	bracken	–	1	–	–	3	–	–	–	–	25	35	Euca	F	H	100
112	Bicheno	litter	–	–	–	bracken	–	1	–	–	2	–	10	L	L	18	30	Euca	F	M	100
113	Bicheno	litter	–	–	–	bracken	–	1	–	–	none	–	10	L	L	30	30	Euca glob	C	M	100
114a	Bicheno	litter	–	–	–	bracken	–	1	100	VH	1.75	–	–	–	–	8	25	Euca tenu	C	M	100
115	Bicheno	litter	–	–	–	bracken	–	–	–	–	4	–	–	–	–	–	–	Euca	F	H	100
116	Bicheno	litter	–	–	–	bracken	–	–	–	–	2	–	95	E	E	8	20	Euca glob	C	?	100
117	Bicheno	litter	–	–	–	sag	–	–	–	–	4	–	5	L	L	32	35	Euca glob	C	H	40
118	Bicheno	litter	–	–	–	sag	–	–	–	–	none	–	20	M	M	30	30	Euca	F	?	90
119	Bicheno	litter	–	–	–	shrub	–	2	100	E	none	–	–	–	–	35	40	Euca	F	H	100
121	Bicheno	litter	–	–	–	shrub	–	–	–	–	none	–	–	–	–	non	–	–	–	–	–
122	Bicheno	litter	–	–	–	bracken	–	–	–	–	2.5	–	–	–	–	non	–	–	–	–	–
124	Bicheno	litter	–	–	–	bracken	–	–	–	–	1.5	–	20	M	M	20	45	Euca	F	M	100
125	Bicheno	0	–	–	–	none	–	–	–	–	–	–	10	L	L	18	40	Euca	F	M	75
126	Bicheno	litter	–	–	–	bracken	–	–	–	–	1.75	–	–	–	–	–	–	Euce	F	VH	0
127	Bicheno	litter	–	–	–	bracken	–	–	–	–	none	–	10	L	L	24	30	Euca	F	VH	60
128	Bicheno	litter	5	30	M	bracken	15	0.5	60	M	1.75	40	–	–	–	28	30	Euca	F	VH	70
106	Freshwater	litter	5	90	VH	bracken	40	0.75	45	H	6	20	10	L	L	28	30	Euca vimi	C	L	10
123	Butlers Hill	litter	–	–	–	bracken	–	–	–	–	4	–	20	H	M	25	30	Euca glob	C	M	10
133	Montumana	litter	–	–	–	bracken	–	–	–	–	–	–	20	M	M	30	35	Euca	F	H	40
134	Montumana	litter	–	–	–	scrub	–	–	–	–	5	–	–	–	–	27	45	Euca obli	F	H	100
135	Montumana	litter	–	–	–	cutting	–	–	–	–	3	–	80	E	E	non	–	–	–	–	–
140	Montumana	litter	–	–	–	bracken	–	–	–	–	none	–	5	L	L	45	5	Euca obli	F	H	25
141	Montumana	litter	–	–	–	scrub	–	–	–	–	10	–	–	–	–	12	40	Euca nite	C	L	100
142	Montumana	litter	–	–	–	cutting	–	–	–	–	4	–	90	E	E	25	25	Euca obli	F	M	100
143	Montumana	litter	–	–	–	none	–	–	–	–	2	–	30	H	H	38	35	Euca obli	F	H	90
144a	Montumana	none	–	–	–	sedge	–	–	–	–	1.5	–	40	M	M	12	70	Euca nite	C	L	50
144b	Montumana	0	–	–	–	none	–	–	–	–	–	–	25	L	L	6	2	Euca niti	C	L	100

		Surface				Near-surface					Elevated					Canopy			Bark		
			Dph	Cvr			Dead	Hgt	Cvr		Hgt	Dead	Cvr	horiz	vert	Hgt	Cvr	spp.	Type	Quan	Char
Plot	Fire	type	cm	%	cont.	type	%	m	%	cont.	m	%	%	cont.	cont.	m	%				%
145	Montumana	litter	–	–	–	bracken	–	–	–	–	6	–	40	H	H	30	35	Euca obli	F	VH	100
146	Montumana	litter	–	–	–	bracken	–	–	–	–	5	–	60	E	E	38	40	Euca obli	F	E	100
147	Montumana	litter	–	–	–	tree	–	–	–	–	2	–	60	E	E	28	35	Euca obli	F	VH	90
88	Molesworth	litter	15	60	H	shrub	–	0.5	60	H	4	–	25	L	L	2	25	Euca obli	F	VH	50
89	Molesworth	litter	–	–	–	shrun	–	–	–	–	6	–	60	H	M	26	40	Euca obli	F	VH	30
90	Molesworth	litter	–	–	–	?	–	–	–	–	none	–	60	VH	M	15	40	Euca obli	F	H	50
91	Molesworth	litter	–	–	–	?	–	–	–	–	none	–	–	–	–	35	45	Euca obli	F	VH	40
92	Molesworth	litter	5	25	M	shrub	–	0.3	10	L	none	–	–	–	–	30	35	Euca obli	F	?	95
93	Molesworth	litter	–	–	–	bricken	–	–	–	–	4	–	–	–	–	10	30	Euca pulc	C	L	20
94	Molesworth	litter	–	–	–	shrub	–	–	–	–	1.5	–	20	M	M	25	25	Euca obli	F	VH	50
95	Molesworth	litter	–	–	–	grass	–	–	–	–	1.5	–	10	L	L	11	30	Euca pulc	C	L	15
96	Molesworth	litter	40	10	H	shrub	–	0.5	20	25	none	–	10	L	L	18	30	Euca pulc	C	L	5
97	Molesworth	litter	10	70	H	grass	40	0.4	30	M	2	10	–	–	–	9	30	Euca tenu	C	L	15
98	Molesworth	litter	–	–	–	bracken	–	–	–	–	none	–	5	L	L	8	25	Euca pulc	C	M	30
99	Molesworth	litter	–	–	–	grass	–	–	–	–	1.5	–	–	–	–	18	30	Euca obli	F	VH	50
100	Molesworth	litter	15	80	VH	shrub	50	1	75	VH	2	25	5	L	L	22	45	Euca obli	F	VH	75
101	Molesworth	litter	10	50	H	shrub	30	1.5	80	E	3	10	60	E	E	25	35	Euca obli	F	VH	80
102	Molesworth	litter	–	–	–	shrub	–	–	–	–	none	–	10	L	L	8	25	Euca	C	L	15
59	Gretna	grass	–	–	–	bracken	–	–	–	–	3	–	–	–	–	4	5	Euca	C	L	30
60	Gretna	grass	–	–	–	grass	–	–	–	–	none	–	10	L	L	7	10	Acac deal	O	L	100
65	Gretna	grass	–	–	–	grass	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
67	Gretna	grass	–	–	–	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: See Appendix A2.1 for data descriptions.; Dph = depth; Cvr = cover; cont. = continuity; Hgt = height; dead = dead fuel; horiz = horizontal; vert = vertical; spp. = species; bark type: F = fibrous, C = candle, O = other; quan = bark quantity; char = bark charring.

A2.4 Fire mapping

A total of 75 fire boundary locations have been mapped by this project using the GDA94/55 datum in MapInfo version 7.8. The raw fire boundaries generated during the fires were converted from line features to polygons. These fire boundaries have been mapped to the nearest 5 min.

All of the fire maps indicate the location of the fire's boundaries. In addition to these mapped areas, there would have been spotfires outside the mapped areas that in most cases have not been mapped. These spotfires would have mainly occurred while the fires were making high-intensity runs.

For each of the fires, boundaries of the areas burnt at different times were estimated from the fire boundaries generated by the fire management agencies during the fires, photographs taken during the fires, interviews with fire personnel, Situation Reports and Incident Action Plans.

The linescans flown by the Victorian DSE on the evenings of 04/01/13 to 06/01/13 were used to map the Forcett–Dunalley, Repulse and Bicheno fires at those times.

For the Forcett–Dunalley, Repulse and Bicheno fires, the final boundaries were on-screen digitised from colour orthorectified aerial photograph mosaics taken following the fires by the Tasmanian Department of Primary Industries, Parks, Water and Environment. These aerial photograph mosaics had a pixel size of 20 cm.

The boundaries for the Giblin River fire were estimated from maps generated by the Parks and Wildlife Service during the fire.

The final boundaries of the Montumana and Molesworth fires were estimated using the fire boundaries generated during the fires by the fire-management agencies in association with ground-checking performed as part of this project.

The final boundary of the Gretna fire was on-screen digitised from Google Earth using a satellite image scanned on 21/02/13.

The following fields were used in the MapInfo table:

Id	row number in map database
IncidentNum	identifier used by fire-management agencies
Name	fire name used in this report and by fire management agencies
Time	time period for mapped fire boundary, EDST
Data source	where data on fire boundary has been obtained from: TFS fire investigations, fire crew photographs and observations, DSE linescans, Situation Reports, aerial photographs, Google Earth, ground-truthing
FuelType	main fuel being burnt: DSF = dry sclerophyll forest, WSF = wet sclerophyll forest, WS = wet scrub, BG = buttongrass, GR = grassland
Intensity	main intensity class for that time period
Area	size of mapped fire, ha
Perimeter	perimeter of mapped fire, km
Easting	X grid reference, six-figure, GDA94/55
Northing	Y grid reference, seven-figure, GDA94/55
Notes	additional information available on mapped fire boundary

A2.5 Weather data

The weather data supplied by the Bureau of Meteorology has been used to estimate the conditions prevailing at the head fire at different times. The weather data for the different firegrounds has been summarised in Appendix 3.

During the Forcett–Dunalley fire, for the period 14:00 03/01/13 to 18:00 04/01/13, weather data from Hobart Airport was used with data from Dunalley being used between 18:00 04/01/13 and 06:00 18/01/13. For the Repulse and Gretna fires, the weather data from Ouse and Bushy Park was averaged. For the Bicheno fire, data from Friendly Beaches was used. For the Montumana fire, data from Luncheon Hill, Smithton aerodrome and Wynyard airport was averaged. For the Molesworth fire, data from Bushy Park and Mt Wellington was averaged.

The data for relative humidity, dew-point temperature, temperature, wind speed at 10 m, wind gusts at 10 m and wind direction at 10 m was collected using Bureau of Meteorology automatic weather stations and averaged over 10-min periods.

Where there was more than ~250-m difference in altitude between the fire's head and the weather station, the relative humidity was estimated by assuming a constant dew-point temperature and correcting the temperature using the dry adiabatic lapse rate (assumed to be 10°C per 1000 m of altitude). This adjustment was performed for the Montumana and Molesworth fires.

Appendix 3. Weather data summary

The Bureau of Meteorology automatic weather station data detailed in Section 2.8 and in the fire description in Section 3 has been summarised below.

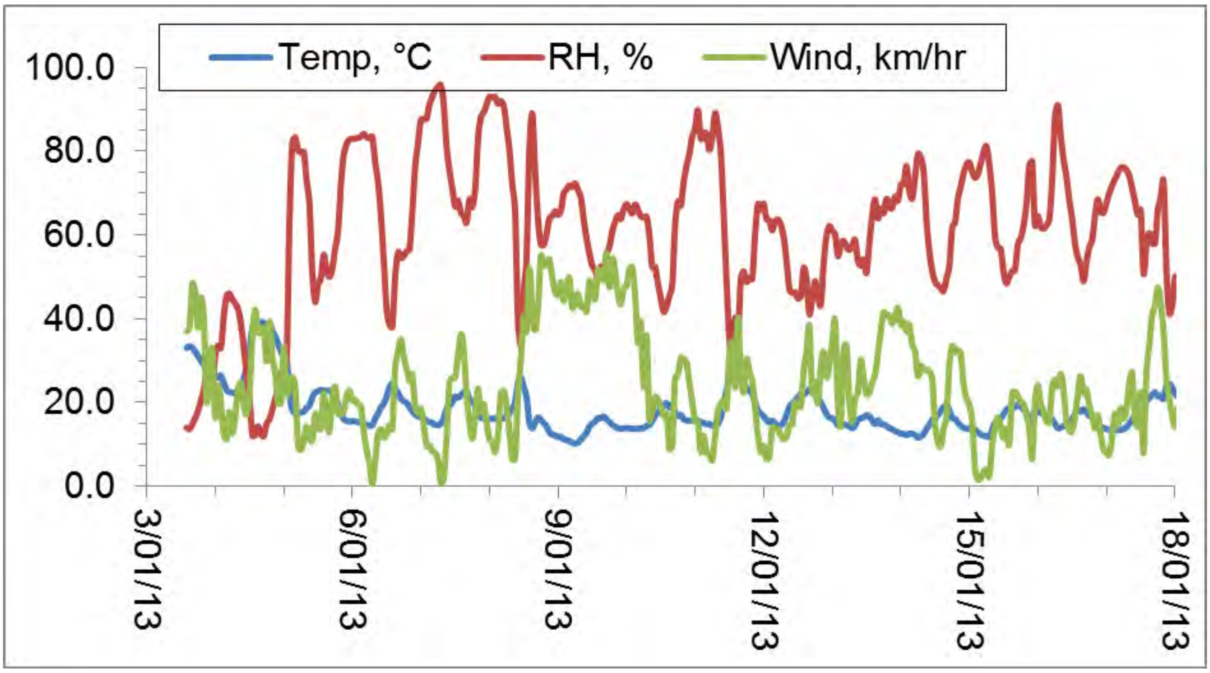


Figure A3.1 Weather data summarised for the Forcett–Dunalley fire between 03 and 18/01/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

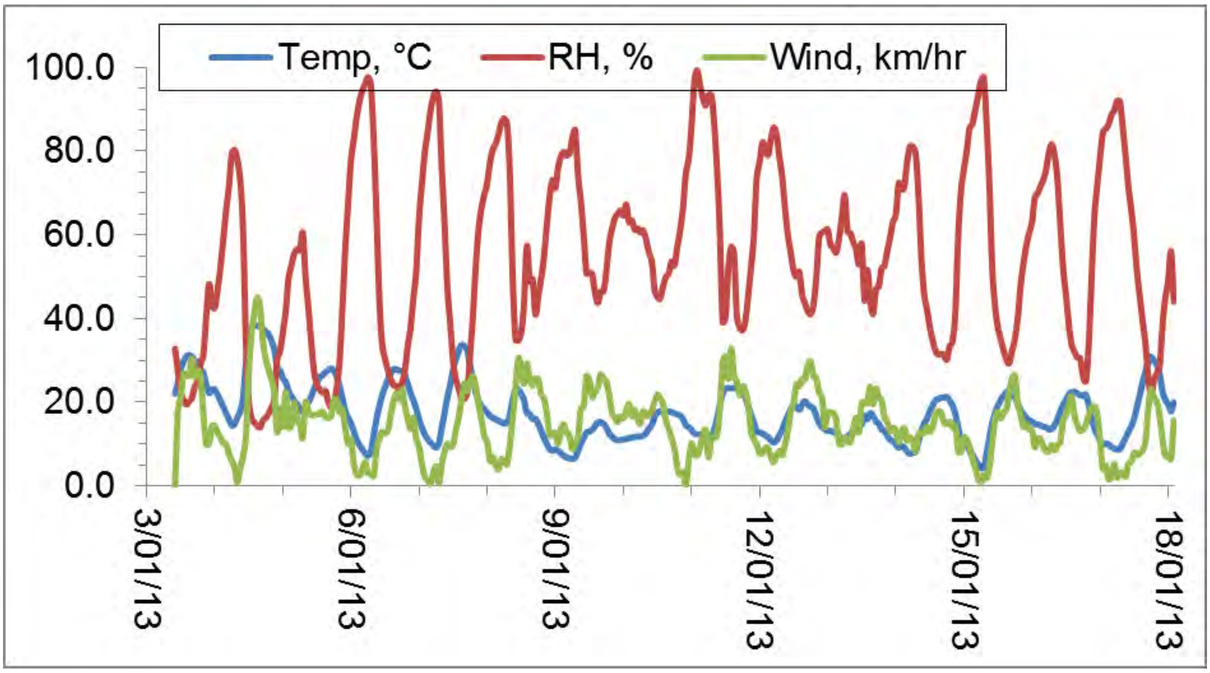


Figure A3.2 Weather data summarised for the Repulse fire between 03 and 18/01/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

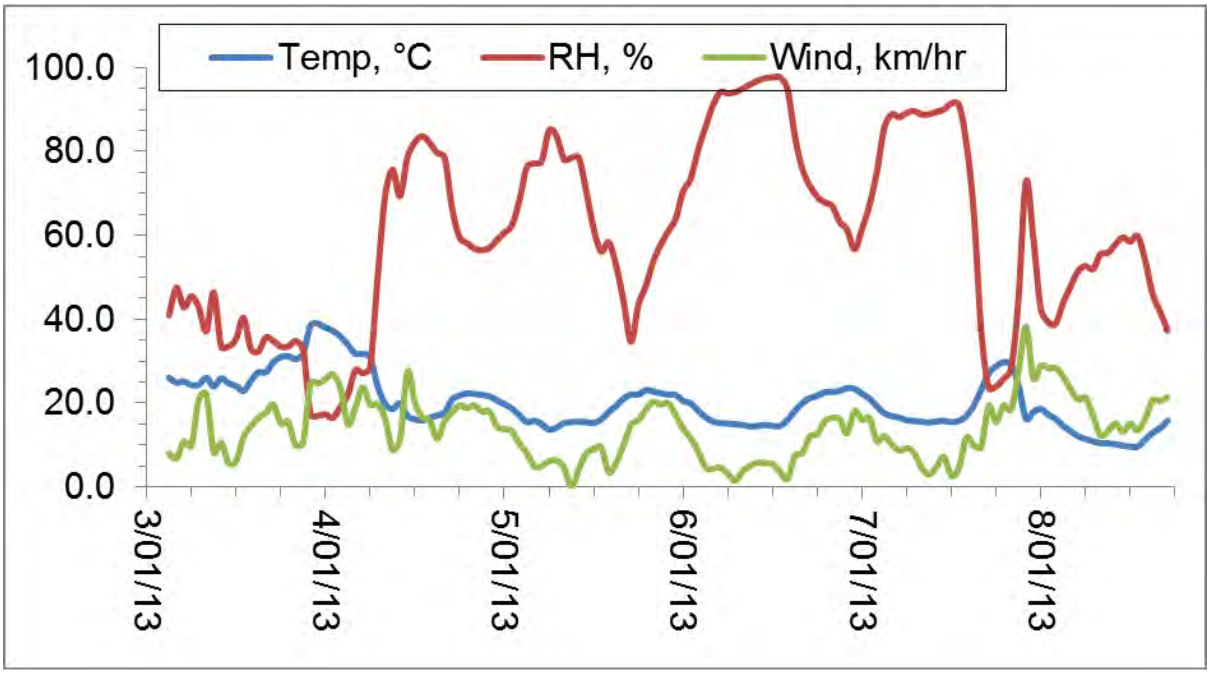


Figure A3.3 Weather data summarised for the Bicheno fire between 03 and 09/01/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

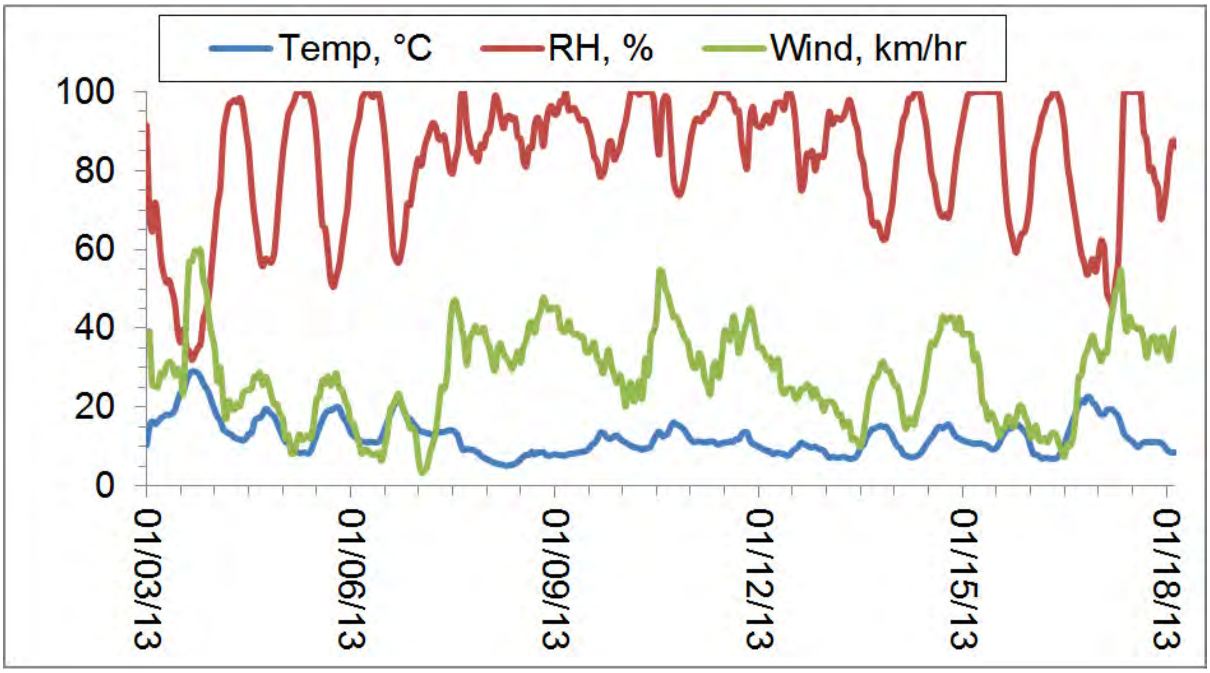


Figure A3.4 Weather data summarised for the Giblin River fire between 03 and 18/01/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

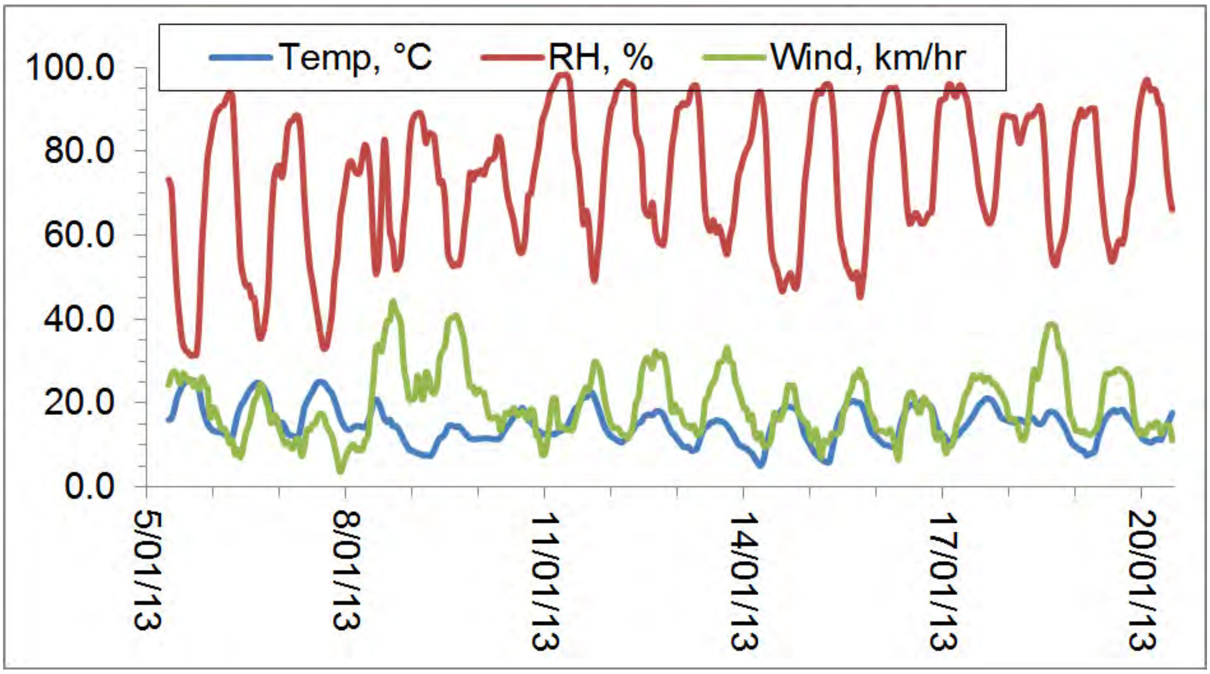


Figure A3.5 Weather data summarised for the Montumana fire between 05 and 20/01/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

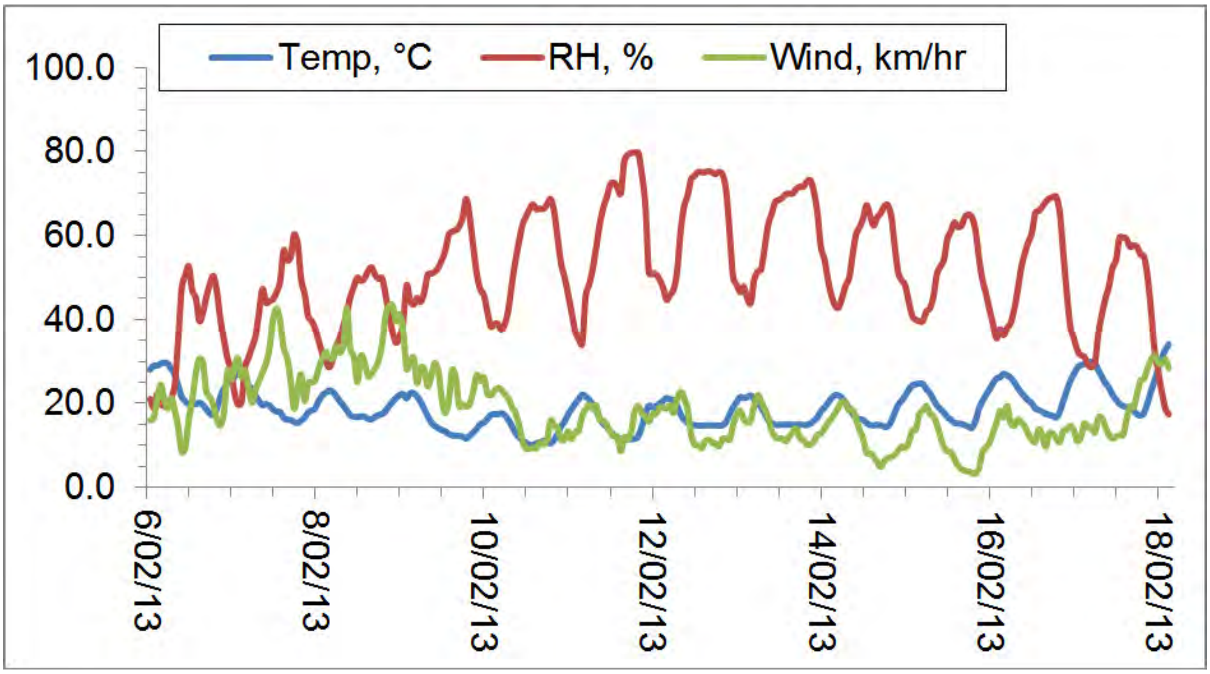


Figure A3.6 Weather data summarised for the Molesworth fire between 06 and 18/02/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

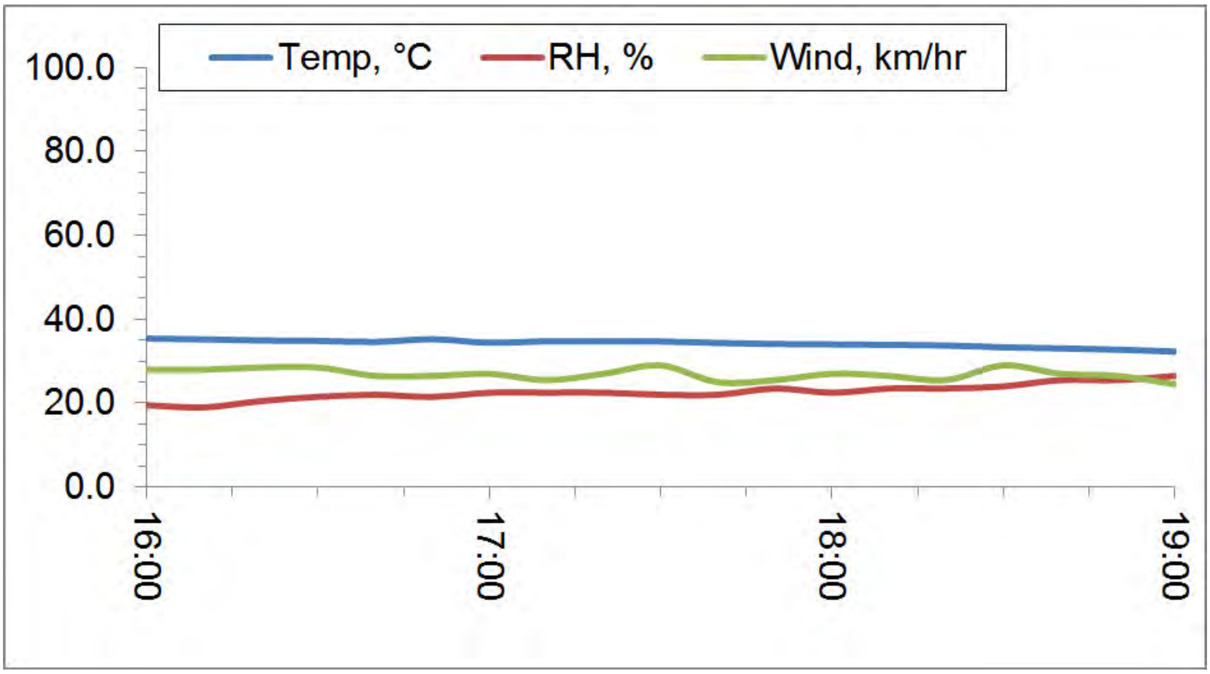
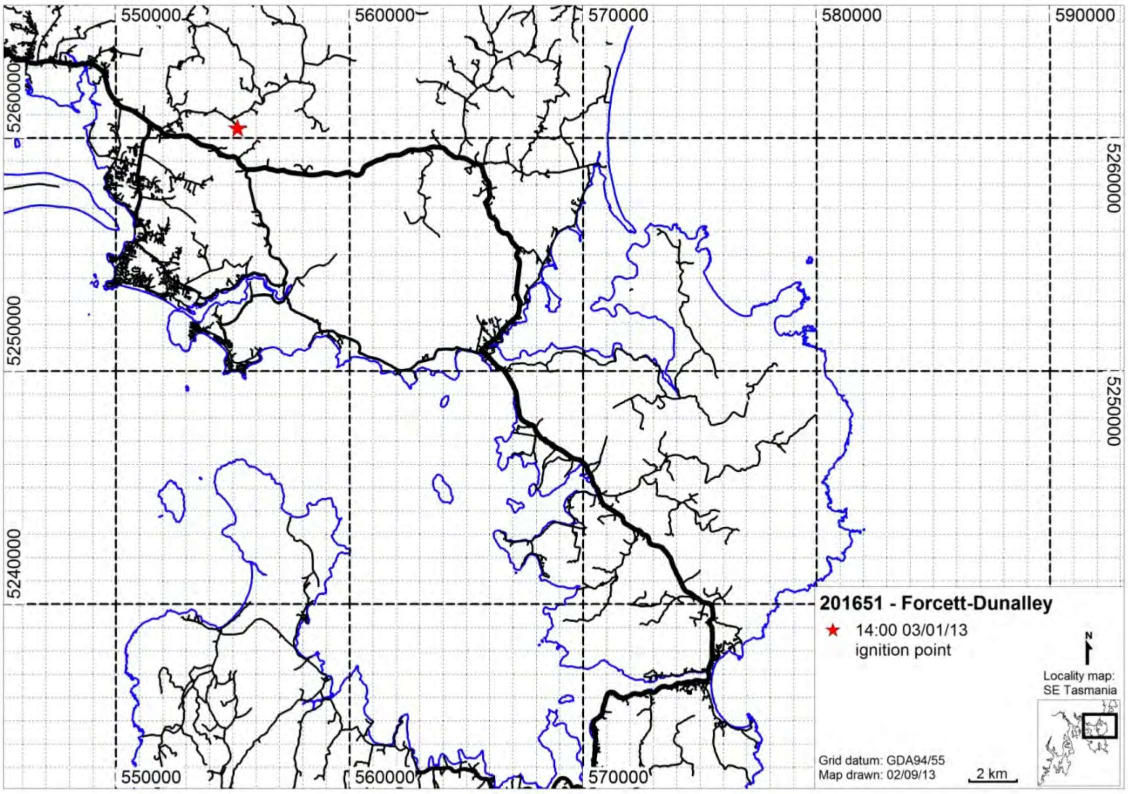


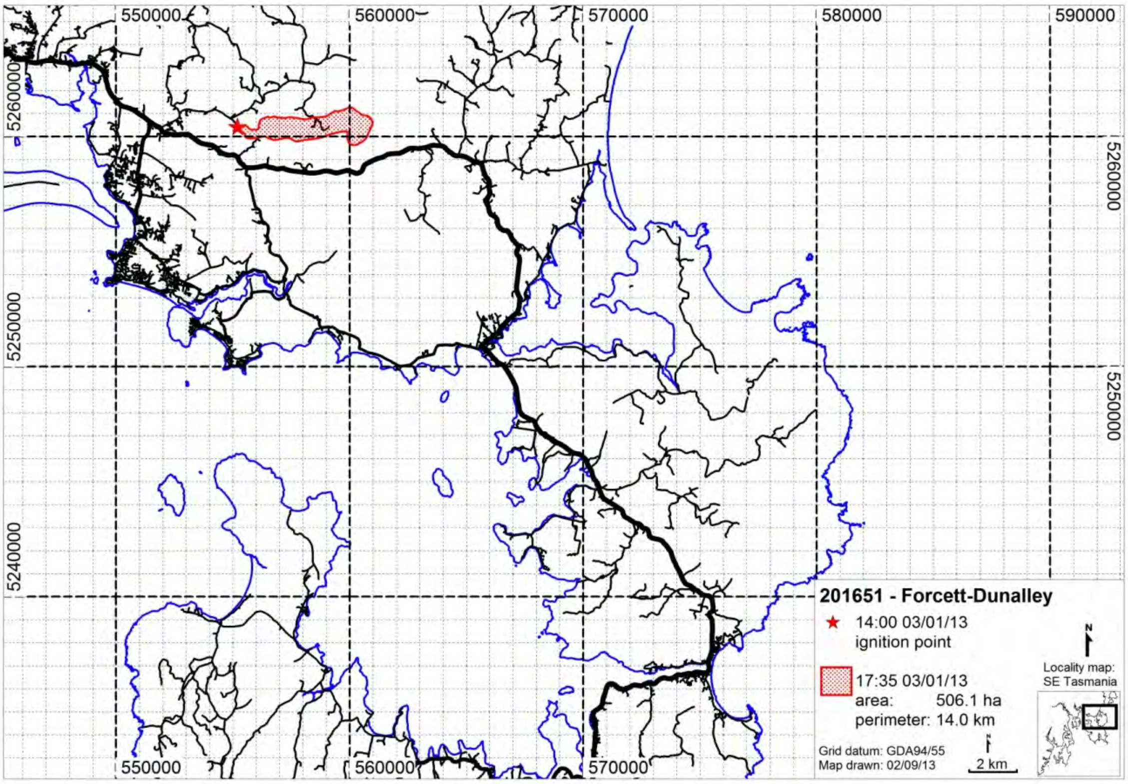
Figure A3.7 Weather data summarised for the Gretna fire between 16:00 and 19:00 on 18/02/13.
Source: Bureau of Meteorology unpublished automatic weather station data.

Appendix 4 Fire spread maps

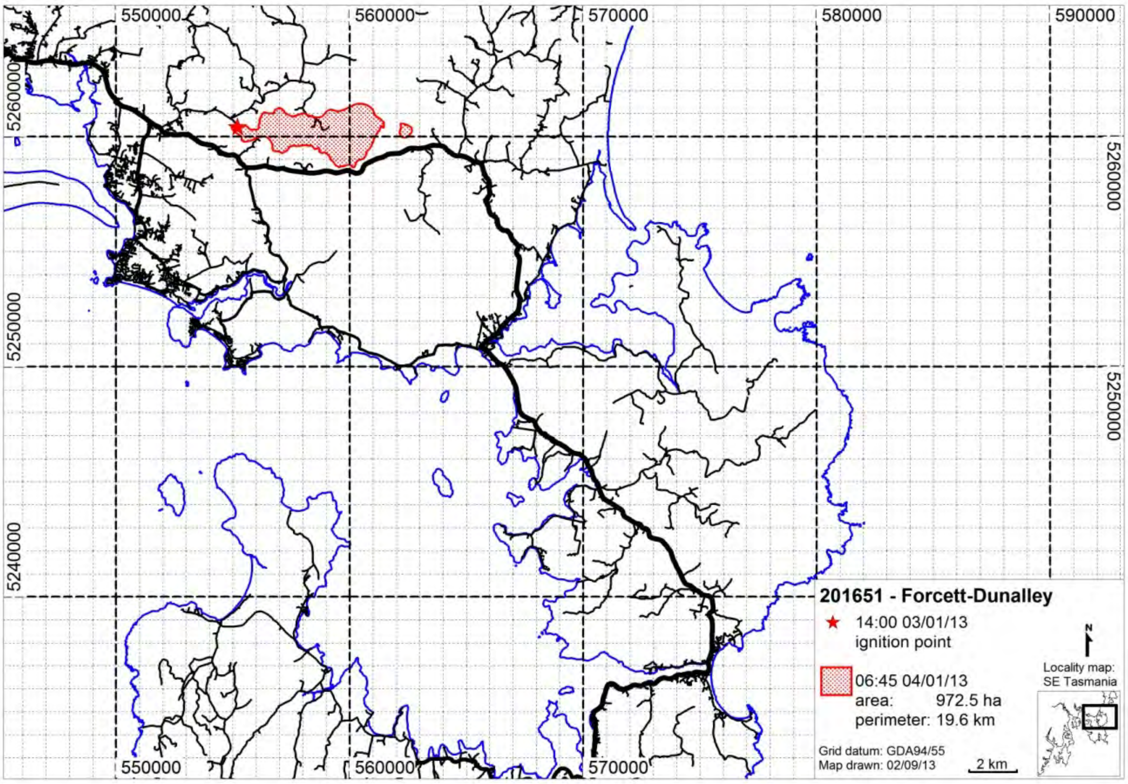
Appendix 4.1 Forcett–Dunalley fire



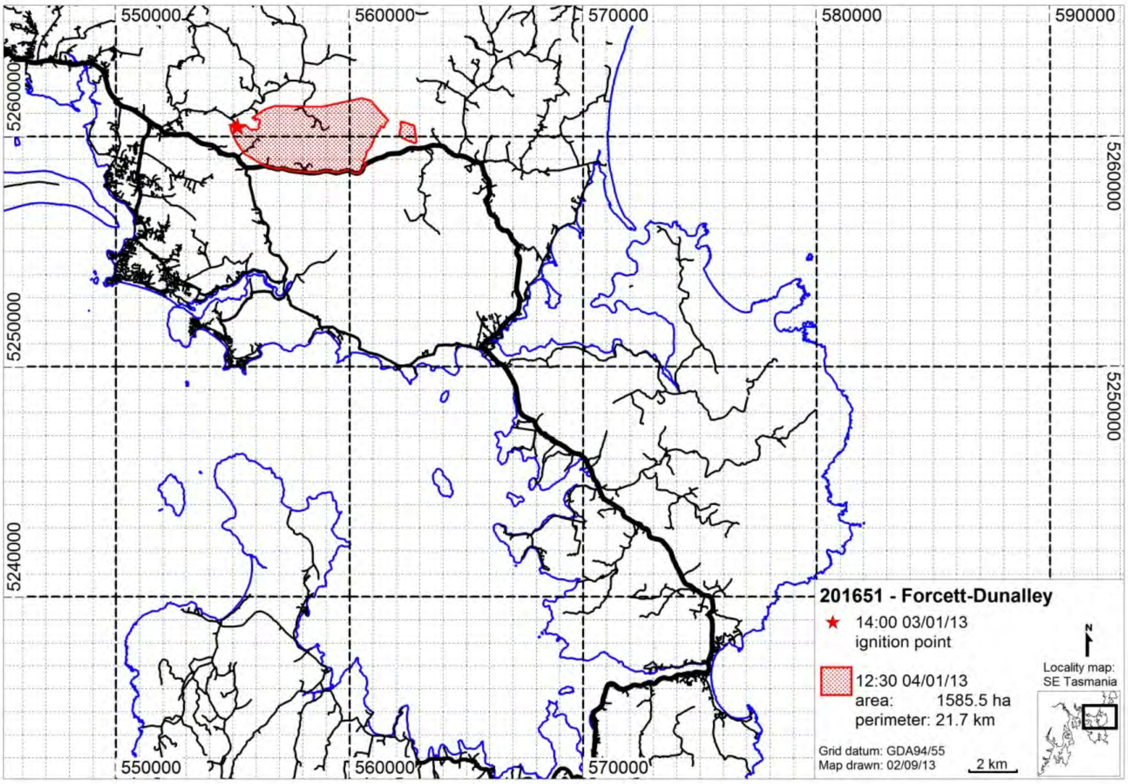
Map A4.1.1 Forcett–Dunalley ignition point at 14:00 EDST 03/01/2013.



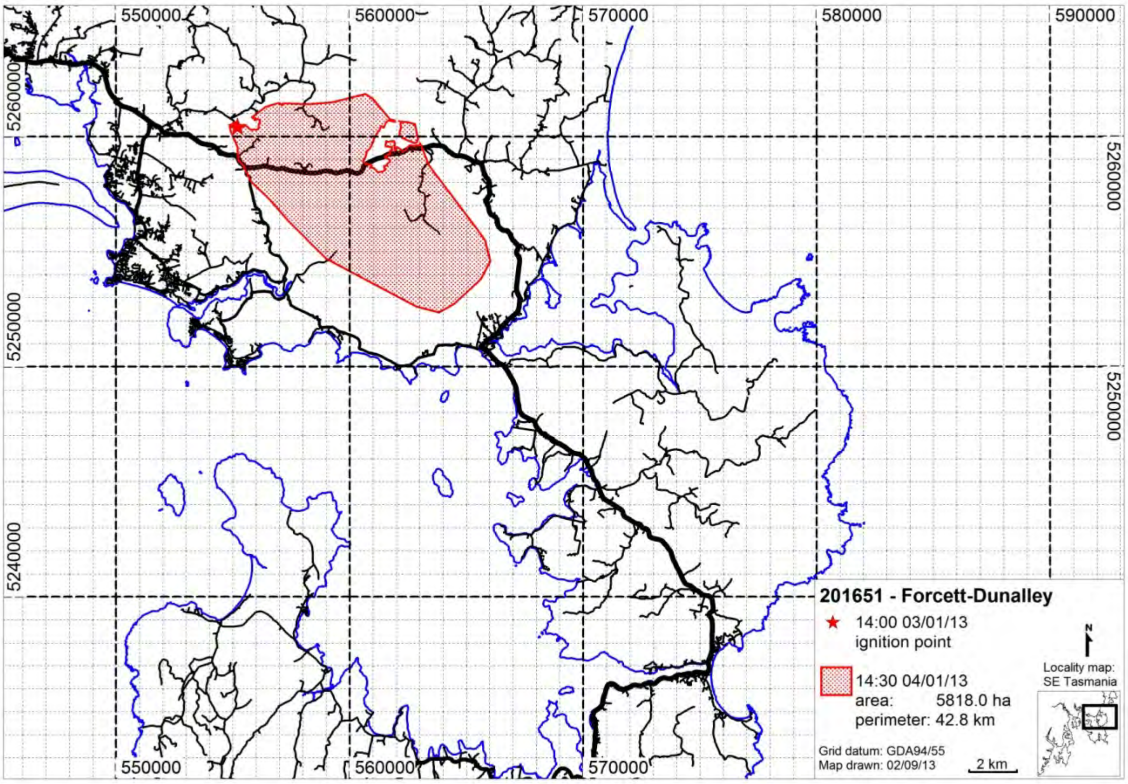
Map A4.1.2 Forcett–Dunalley fire at 17:35 EDST 03/01/2013.



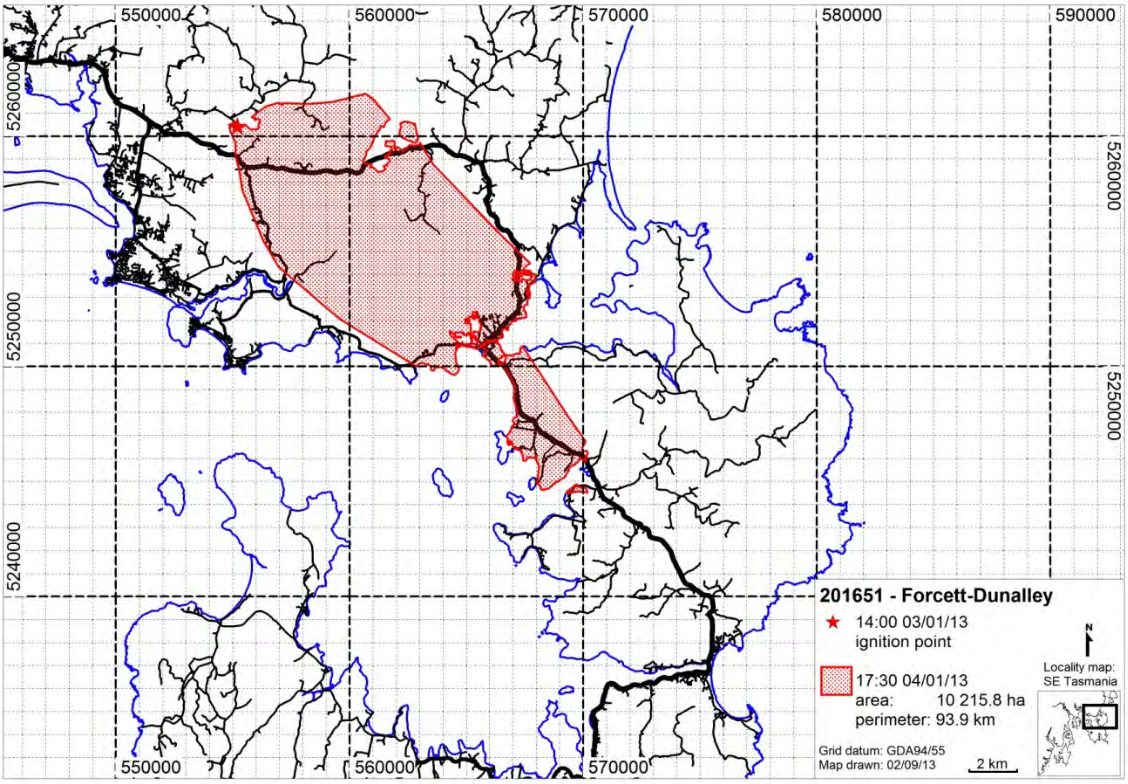
Map A4.1.3 Forcett–Dunalley fire at 06:45 EDST 04/01/2013.



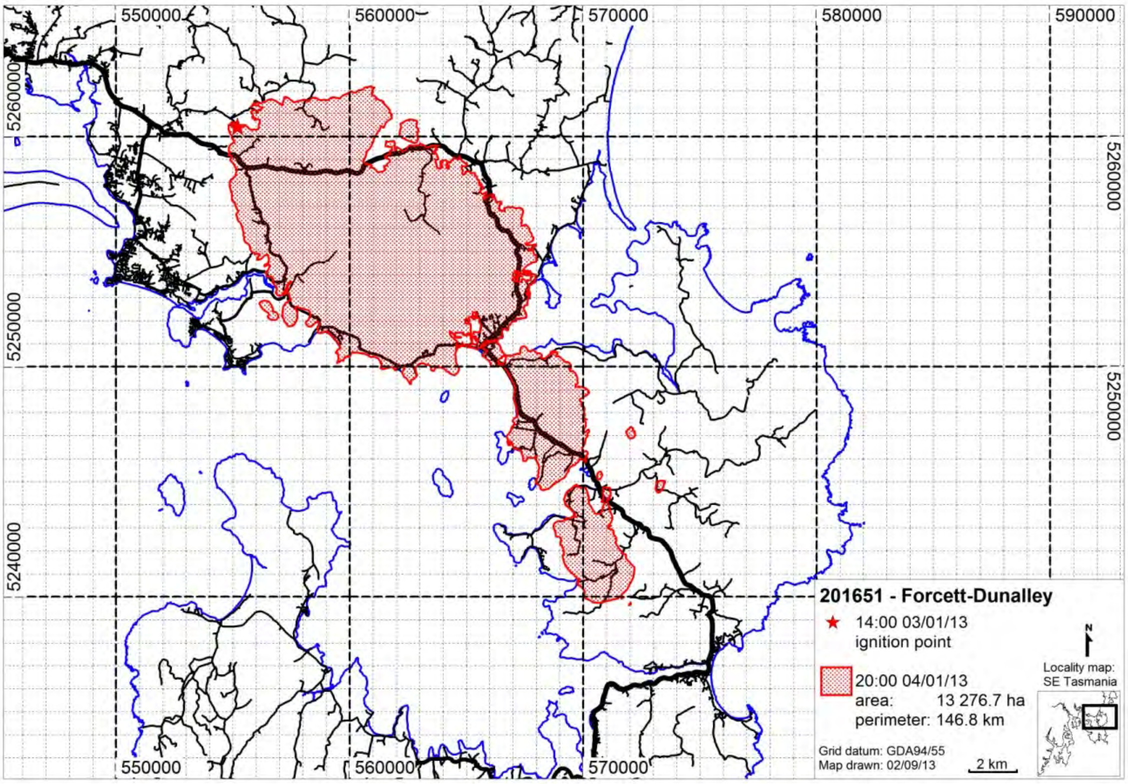
Map A4.1.4 Forcett–Dunalley fire at 12:30 EDST 04/01/2013.



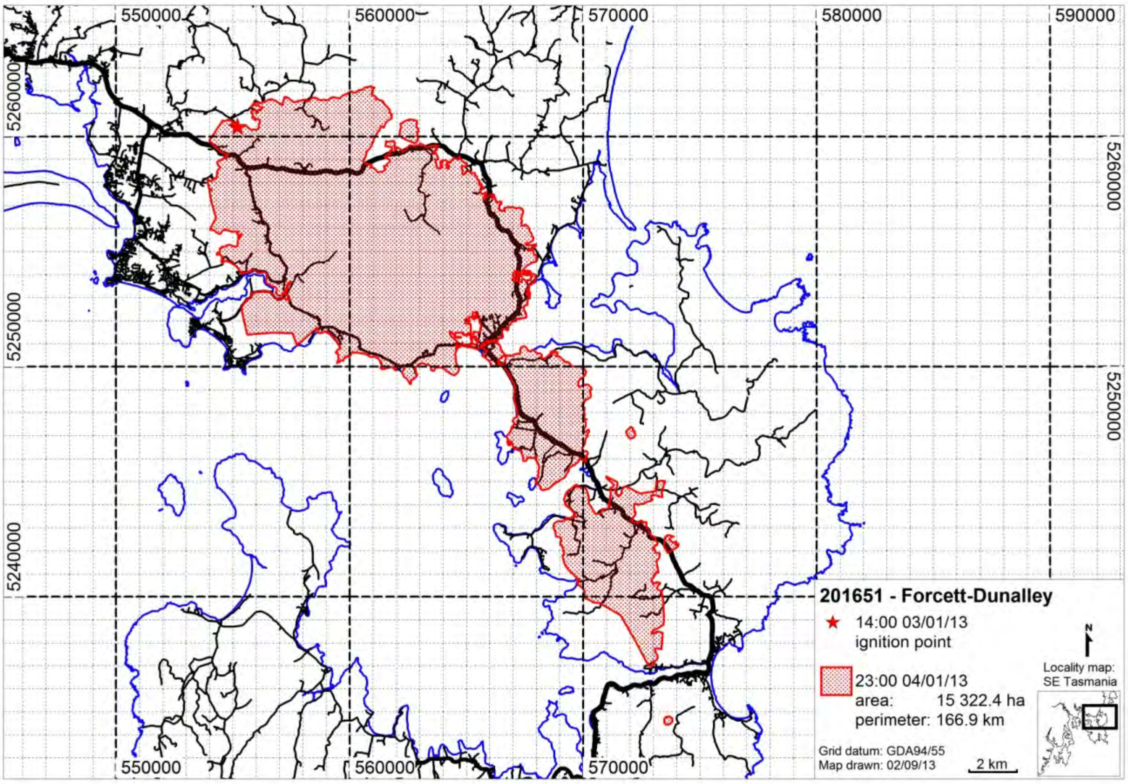
Map A4.1.5 Forcett–Dunalley fire at 14:30 EDST 04/01/2013.



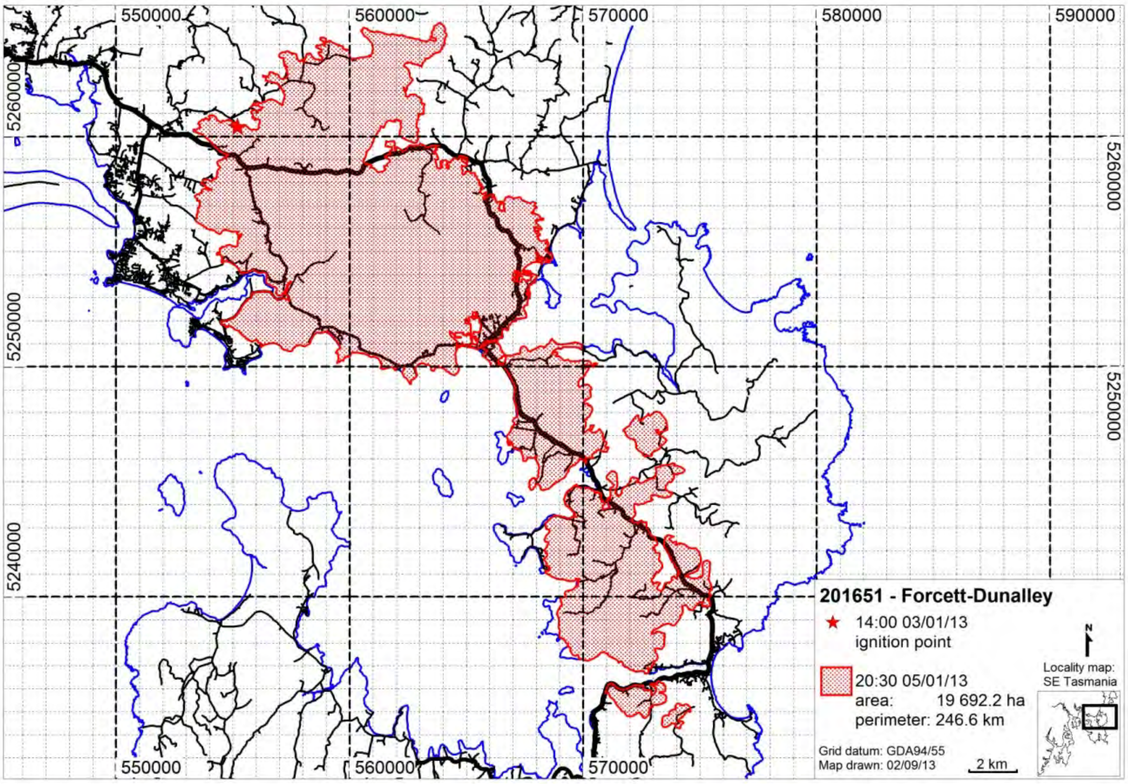
Map A4.1.6 Forcett–Dunalley fire at 17:30 EDST 04/01/2013.



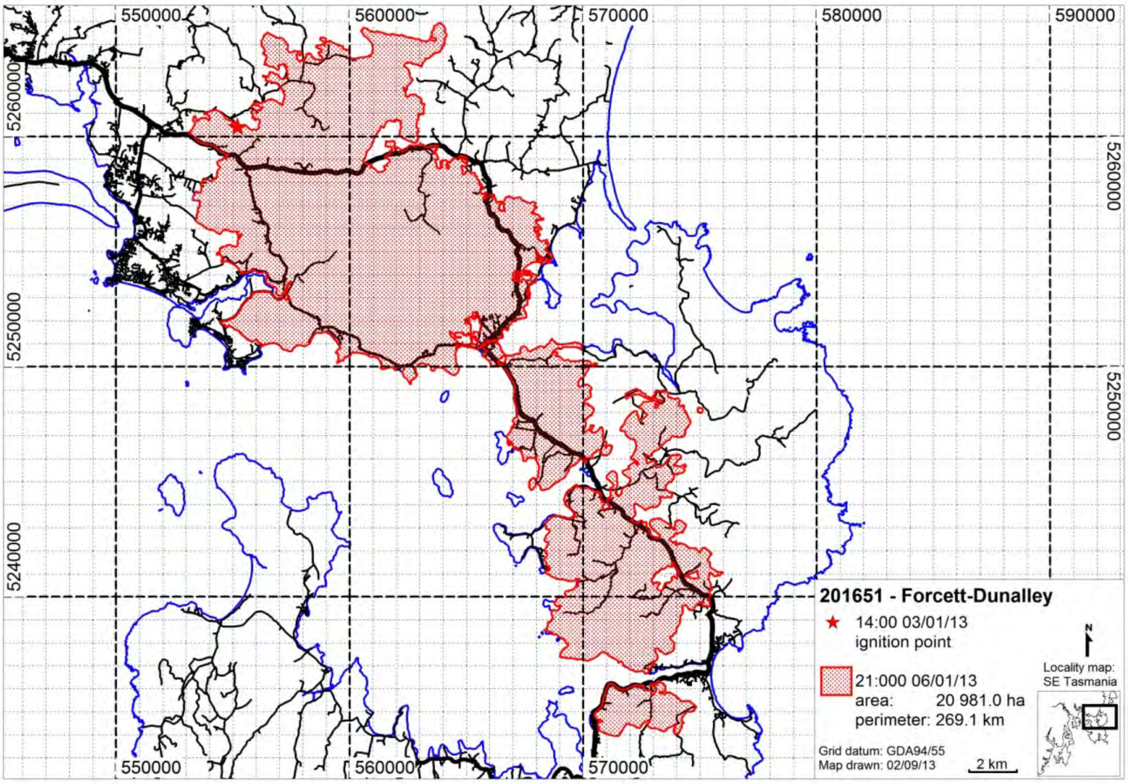
Map A4.1.7 Forcett–Dunalley fire at 20:00 EDST 04/01/2013.



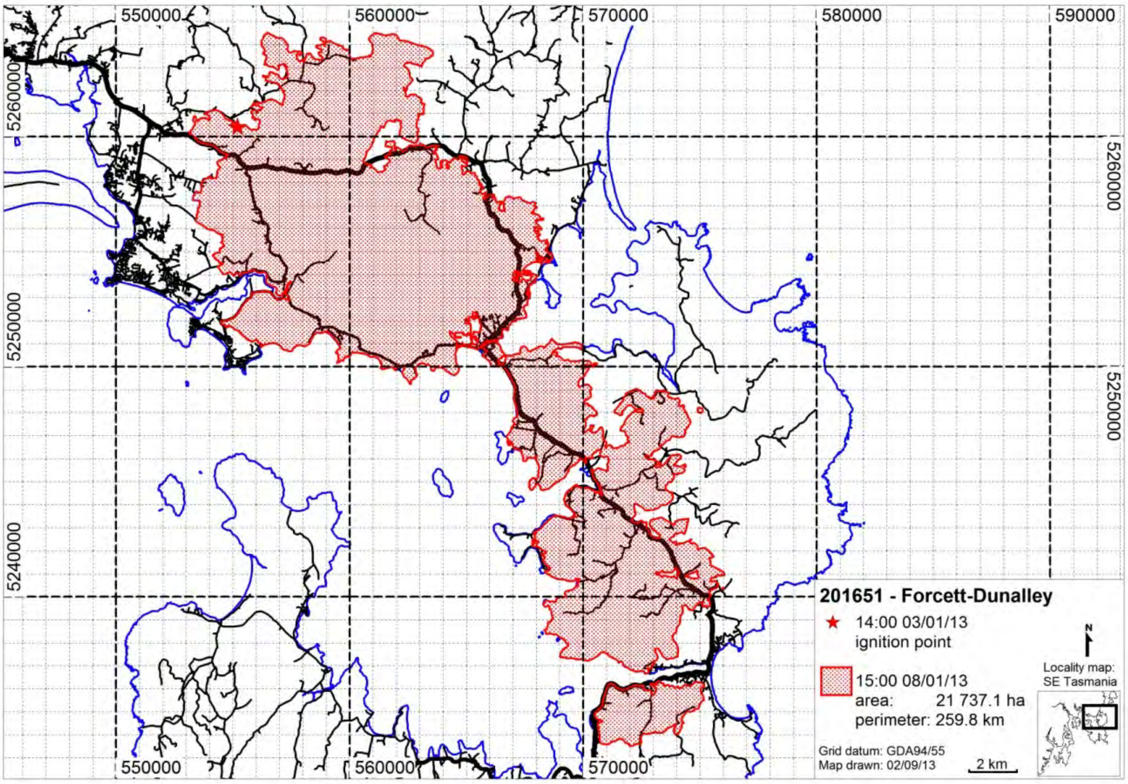
Map A4.1.8 Forcett–Dunalley fire at 23:00 EDST 04/01/2013.



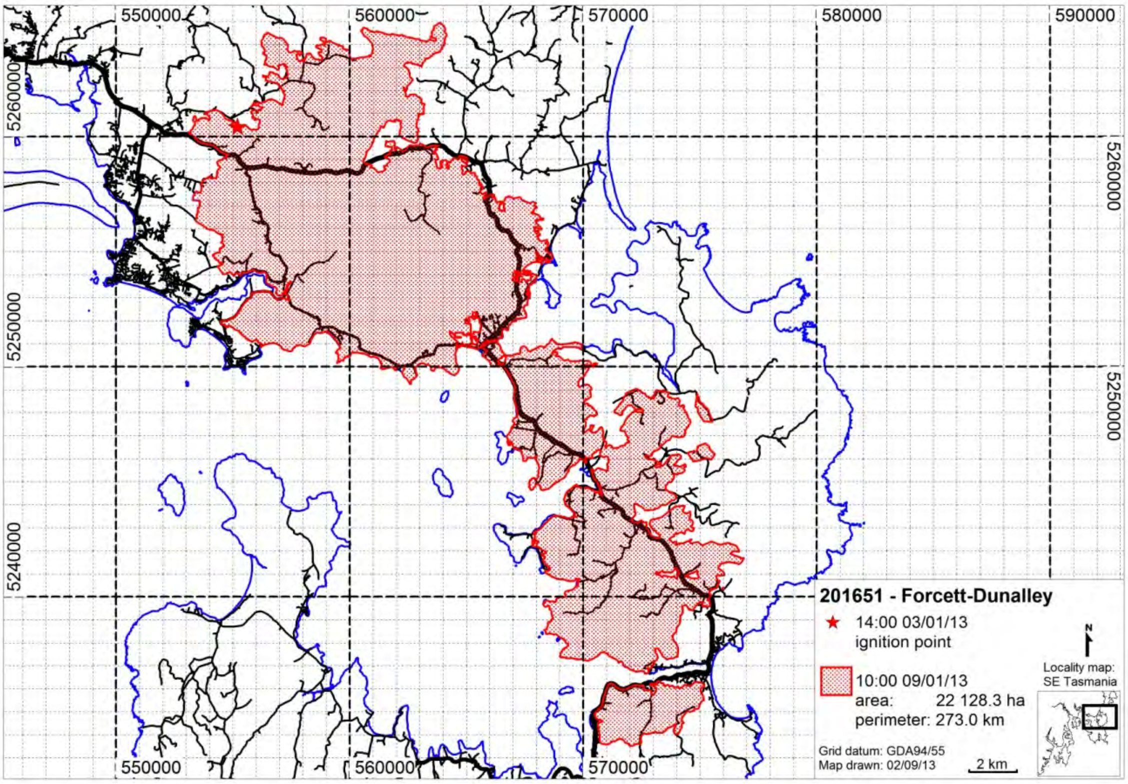
Map A4.1.9 Forcett–Dunalley fire at 20:30 EDST 05/01/2013.



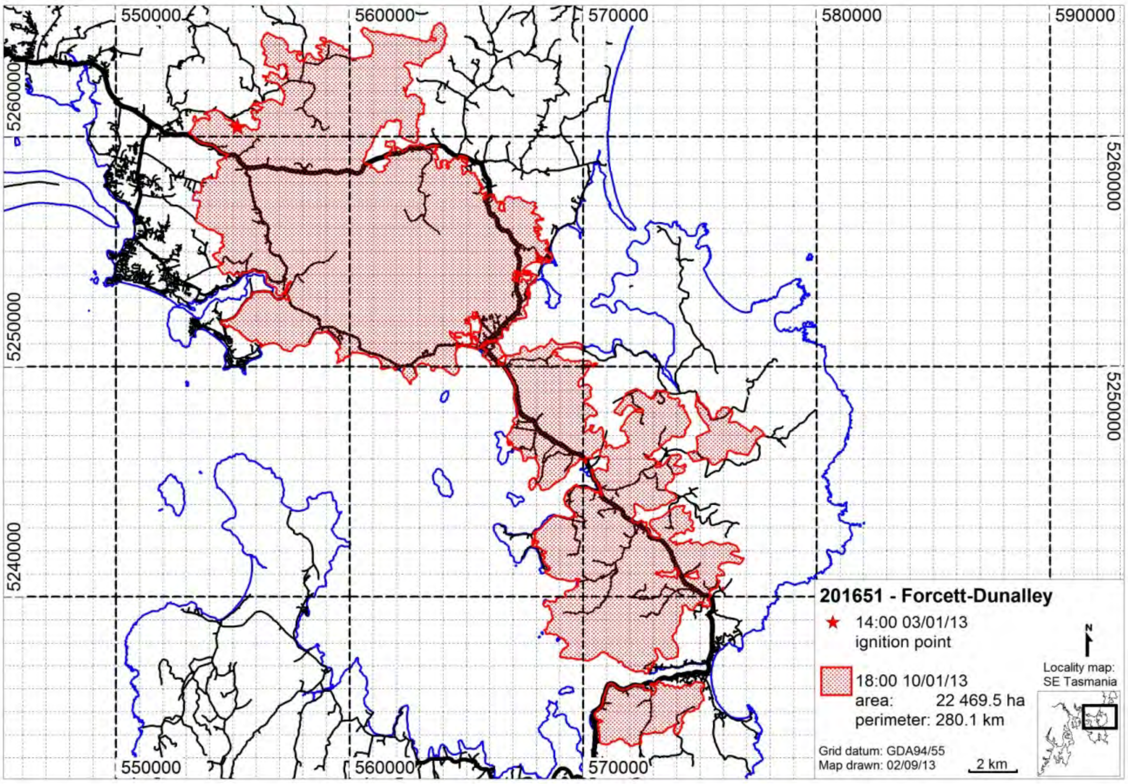
Map A4.1.10 Forcett–Dunalley fire at 21:00 EDST 06/01/2013.



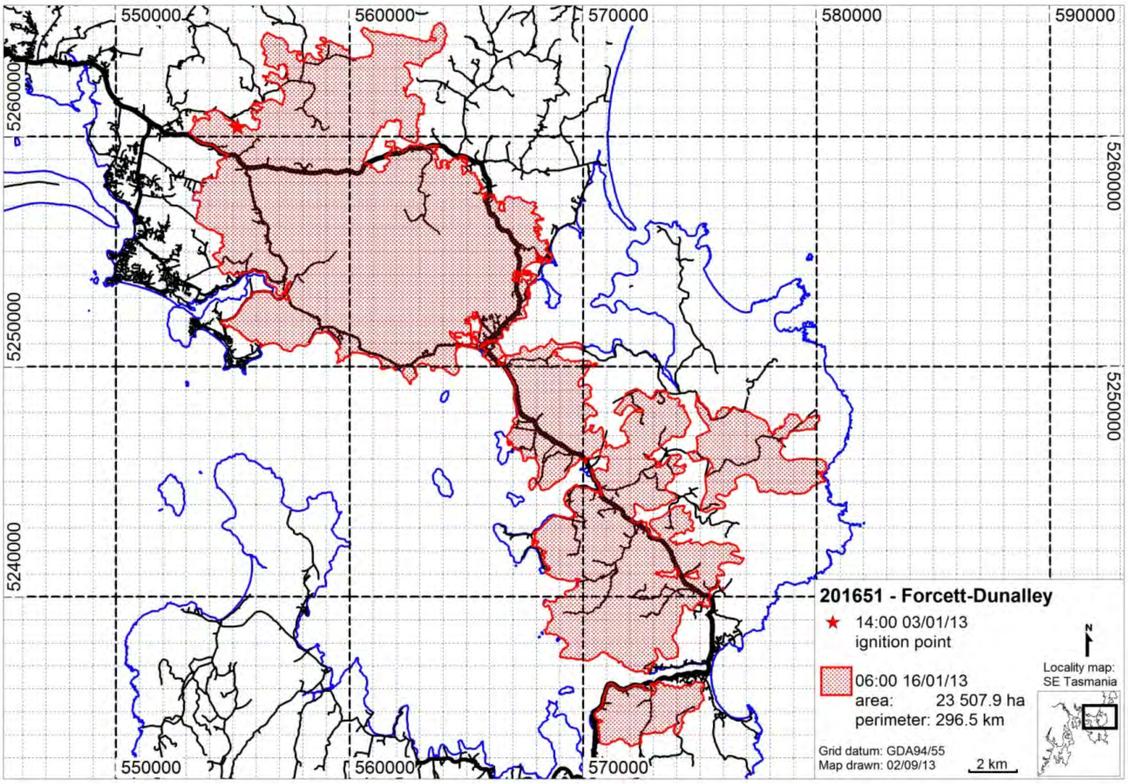
Map A4.1.11 Forcett–Dunalley fire at 15:00 EDST 08/01/2013.



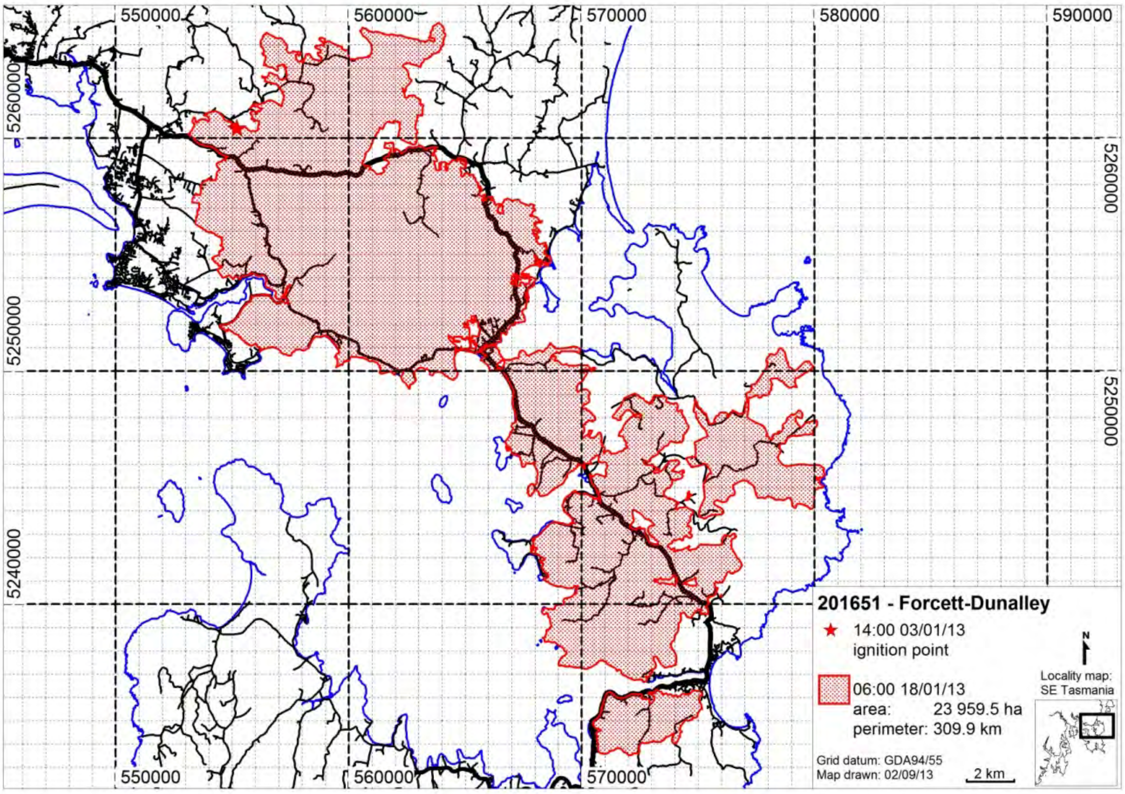
Map A4.1.12 Forcett–Dunalley fire at 10:00 EDST 09/01/2013.



Map A4.1.13 Forcett–Dunalley fire at 18:00 EDST 10/01/2013.

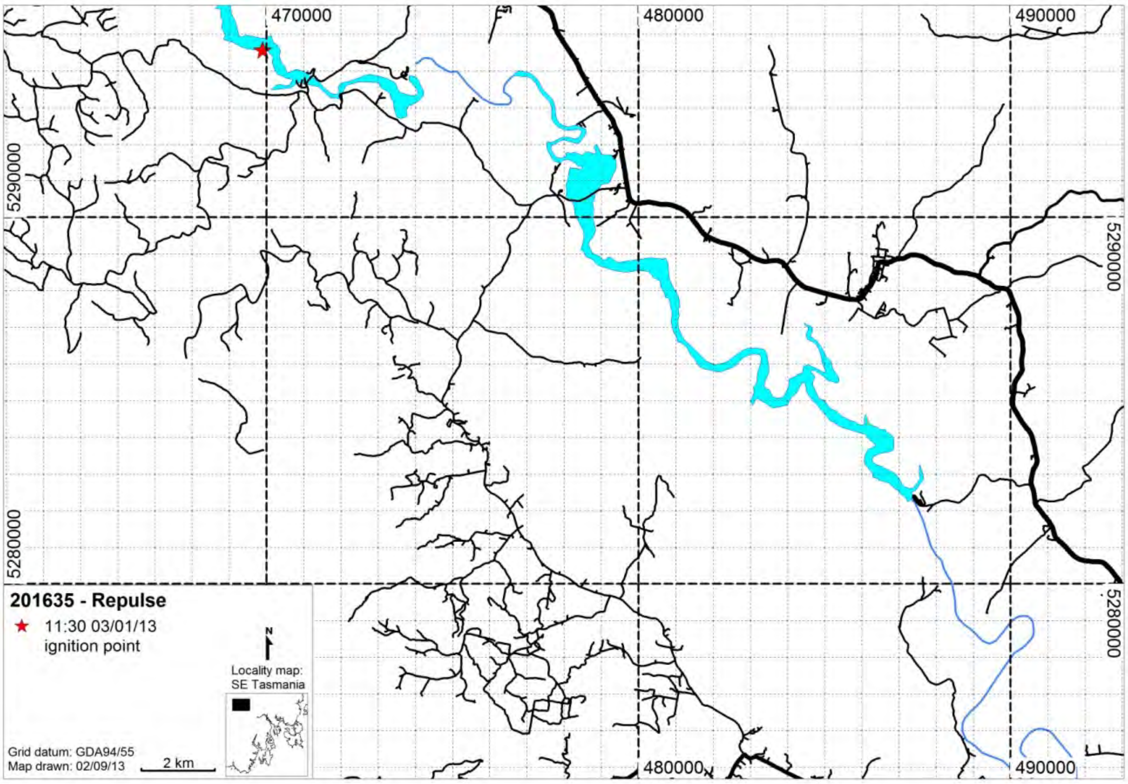


Map A4.1.14 Forcett–Dunalley fire at 06:00 EDST 16/01/2013.

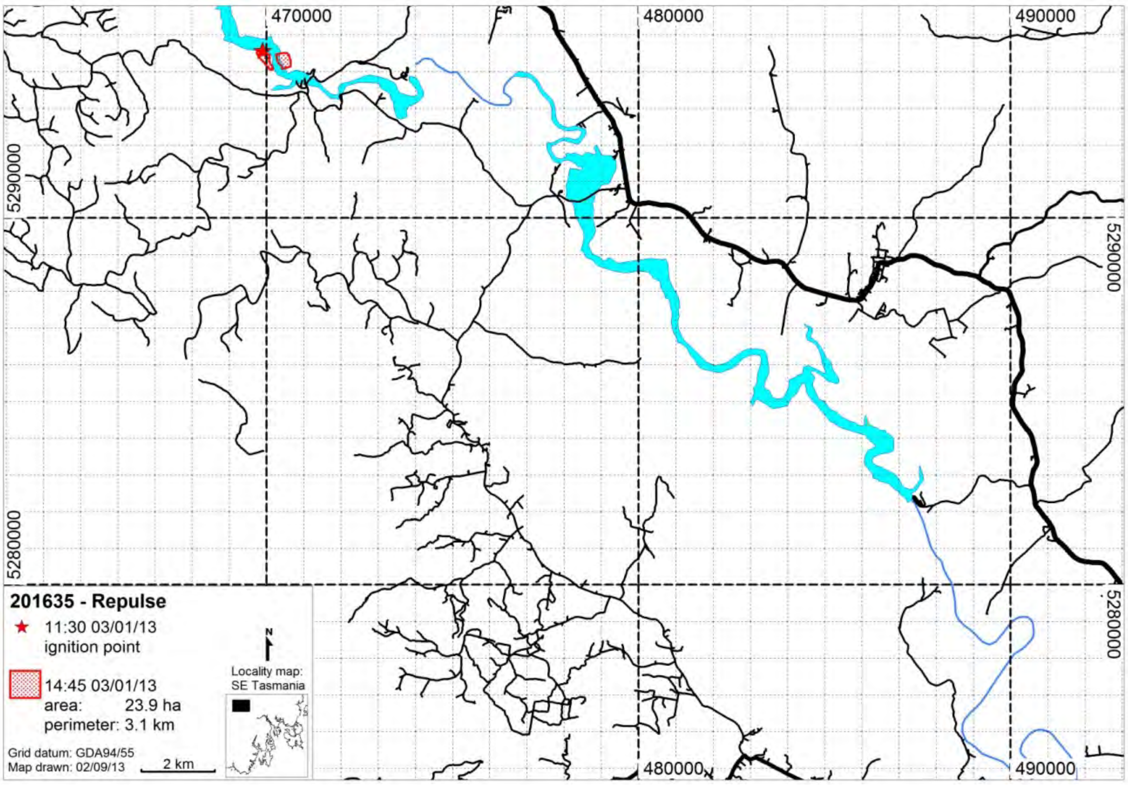


Map A4.1.15 Forcett–Dunalley fire at 06:00 EDST 18/01/2013 final boundary.

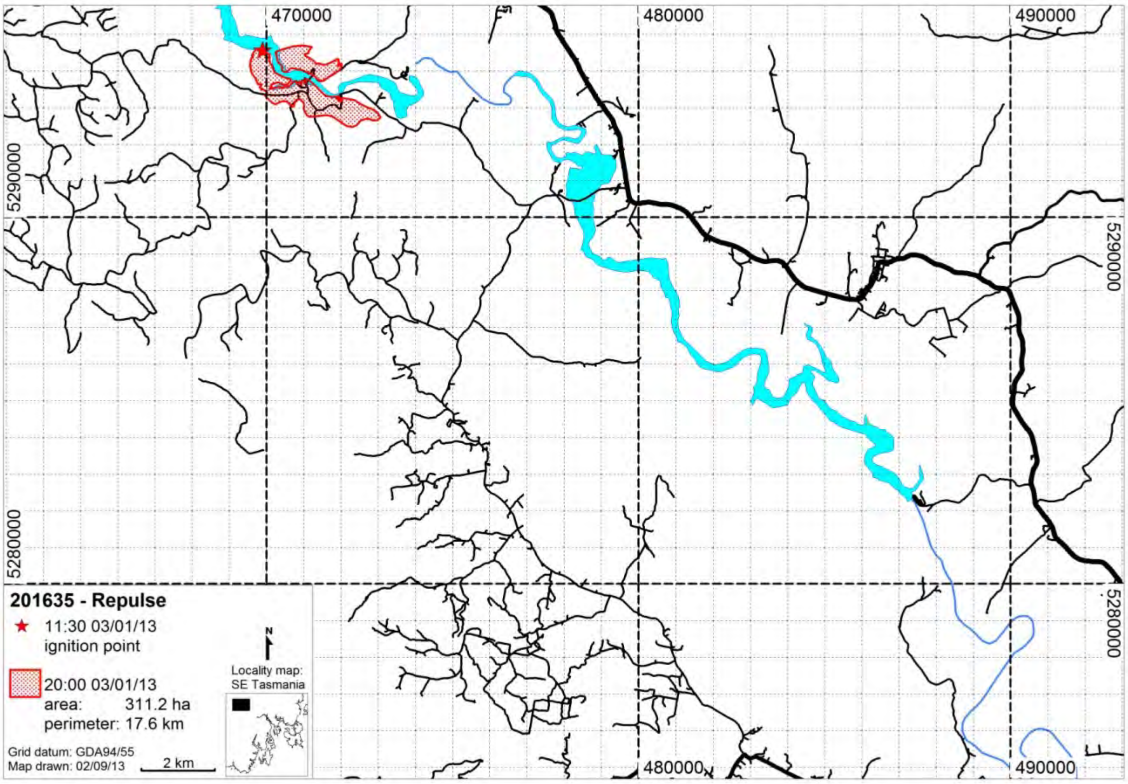
Appendix 4.2 Repulse fire



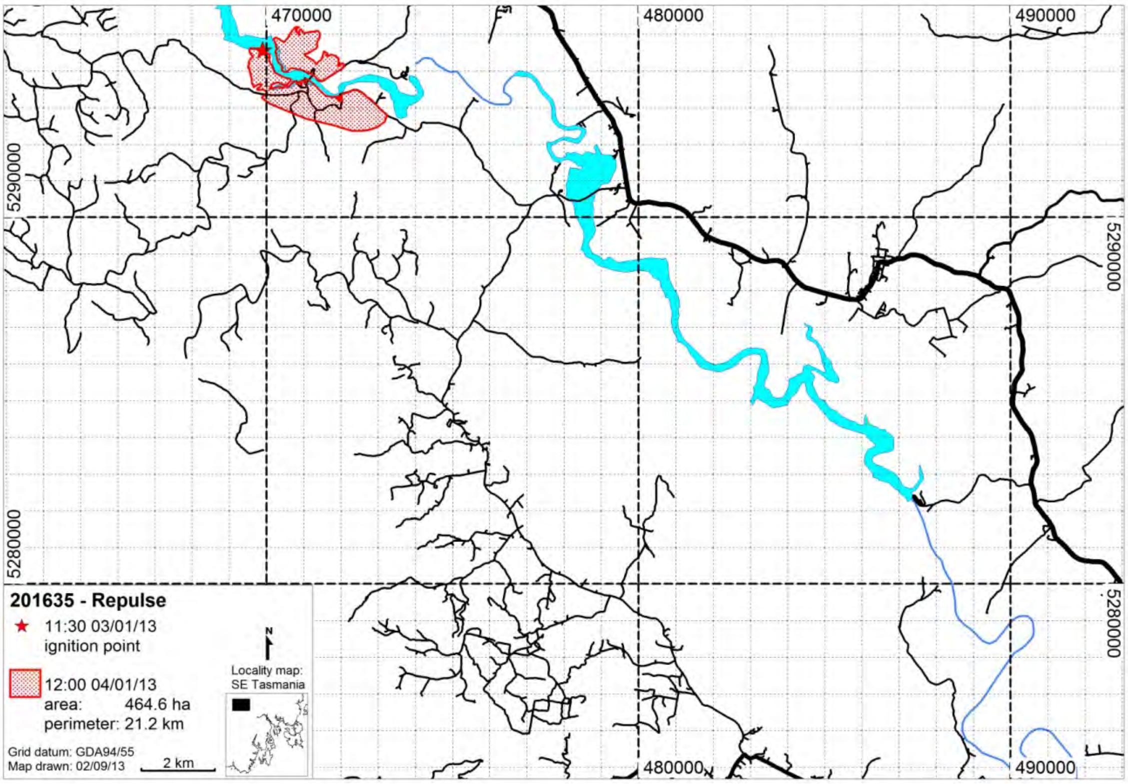
Map A4.2.1 Repulse fire ignition point at 11:30 EDST 03/01/2013.



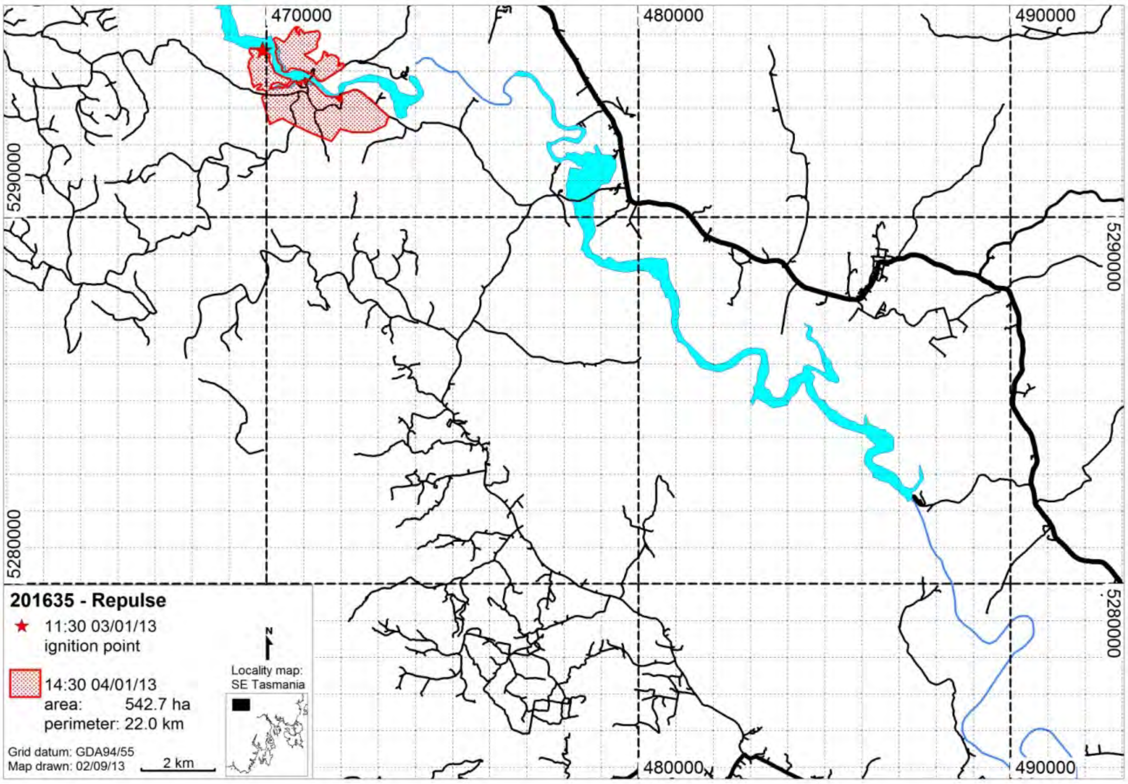
Map A4.2.2 Repulse fire at 14:45 EDST 03/01/2013.



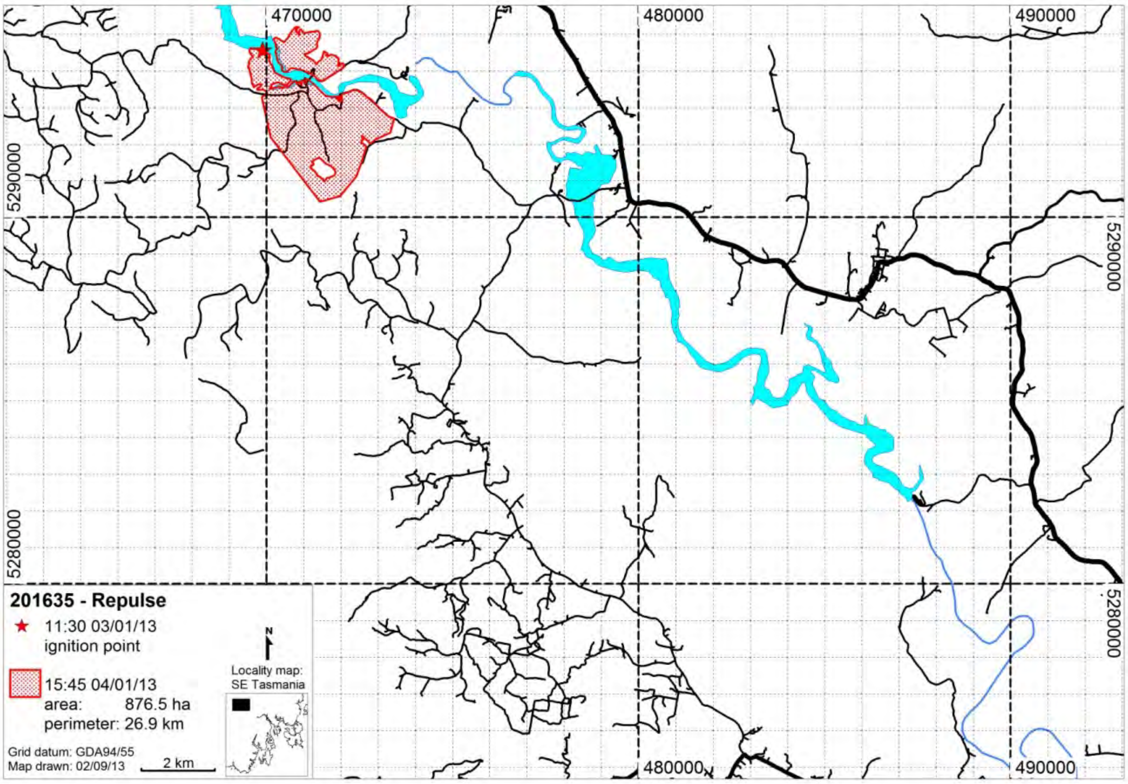
Map A4.2.3 Repulse fire at 20:00 EDST 03/01/2013.



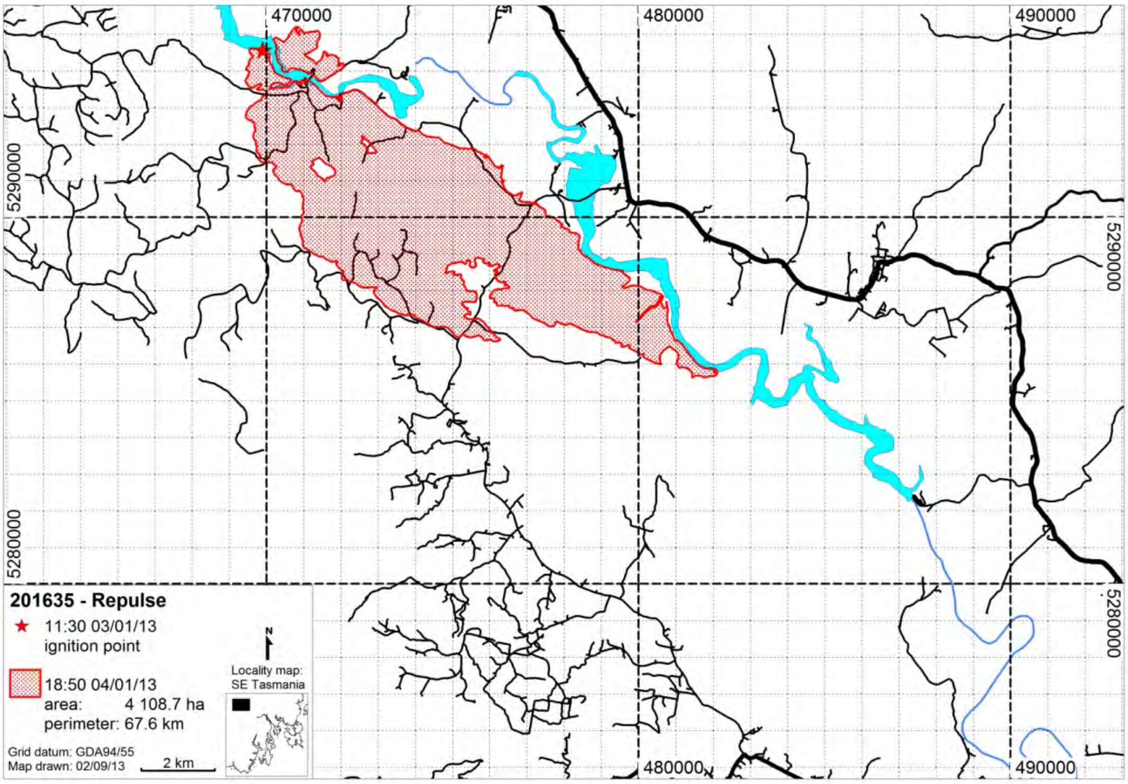
Map A4.2.4 Repulse fire at 12:00 EDST 04/01/2013.



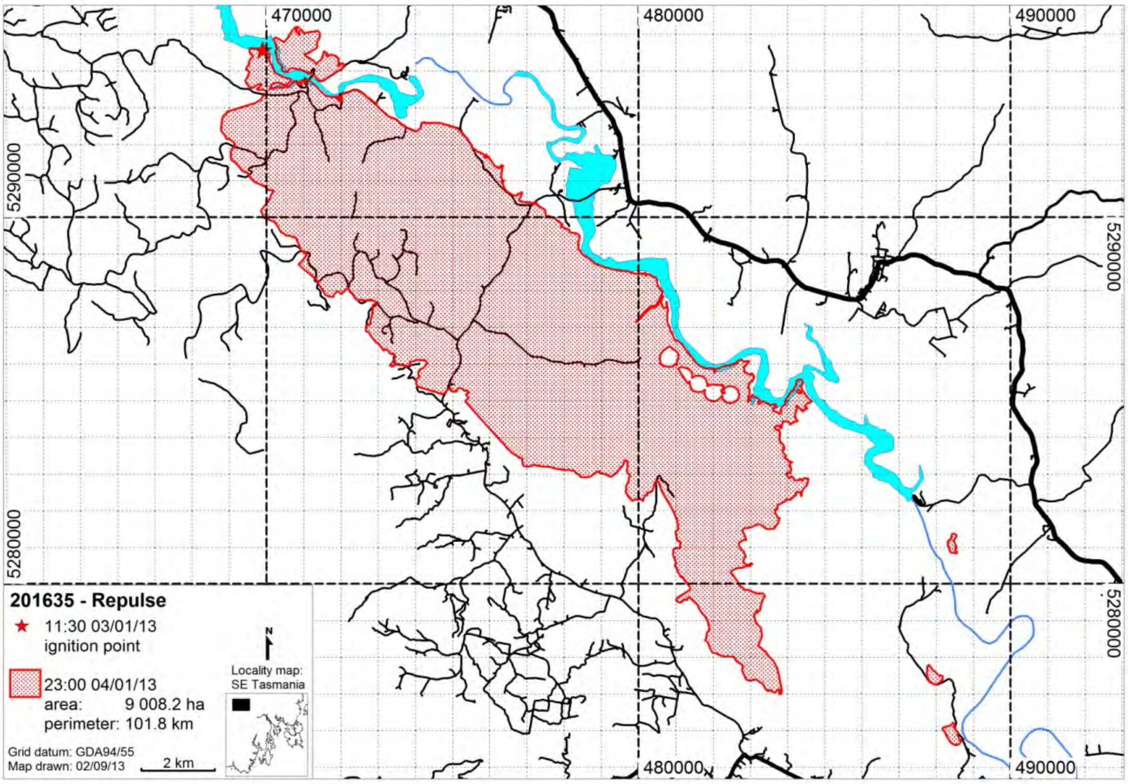
Map A4.2.5 Repulse fire at 14:30 EDST 04/01/2013.



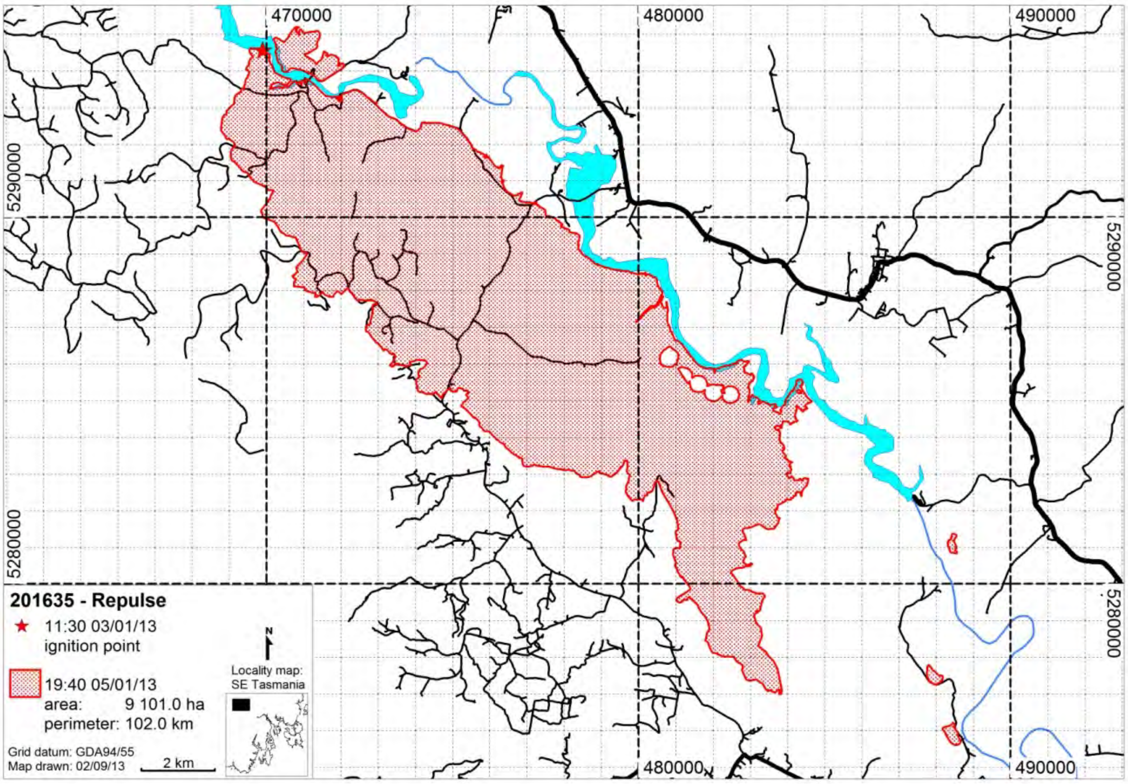
Map A4.2.6 Repulse fire at 15:45 EDST 04/01/2013.



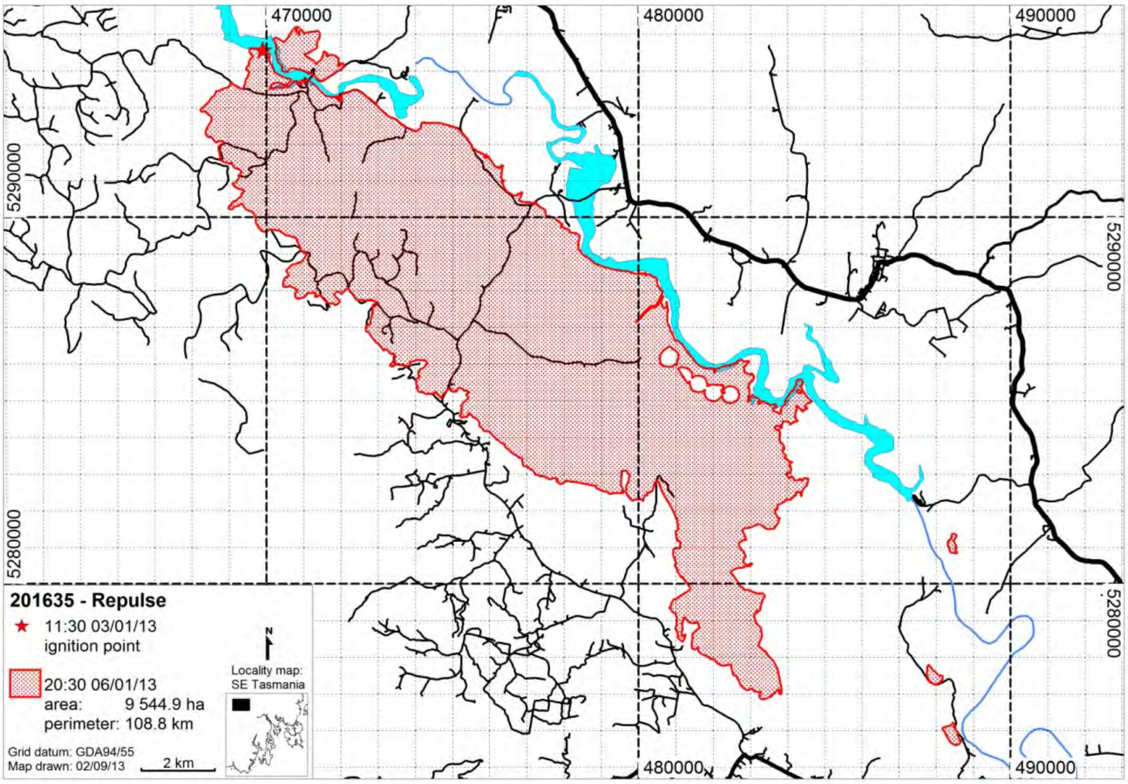
Map A4.2.7 Repulse fire at 18:50 EDST 04/01/2013.



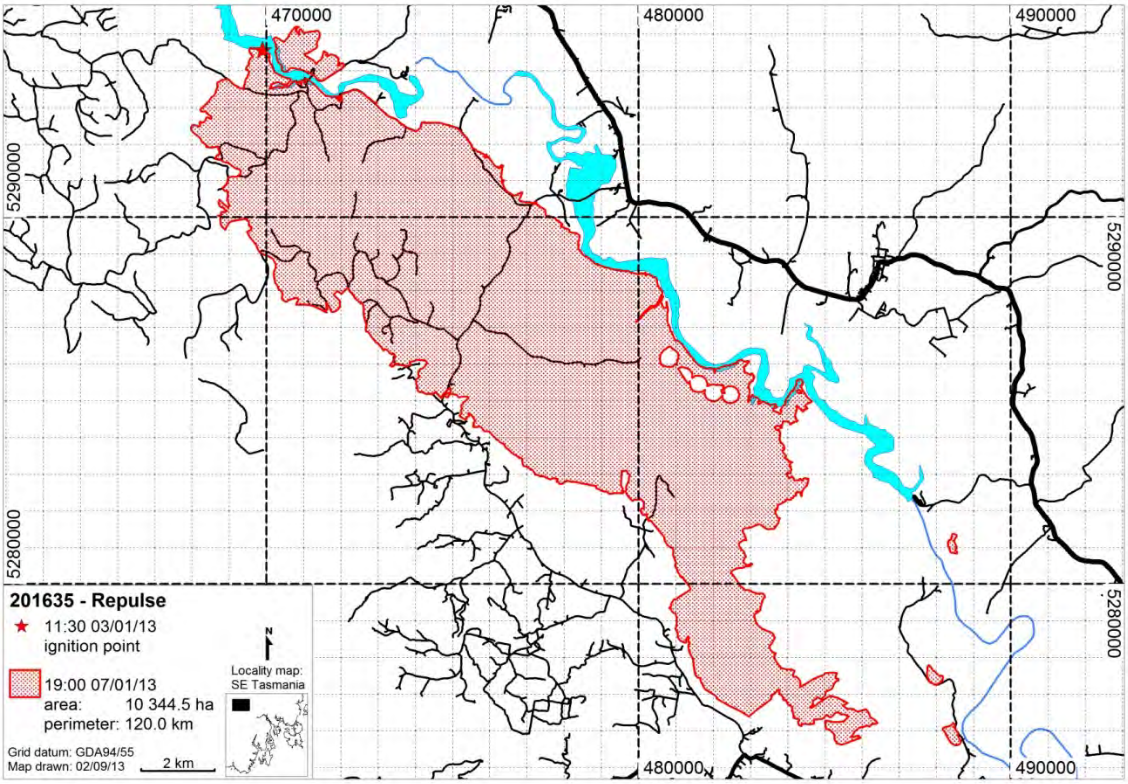
Map A4.2.8 Repulse fire at 23:00 EDST 04/01/2013.



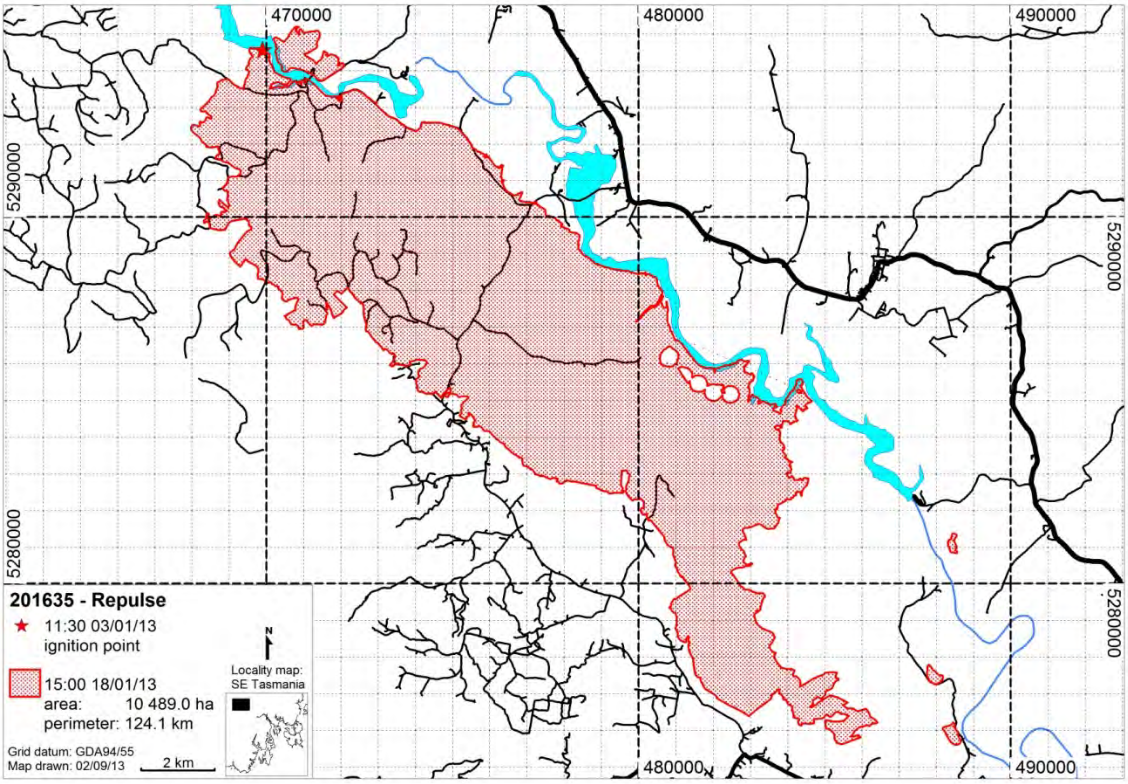
Map A4.2.9 Repulse fire at 19:40 EDST 05/01/2013.



Map A4.2.10 Repulse fire at 20:30 EDST 06/01/2013.

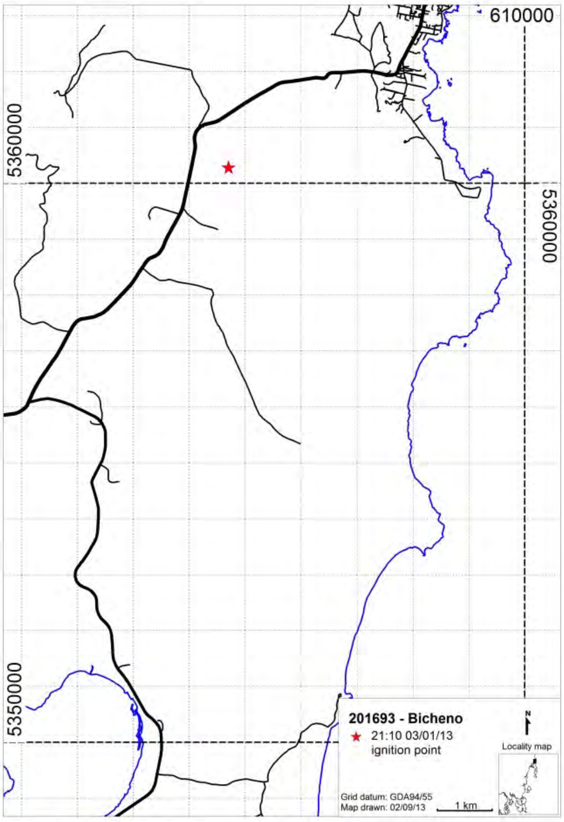


Map A4.2.11 Repulse fire at 19:00 EDST 07/01/2013.

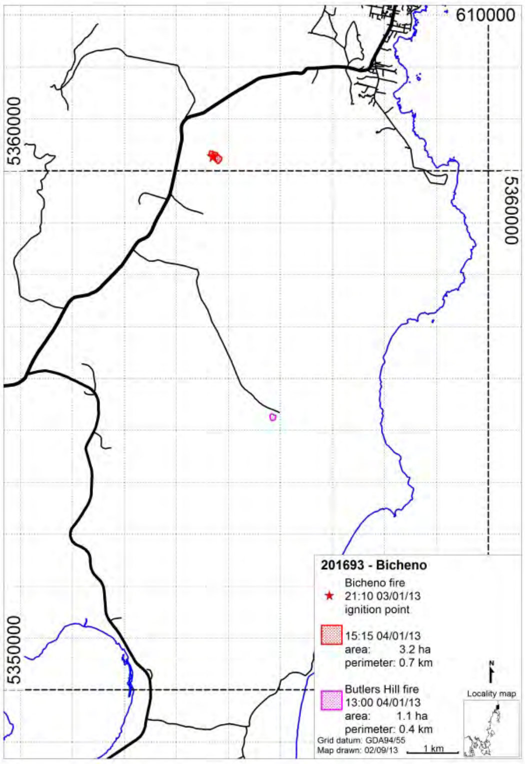


Map A4.2.12 Repulse fire at 15:00 EDST 18/01/2013 final boundary.

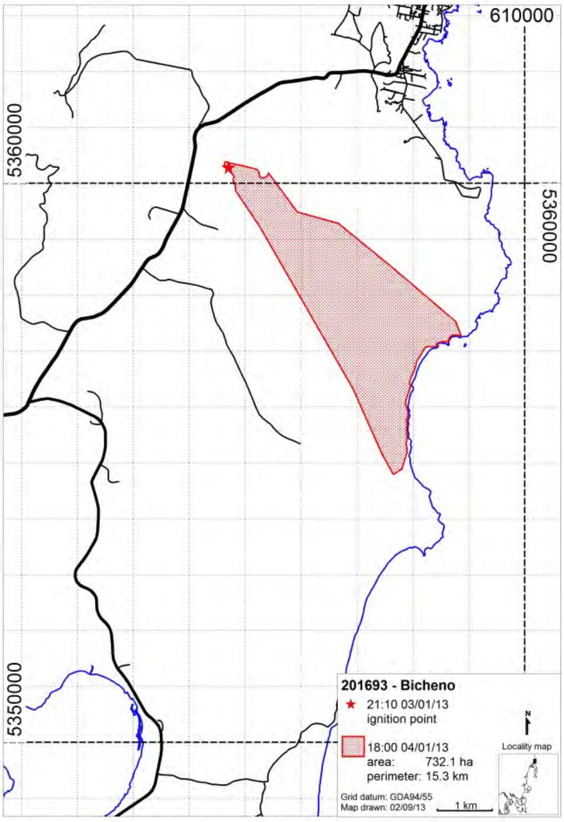
Appendix 4.3 Bicheno fire



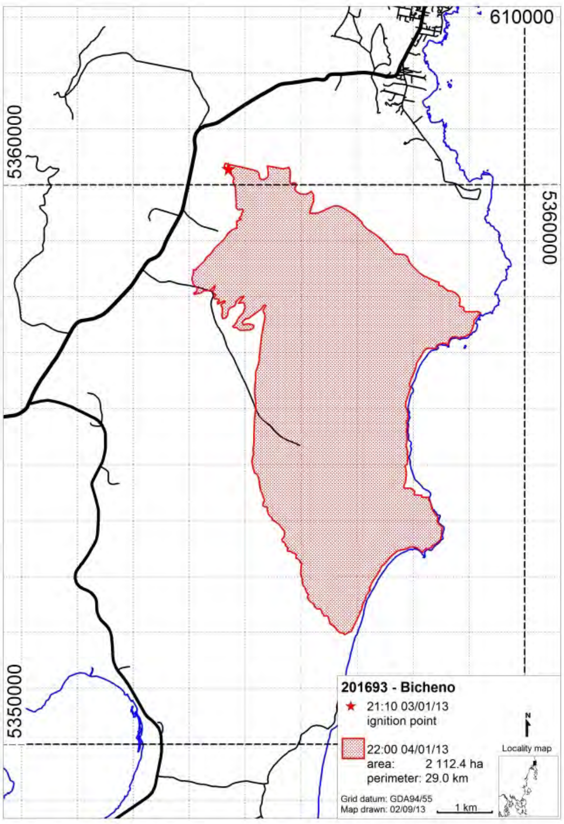
Map A4.3.1 Bicheno fire ignition point at 21:10 EDST 03/01/2013.



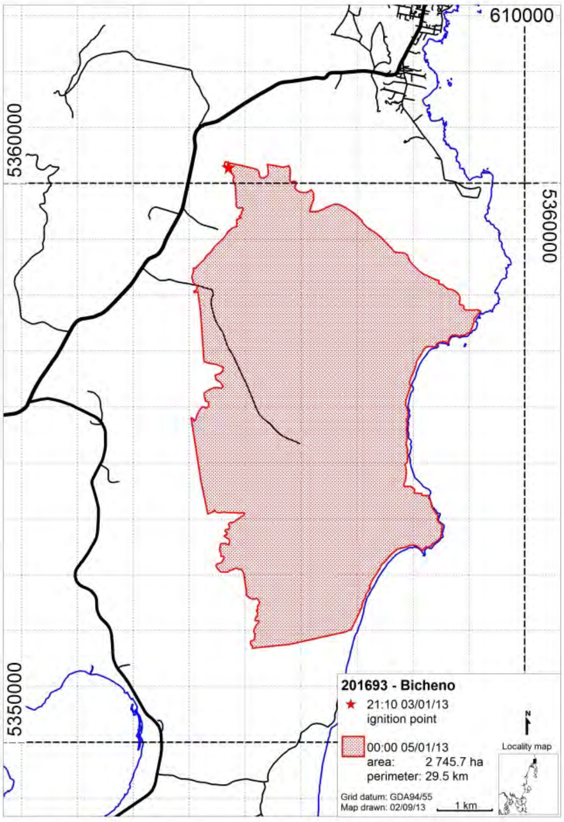
Map A4.3.2 Bicheno fire at 15:15 and Butlers Hill fire at 13:00 EDST 04/01/2013.



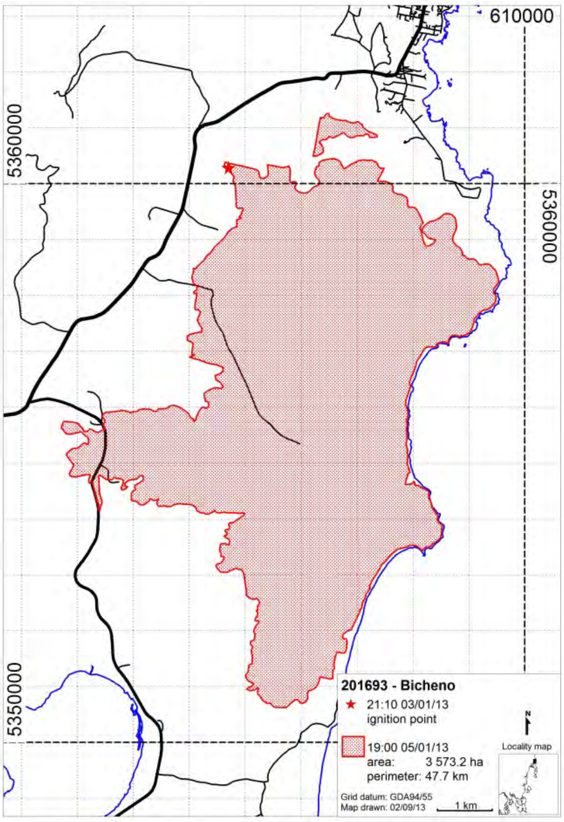
Map A4.3.3 Bicheno fire at 18:00 EDST 04/01/2013.



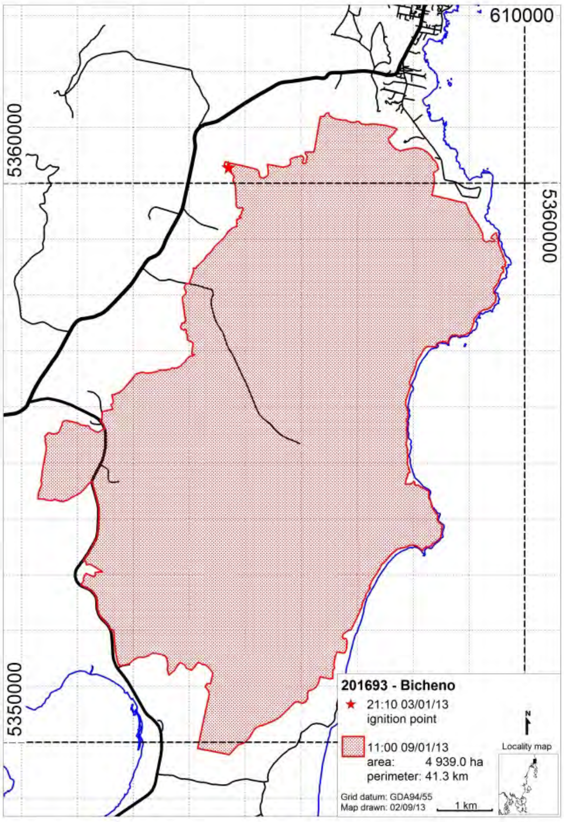
Map A4.3.4 Bicheno fire at 22:00 EDST 04/01/2013.



Map A4.3.5 Bicheno fire at 00:00 EDST 05/01/2013.

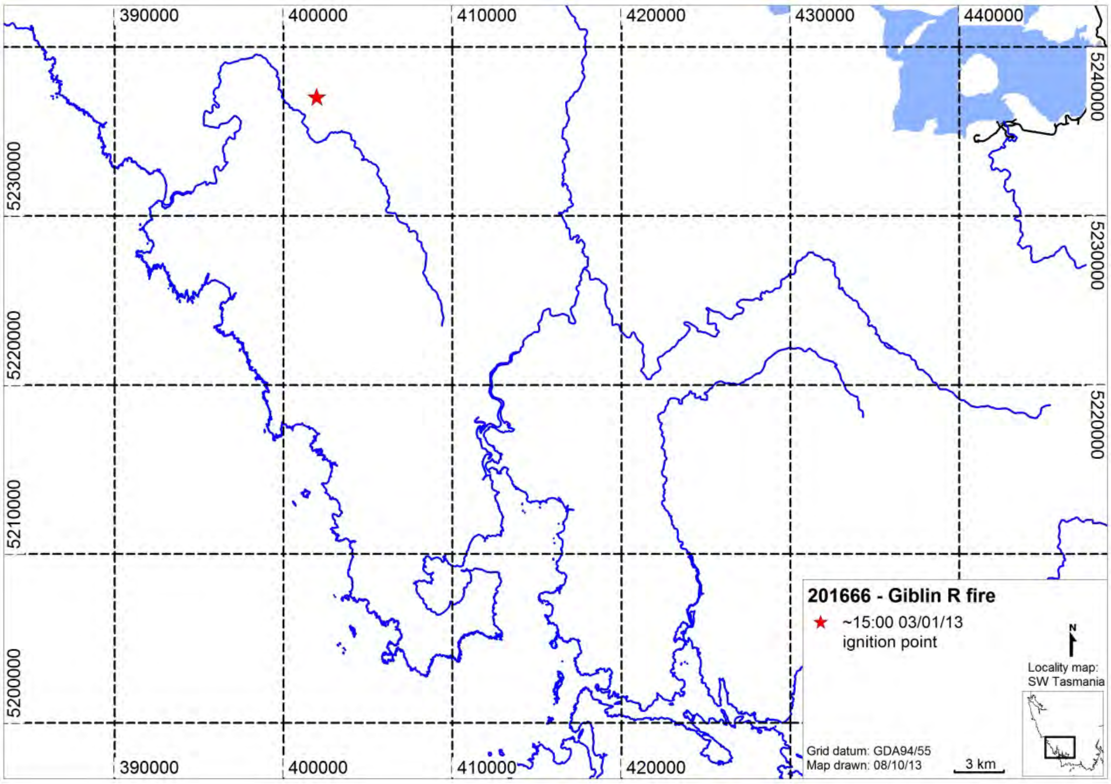


Map A4.3.6 Bicheno fire at 19:00 EDST 05/01/2013.

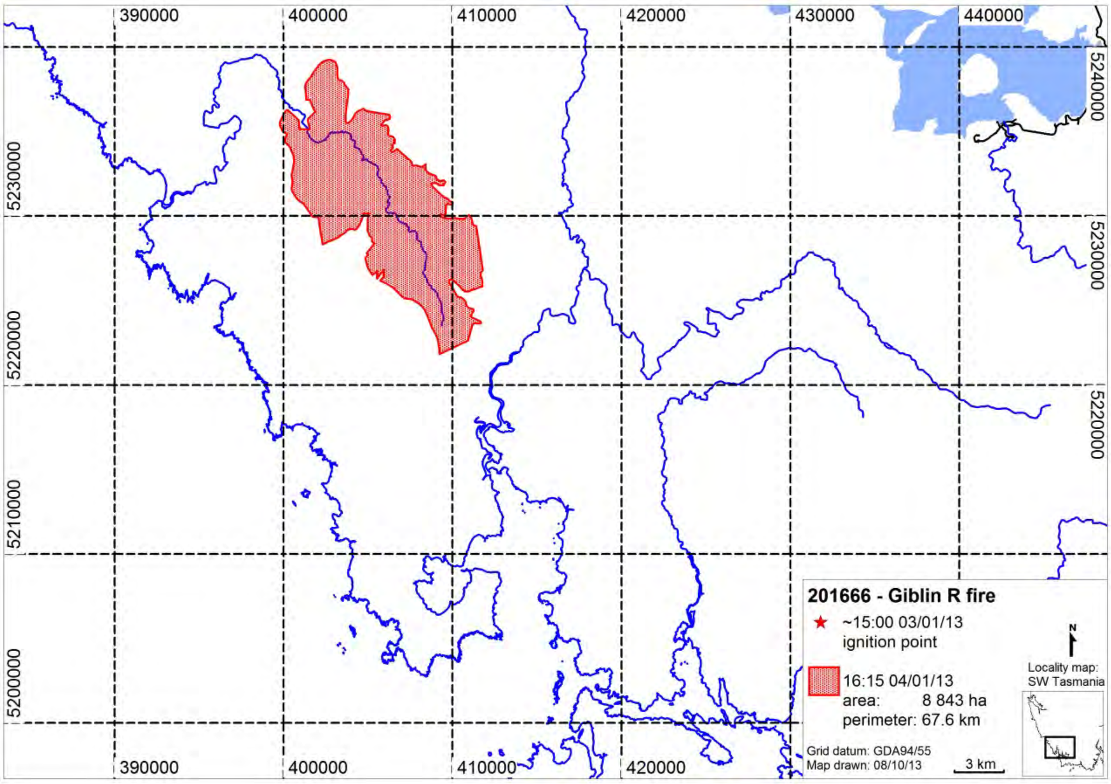


Map A4.3.7 Bicheno fire at 11:00 EDST 09/01/2013 final boundary.

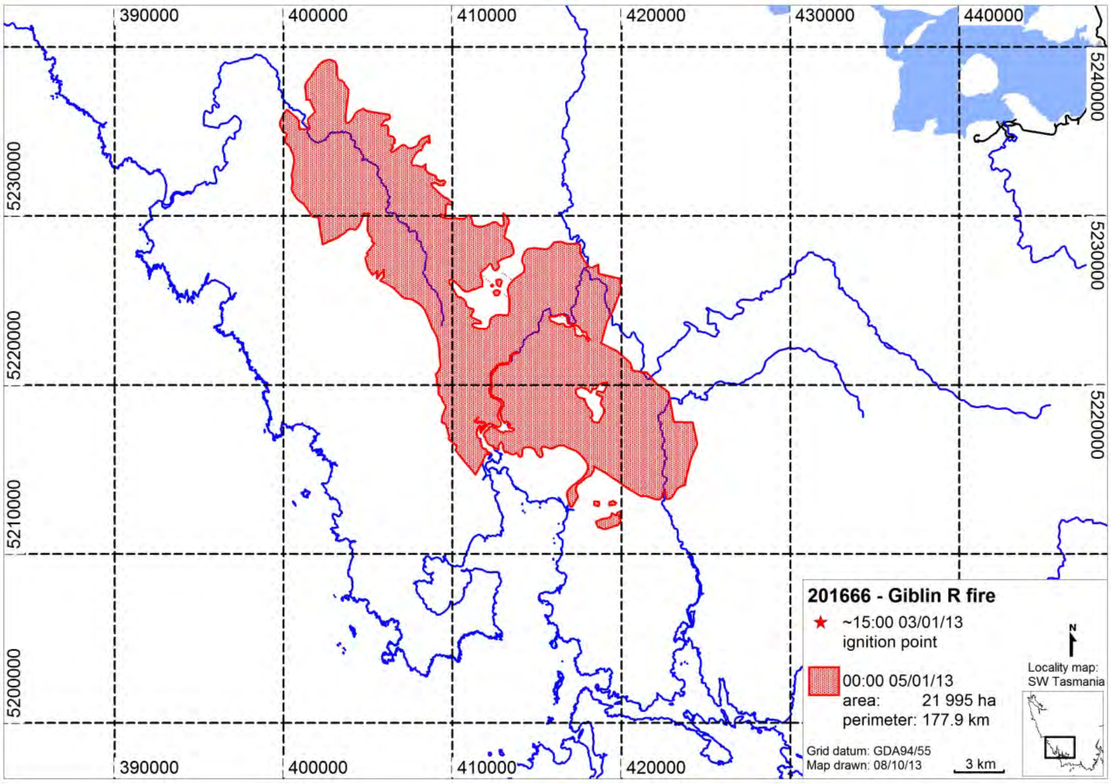
Appendix 4.4 Giblin River fire



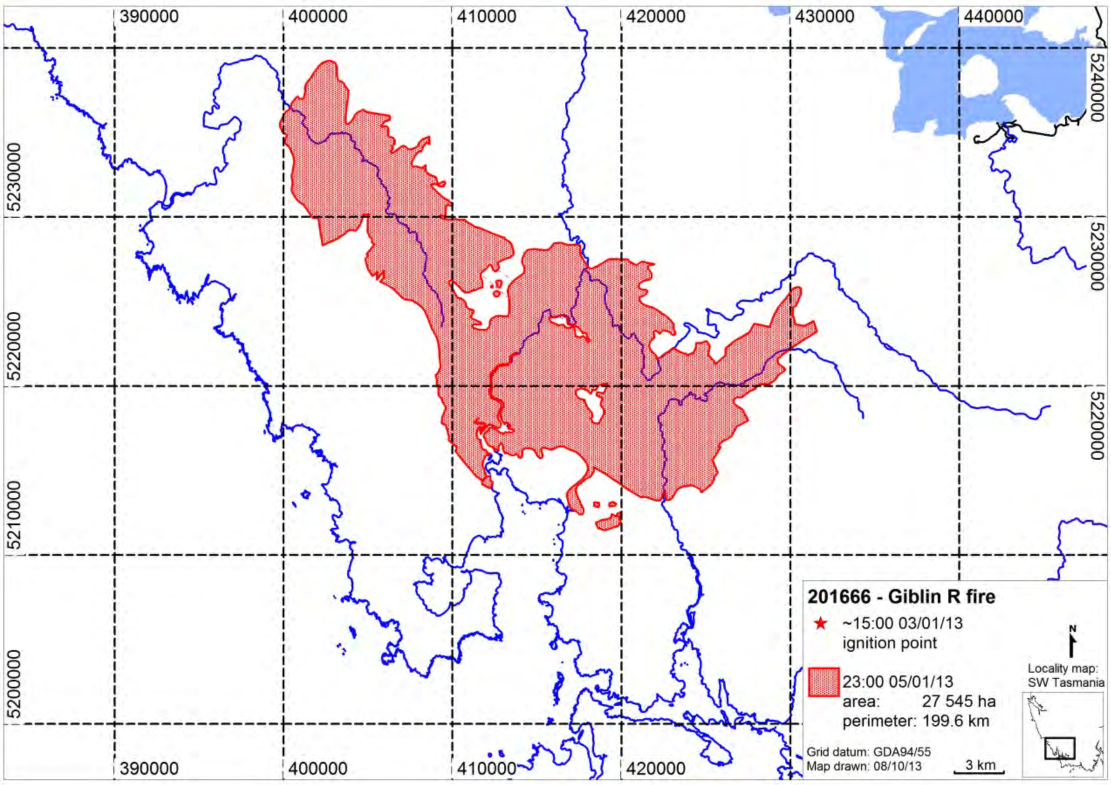
Map A4.4.1 Giblin River fire ignition point at about 15:00 EDST 03/01/2013.



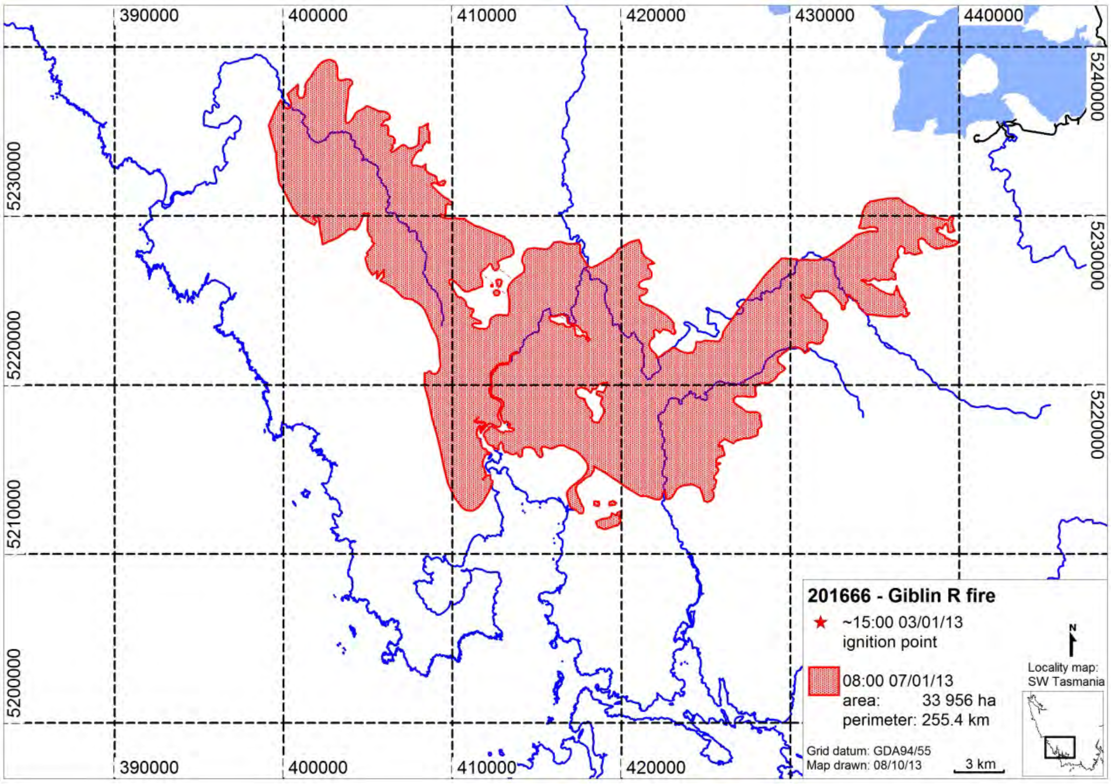
Map A4.4.2 Giblin River fire at about 16:15 EDST 04/01/2013.



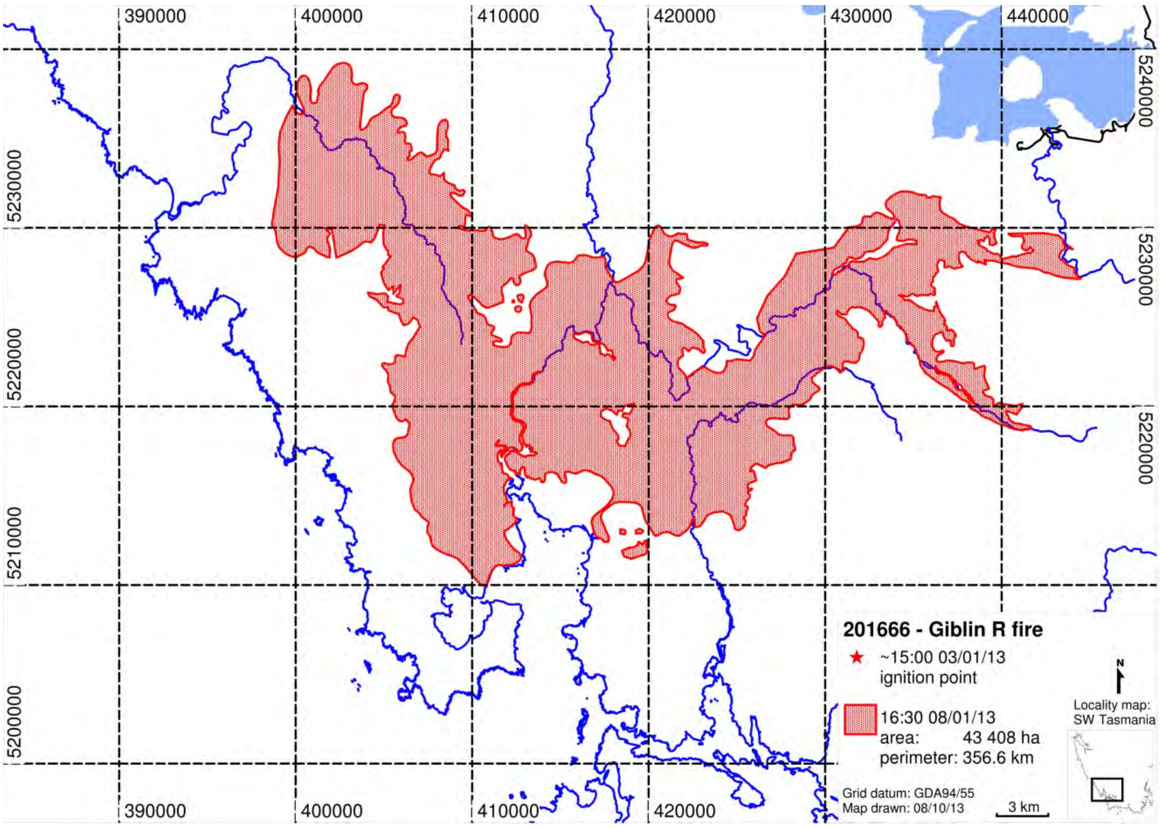
Map A4.4.3 Giblin River fire at about 00:00 EDST 05/01/2013.



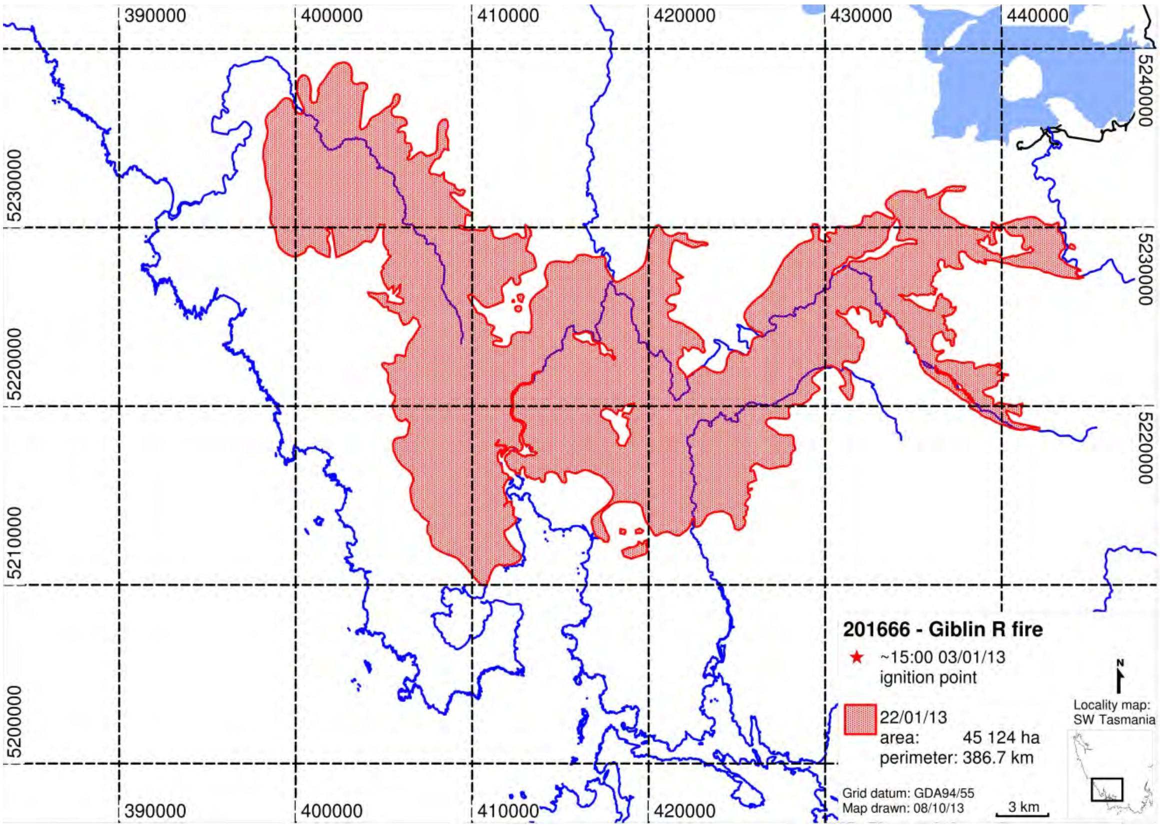
Map A4.4.4 Giblin River fire at about 23:00 EDST 05/01/2013.



Map A4.4.5 Giblin River fire at about 08:00 EDST 07/01/2013.

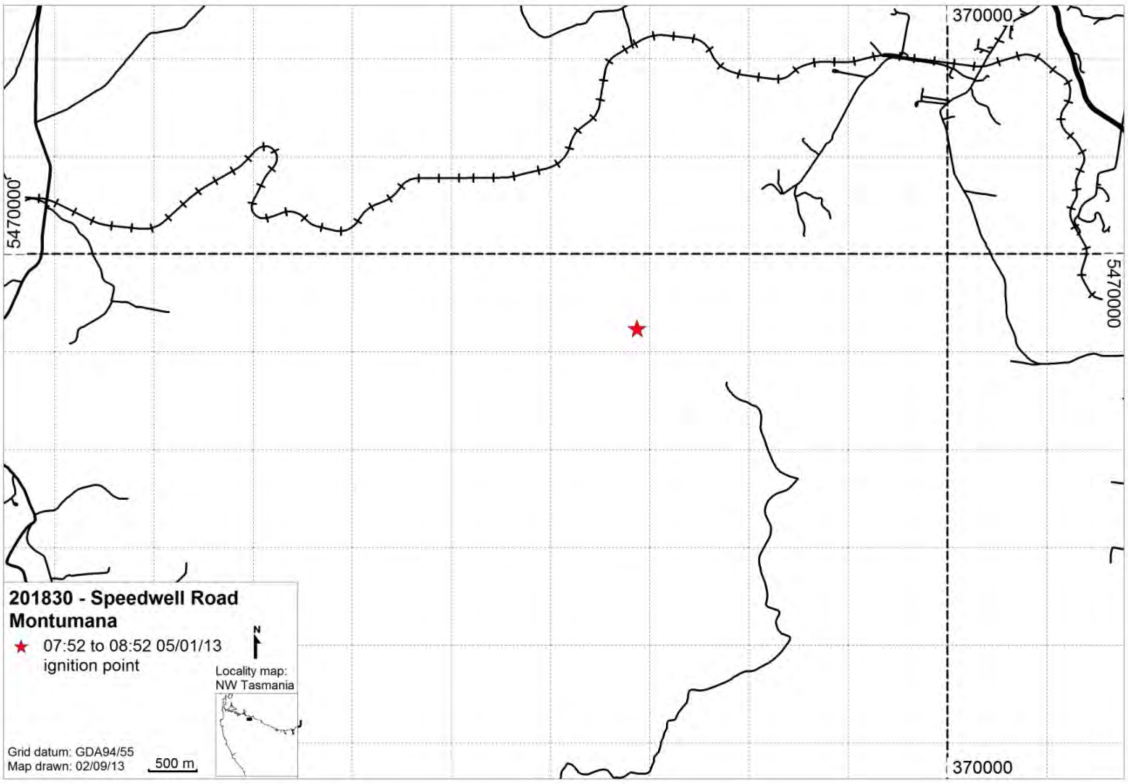


Map A4.4.6 Giblin River fire at about 16:30 EDST 08/01/2013.

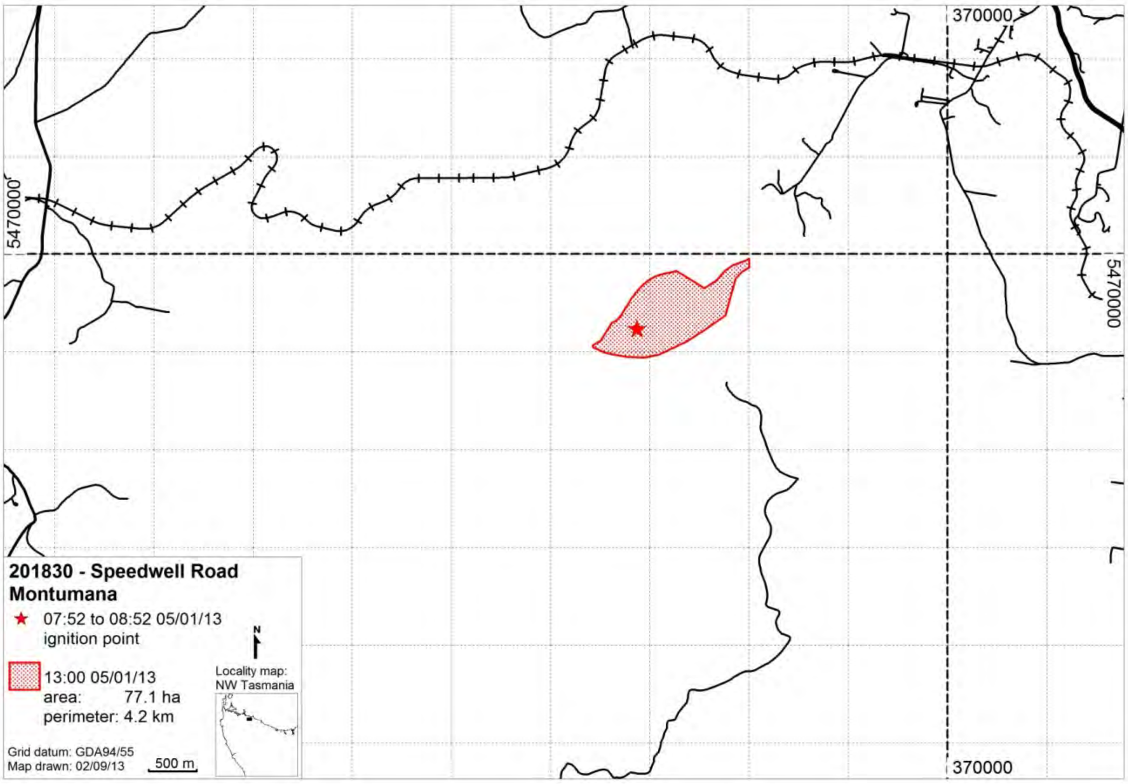


Map A4.4.7 Giblin River fire 22/01/2013 final boundary.

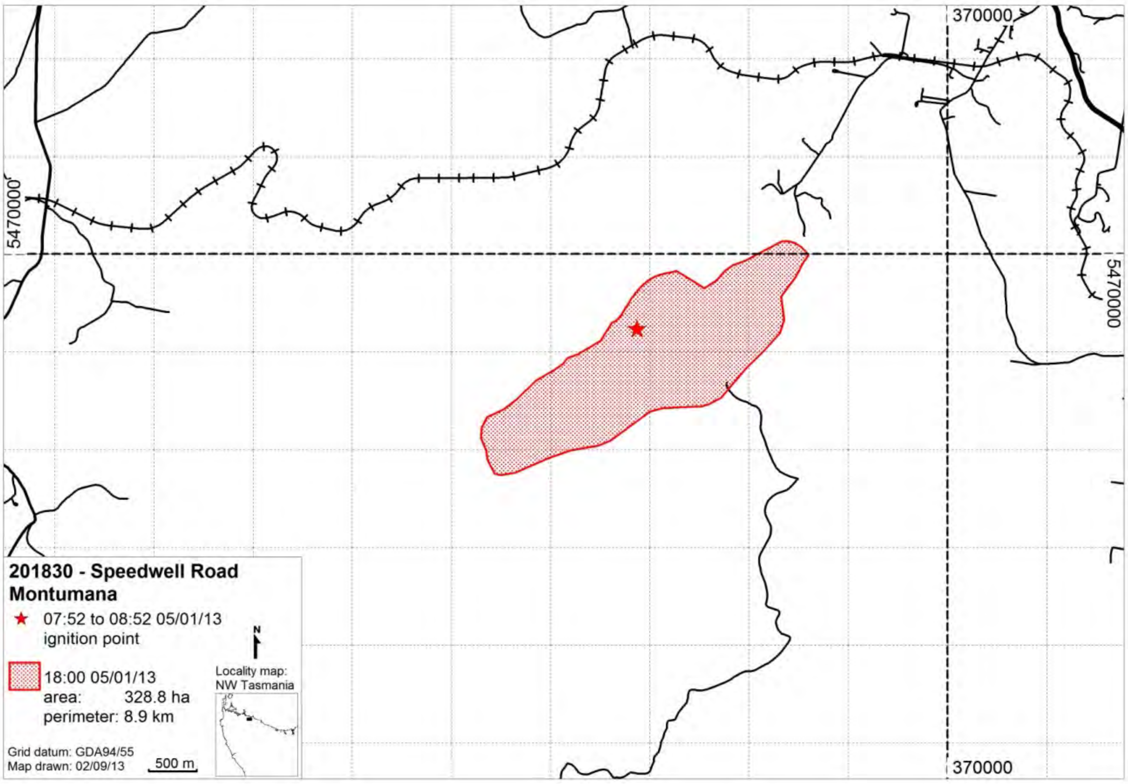
Appendix 4.5 Speedwell Road, Montumana fire



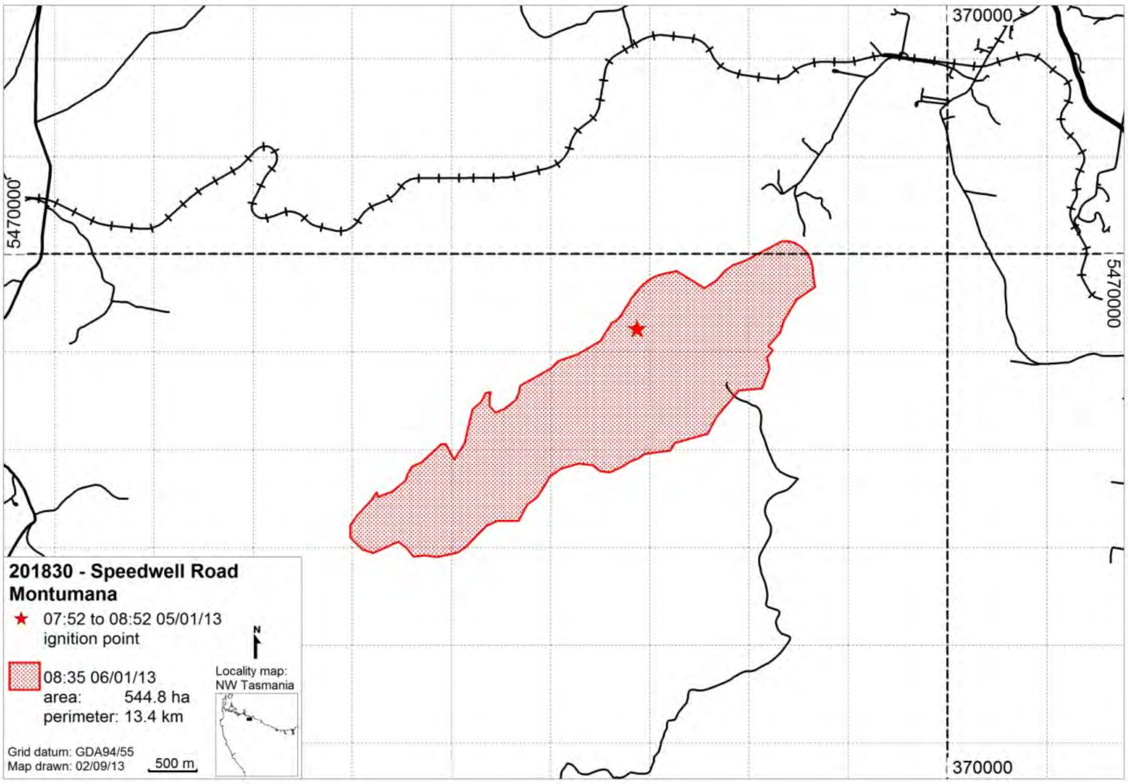
Map A4.5.1 Montumana fire ignition point between 07:52 and 08:52 EDST 05/01/2013.



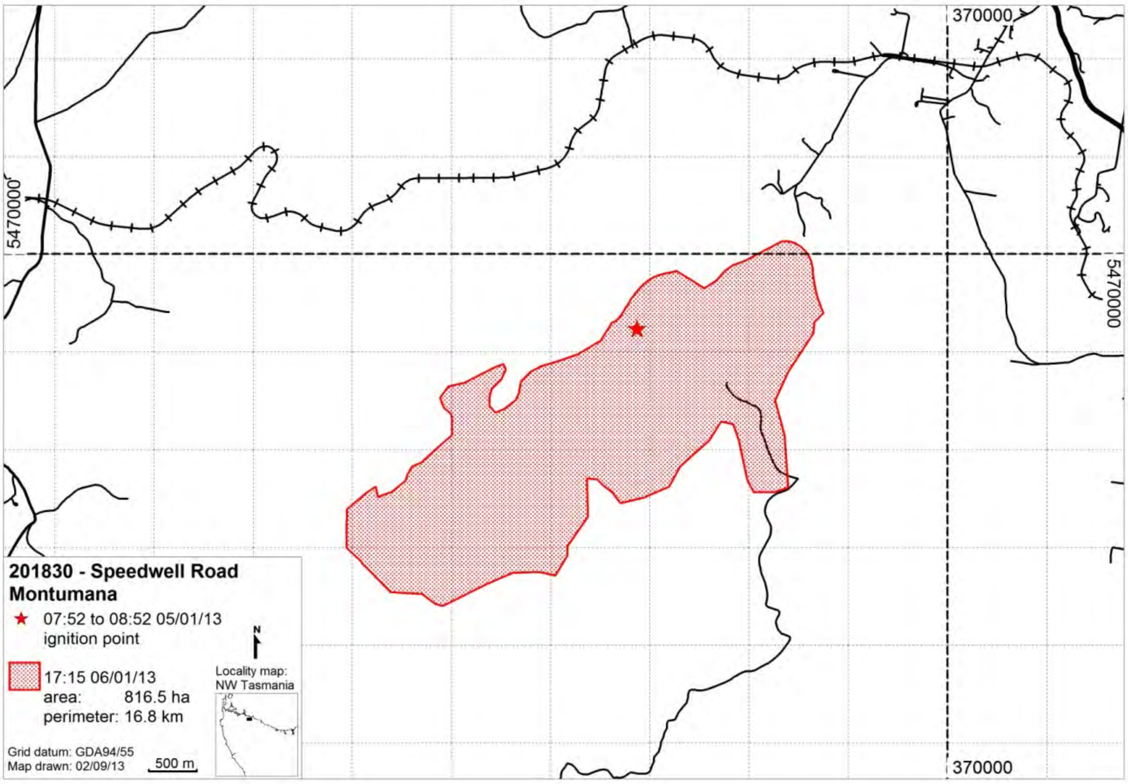
Map A4.5.2 Montumana fire at 13:00 EDST 05/01/2013.



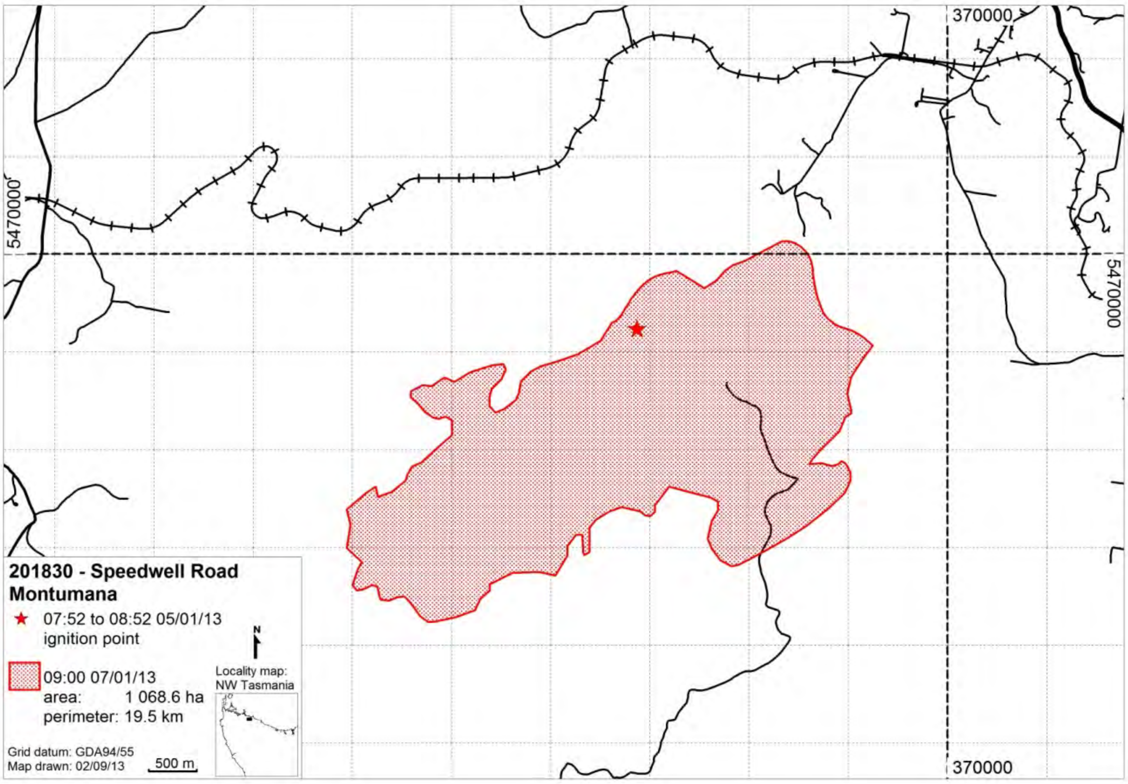
Map A4.5.3 Montumana fire at 18:00 EDST 05/01/2013.



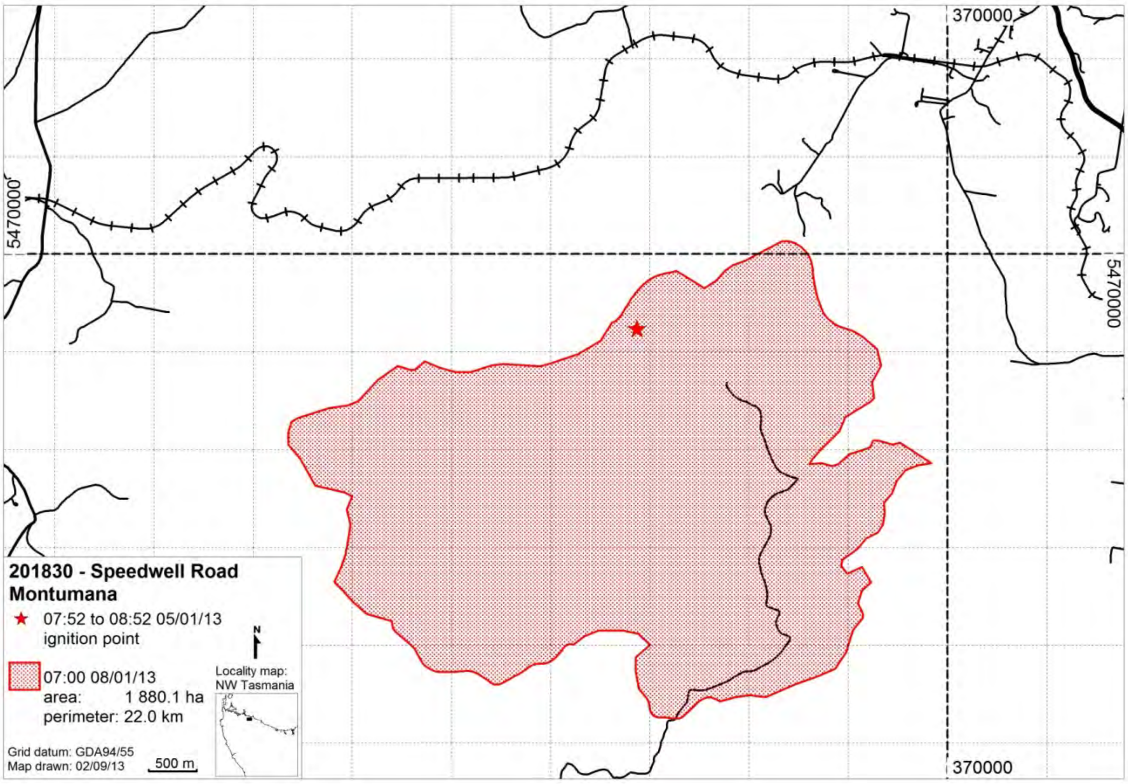
Map A4.5.4 Montumana fire at 08:35 EDST 06/01/2013.



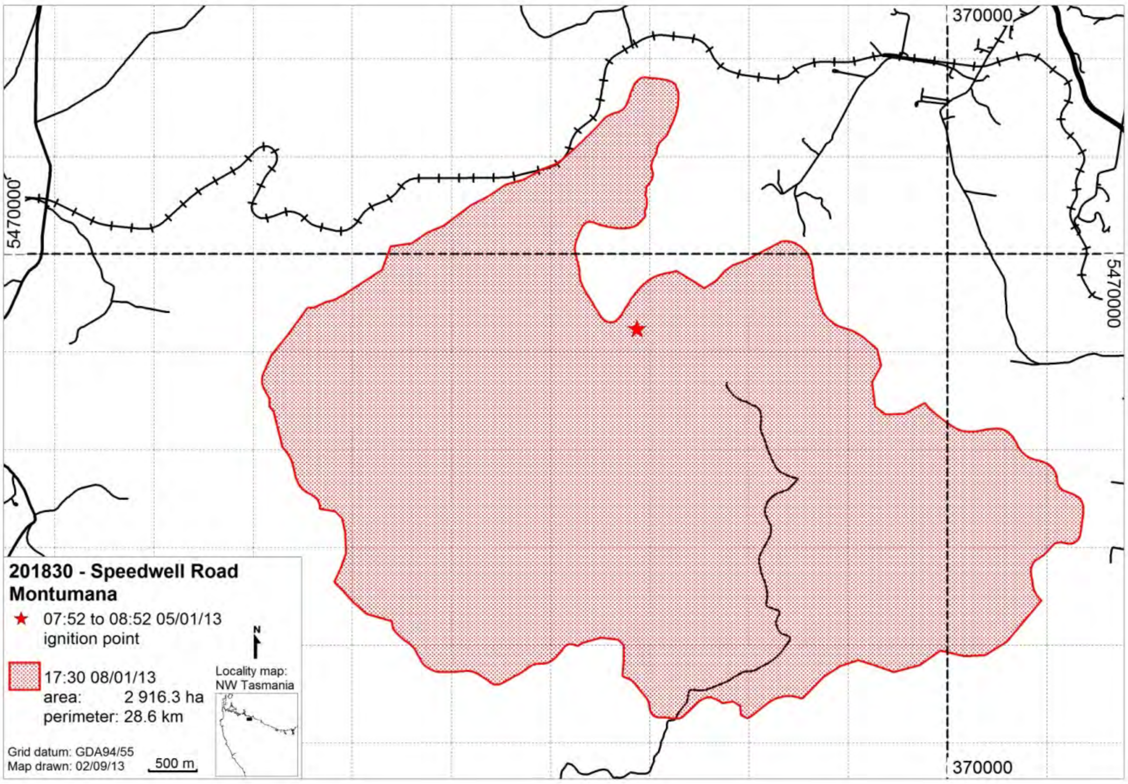
Map A4.5.5 Montumana fire at 17:15 EDST 06/01/2013.



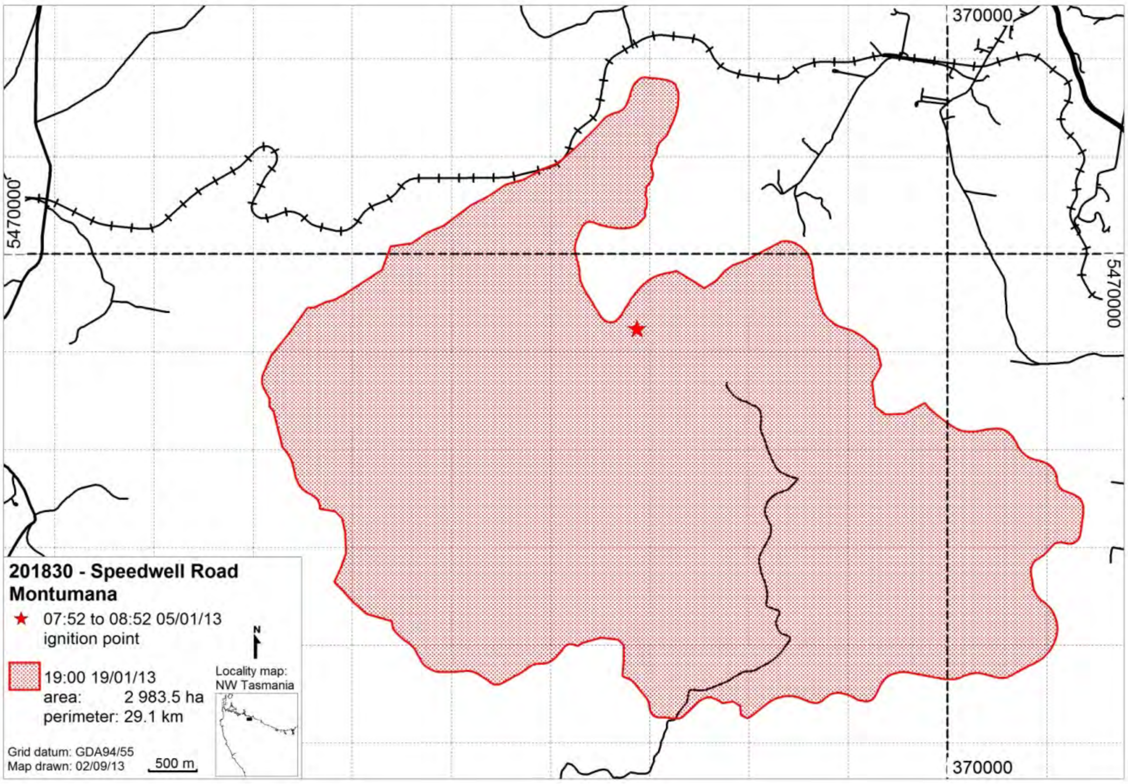
Map A4.5.6 Montumana fire at 09:00 EDST 07/01/2013.



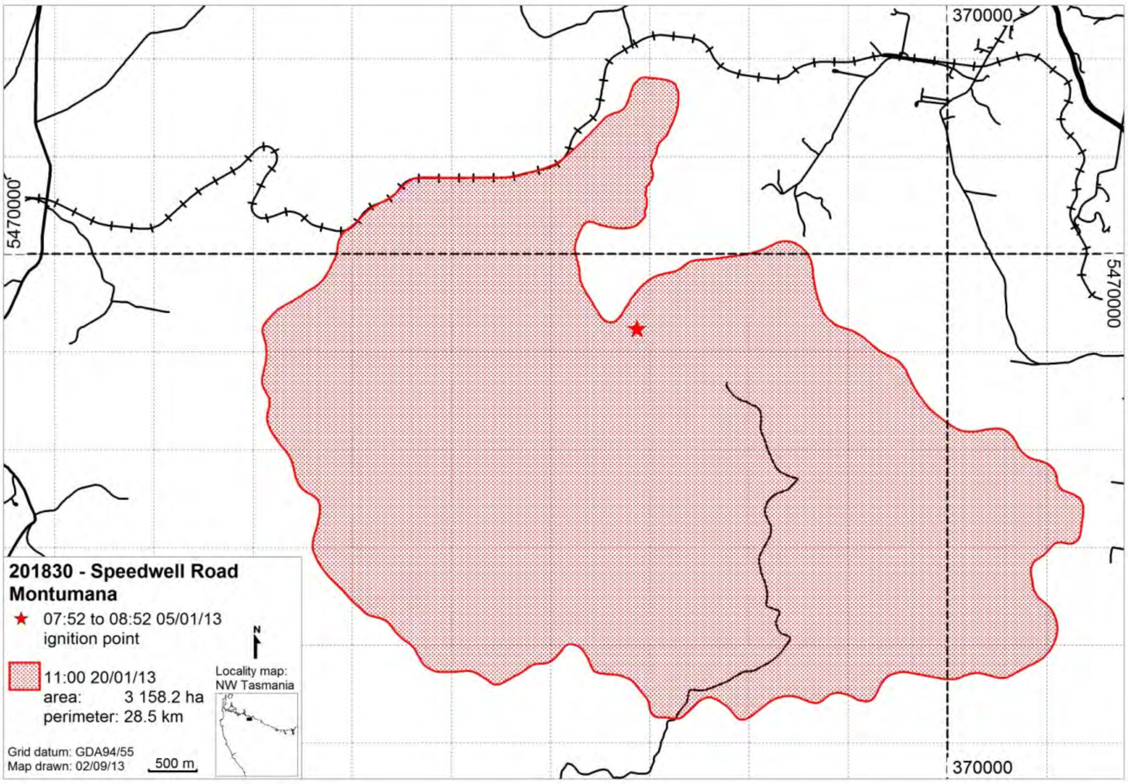
Map A4.5.7 Montumana fire at 07:00 EDST 08/01/2013.



Map A4.5.8 Montumana fire at 17:30 EDST 08/01/2013.

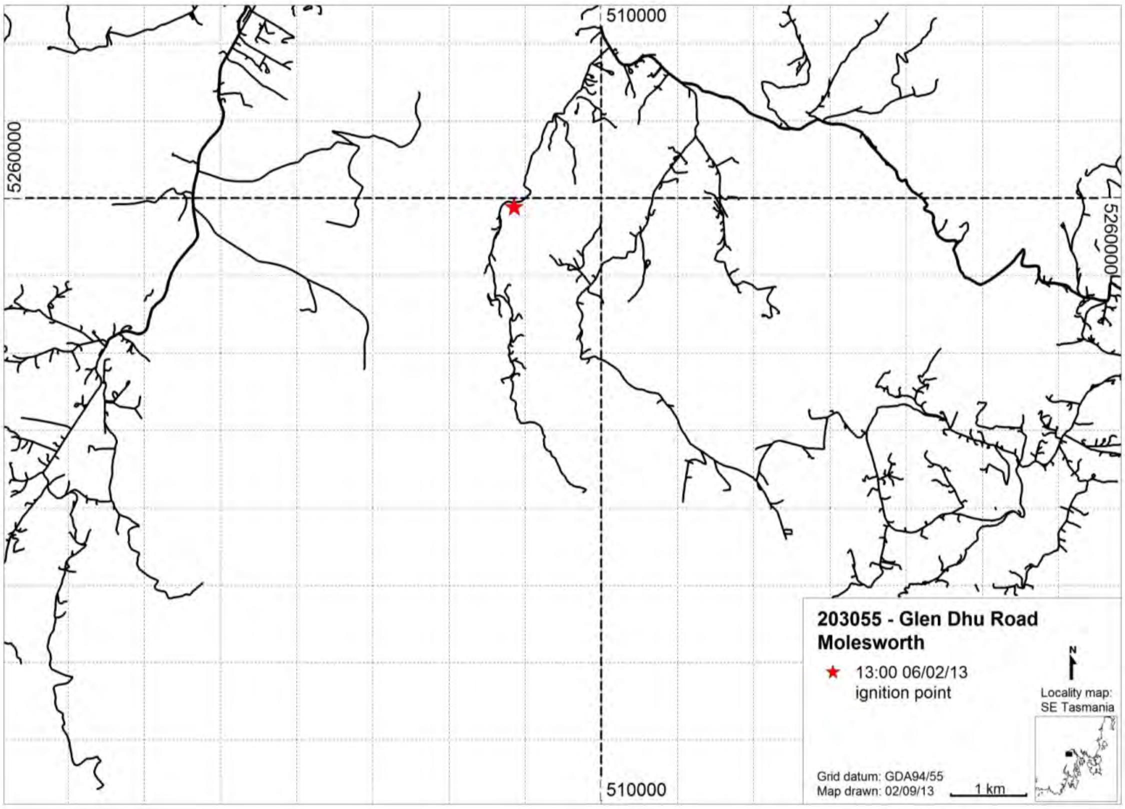


Map A4.5.9 Montumana fire at 19:00 EDST 19/01/2013.

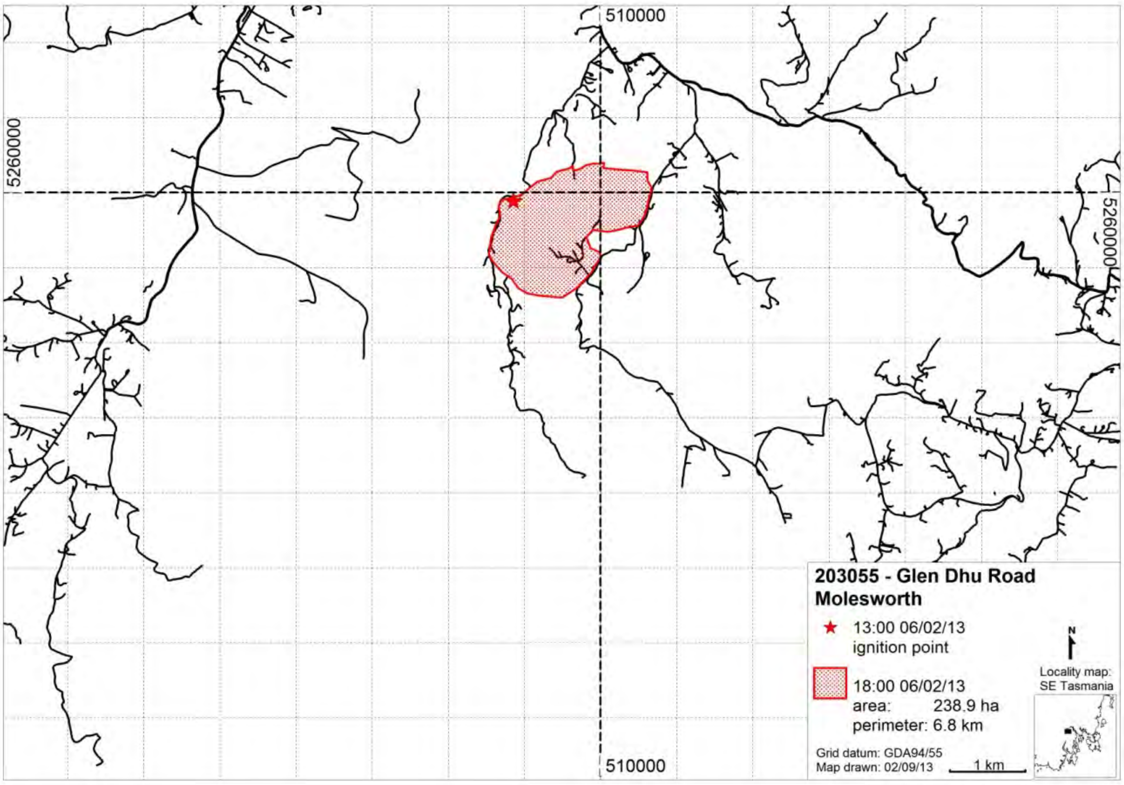


Map A4.5.10 Montumana fire at 11:00 EDST 20/01/2013 final boundary.

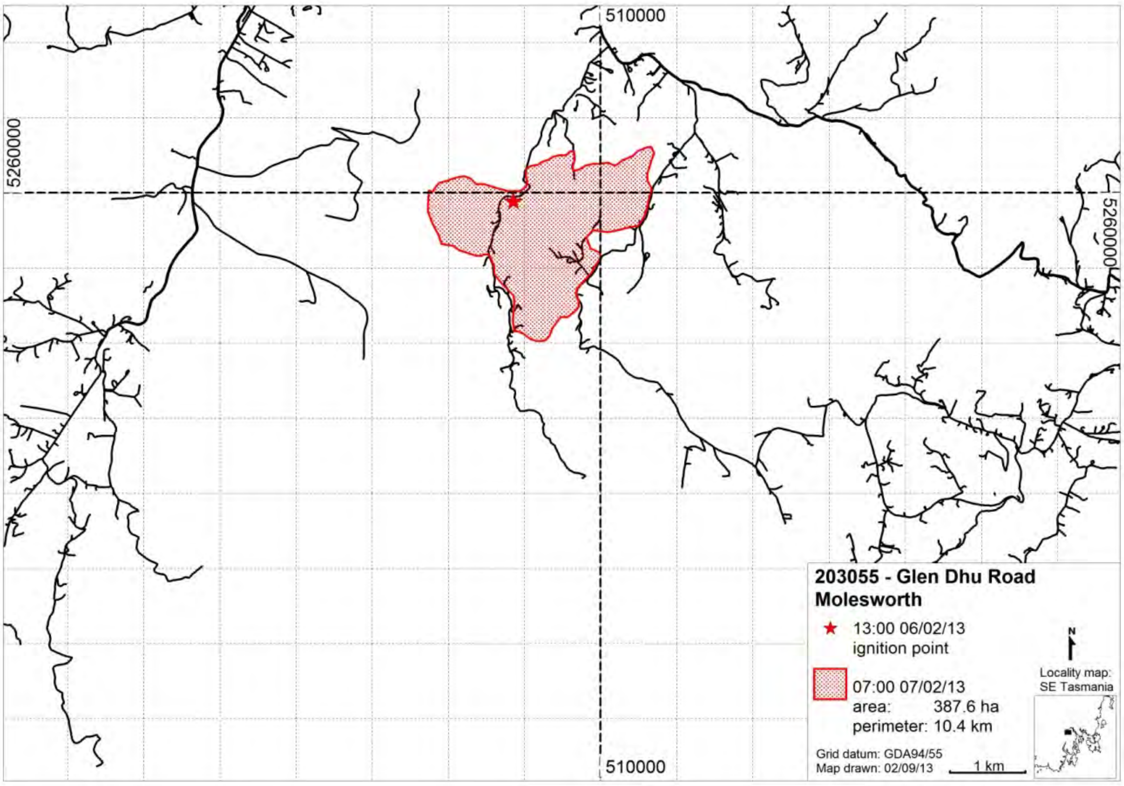
Appendix 4.6 Glen Dhu Road, Molesworth fire



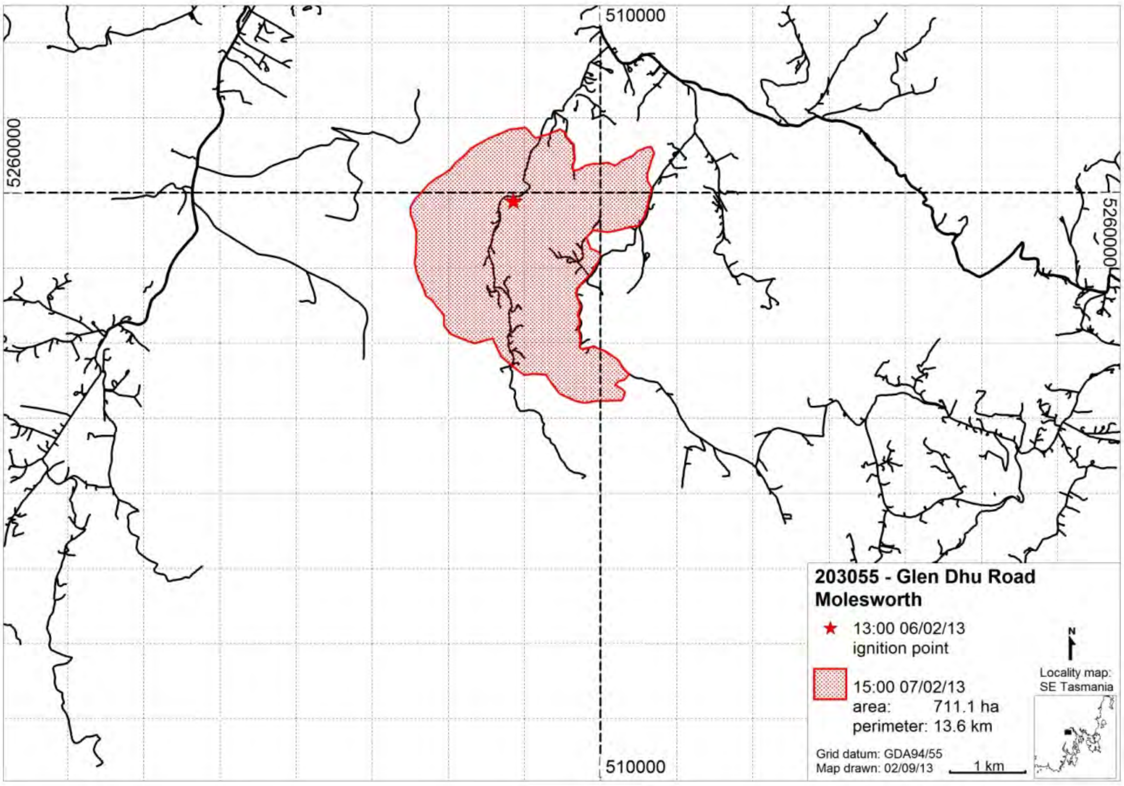
Map A4.6.1 Molesworth fire ignition point at 13:00 EDST 06/02/2013.



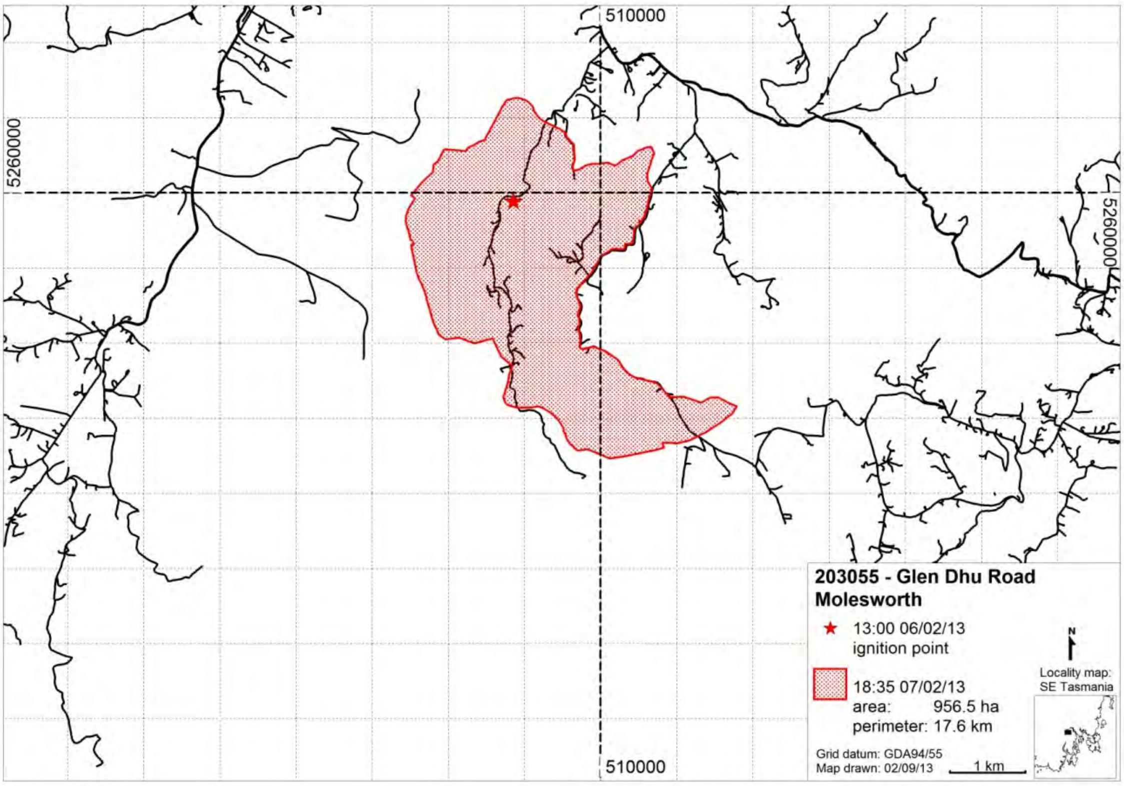
Map A4.6.2 Molesworth fire at 18:00 EDST 06/02/2013.



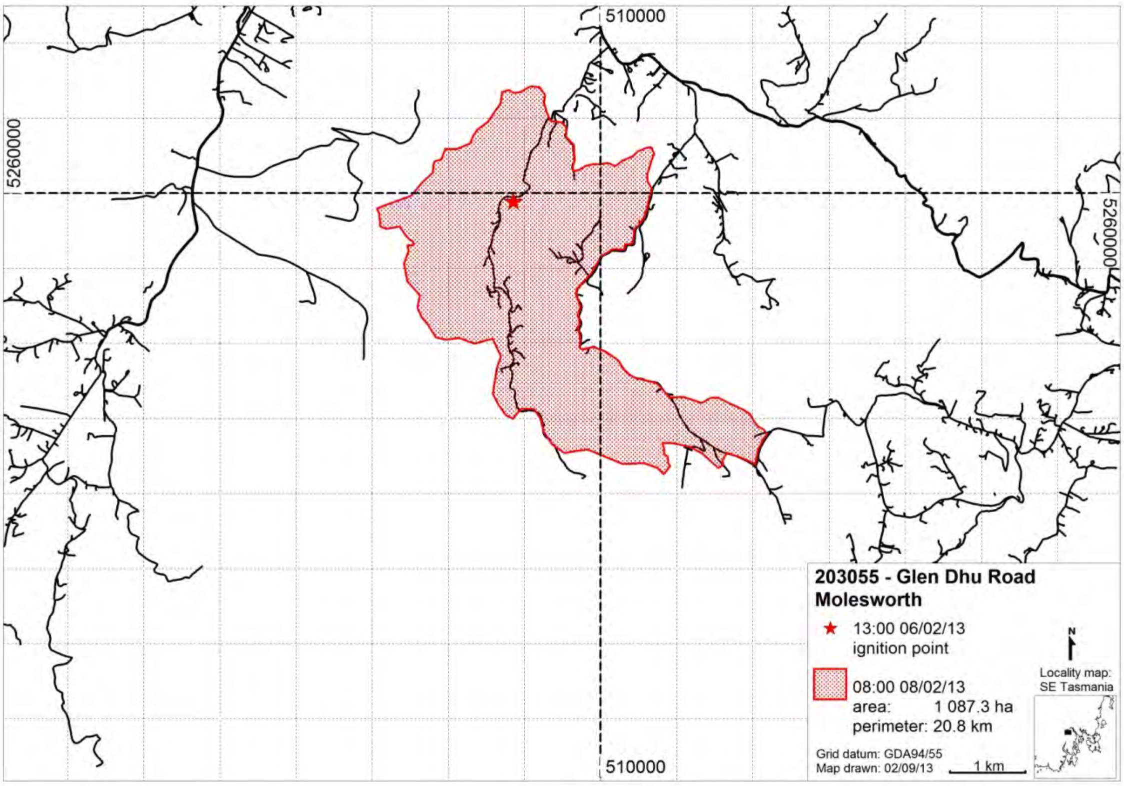
Map A4.6.3 Molesworth fire at 07:00 EDST 07/02/2013.



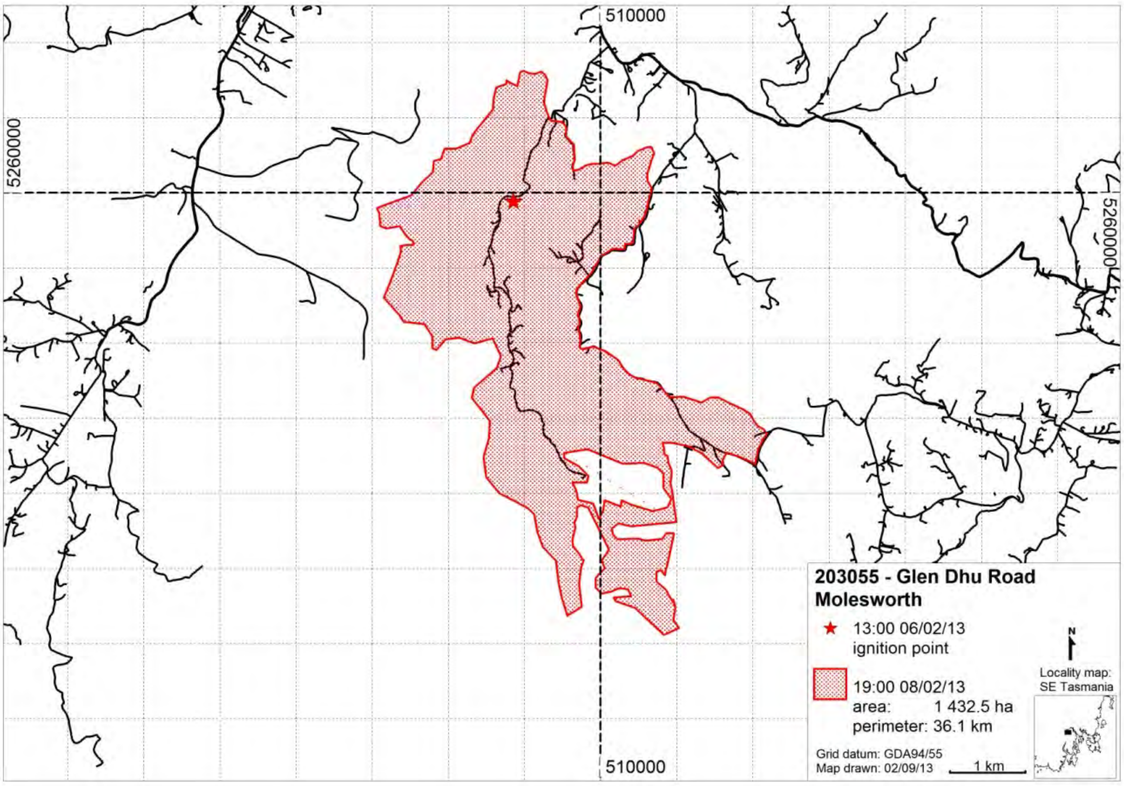
Map A4.6.4 Molesworth fire at 15:00 EDST 07/02/2013.



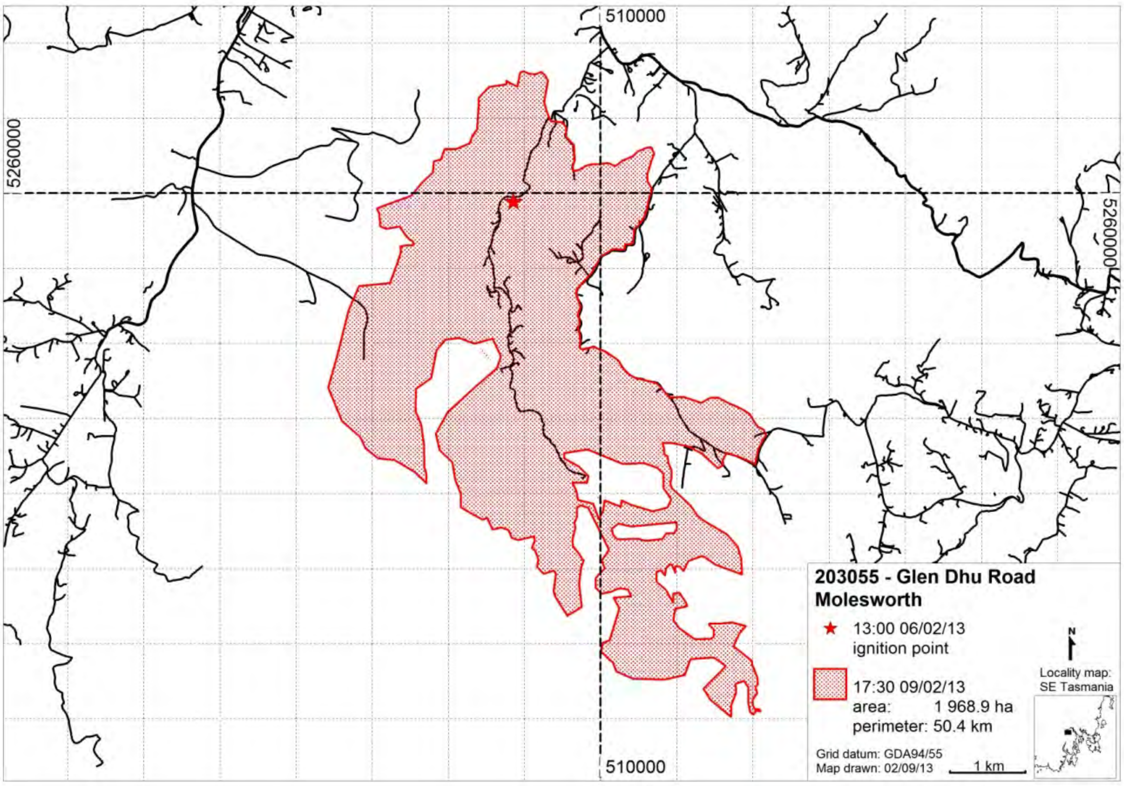
Map A4.6.5 Molesworth fire at 18:35 EDST 07/02/2013.



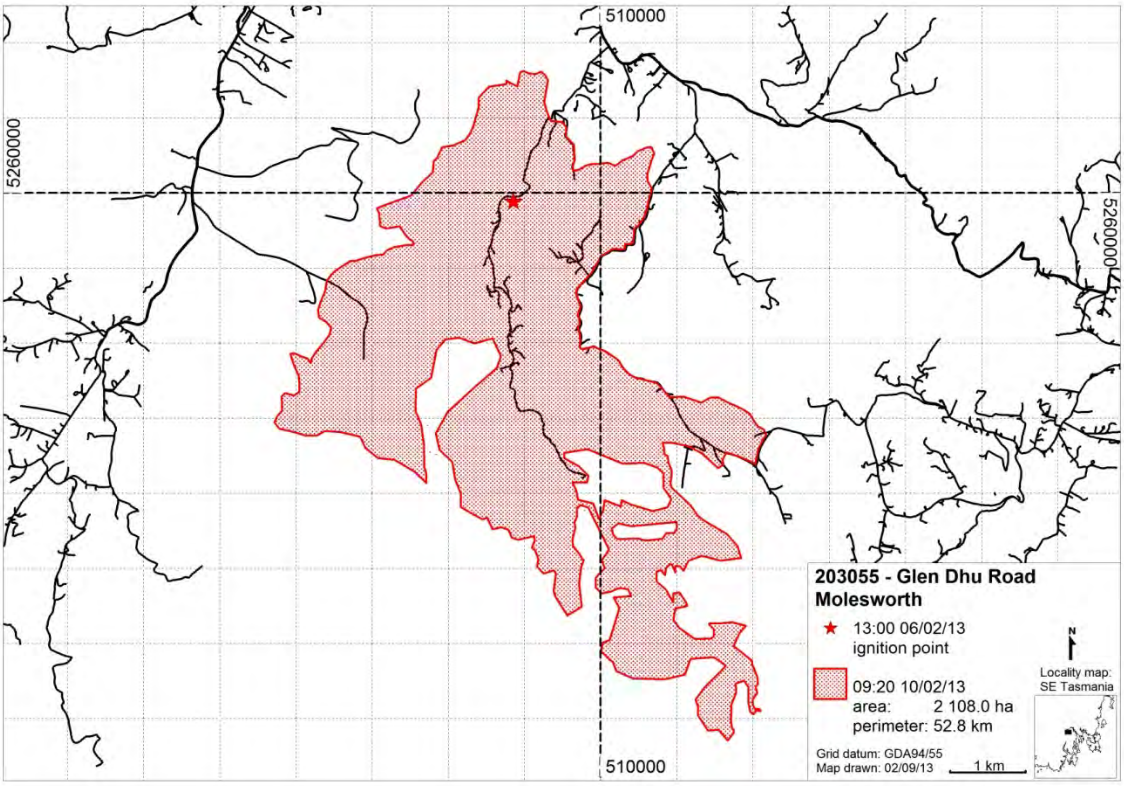
Map A4.6.6 Molesworth fire at 08:00 EDST 08/02/2013.



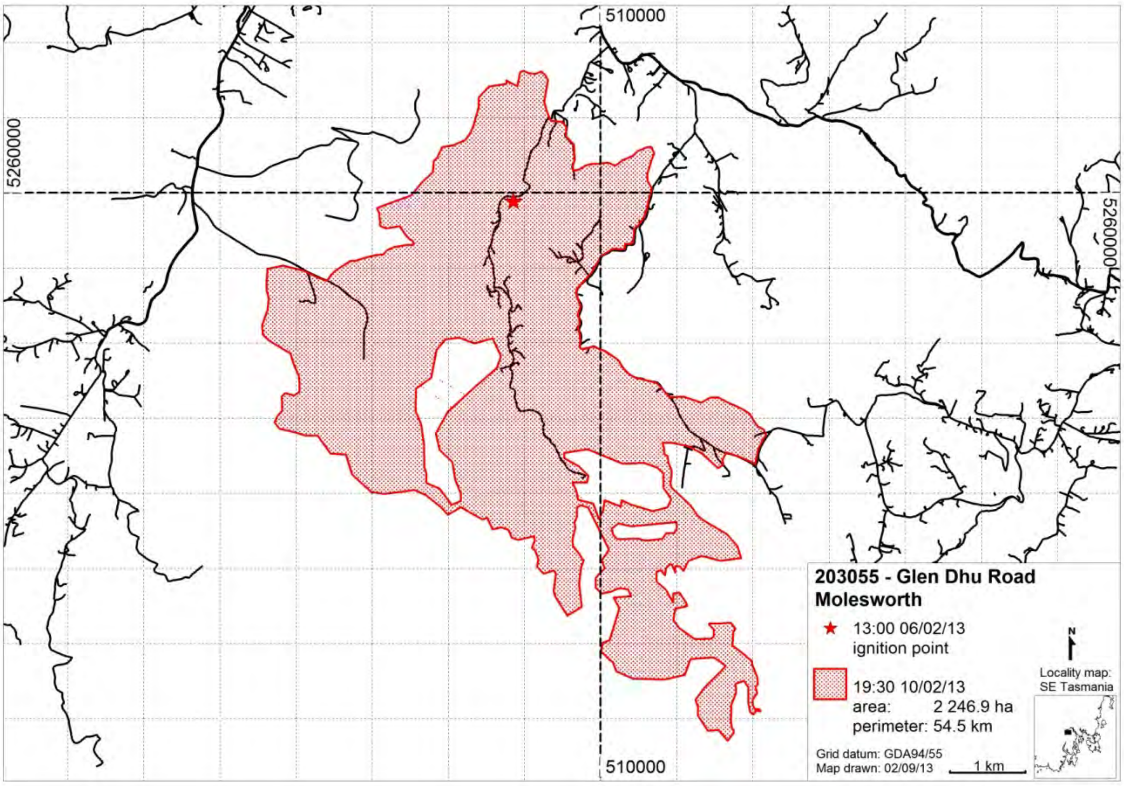
Map A4.6.7 Molesworth fire at 19:00 EDST 08/02/2013.



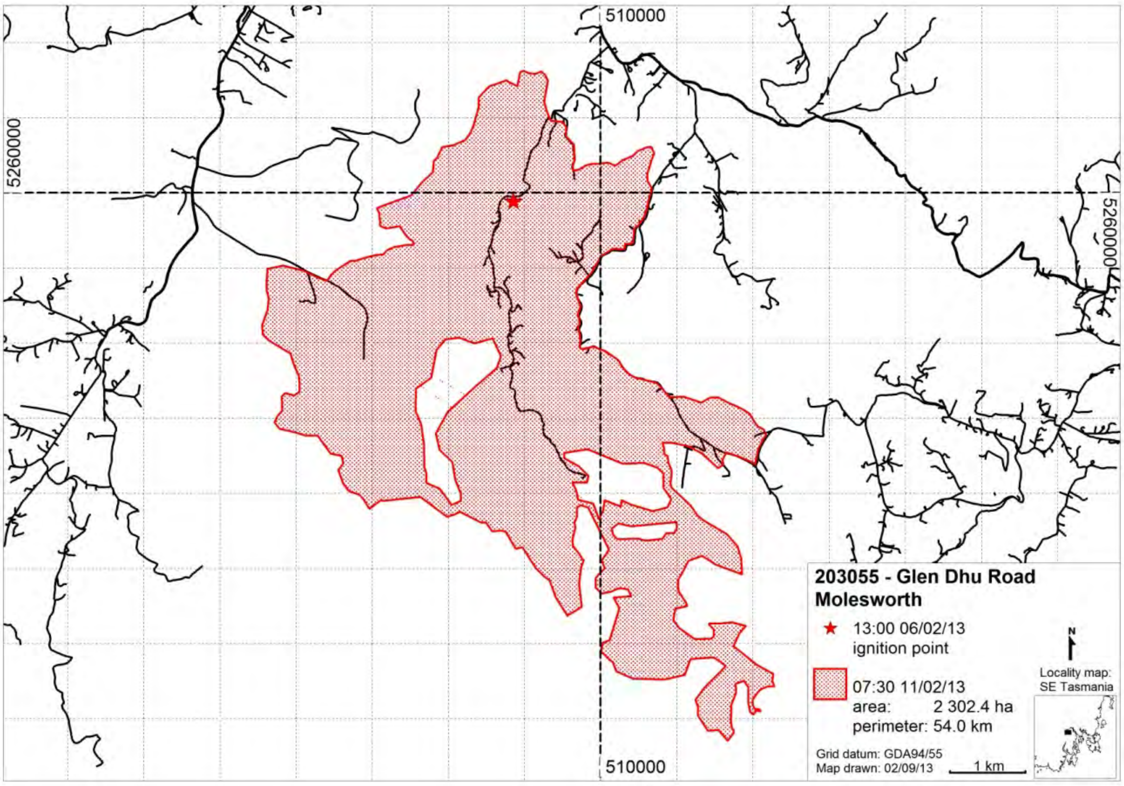
Map A4.6.8 Molesworth fire at 17:30 EDST 09/02/2013.



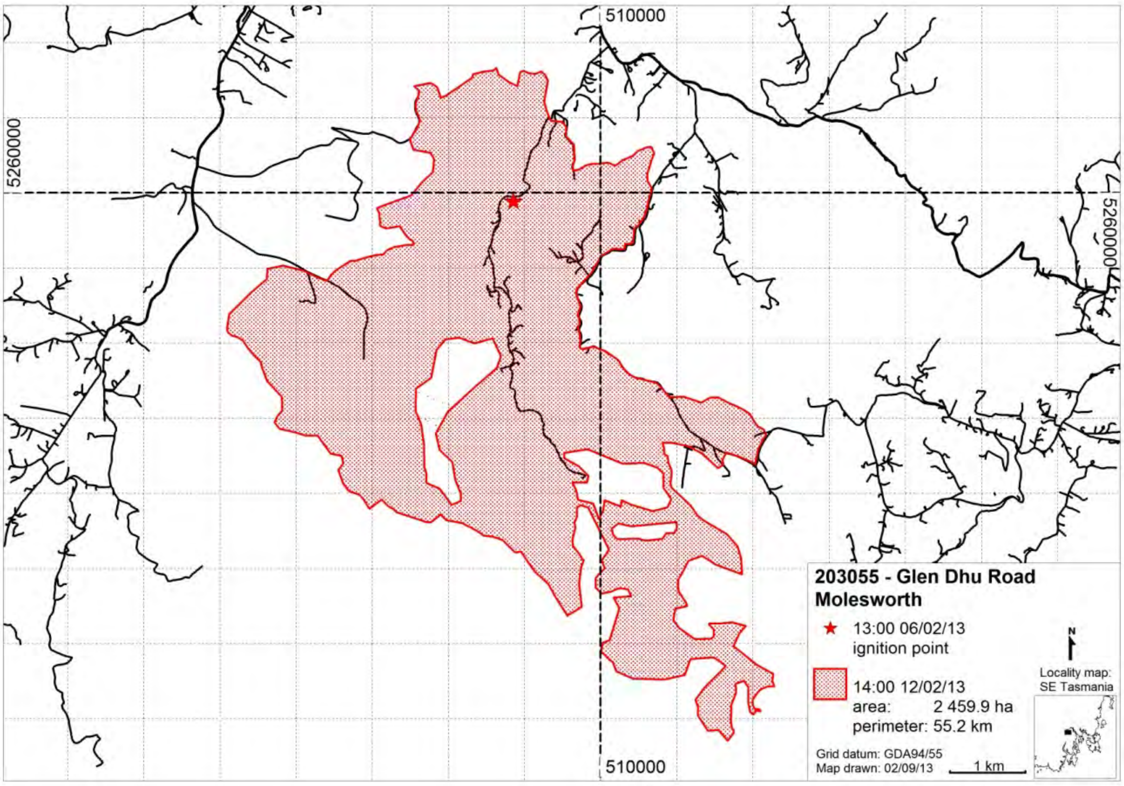
Map A4.6.9 Molesworth fire at 09:20 EDST 10/02/2013.



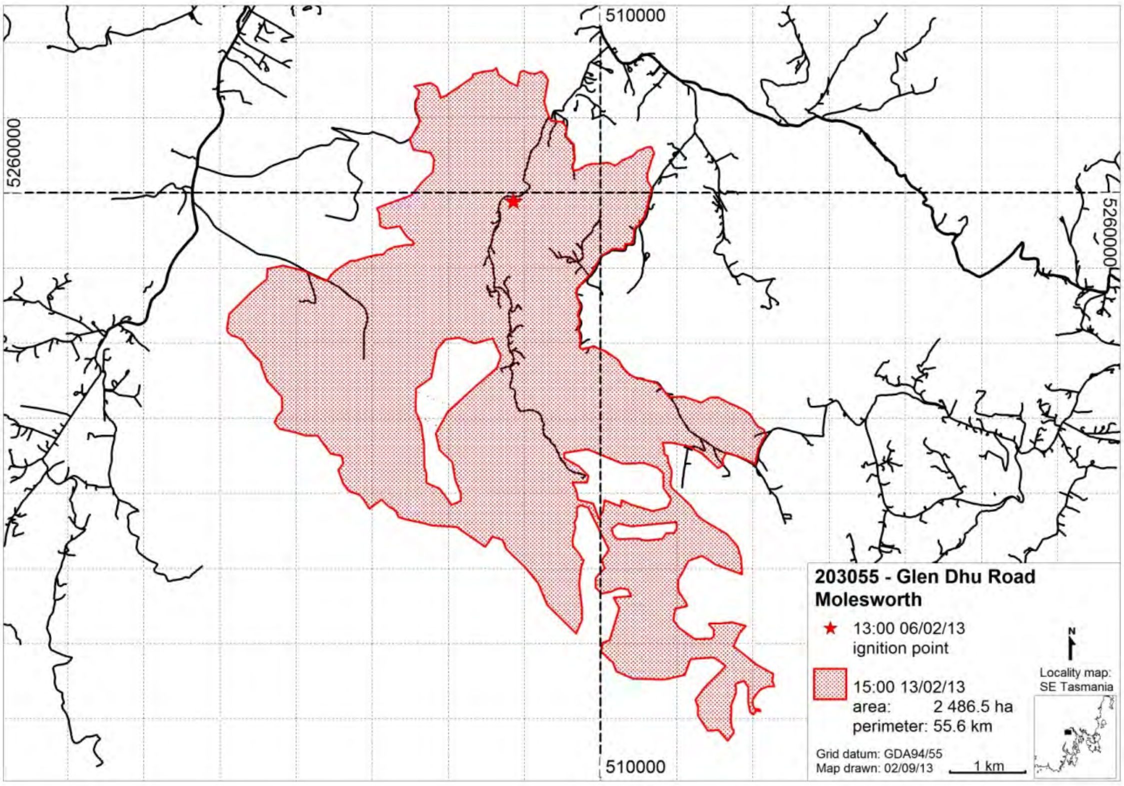
Map A4.6.10 Molesworth fire at 19:30 EDST 10/02/2013.



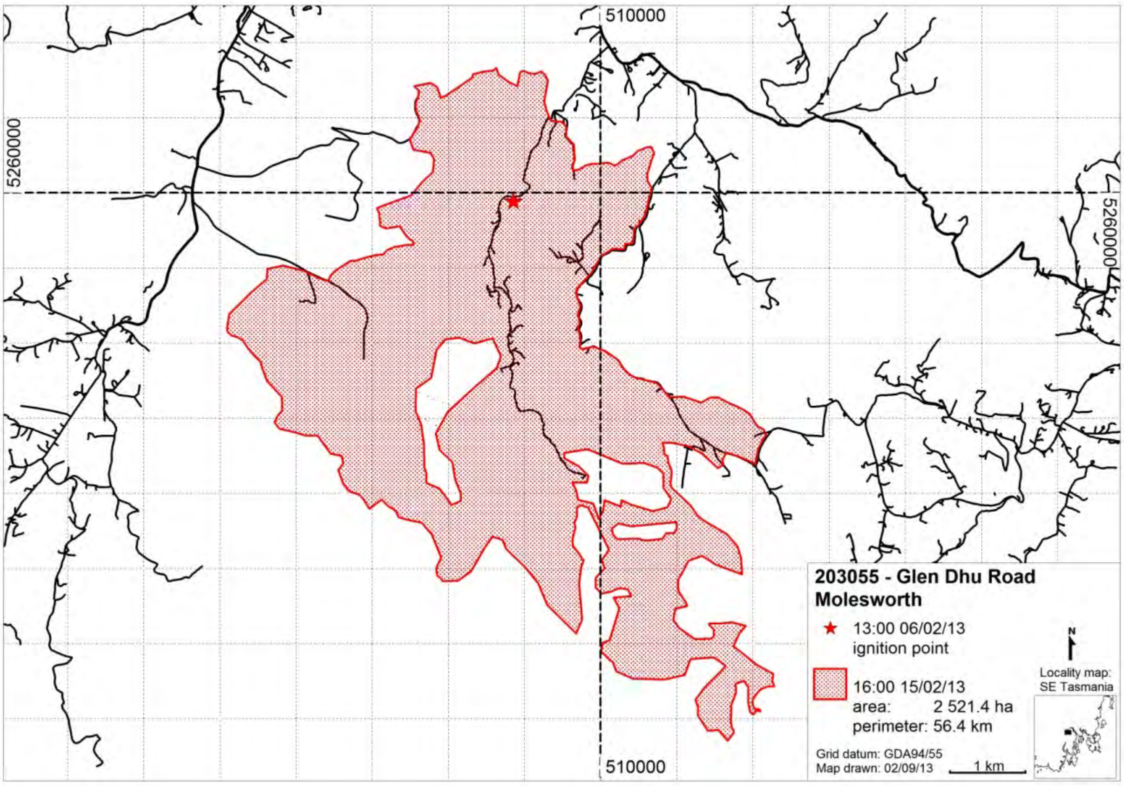
Map A4.6.11 Molesworth fire at 07:30 EDST 11/02/2013.



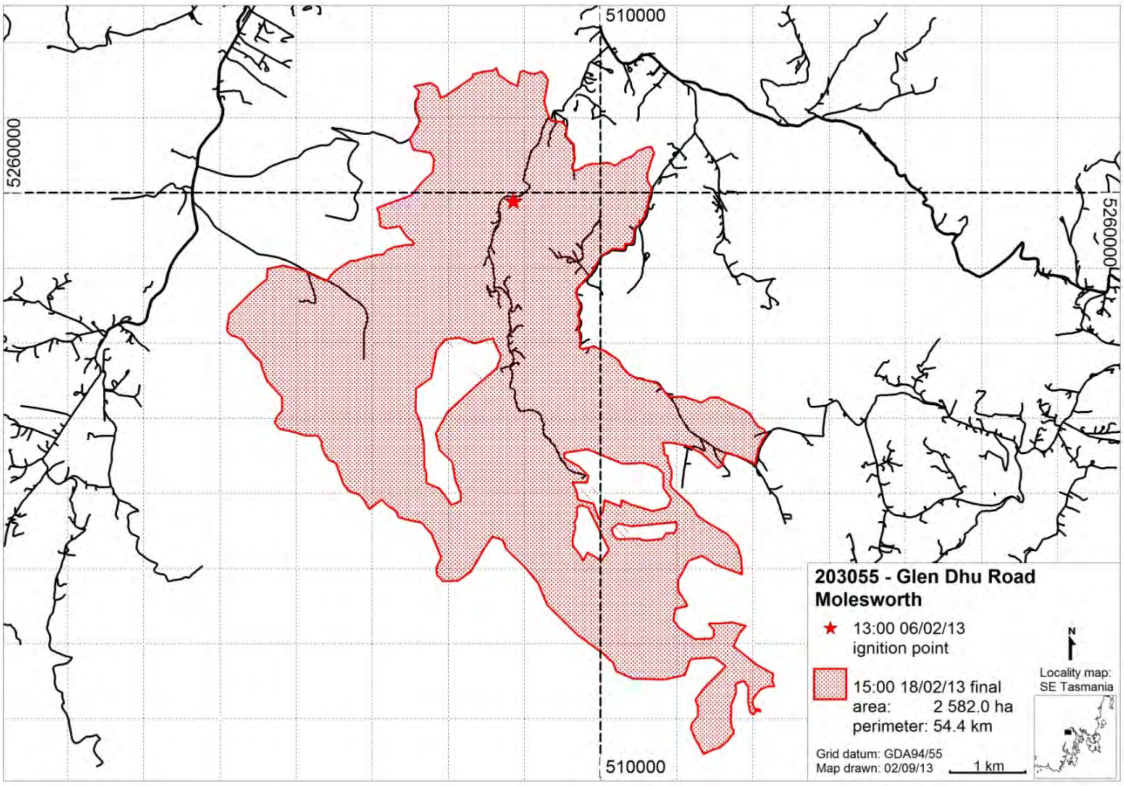
Map A4.6.12 Molesworth fire at 14:00 EDST 12/02/2013.



Map A4.6.13 Molesworth fire at 15:00 EDST 13/02/2013.

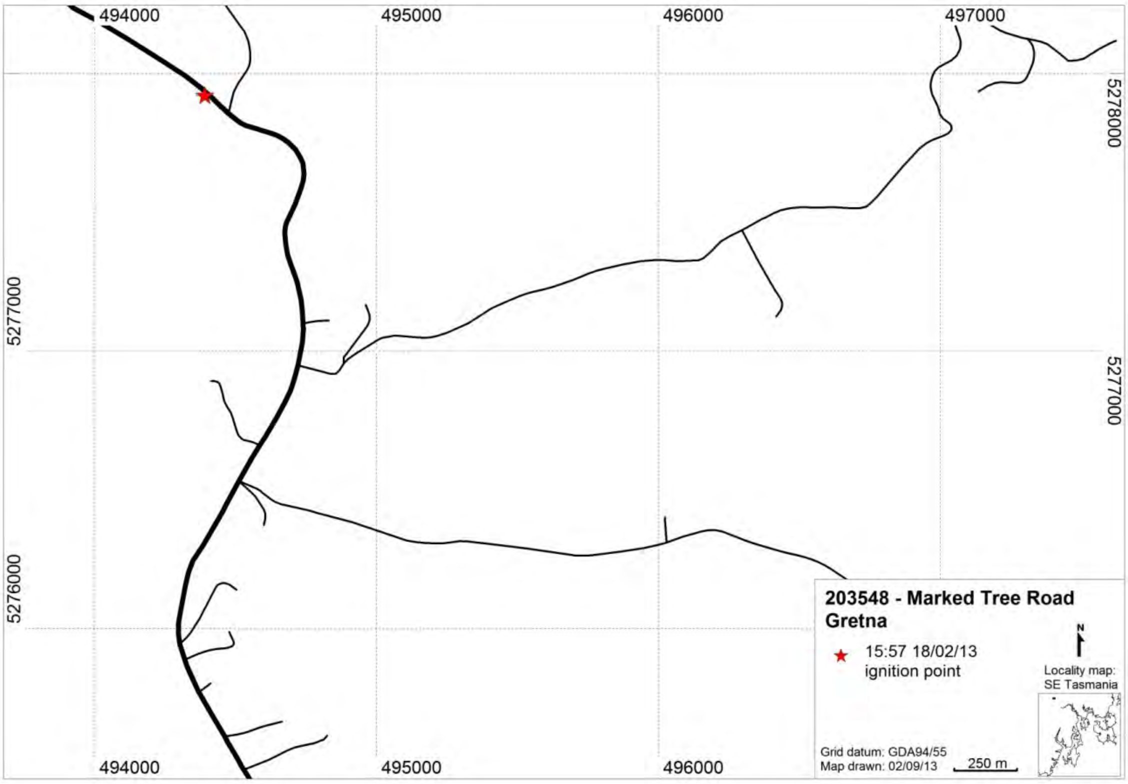


Map A4.6.14 Molesworth fire at 16:00 EDST 15/02/2013.

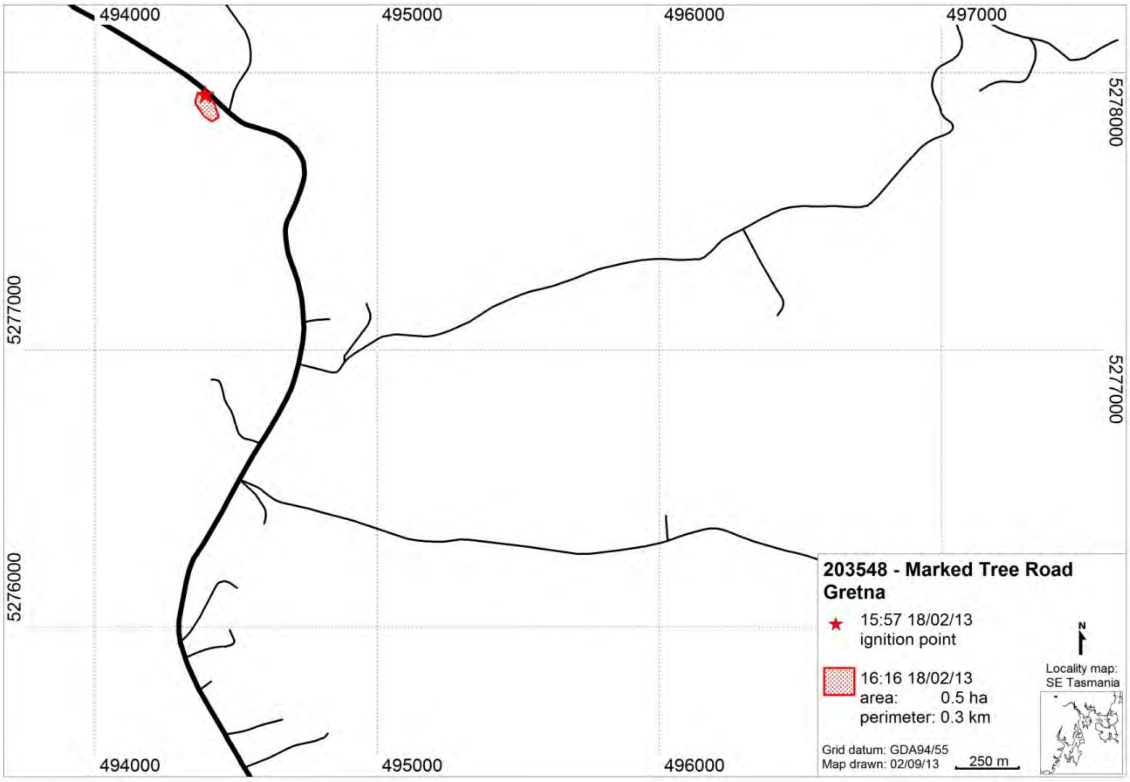


Map A4.6.15 Molesworth fire at 15:00 EDST 18/02/2013 final boundary.

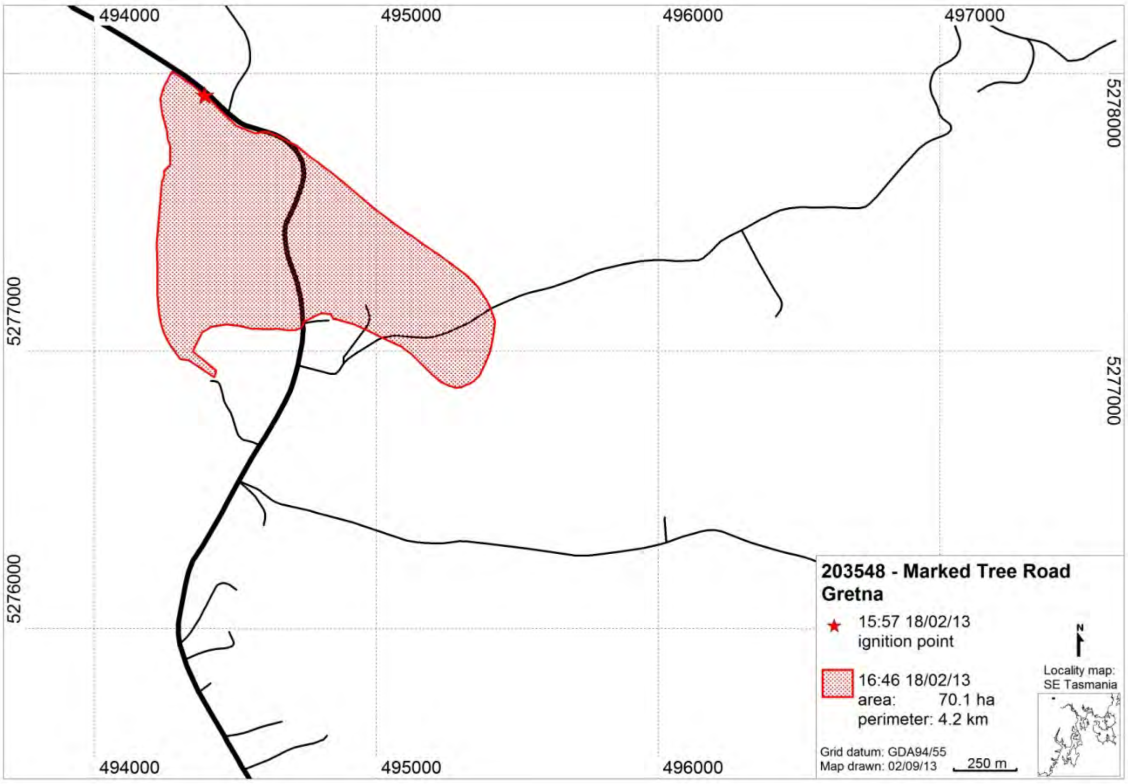
Appendix 4.7 Marked Tree Road, Gretna fire



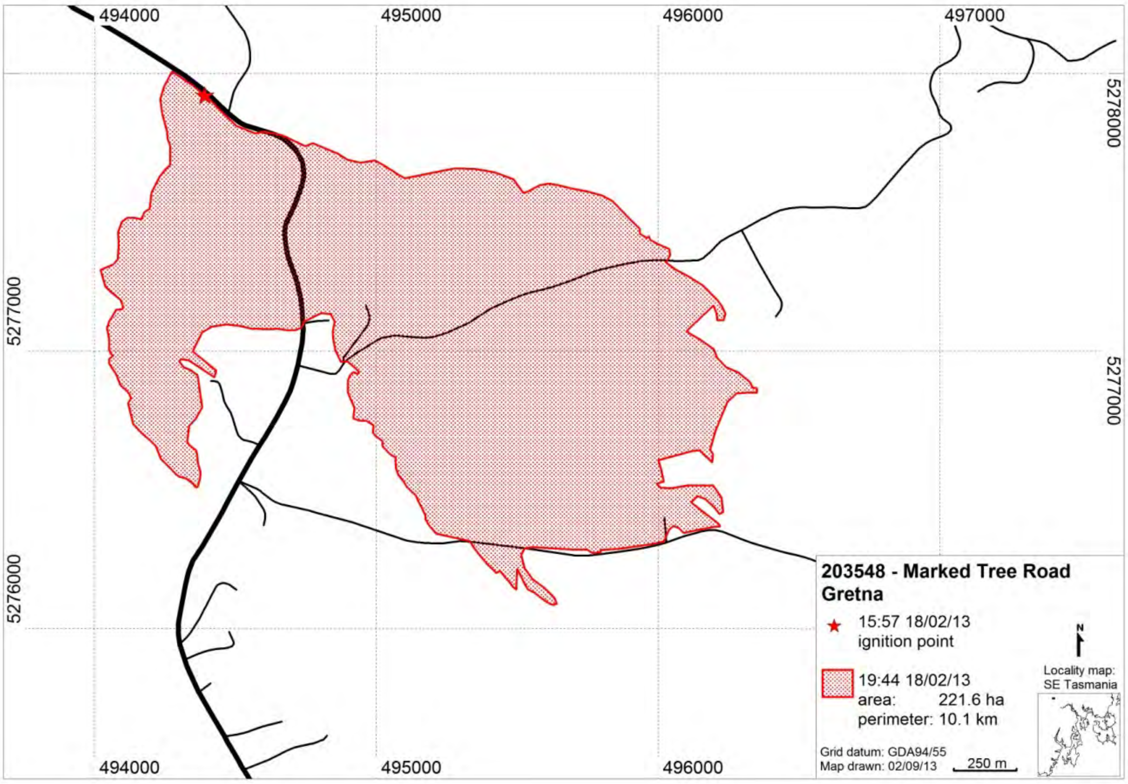
Map A4.7.1 Gretna fire ignition point at 15:57 EDST 18/02/2013.



Map A4.7.2 Gretna fire at 16:16 EDST 18/02/2013.



Map A4.7.3 Gretna fire at 16:46 EDST 18/02/2013.



Map A4.7.4 Gretna fire at 19:44 EDST 18/02/2013 final boundary.