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Wye River / Separation Creek
Post-bushfire building survey findings

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Victorian Country Fire Authority (CFA), Department of Environment, Land, Water and Planning (DELWP), Emergency Management Victoria and the Colac – Otway Shire Council

Executive summary

Following the Wye River fire event the CFA commissioned CSIRO to perform a review and provide a report on house losses in the Wye River fire footprint. This report identifies factors that led to the loss, damage and survival of houses and illustrates these factors by presenting examples of houses within the fire footprint. This report has a strong focus on houses built under Bushfire Management Overlay (BMO) provisions.

This study found seven examples of houses built to the regulatory standards, which have been in place since 2010, that were impacted by fire. Of these seven houses, four were lost to fire and three survived. Although the number of buildings in this sample is small, it does suggest a higher survival rate than the 80% loss rate experienced in the region affected by fire. The fourteen houses built to planning and building regulatory standards between 2003 and 2010 fared much better; three were lost to fire and eleven survived. It is clear from the study that the house loss rate would have been significantly higher if suppression was not provided by ground and aerial crews.

The townships of Wye River and Separation Creek experienced a broad scale surface fire spread through a combination of dried grasses and litter fuels originating from extensive established tree coverage. The main impact of the fire on houses was through ignition of heavy fuel elements that were adjacent to or under buildings. These include adjacent houses (house-to-house ignition), combustible retaining walls, combustible decking, combustible stairways, vehicles, stored equipment, plastic water tanks and firewood. It is clear that buildings built to the bushfire regulatory standards as well as buildings that were not built to the bushfire regulatory standards were subject to these heavy (domestic) fuels, and many were not capable of withstanding the radiant heat or flame contact from these fuels. This appears to be a key reason why such a large house loss rate was experienced. There were few examples of fire spread through surface fuels that were sufficiently intense to provide radiation exposure levels capable of compromising houses directly, these were limited to a few areas within the township.

Surface fuels within the township were readily ignited by embers which rained down on the township, this meant that many parts of the township were simultaneously ignited. Subsequently the fire spread up through surface fuels in the township in multiple fire fronts. During this time people outside their houses would have been presented with life threatening exposure levels of radiant heat, flame and smoke. These surface fires spread would have seamlessly transitioned into heavy fuel ignition throughout the township involving a number of houses. The combustion of these heavy fuels would have also provided life threatening levels of radiant heat, flame and smoke to anyone in the area that was not able the shelter in a house or vehicle including fire fighters. The steep terrain and challenging access within the township meant that risk to life of occupants forced to leave burning houses would have been high. Roadways cut into steep slopes and house access via steep driveways meant that any egress during the fire by foot or by vehicle would be difficult and life threatening. Very few clear areas for refuge were found within the fire-affected areas of the townships. Despite these difficulties, no lives were lost, which is testament to the warning given to occupants prior to the arrival of the fire and the willingness of occupants to heed these warnings.

1 Introduction and scope

On 19 December 2015, lightning ignited a bushfire in the Otway Ranges National Park near Lorne [1]. Early on 25 December, severe fire weather conditions, including a strong northerly wind, led to the fire jumping containment lines and impacting numerous communities along the Great Ocean Road. The fire continued to burn for a number of weeks in steep, difficult and heavily treed terrain [1]. By the morning of 26 December, overnight rain and cooler conditions slowed the fire. Over 100 houses were lost in the Wye River and Separation Creek Region [2].

Following the Wye River fire event the CFA commissioned CSIRO to perform a review and commentary of surviving and destroyed houses in Wye River and Separation Creek with the aim of identifying factors that led to the loss, damage and survival of houses and to illustrate these factors by citing examples from the fire footprint. Of particular interest are the more recently constructed houses built under the Bushfire Management Overlay (BMO) provisions (VC109).

In order to deliver this report CSIRO undertook the following activities:

- attended the fire-affected area as part of a multi-agency (CSIRO, CFA) survey initiative
- gathered information from various sources to describe the nature of the fire and fire suppression activities around these selected houses
- gathered information (from the local council and CFA) on the nature of building regulatory standards for the selected houses
- gathered information around the likely state of the houses prior to fire arrival
- identified issues likely to have contributed to the loss, damage or survival of houses.

The report is intended to be used by the CFA to inform the provision of community information, education and engagement activities.

Surveys were carried out from 6 to 8 January 2016 to examine the remains of the destroyed, partially damaged and unaffected houses as well as their surroundings within the fire perimeter.

The surveys aimed to provide a better understanding of the mechanisms of house failure or house survival and is based on previous post bushfire surveys [3, 4]. Detailed information on individual properties was collected by geo-referencing and attributing relevant elements of structures, surrounding objects and other pertinent information (e.g. degree and cause of damage, site details and combustible elements). This report provides the findings of the review of this data combined with other available information that relates to weather, fire arrival and spread observations to gain a better understanding of structural design, building regulatory standards and planning issues.

2 Township design, layout and use

Wye River and Separation Creek are Victorian coastal towns in the Colac Otway Shire, around 155 km west of Melbourne (Figure 1). The towns are adjacent to the native forests of the Otway Ranges National Park, with native bushland coalescing into urban development from the steep ridges to the north-west, all the way to the coast at the south-eastern border of the townships.

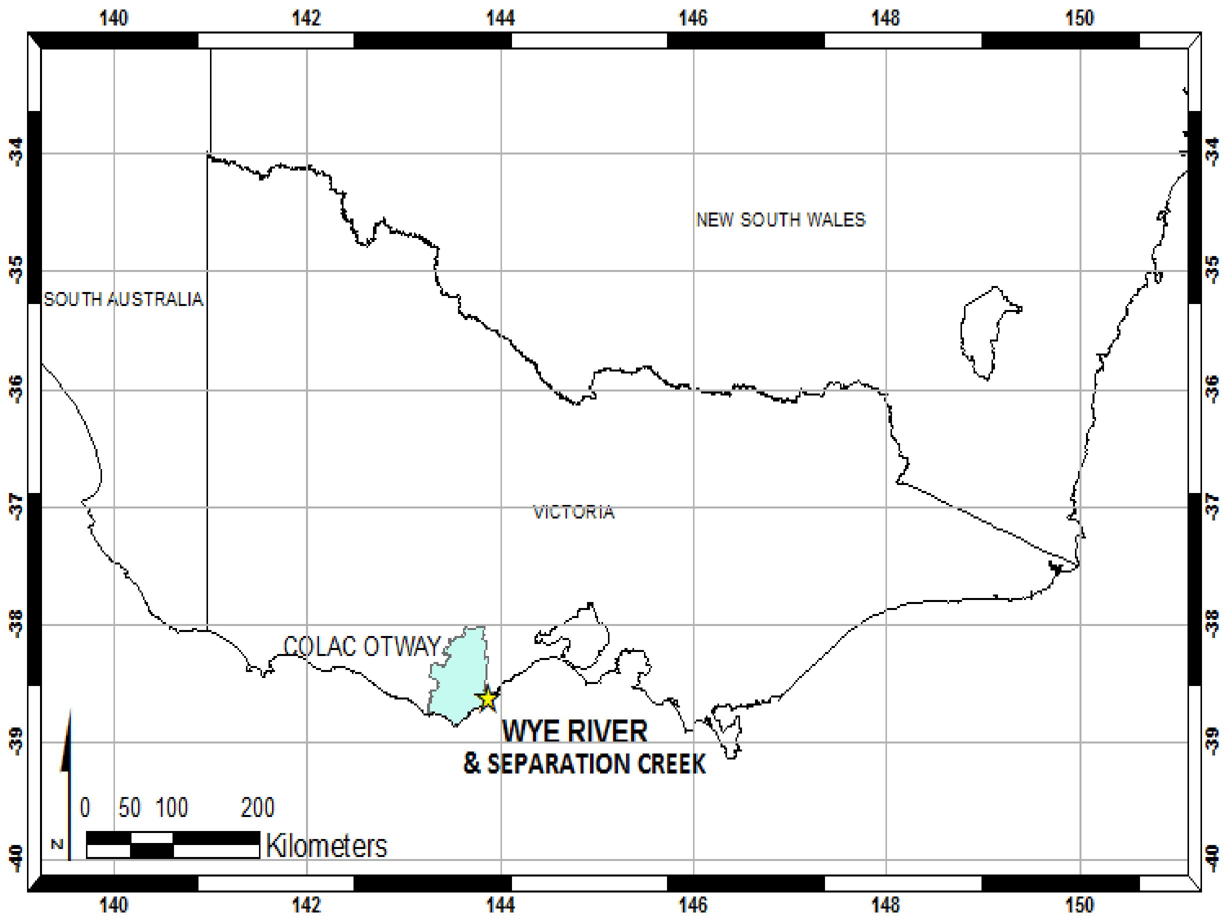

Figure 1: Map showing the location of Wye River, Victoria.

2.1 Terrain

Both Wye River and Separation Creek are built on steep south-eastern facing slopes. The townships extend from the coast up these slopes (Figure 2). The ridges are covered predominantly by native bushland. Some housed areas of Wye River and Separation Creek reach gradients higher than 30 degrees (Figure 3). Because of the steep terrain, many road and driveway cuttings require extensive land stabilisation. House and other building access is typically via narrow gravel roads and driveways, which makes access for fire suppression and rapid egress difficult.

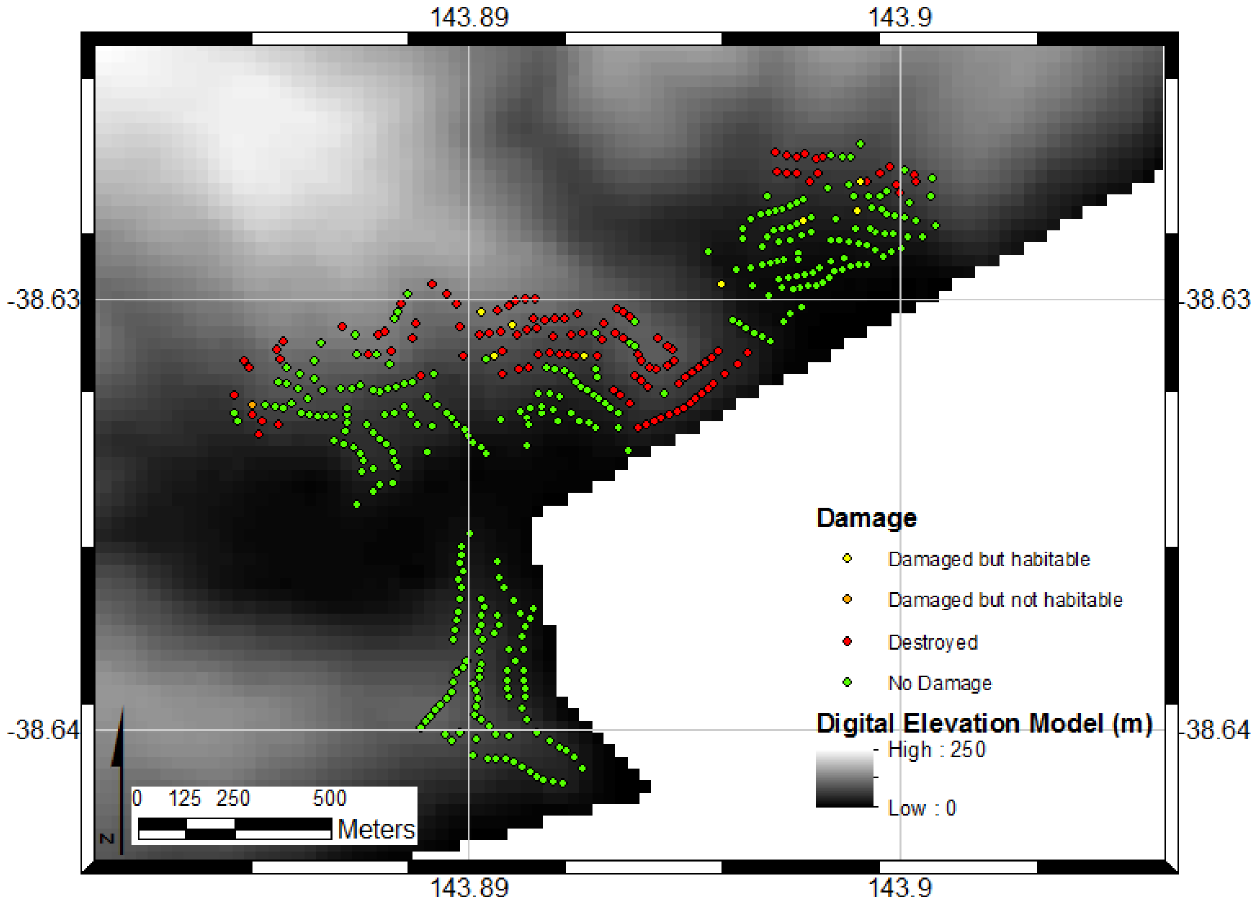

Figure 2: Digital elevation model for the townships of Wye River and Separation Creek based on Shuttle Radar Topography Mission (SRTM) data.

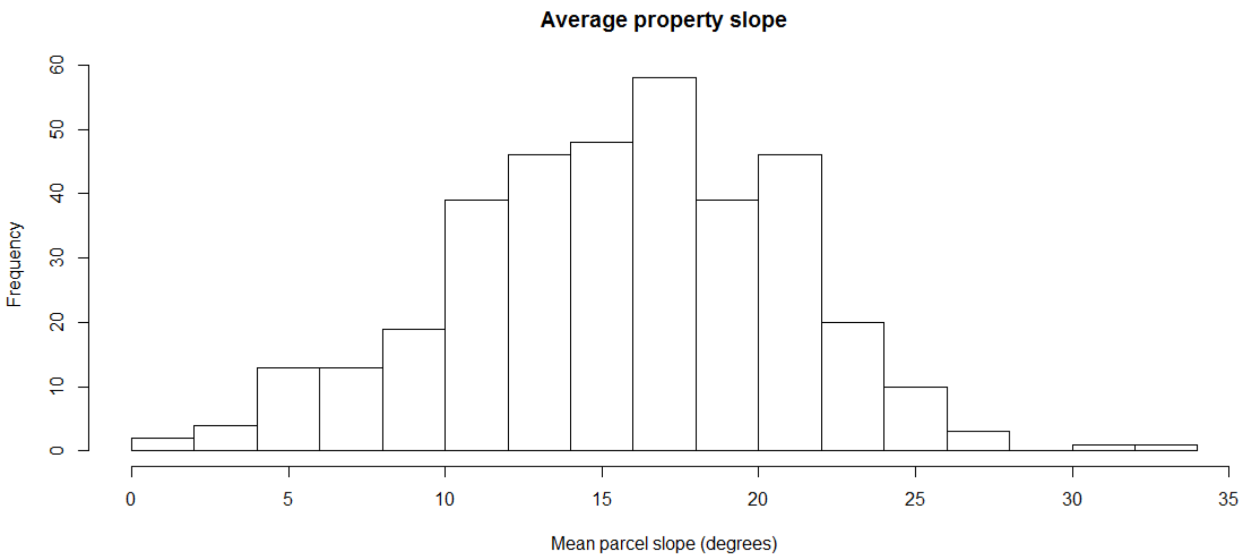

Figure 3: Distribution of slopes for parcels of land in the Wye River and Separation Creek townships.

2.2 Land stabilisation

Land stabilisation includes extensive use of retaining walls throughout the fire-affected areas. Some walls are built using non-combustible materials such as concrete. However, the vast majority of walls are constructed of combustible materials such as timber (Figure 4).

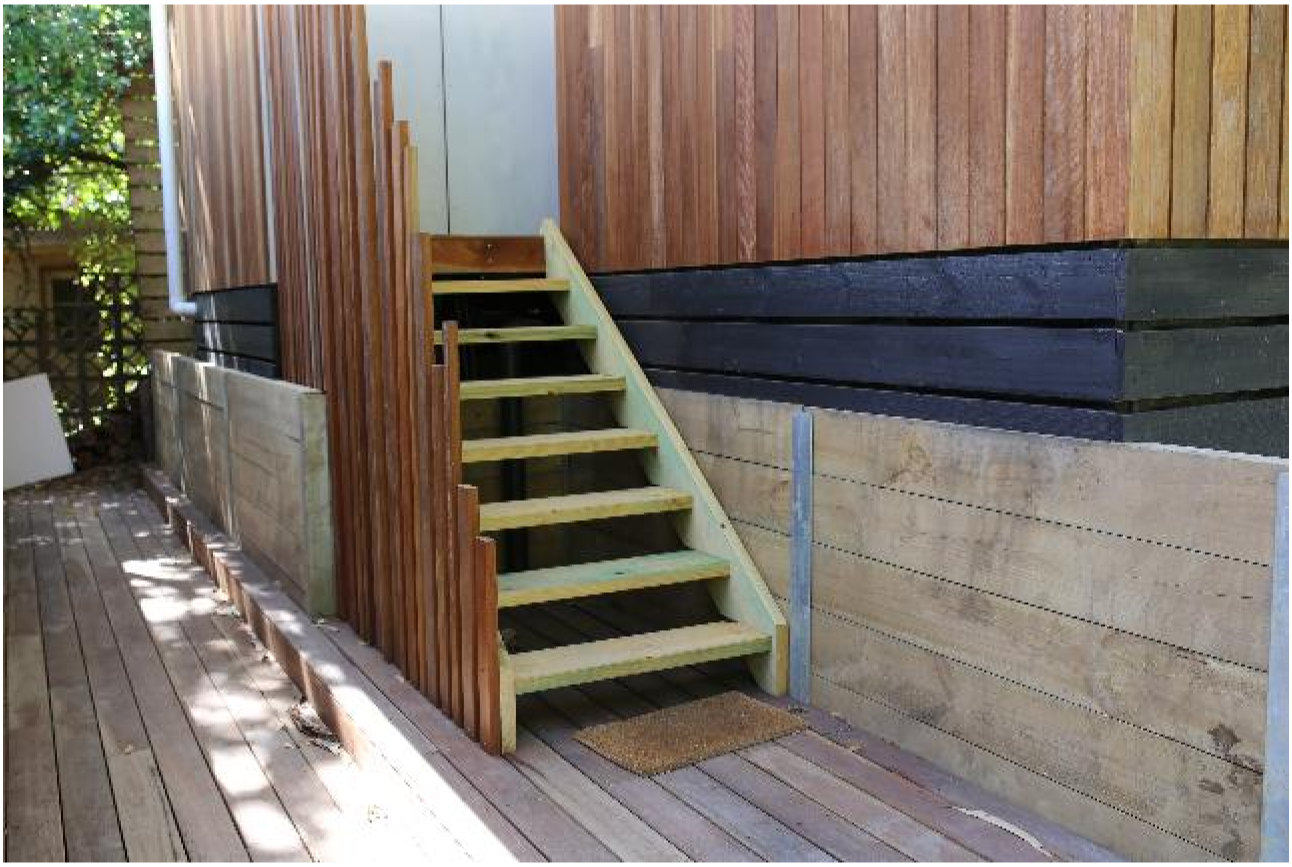

Figure 4: Example of land stabilisation using timber sleepers in proximity to other combustible features within Wye River.

2.3 Tree canopy

The vegetation of the broader Otway Ranges National Park includes moist rainforest gullies, drier inland forests, and heathlands and woodlands along with coastline. No distinct border exists between the forests and urban areas of the townships (Figure 5). Rather, houses embrace the native vegetation, with tall forest canopies extending throughout most of the residential zone properties.

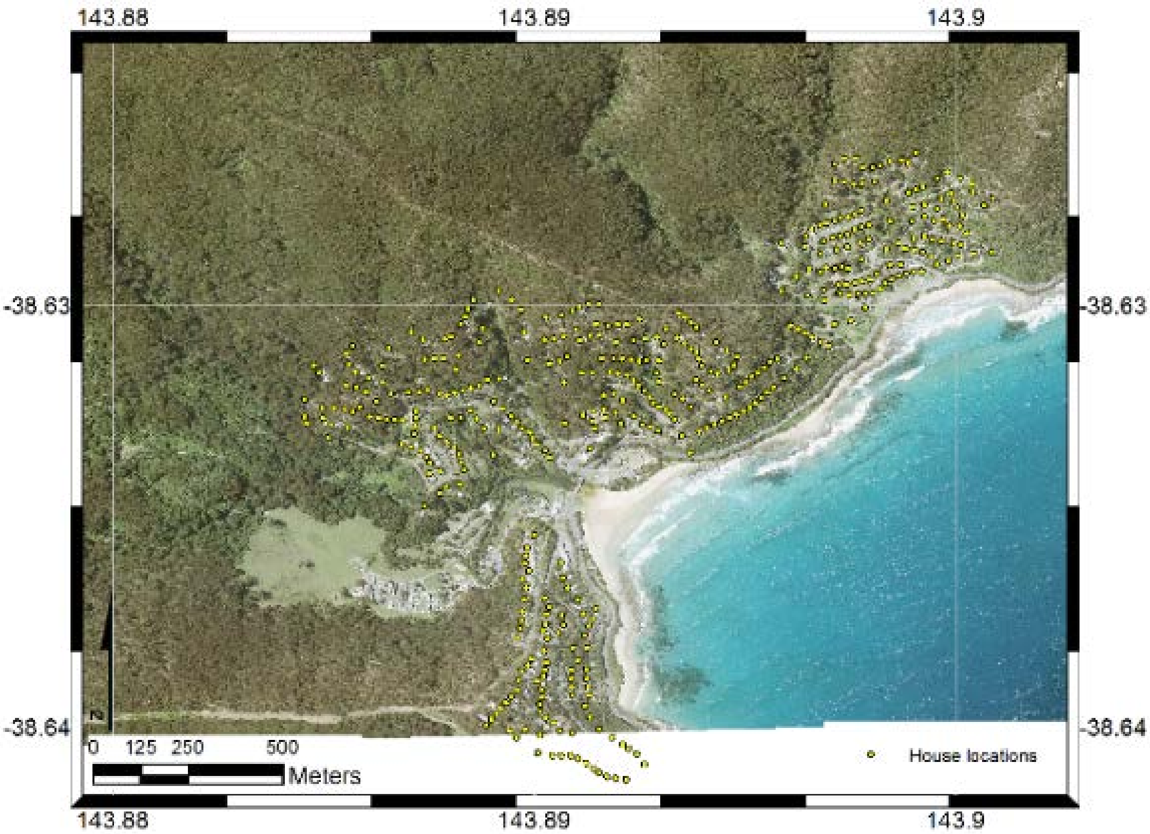

Figure 5: Pre-fire high-resolution aerial imagery overlaid with house location.

Mature native trees provide important land stabilisation, shade and wind attenuation to the township. However, they also deposit extensive leaf, bark and twig debris on buildings and the surrounding landscape (Figure 6). This litter, in combination with cured grasses, provides a near continuous surface fuel layer, broken only by areas of hard surfacing or roadways where wind, run off and/or local traffic shifts the surface fuels.

Figure 6: Typical leaf, bark and twig debris.

2.4 Occupancy

The township has a small proportion of permanent residents. The majority of houses are owned as a secondary residence, such as holiday houses or investment properties. During the summer period, some houses may be vacant or occupied by a non-owner.

Early on 25 December, warnings encouraged residents of Wye River and Separation Creek to evacuate. It is understood that impacted houses were vacated prior to the arrival of the fire and no lives were lost during the fire event.

2.5 House design and character

Schedule 1 to the neighbourhood character overlay of the Colac Otway Planning Scheme states:

The existing and preferred character of the township is characterised by buildings nestled within the often steep topography and the indigenous and native vegetation. The buildings sit below the tree canopy height, and there is sufficient space around them to accommodate substantial vegetation, as well as clearances required for wildlife management. The buildings are of varying low scale designs, but contain elements that respond to the coastal location including the predominance of non-masonry materials, metal roofing, balconies and transparent balustrades. Buildings typically have flat or single pitch roofs, and while often being two-storey or split level, they do not dominate the surrounding. A lack of or transparent styles of fencing enables the vegetation to flow across the boundaries and between public and private domains, and roads with unmade edges add to the informal feel of the township.

Largely, this preferred character is present in the development of the townships of Wye River and Separation Creek. This is true of older buildings that have influenced the specification of the overlay, as well as new buildings, which have adhered to the specified character. Native vegetation is contiguous throughout, fences are uncommon, open decking and balustrades abound and natural timber cladding is frequently used.

Building design varies significantly depending on the age of the building and the slope of the block. Although masonry buildings are uncommon, a wide variety of cladding, roofing and framing materials are used. Slab on ground construction is uncommon, partly influenced by the neighbourhood character overlay and partly by the impracticality given the steep slopes. In most cases houses are designed with suspended timber flooring, where supports are provided by either steel or timber piers, with one corner or side of the floor closer to ground level.

It is also worth noting the township is subject to the 10/50 vegetation management rule provided by the state planning system as well as a wide range of planning and zoning overlays, listed in Figure 7.

Planning Zone:	TOWNSHIP ZONE (TZ)
	SCHEDULE TO THE TOWNSHIP ZONE
Planning Overlays:	BUSHFIRE MANAGEMENT OVERLAY (BMO OR WMO)
	DESIGN AND DEVELOPMENT OVERLAY (DDO)
	DESIGN AND DEVELOPMENT OVERLAY - SCHEDULE 4 - WEATHER PROTECTION (DDO4)
	EROSION MANAGEMENT OVERLAY (EMO)
	EROSION MANAGEMENT OVERLAY - SCHEDULE 1 (EMO1)
	NEIGHBOURHOOD CHARACTER OVERLAY (NCO)
	NEIGHBOURHOOD CHARACTER OVERLAY - SCHEDULE 1 (NCO1)
	SIGNIFICANT LANDSCAPE OVERLAY (SLO)
	SIGNIFICANT LANDSCAPE OVERLAY - SCHEDULE 2 (SLO2)

Figure 7: Planning zones and overlays relevant to the Wye River and Separation Creek townships.

These provisions are likely to interact with the ability to implement various bushfire mitigation measures.

2.6 House maintenance

2.6.1 SUBFLOOR AREAS

Given the steep slopes, a large proportion of the houses (including those built to recent regulatory standards) within the fire-impacted area project out from ground level with exposed subfloors. This creates the opportunity for storage of heavy fuels such as plastic water tanks, building materials, small garden sheds, boats and kayaks (Figure 8). Sheds underneath houses are common because of the steep slopes. This is of particular interest because current building and planning requirements do not respond to the presence of these fuel types.

Figure 8: A house on Wallace Street, Wye River which was not impacted by fire showing under house fuel loading.

The steep terrain also means retaining walls are prominent throughout the fire-impacted area. A large proportion of these are constructed using timber sleepers (Figure 4).

2.6.2 TOWN GAS SUPPLY

The townships of Wye River and Separation Creek have no natural gas supply. Liquefied petroleum gas (LPG) pressure vessels are common and are usually situated close to houses.

3 Fire weather context

The month of December 2015 was the sixth-warmest month for nationally-averaged mean temperature on record in Australia, according to the Australian Bureau of Meteorology (BOM) monthly weather review [5]. The nearest automatic weather station (AWS) to the Wye River and Separation Creek townships, with available data, is at Aireys Inlet, 25 km to the east and Cape Otway AWS, 41 km to the west. For each station, half-hourly weather records are available. The relative humidity and temperature on the day preceding and on the day of the fire (24 and 25 December) is shown in Figure 9 (Aireys Inlet) and Figure 10 (Cape Otway).

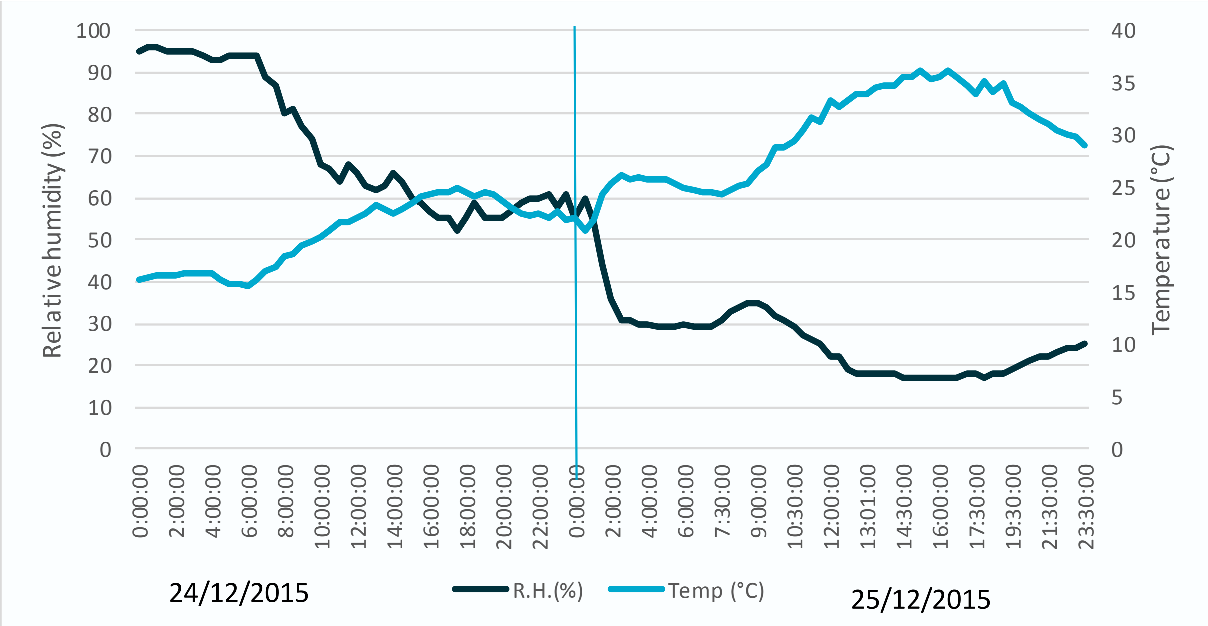

Figure 9: Half-hourly observations of relative humidity and temperature recorded at the Aireys Inlet AWS (90180) on 24 and 25 December 2015.

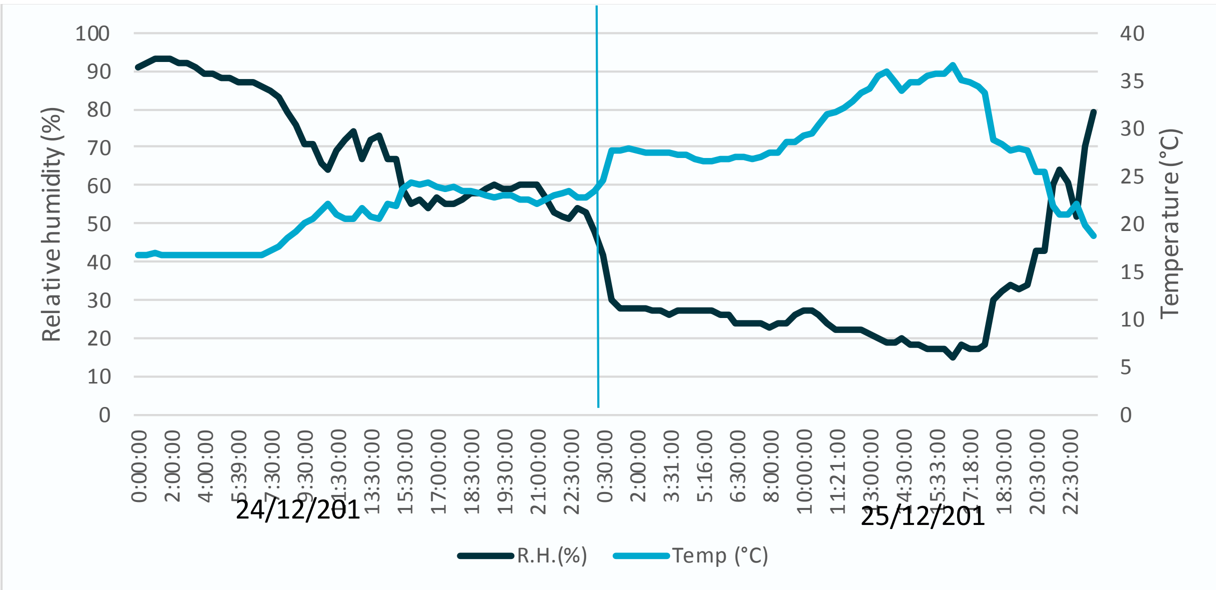

Figure 10: Half-hourly observations of relative humidity and temperature recorded at the Cape Otway AWS (90015) on 24 and 25 December 2015.

Both Figure 9 and Figure 10 show cool, damp early morning conditions on 24 December with the humidity approaching 95%, followed by moderate daytime conditions where temperatures approached 25°C and 50% relative humidity. As the day progressed into evening, the conditions persisted until just after midnight when the temperatures at both stations rose and humidity levels dropped. This coincides with a swing in the wind direction to a northerly and an elevation in wind speed. The conditions persisted for the rest of the morning, with a further increase in temperature and reduction in relative humidity as the day progressed. With the warm and dry overnight conditions preceding the fire event, fuel elements within the townships would not have regained the moisture lost during the daylight hours of 24 December and would have continued to dry throughout the day of 25 December prior to the arrival of the fire. The wind speed and direction profiles are shown in Figure 11 and Figure 12.

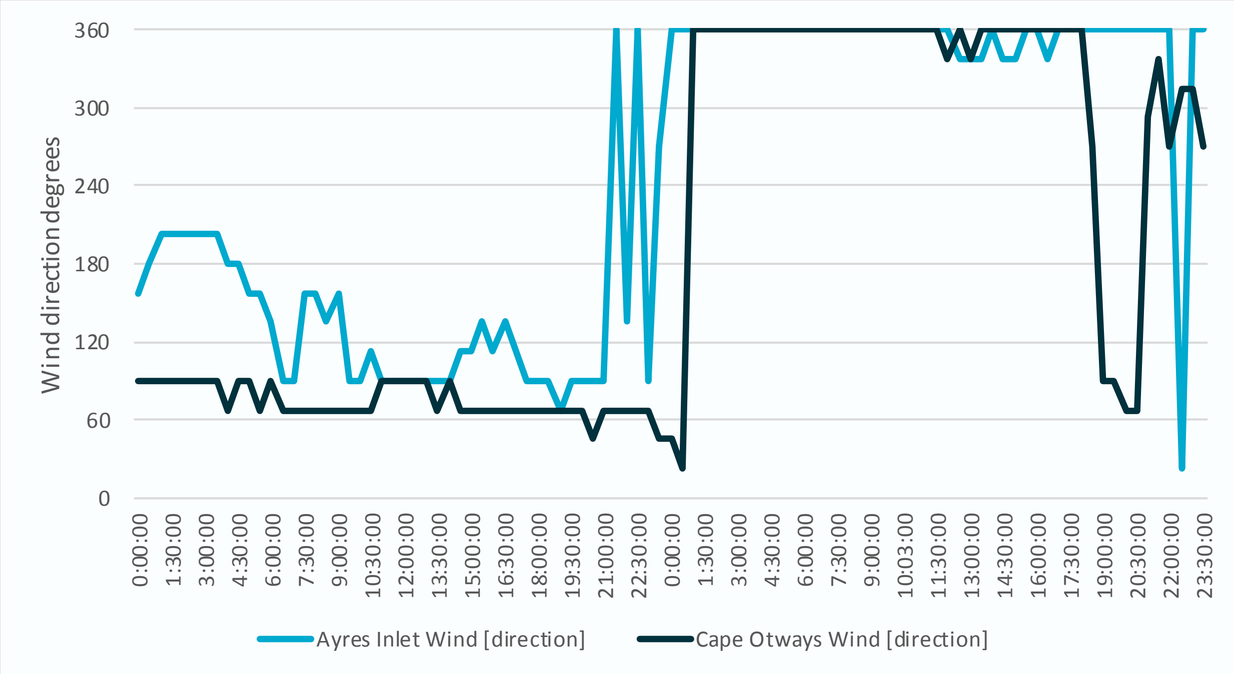

Figure 11: Half-hourly observations of wind direction recorded at the Cape Otway AWS (90015) and Aireys Inlet AWS (90180) on 24 and 25 December 2015.

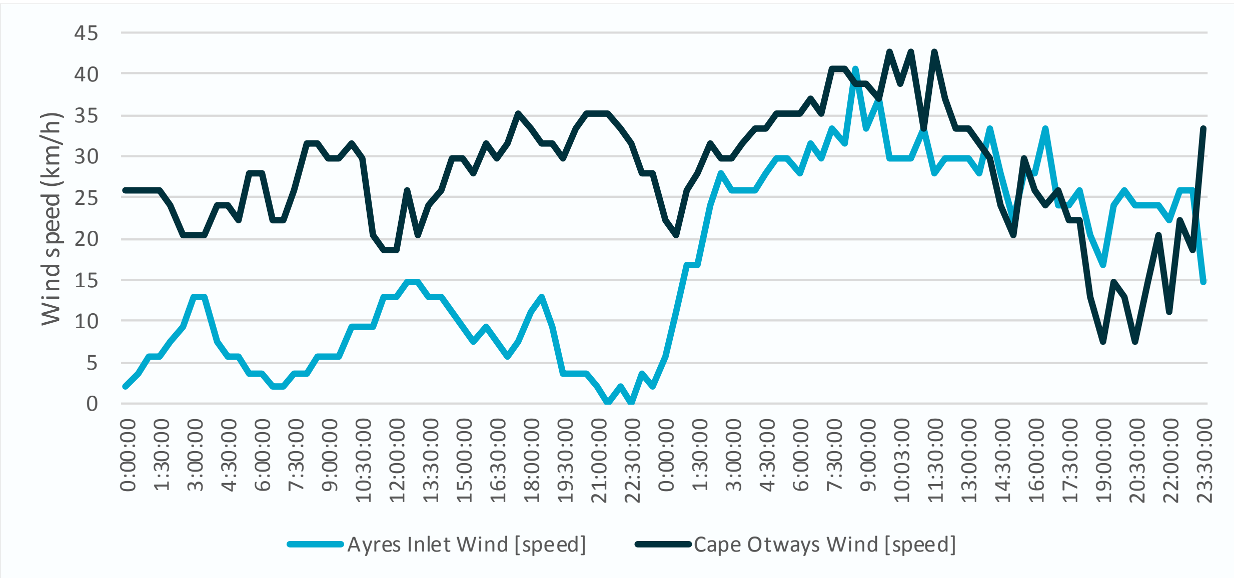

Figure 12: Half-hourly observations of average wind speed recorded at the Cape Otway AWS (90015) and Aireys Inlet AWS (90180) on 24 and 25 December 2015.

Based on AWS data from Aireys Inlet (90180), Cape Otway (90015) and Lorne (90185), the rainfall for the Wye River region was well below (-42%) the December state average (see Figure 13 and Table 1). In the calculation of long-term fuel dryness, only rainfall in excess of 5 mm is considered enough to increase long-term fuel moisture.[1] The first 5 mm of any rainfall event is assumed to be lost due to canopy interception and subsequent evaporation. None of the AWS rainfall data indicated an event exceeding 5 mm in the month leading up to the bushfire. The AWS data resulted in a Keetch–Byram [6] Drought Index (KBDI) of 80 at Aireys Inlet (90180) and 83 at Cape Otway (90015) on the day of the fire. These levels are considered 'serious' with respect to fuel ignition potential[2] and led to a drought factor of 9.3 for input into Forest Fire Danger Index (FFDI) calculations. These low soil moisture levels mean that fuel elements adjacent to or in contact with the soil will also be at low moisture levels.

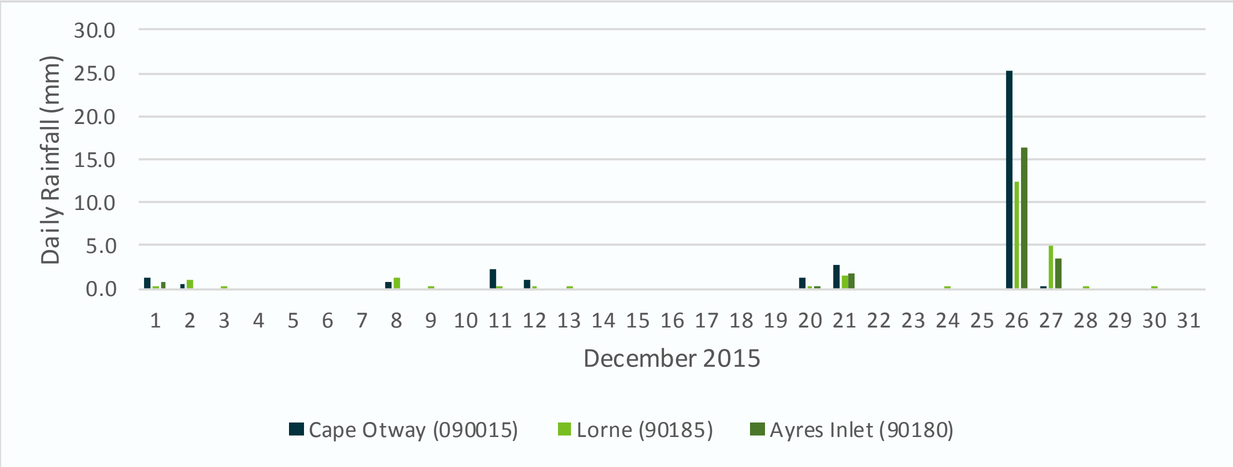

Figure 13: Daily rainfall[3] (mm) for December 2015.

Table 1: Monthly rainfall[4] and summary statistics.

	Aireys Inlet (90180)	Cape Otway (90015)	Lorne (90185)
December 2015 – Total rainfall (mm)	22.6	35.4	23.4
Summary statistic all year (December)			
Mean	39.8	52.9	71.4
Lowest	13.8	2.6	15
5th percentile	18.7	14.3	21.3
10th percentile	20.6	20.3	23.4
Median	35.8	45.8	65.6
90th percentile	56.4	90.1	126.7
95th percentile	72.4	106.4	154
Highest	120.2	153.7	204.4

[1] http://www.dfes.wa.gov.au/safetyinformation/fire/bushfire/BushfireInfoNotesPublications/DFES-InfoNote-WhatisKBDI.pdf (accessed March 2016).

[2] The values of the KBDI ranges. The KBDI scale ranges from zero, where the soil is saturated with water, to 200, the wilting point for vegetation.

0–24 mm Mild
25–62 mm Average
63–100 mm Serious
101–200 mm Extreme

[3] Observations of daily rainfall are nominally made at 09:00 local time and record the total for the previous 24 hours. Rainfall includes all forms of precipitation that reach the ground, such as rain, drizzle, hail and snow. http://www.bom.gov.au/climate/data/ (accessed March 2016).

[4] The monthly rainfall is the total of all available daily rainfall for the month. Observations of daily rainfall are nominally made at 09:00 local time and record the total for the previous 24 hours. http://www.bom.gov.au/climate/data/ (accessed March 2016).

On 25 December, the temperature in the Wye River area reached approximately 36°C at around 16:30, with a relative humidity of 17% (Figure 9). Wind was blowing from a north/north-westerly direction with gusts of nearly 33 km/h. Based on temperature, relative humidity, wind speed and KBDI data, the FFDI reached a peak at 16:30 of 49 in Aireys Inlet and 43 in Cape Otway (Figure 14). At a FFDI of 49 the weather condition are considered to be at a fire danger rating of 'Very High'.

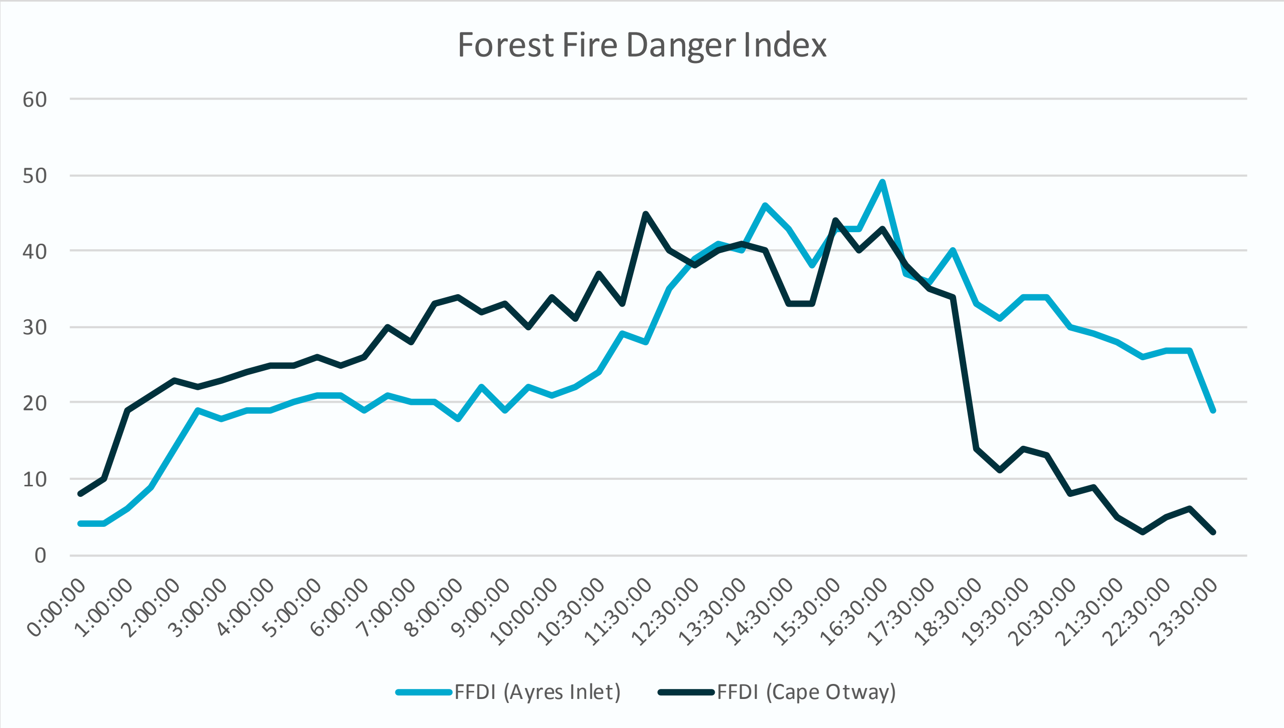

Figure 14: FFDI on 25 December 2015 based on the Aireys Inlet and Cape Otway AWS data.

4 Fire arrival at the townships

A composite of thermal line scan imagery (Figure 15) shows the progression of the fire on 25 December through the region surrounding Wye River and Separation Creek. The time of impact with the townships occurred between the first scan, taken at 13:20, and the second, at 15:50.

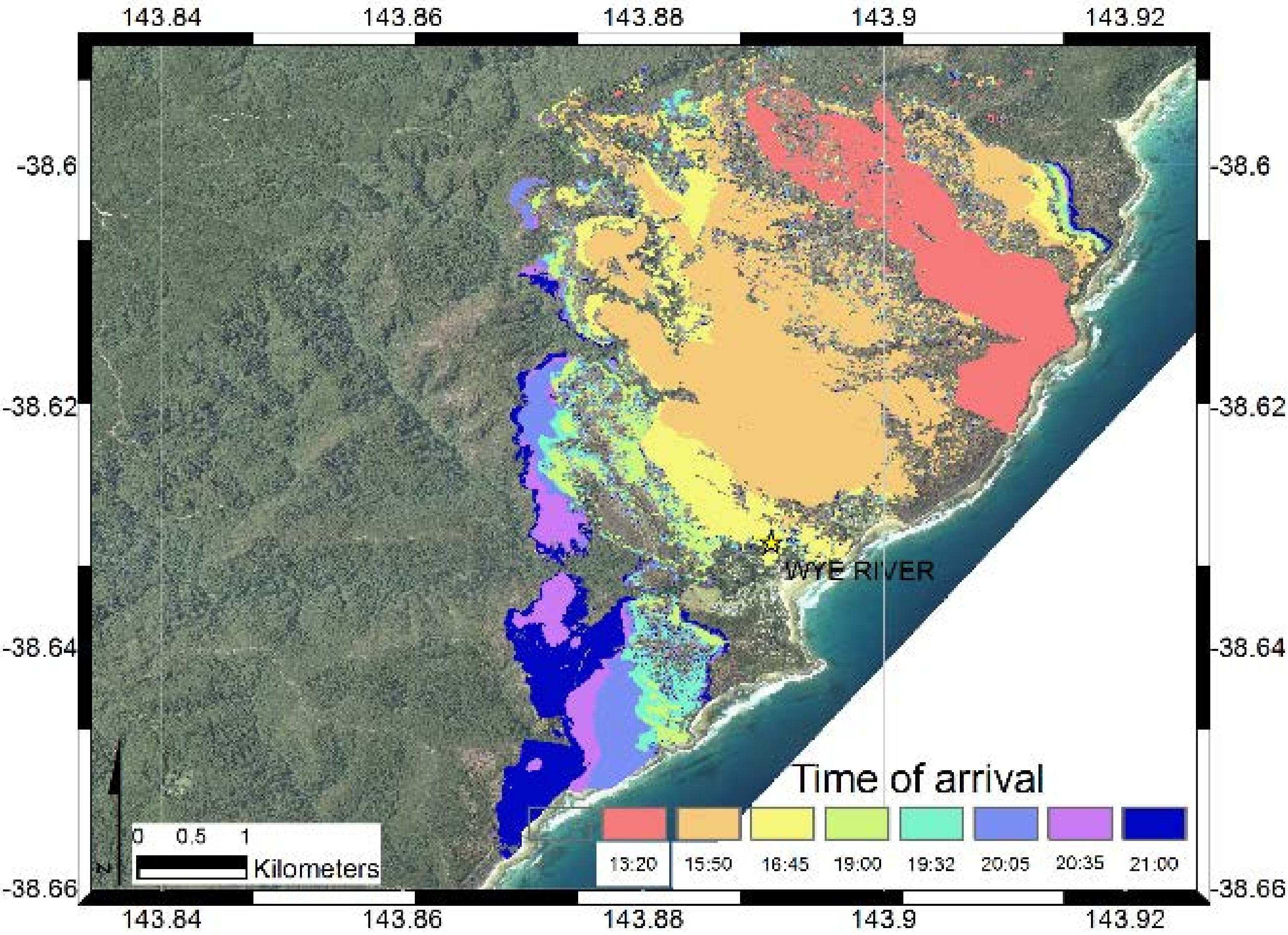

Figure 15: Time of arrival as derived from thermal line scan imagery.

Separation Creek was the first area impacted by fire. The fire arrived in the Separation Creek township by a number of point ignitions from airborne embers. The fires that developed from the ignition points grew within the township with a tendency to spread upslope and back towards the advancing fire front.

At 15:07:40 five spot fires were active within Separation Creek. One of these developed below the corner of Bass Avenue and Harrington Street, and a further four developed in the vicinity of Mitchell Grove. These spot fires are indicated by the blue arrows in Figure 16.

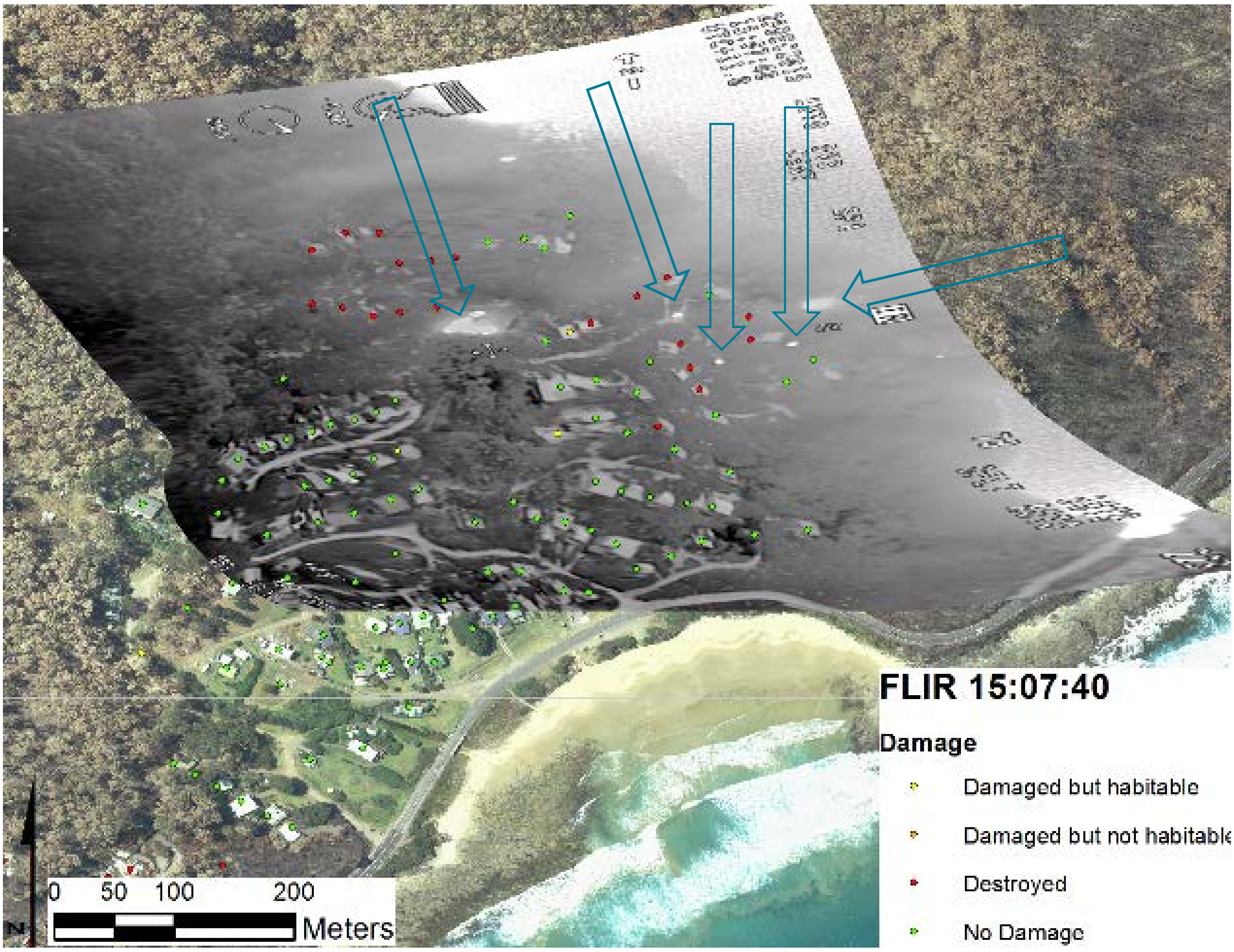

Figure 16: 15:07:40 Separation Creek fire arrival.

Figure 17 is a similar image one minute later showing the development of these spot fires and a further break out (marked with a blue arrow) in a vacant block on Olive Street approximately 400 metres ahead of the advancing fire front. The fire below the corner of Bass Avenue and Harrington Street was in a densely vegetated gully. The fire spread rapidly upslope towards the approaching main fire front. It appears that the smoke from each of these fires was drawn east towards the approaching fire front.

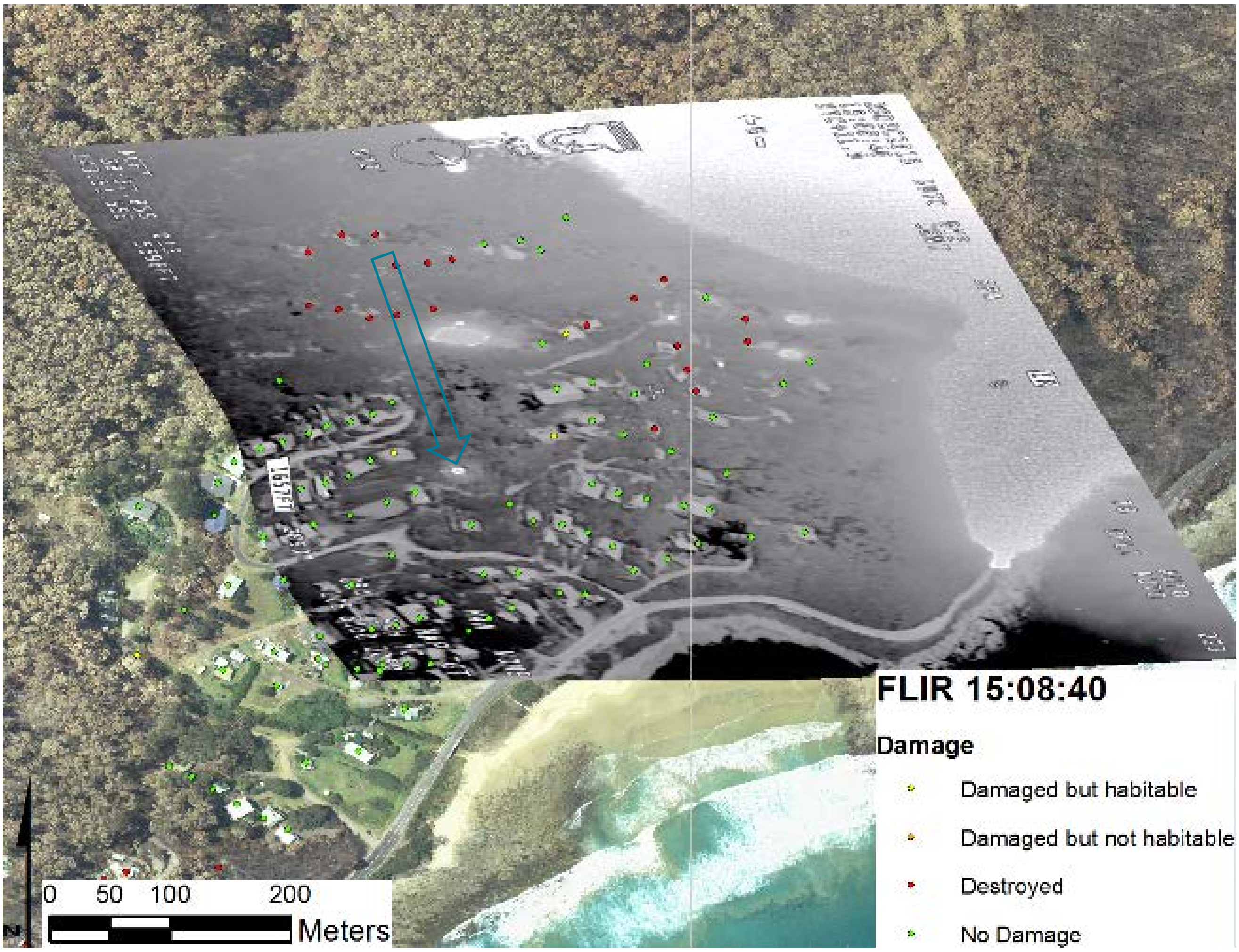

Figure 17: 15:08:40 Separation Creek fire arrival.

Figure 18 shows the same scene seven minutes later. All of the spot fires developed rapidly and were drawn back towards the advancing fire front. The fires near Mitchell Grove appears to also have developed rapidly. A new spot fire has developed adjacent to Bass Avenue and is marked by a blue

arrow. The spot fire identifed by the blue arrow in Figure 17 adjacent to Olive Grove has developed the most rapidly most likely due the a cobmination of slope and vegetation structure.

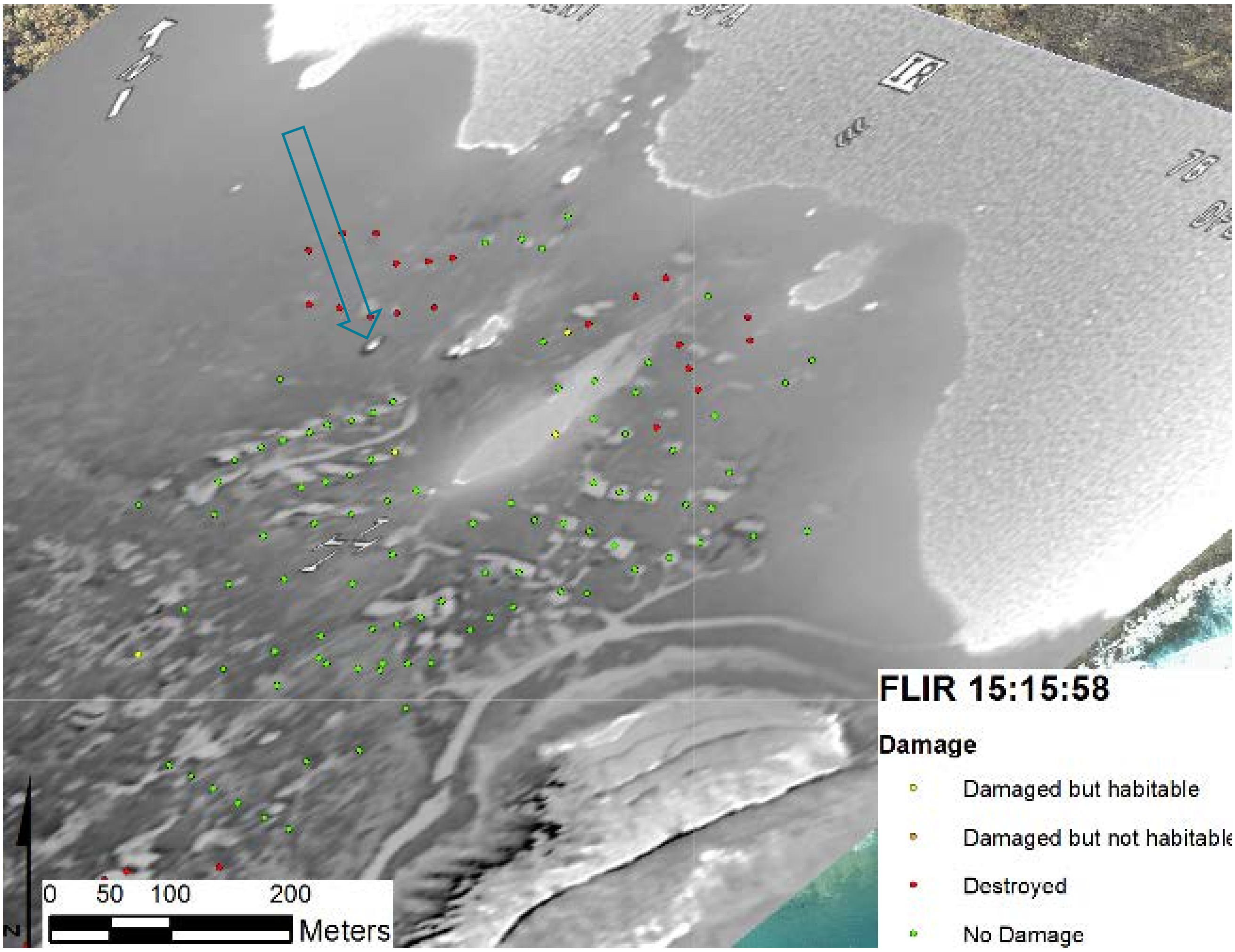

Figure 18: 15:15:58 Separation Creek fire arrival.

5 Observations of fire spread within the townships

This section provides observations of fire progression using a combination of fire line scans and forward looking infrared (FLIR) imagery. An explanation of the nature of these line scans and how they were created can be found in Appendix B

The first line scan, taken once the fire had arrived in the townships at 15:50, is shown in Figure 19. The fire front arrived at the back of Separation Creek and started to burn downslope and merge with developing spot fires within Separation Creek. This fire activity appears to involve multiple houses.

The first spot fires developed along the ridge behind the perimeter of the Wye River township, adjacent to houses, a few hundred metres ahead of the advancing fire front.

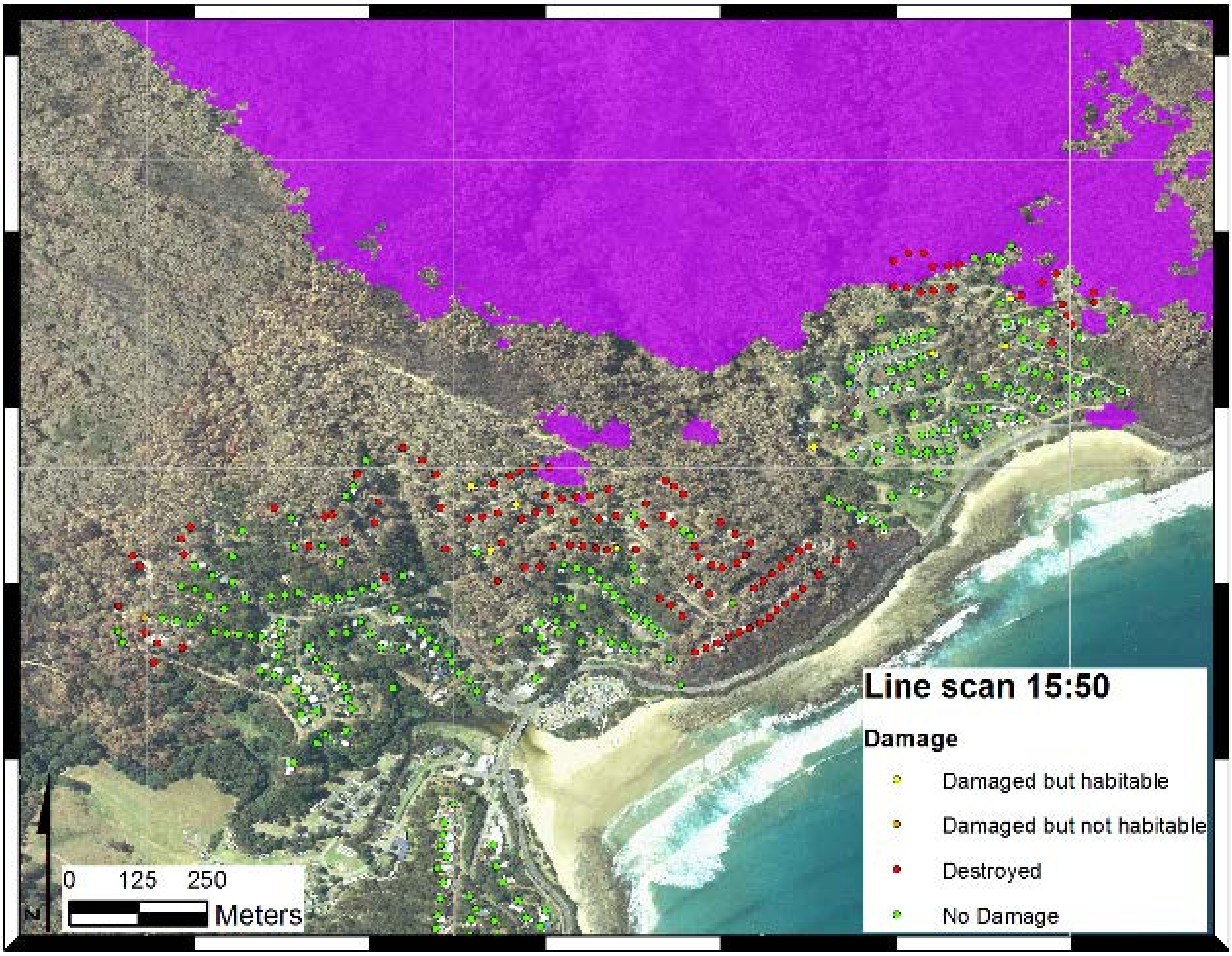

Figure 19: 15:50 Line scan.

Figure 20 is the second line scan taken 55 minutes later. The scan shows that the fire front moved past Separation Creek, with heat signatures evident from many of the burning houses in Separation Creek. Five additional spot fires seem to have developed within Separation Creek that appear to have led to some house damage but no complete losses, possibly due to the fire-fighting activities around these isolated spot fires. The main heat signatures are from the combustion of houses within Separation Creek, indicating that nearly all houses lost in the region are at this time ignited. The two regions where extensive house losses occurred would most likely have been too difficult to access due to the large number of simultaneous house fires in close proximity.

This line scan (Figure 20) also shows the Wye River township in the middle of a fine fuel burn through phase. The combination of ground observations and this image suggests that the area was impacted with embers emanating from behind the township, creating many simultaneous ignitions of surface fuels throughout the fire-affected areas of the Wye River township. This mass ignition and rapid fine fuel spread would have presented a major hazard to fire fighters and residents (if present) in this region. The foreshore area below Iluka Avenue (marked with a blue circle) appears to have developed from a series of spot fires that merged and ran upslope into and past houses along the street.

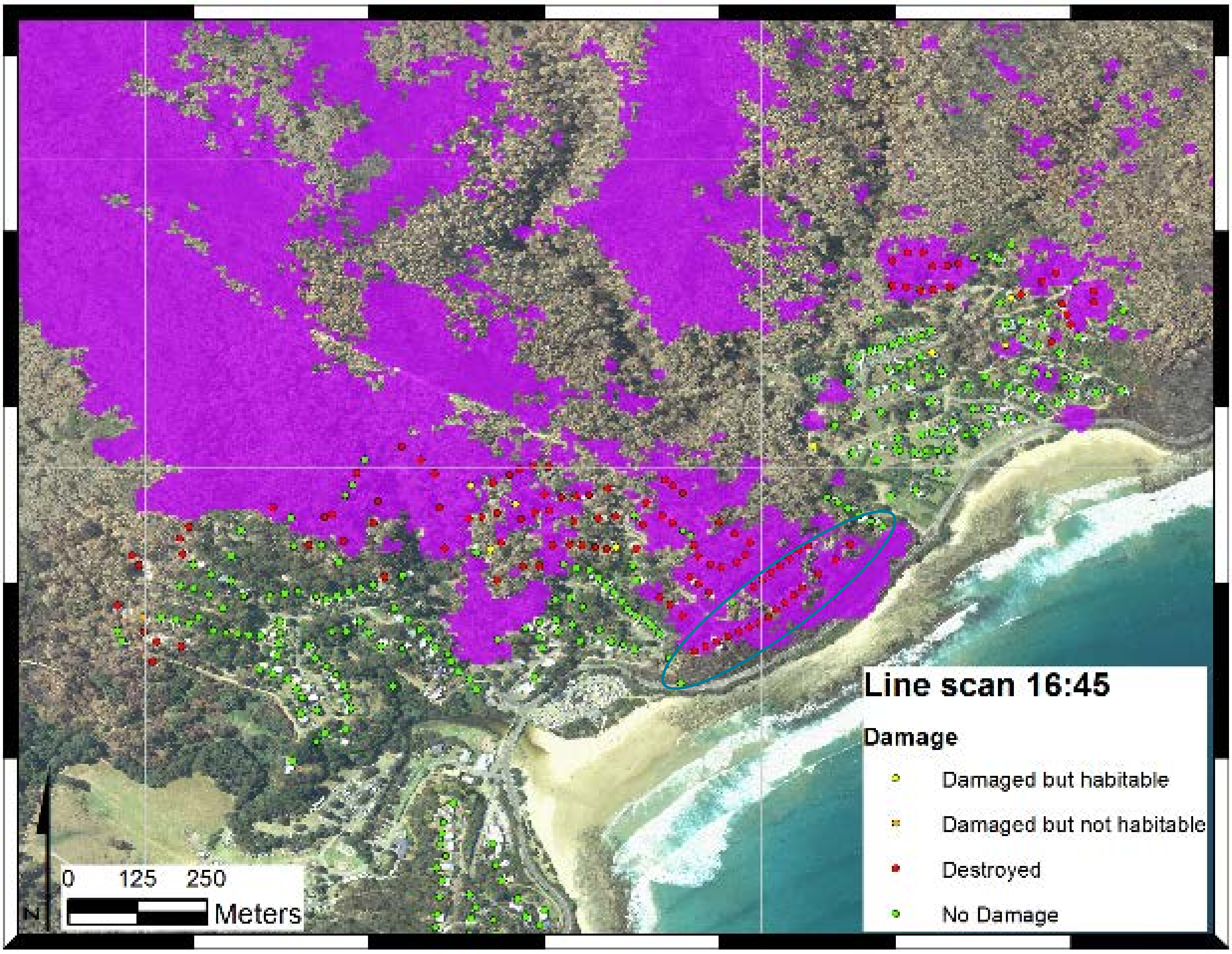

Figure 20: 16:45 Line scan.

Figure 21 is a pre-fire image of this region highlighting the extent and separation distance between the houses and vegetation. The slope in this coastal vegetation is such that flame fronts formed against the prevailing wind with enough intensity to generate radiation levels and possible flame contact sufficient to ignite houses.

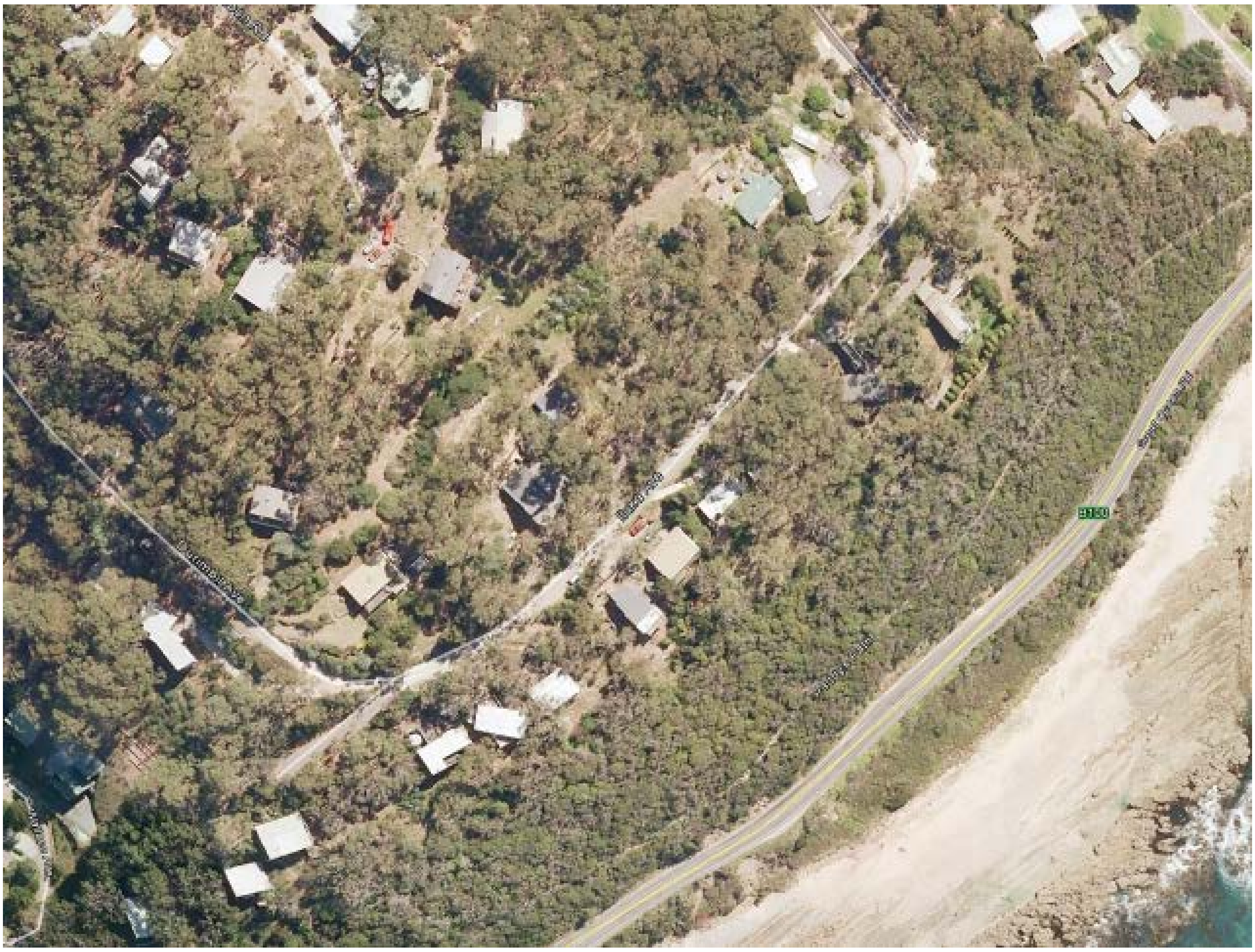

Figure 21: Image showing the location of Iluka Avenue and coastal vegetation ignited by embers.

Figure 22 shows an FLIR image take at 18:00, approximately one hour and fifteen minutes later. This image was used in the absence of any available line scan data during this period. The image shows extensive heat signatures in the areas of house loss in the Separation Creek and Wye River townships. The completion of fine fuel burn out appears to have occurred in some areas of the Wye River township, while other areas show broad scale fire activity. The region below and along Iluka Avenue shows strong fire activity, suggesting that all houses were well alight while fuels along the foreshore were still burning out. It should be noted that the FLIR image in Figure 22 provides a more sensitive heat signature than in the line scan images provide before (Figure 20) and after (Figure 24).

Figure 22 also identified fire progression to involve some additional houses in the westerly extent of the image and new spot fires forming in this region, indicated by a rectangle.

The FLIR image in Figure 23 provides a close up of a spot fire within the blue circle in Figure 22. This isolated spot fire did not develop further to impact houses and may have been supressed by aerial or ground crews. Figure 23 also shows a number of airborne embers, which had already travelled more than two hundred metres from nearby fire fronts.

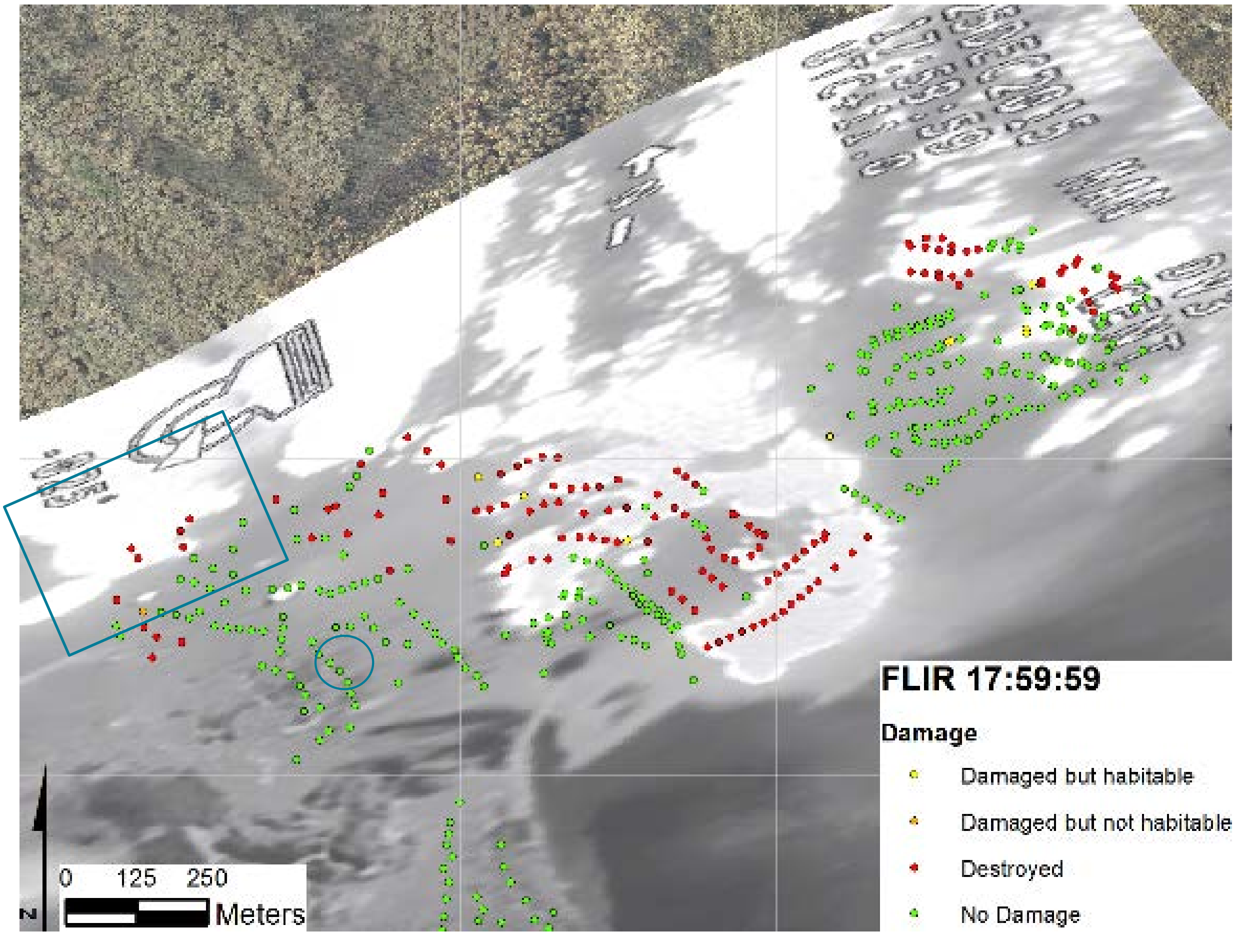

Figure 22: 18:00 FLIR image.

Figure 23: 18:01 Greyscale forward looking infrared (FLIR) imagery showing a spot fire igniting behind a row of houses. Darker colours are cooler (e.g. water bodies) and white colours represent significant heat.

Figure 24 was taken one hour later at 19:00. The scan shows clear heat signatures from nearly all burning houses in Separation Creek but the more defined and isolated patches indicate a reduction in overall intensity.

The fine fuel burnout phase had also passed the Wye River township except in the westerly extent, where there is a heat signature over a broad area including areas where houses were lost; these may have already ignited or were in the process of being ignited. At this stage nearly all of the fire affected houses in Wye River appear to be either ignited or were in the advanced stages of burning out.

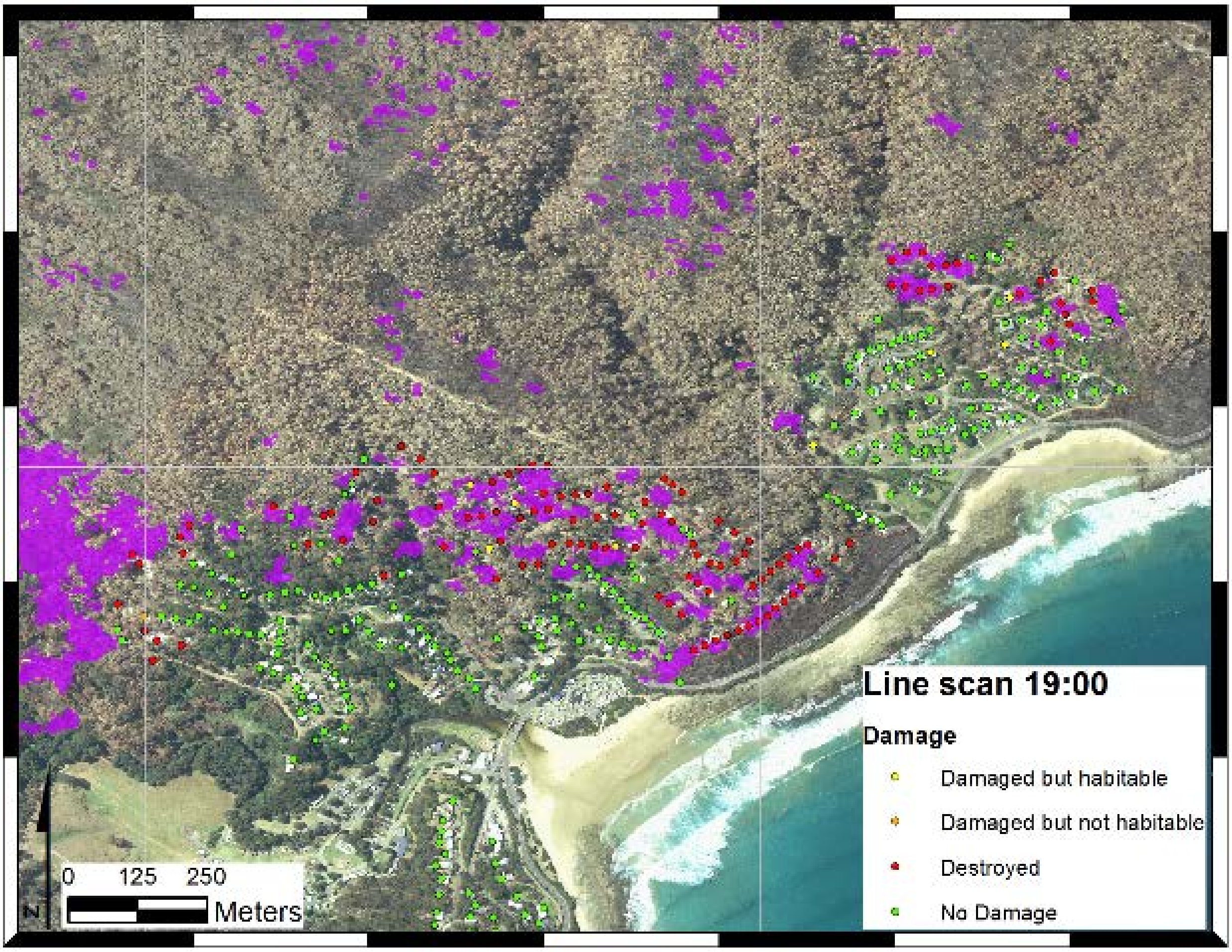

Figure 24: 19:00 Line scan.

Figure 25 was take at 19:32, 32 minutes later. This shows that all fine fuel burn out was complete with heat signatures present for nearly all houses that were lost in the fire event. These heat signatures continued to reduce in size except for those in the westerly extent of the image.

Figure 26, Figure 27 and Figure 28 show the progressive completion of burn out of all structures.

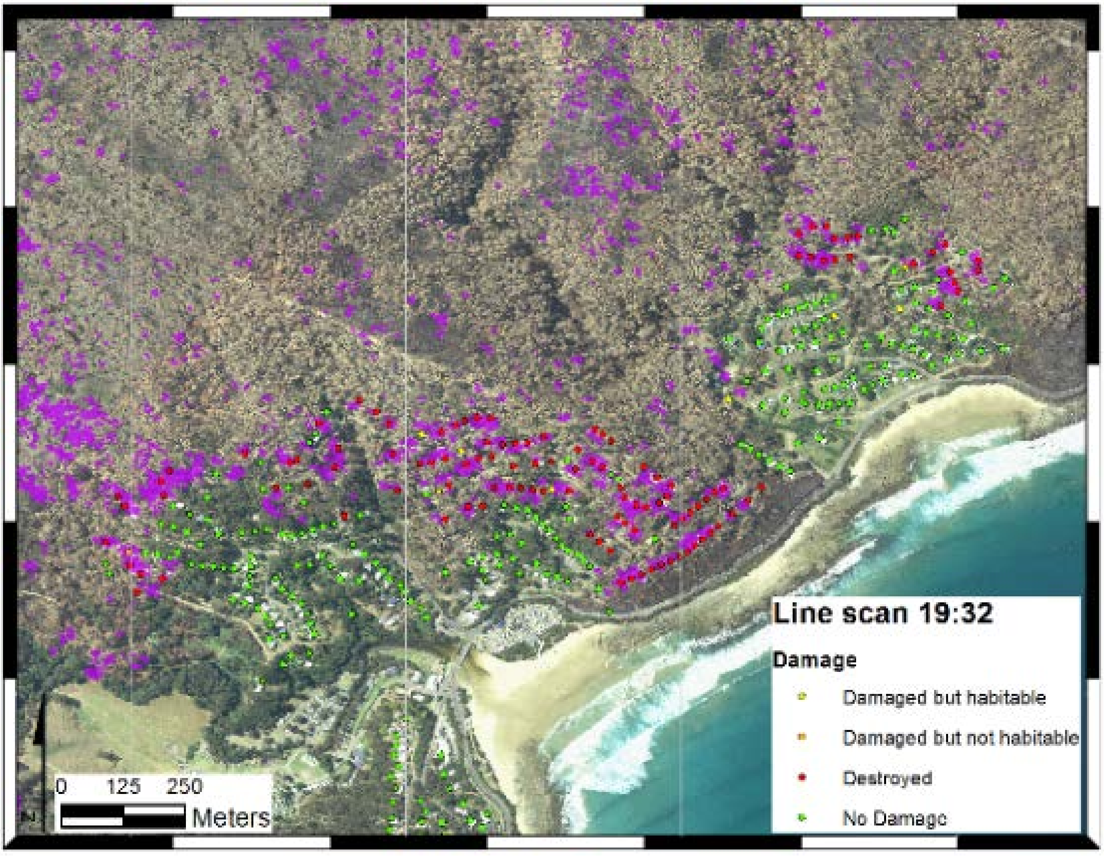

Figure 25: 19:32 Line scan.

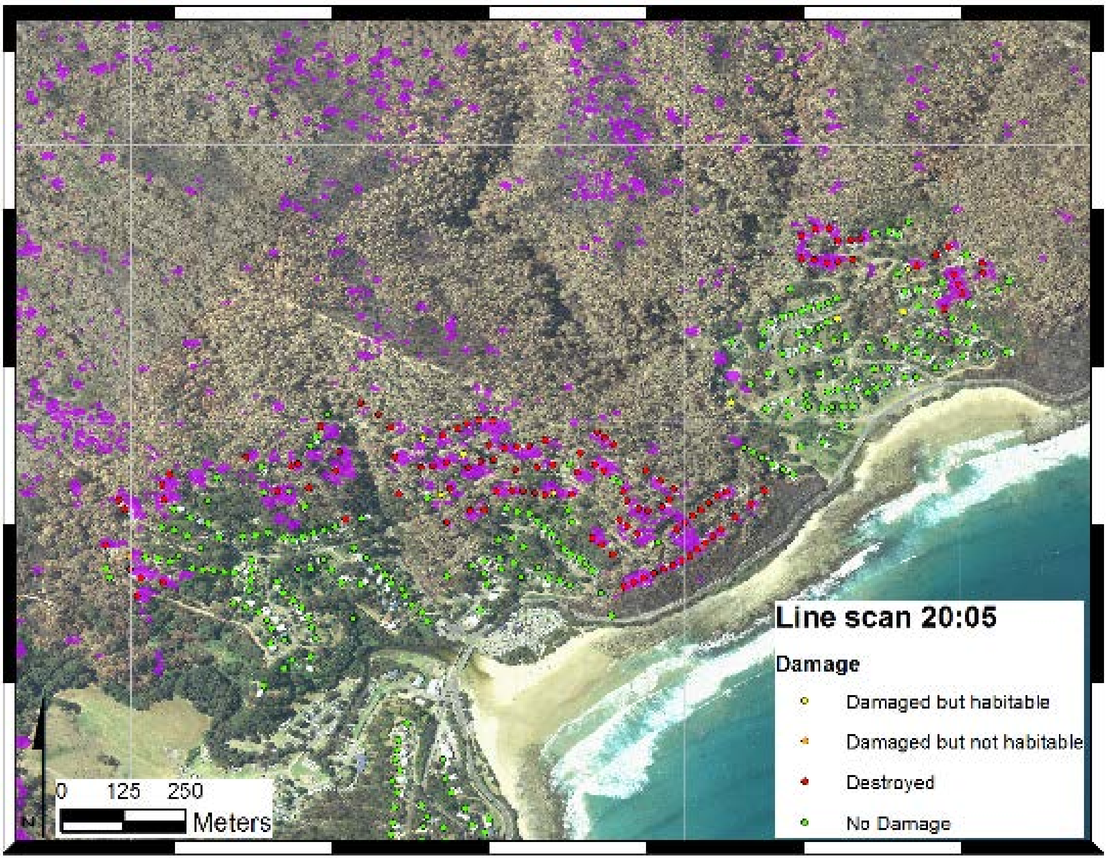

Figure 26: 20:05 Line scan.

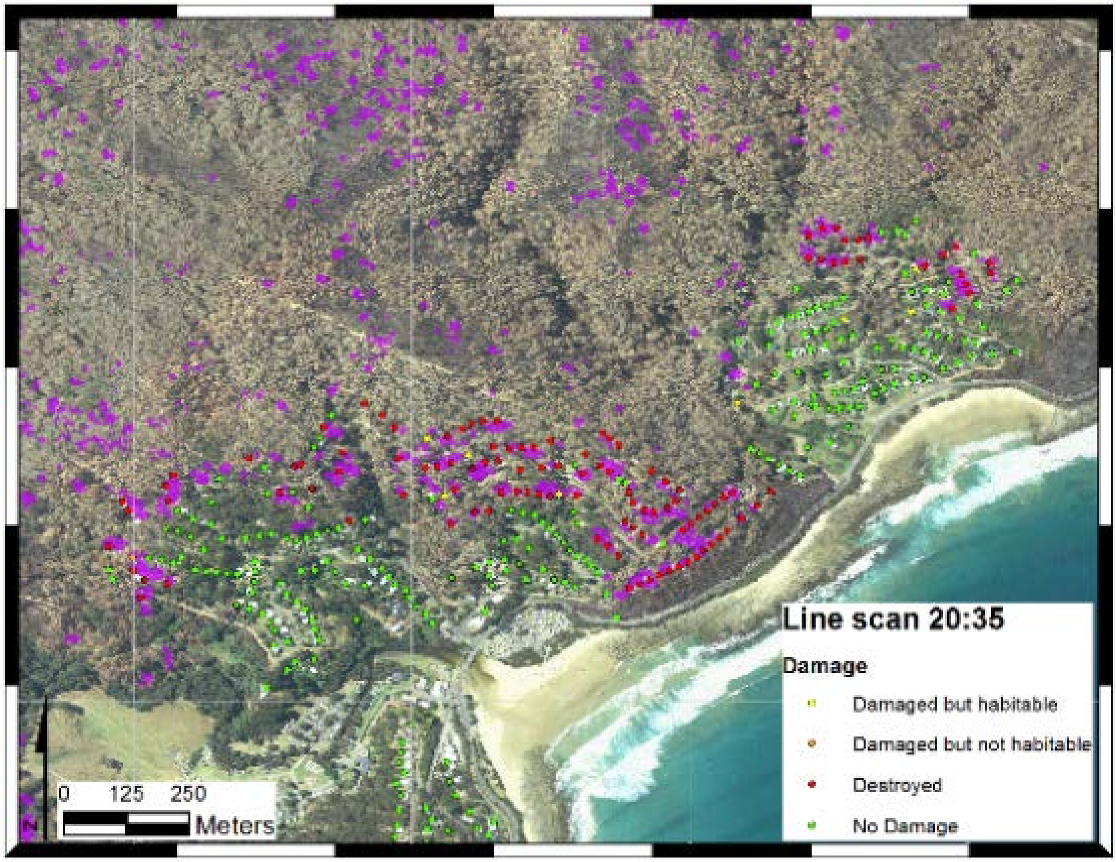

Figure 27: 20:35 Line scan.

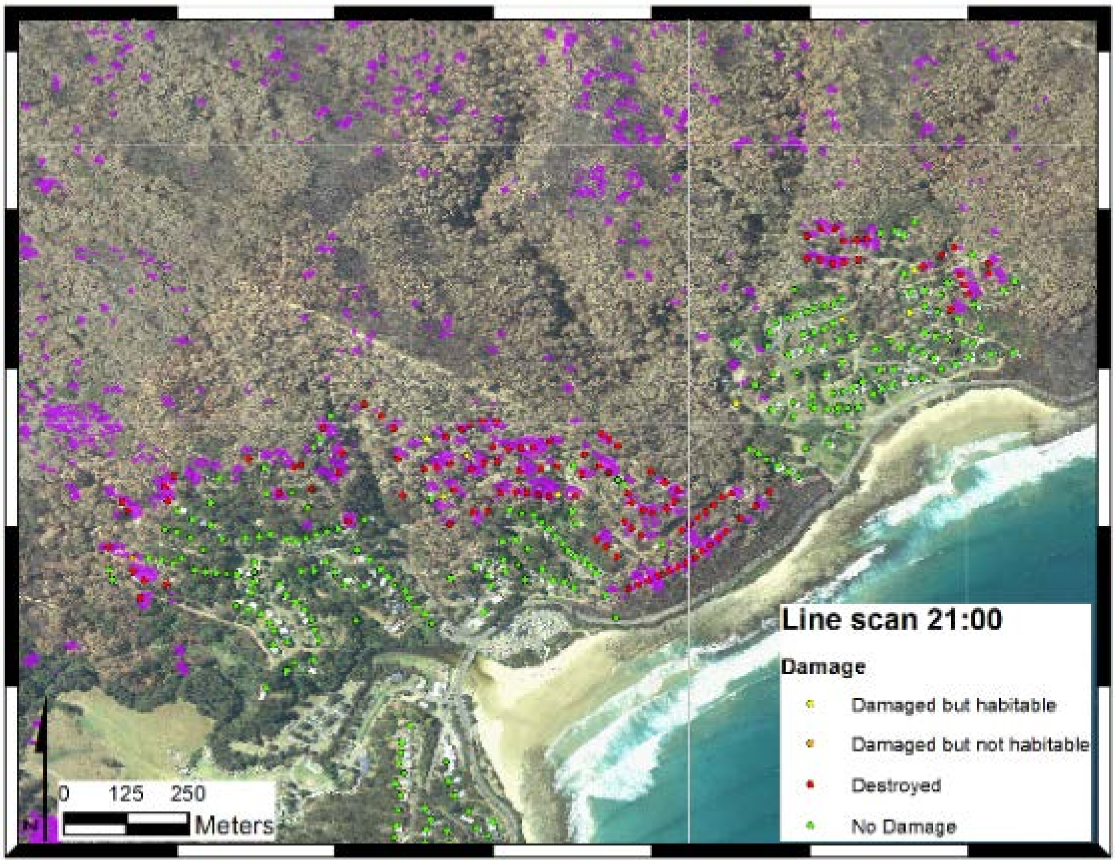

Figure 28: 21:00 Line scan.

6 Observations of house impact

Post-fire surveys were conducted throughout Wye River and Separation Creek by the CSIRO, the Victorian CFA, DELWP and local Council. The survey teams focussed on the collection of evidence of fire arrival at houses built to bushfire specific building and/or planning regulations in the impacted area. Signs of high fire severity were observed, such as indications of radiant heat load to buildings. Vegetation scorch and leaf freeze (scorch of wind-blown foliage) around these houses was also observed as an indication of the direction of fire spread, which was predominantly upslope towards and past buildings.

In the days preceding 25 December, the bushfire burned towards Wye River in native bushland to the north-west. Even though the winds responsible for driving the fire towards the township on the day of the fire came from the north or north-east, surveys did not reveal any evidence of a fire front arriving from this direction and interacting directly with structures. It appears that terrain and coastal wind effects around the township meant that spotting ahead of the approaching fire fronts ignited and burnt back upslope towards the approaching fire, reaching the perimeters of the townships before the approaching fire front.

Fire-impacted areas of Wye River and Separation Creek were typically the steepest areas, which reach gradients approaching 30 degrees (Figure 29).

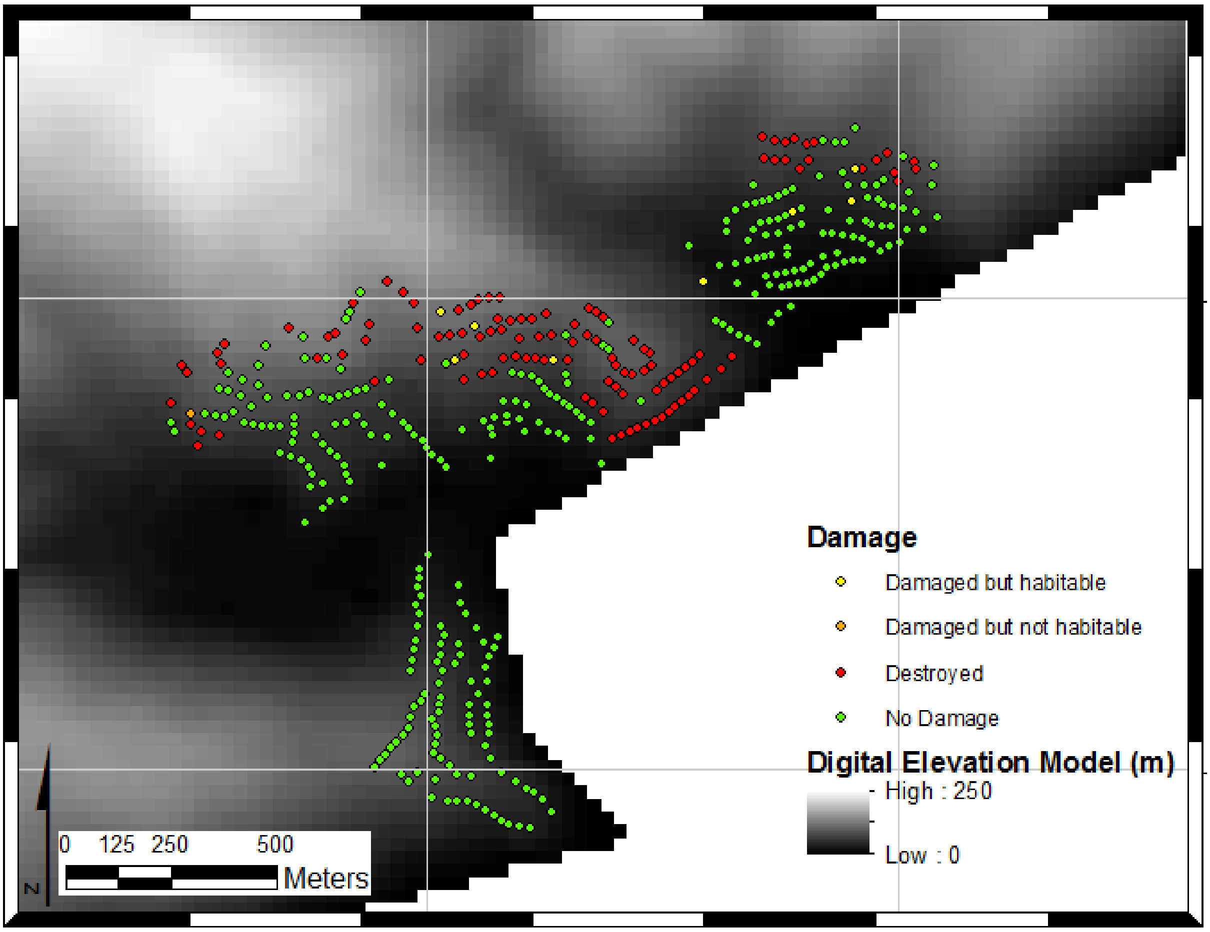

Figure 29: Digital elevation model for the townships of Wye River and Separation Creek showing house damage (based on Shuttle Radar Topography Mission (SRTM) data).

Fire ignited by spotting spread uphill and more slowly spread laterally across the slope, supported by surface and near surface fuels. Leaf freeze observations throughout the affected areas confirmed that the dominant fire direction was upslope, indicating that below the canopy the convection force of the fires was stronger than ambient wind effects. There were localised areas below Iluka Avenue Wye River and along creek lines where flames involved elevated fuels, supporting significant flame heights. Other than these areas, the average solid body flame heights within the township appeared to be typically less than 0.4 metres. As detailed in Section 5 the fine fuel burnout phase followed a mass spotting event hence rapidly involved an extensive area without any clear indication of fire arrival and progression. This circumstance would make it particularly hazardous for a resident to plan an exit path for ground crews to safely or effectively manage fire ignitions and subsequent spread.

Ground observations identified that most houses were impacted by either surface fire or the subsequent heavy fuel element burn out. The ground fire spread involved surface fuels and near surface heavy fuel elements. Generally, the solid body flame height appears to have been up to 0.4 metres from these surface fuels. Some secluded gullies within the township burnt with higher intensity, but these fire runs did not impact buildings. The houses along Iluka Avenue appear to have been the only houses affected by a higher fire severity from adjacent vegetation. As the extensive fine fuel fires ignited heavier fuel elements and houses the risk of flame impact, radiation exposure and smoke exposure would not have abated and in many areas would have increased in severity.

Many examples of destroyed timber retaining walls surrounded impacted houses (Figure 30). Combustible materials were an obvious factor in their low survival rate, as were the low soil moisture levels described in Section 2. It is likely that combustible retaining wall elements in contact with soils were also low in moisture content at the time of fire arrival, leading to a higher likelihood of ignition, more severe combustion and more extensive timber burn out.

Where timber (in particular treated pine) retaining walls were in contact with or within a few metres of a building, their combustion is likely to have contributed to house loss. Figure 30 provides an example of a large timber retaining wall that was burnt out.

Figure 30: Driveway off Karingal Drive, Wye River. An example of burnt out timber retaining wall sleepers.

Where treated pine is used there is also the risk of toxic smoke emissions during the fire and toxic ash residue on the ground and blown by the wind after the fire. Timber retaining walls also provided a direct threat to buildings, or subsequent ignition or heat exposure to other adjacent elements, such as LPG pressure vessels. LPG pressure vessels are common in the townships and generally were observed to have vented, as they are designed to do when overheated. There were a few instances where these cylinders appear to have vented towards structures and are likely to have contributed to the loss of the house. An example is provided in the case study in the appendix in Section A.2.4, where pressure vessels vented towards the house.

Strong evidence existed of house-to-house fire spread. This is not unusual once a fire impacts a township e.g. [7]. However, despite the generally large distances between buildings in the fire-affected area, house-to-house ignition appears to have still been a significant factor. There was clear evidence of damage and loss where houses up to 12 metres apart, including indications of high radiant heat levels. These distances are greater than is typically found in other post-bushfire studies. A key factor in house-to-house spread at these greater distances was due to the low wind speeds in the townships during and after the fire event. Houses at these distances emit radiant heat to adjacent houses, causing them to increase in temperature. The ambient winds act to cool the houses and limit the peak temperature of the adjacent houses. The lower wind speeds in this fire event were less effective at providing this cooling effect.

Fire in the heavier fuels stored under and adjacent to the houses subfloor area such as plastic water tanks, building materials, small garden sheds, boats and kayaks, also appears to have been a significant factor in many of the losses.

While extensive surface litter provided a near continuous flammable fuel bed, the built elements within the township represented the vast majority of the fuel load. Some of these built elements ignited by the initial spread of fire through surface litter fuels. The built elements then continued to burn for many hours, igniting other built elements. The extensive number of houses burning in the fire affected area would have meant that these areas would have been life threatening for any residence present as well as fire fighters.

To summarise, the primary progression of spread mechanisms involved:

- long distance spotting from the fire front outside the perimeters of the townships
- ignition of surface fuels below structures within the townships
- surface fire spread through fine surface fuels and near surface vegetation onto built elements.

It is interesting to note that localised ember spread within the townships was not as prevalent as other surveyed bushfire events involving house losses of more than 100 houses. This may be due to the relatively low wind speeds within the townships at the time of fire activity. The low wind speeds also appeared to exacerbate the prevalence of house-to-house ignitions at distances previously considered sufficient. These spread mechanisms supported the initial progression of fire within the townships and provided flame contact as follows:

- interaction between fine surface fuels and heavy fuel elements adjacent to houses
- interaction between fine surface fuels and combustible elements on the houses themselves
- interaction between fine surface fuels and LPG pressure vessels providing the potential for gas flares and explosions.

Heavy fuel elements then interacted with each other in the advanced stage of fire development within the township through the following mechanisms:

- flame contact from one heavy fuel element to another
- radiant heat transfer from burning heavy fuel elements to other nearby elements, e.g. retaining walls, fences or house cladding
- flame or radiant heat transfer to LPG pressure vessels providing the potential for a gas flares and explosions.

The interaction of fire with established tall trees also increased the risk of tree and branch strike because fire weakens knots and flaws in trees. Branch or tree strike, either on buildings or across roadways, is a common risk during and after bushfire arrival. While there was no direct evidence of tree strike onto houses subject to recent regulatory standards, evidence of direct tree strike either during or in the days following the fire event were apparent with some houses (Figure 31).

Figure 31: A house on Wallace St Wye River, subject to tree strike cause by fire interaction at the base of a tree.

A detailed set of case studies of fire impacted regulated houses is provided in Appendix A

7 House loss context

7.1 Suppression

Most affected buildings were not occupied when the fire impacted the area, because an extensive evacuation had taken place. A number of fire crews were active in the affected areas. A complete understanding of their locations and activities was not available at the time of compiling this report. The house surveys revealed evidence of some rake-hoe activity, direct suppression of buildings and modification of urban fuels (e.g. removal of doormats (Figure 32), relocation of 9 kg LPG pressure vessels).

Figure 32: An example of the removal of a doormat from a deck.

There was also evidence of extensive aerial water bombing activity throughout the affected areas. Indications included water wash marks (Figure 33 and Figure 34) on the landscape surrounding the houses and limited examples of house gutter deflection and other minor roof damage due to a sudden deluge of water.

Figure 33: Silt washed onto decking from an adjacent water drop

Figure 34: Vegetation between houses showing signs of water impact from water bombing

As detailed in Section 5, the conditions within the township presented a risk to any occupants present both during the initial fine fuel based fire spread and the following heavy fuel burn out phase. This risk would have provided many challenges to fire crews active in the township. The fine fuel based fire spread provided risks to crew of crew vehicle burnover on the narrow roads cut into the terrain, and the heavy fuel burn out phase involved an extensive number of houses with life-threatening radiant heat levels and toxic smoke at ground level. Steep slopes promoted smoke plume attachment to the ground, presenting a risk to fire crews attempting to use roads above houses that were actively burning.

7.2 Water supply

No reticulated water supply is available within the townships. Domestic water supplies to individual houses are typically provided via a pressure pump from tanks that are located under or adjacent to buildings. Houses built to fire regulatory standards were required to have between 5,000 and 10,000 litres of fire-fighting water available. However, this was dependent on lot size and when the dwelling was approved. For BMO houses, this requirement included the specification that tanks be non-combustible. Access to this water was often through a remote suction point. According to CFA accounts, access to this water during the fire was critical in their ability to control further spread of the fire through the township.

7.3 Extent of loss

Due to the nature of the fire spread within the townships there is a clear spatial delineation between those buildings that were impacted by the fire and those that were not impacted. Of the buildings within the fire area, roughly 80% were lost to fire.

8 Implications for regulation

The fire event raises a range of 'what if' questions around risks to life if there is insufficient warning or inclination for the building occupants to evacuate. While survival from low-level surface fire spread can be provided by sheltering in buildings, the risk of loss of life for those that need to evacuate buildings past other burning buildings and heavy fuel elements is high for all fire impact scenarios of these townships. This may require additional building and planning controls to limit the likelihood of house loss to an appropriate threshold and the prevalence of combustible heavy fuel elements along the egress routes in the townships.

8.1 Regulation

For context the paragraph below is the opening paragraph of the forward for AS3959-2009 [8].

This standard is primary concerned with improving the ability of building in designated bushfire-prone areas to better withstand attack from bushfire thus giving a measure of protection to the building occupants (until the fire front passes) as well as to the building itself.

There were approximately 80 planning referrals to the CFA in Wye River and Separation Creek, from as early April 2003. Both building and planning requirements have evolved significantly from 2003 to the present. There is a reasonable level of complexity in categorising these referrals to determine whether they resulted in an actual building and/or planning outcome. The nature and stringency of these outcomes has evolved over time, ranging from the requirement for stored water supplies to integrated sets of building and planning requirements.

These requirements can be broadly categorised into two categories: those that were built since the introduction of AS3959-2009 [8] revisions and those prior. To gauge the relative effectiveness of the two categories, a review of past building approvals was undertaken to determine which houses were completely built or upgraded to meet these regulatory standards. The review identified seven houses built to the AS3959-2009 [8] standard and fourteen to prior regulatory standards which were complete to the point of obtaining a certificate of occupancy. Other houses may have been largely complete but are not included in the analysis as minor construction details can have a major impact on building performance in bushfires. Of particular interest is the apparent performance of houses in these two categories as shown Table 2 below.

Table 2: Survival outcomes for AS3959-2009 and houses built to prior regulatory standards.

	Destroyed	Surviving
AS3959-2009	4	3
Prior to AS3959-2009	3	11

For both categories there appears to be a marginal improvement over the 80% loss rate experienced across the fire-affected area generally. The AS3959-2009 [8] category had a 57% loss rate and the category prior to these regulatory standards had a 21% loss rate. Given the low numbers in the sample this should be treated as a rough indication of the survival prospects of houses built to the recent regulatory standards under these exposure conditions, rather than as a definitive measure of performance. It is recommended that a detailed review of the changes around the construction provisions of subfloor and other near ground building elements be conducted to understand whether this could have affected the outcomes for these buildings.

8.2 Building controls

The research study highlights a range of specific weakness in the near ground material and design specifications of current regulatory standards, which for bushfire attack levels (BAL) up to and including

BAL-29 allow combustible stumps, bearers, flooring, decking, stair and balustrades within close proximity to the ground. These elements were either directly threatened by fire spread through typical levels of fine fuel and grasses within the townships or ignited by typical heavy fuel elements that resided under or adjacent to the buildings. The typical elements included retaining walls, stored materials, vegetation, plastic water tanks and vehicles.

Some of these weaknesses are only specifically addressed in BAL-40 and BAL-FZ (flame zone) construction levels, which specify that heavy fuel elements should not be located under or adjacent to BAL-40 and BAL-FZ buildings.

Resistance to heavy fuel element combustion is not formally recognised as a fire load in current bushfire related building codes. BAL-FZ construction is the most likely to resist this heavy fuel exposure, and the higher BAL level in the newly adopted National Association of Steel-Framed Housing (NASH) building standard offers some design redundancy to improve resistance to this exposure.

8.3 Planning controls

The Wye River and Separation Creek townships have terrain and tree coverage factors that introduce additional risks to life and property. These factors combine to increase the likelihood of house loss and reduce the likelihood of survival outside a building during a fire event.

The research study identified a number of matters worthy of further consideration:

- the materials used and location of retaining walls proximal to buildings
- the separation distances between buildings within the township to limit structure-to-structure spread
- other shelter in place contingencies such as personal fire shelters with extended periods of occupancy
- alternative ways of specifying likely sight exposure for the given terrain and landscape factors.

9 References

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7. Leonard, J., & Blanchi, R. (2005). "Investigation of bushfire attack mechanisms involved in house loss in the ACT Bushfire 2003". CSIRO Manufacturing & Infrastructure Technology.

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Appendix A

A.1 Case study – Karingal Drive, Wye River

A.1.1 KEY LEARNINGS

This house on Karingal Drive was completed in February 2013 to BAL-40 construction requirements. It survived with damage to its decking and decking support structure. The main threat to the house and decking was from the combustion of treated pine retaining walls adjacent to and below the structure and deck. The house's steel support structure and non-combustible subfloor, cladding, window frames and doors were effective in resisting ignition in combination with aerial suppression activities.

Even though the fire arrival context was far below the worst-case exposure scenario assumed for BAL-40 construction, the fuel elements adjacent to the building may have been sufficient to cause building loss if aerial suppression did not occur.

A.1.2 HOUSE LOCATION

The house location is indicated by the yellow dot at the tip of the blue arrow (Figure 35).

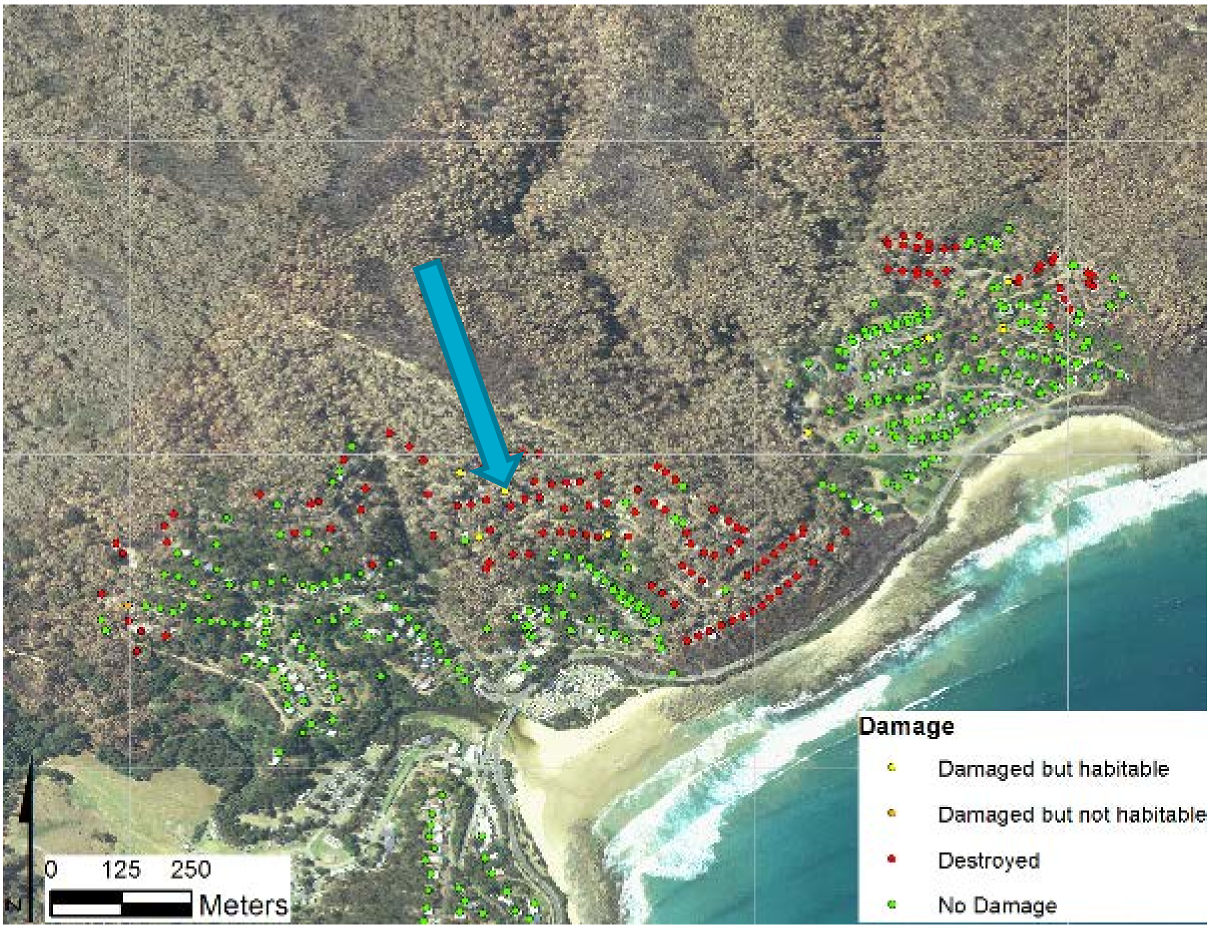

Figure 35: House on Karingal Drive, Wye River.

A.1.3 HOUSE DESIGN

This house was built to the BAL-40 construction requirement. It is of modular construction, utilising steel for its supports and internal framing. The cladding is also metal, as is the window framing material. The underfloor area of the house is not clad, and instead uses non-combustible James Hardie Scyon flooring sheets (see Figure 36).

Figure 36: Under floor system, steel and James Hardie Scyon flooring.

A.1.4 FIRE ARRIVAL AND IMPACT DESCRIPTION

This house was exposed to a low-level surface fire, which followed the slope moving up to and past the building (Figure 37). This location was impacted between 15:30 and 16:45 by a fine fuel burn through.

Figure 37: Fire arrival upslope, involving some dead tree stumps.

This low-level surface fire spread ignited various heavy fuel elements such as retaining walls adjacent to the decking as shown in Figure 38.

Figure 38: Retaining wall combustion below the deck.

During active burning of these retaining walls, aerial water bombing drops washed down over the retaining walls and under the building. This water bombing appeared to be effective at supressing the burning of the retaining walls and limiting the duration and intensity of flame exposure on the buildings and attached deck (Figure 39).

Figure 39: Deck–retaining wall interaction with evidence of water wash from aerial suppression.

The BAL-40 compliant decking was made of a plastic–wood composite with fire retardant additives. This showed signs of charring where flames had impinged on the decking boards. The boards did not appear to have encouraged flame spread. The deck was supported by galvanised steel bearers and posts, which were effective in supporting the decking structure and building throughout the fire event (Figure 40).

Figure 40: Impacted decking and support structure.

Other than the retaining walls, the only other significant combustible materials found under the house were two full polyethylene water tanks (Figure 41). While the PVC piping that was not full of water suffering some deformation, the polyethylene tanks were not sufficiently close to other stored materials or the combustible retaining wall to receive direct flame contact.

Figure 41: Water tanks and piping in subfloor area.

Some ember attack was evident as shown in Figure 42. The decking and support structure appeared to be effective in retarding flame development from the ember attack.

Figure 42: Ember scorch marks on plastic–wood composite decking.

The BAL-40 compliant windows utilised a flexible pull down fire shutter as shown in Figure 43. These shutters were not deployed during fire exposure but radiation levels were not sufficient to cause damage to the exposed windows.

Figure 43: Window with pull down fire shutter.

The inclusion of gutter guards and a simple roof profile also appeared to limit the likelihood of a roof ignition (Figure 44).

Figure 44: Simple roof profile with metal gutter guards.

Figure 45: Side exposure on East facing wall

A.2 Case study – Durimbil Avenue, Wye River

A.2.1 KEY LEARNINGS

This house may have ignited from a variety of processes, if ember attack, including low-level fire spread, did not directly ignite the house it is likely that the combustion of the decking and retaining walls, and LPG pressure vessel flaring, would have caused ignition of the house.

A.2.2 HOUSE LOCATION

This house was located at the tip of the blue arrow in Figure 46.

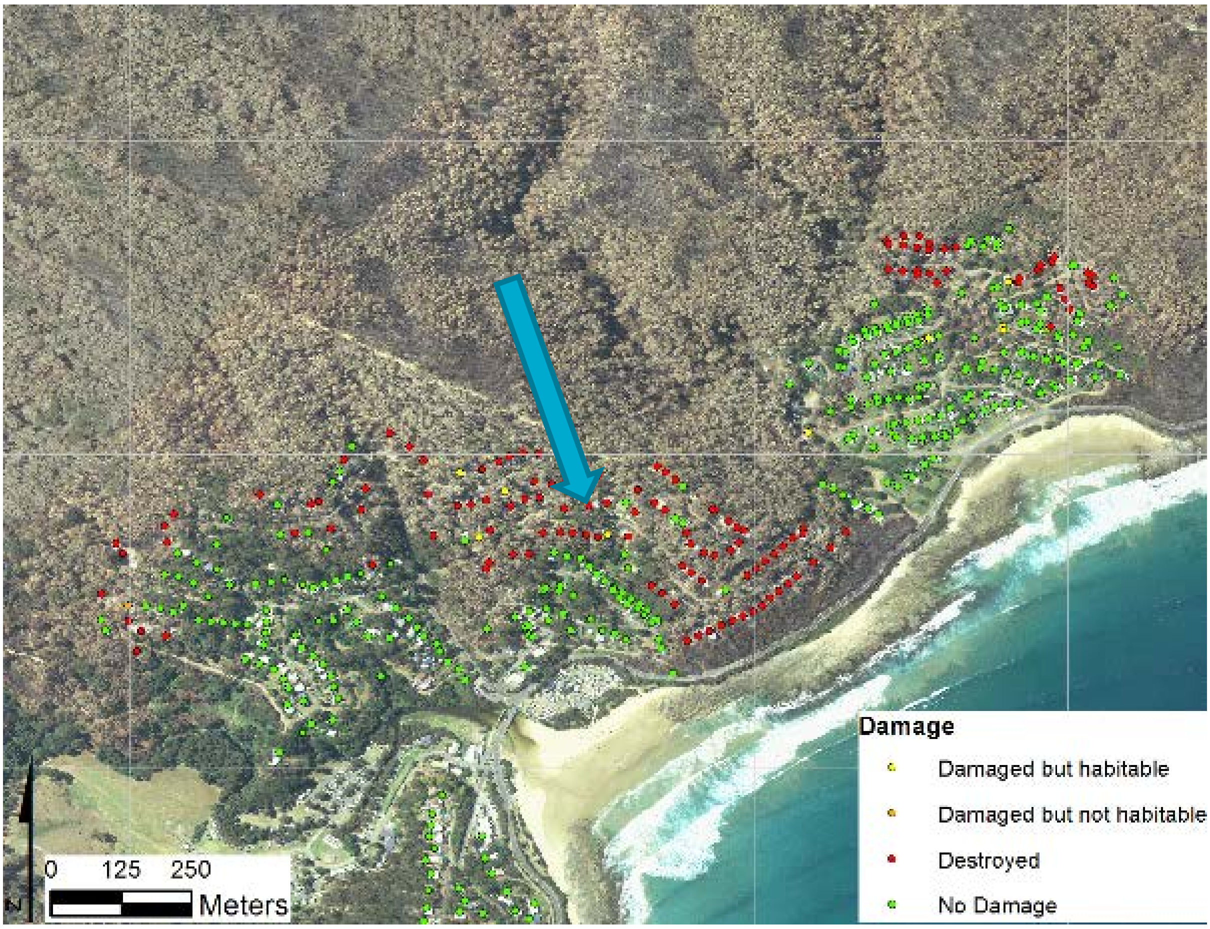

Figure 46: House on Durimbil Avenue, Wye River.

A.2.3 HOUSE DESIGN

This house was completed in August 2005 to Wildfire Management Overlay (WMO) requirements after being categorised as Medium level of Bushfire Attack in accordance with AS3959-1999.[5] The key requirements are a static water supply of at least 10,000 litres and vegetation management in an inner and outer zone in accordance with the WMO. This vegetation management consists of an inner zone forming a

[5] Standards Australia (1999) Australian Standard AS 3959 Construction of buildings in bushfire-prone areas, Standards Australia

10 metre perimeter around the house clear of elevated fuels no greater than grass less than 100 mm, and litter fuels less than 20 mm in depth. At least 50% of the outer zone must be clear of elevated fuel.

Figure 47 provides and indicative photo of the house design and surrounding vegetation elements in the years preceding the fire event. The house appears to have had a non-combustible facade and metal clad roof. It also appears to have had treated pine retaining walls running up to and under the house.

Figure 47: Indicative photo from Durimbil Avenue at February 2010 (Google Street View).

A.2.4 FIRE ARRIVAL AND IMPACT DESCRIPTION

This house was exposed to a low-level surface fire, which followed the slope moving up to and past the building. This location was impacted between 15:30 and 16:45 by a fine fuel burn through. The fine fuel spread appears to have occurred below the shrubs, which received some leaf scorch as it passed (Figure 48 and Figure 49).

Figure 48: House on Durimbil Avenue showing intact elevated vegetation adjacent to building.

Figure 49: House on Durimbil Avenue showing adjacent vegetation scorch.

This fine fuel burn through appears to have ignited treated pine retaining walls and timber decking elements adjacent to the house (Figure 50).

Figure 50: Burnt retaining walls adjacent to house.

These retaining walls also burnt in close proximity to four 65 kg LPG pressure vessels (Figure 51). These pressure vessels stood on a poured concrete slab against a metal frame, which supported the copper pipes attached to the pressure vessels. The fire in the adjacent retaining walls was sufficient to heat the pressure vessels, causing the pressure to increase and flare from the safety release of some of the pressure vessels.

Figure 51: LPG pressure vessels adjacent to house.

The flaring from these pressure vessels pointed directly towards the house (Figure 52).

Figure 52: House on Durimbil Avenue showing house and location of pressure vessels.

A.3 Case study – Koonya Avenue, Wye River

A.3.1 KEY LEARNINGS

This house appeared to have not been exposed to an extensive attack from adjacent vegetation, instead it was subject to surface fire approaching 0.4 meters in height and ember attack. The house was required to be built to BAL-40 construction requirements. The approach taken to comply to BAL40 was unusual and may represent a key weakness in AS3959-2009 [8]. The construction approach was to externally cladding the houses timber frame in plasterboard to achieve a compliant fire rated wall system. An additional external cladding of stained cedar was then used over the plasterboard to create a very aesthetically pleasing a exterior finish. The use of combustible cladding over the fire rated wall appears to be allowed by the standard [8] and is currently opening promoted as a compliance solution on various websites including the following:

http://www.5startimbers.com.au/downloads/Design_Guide_04_Building_Timber_Bushfire_Areas_3-9_MB.pdf

(accessed March 2016)

Unfortunately the cedar cladding would have been readily ignited by either the ground fire and/or ember attack, and while the plasterboard cladding would have provided some protection for the timber framing underneath the windows, doors and roof would have sustained direct flame attack in excess of what BAL40 compliant roof, door and window systems are designed to withstand. The likely fire severity and transition to an internal fire raises major concerns regarding occupant safety and egress for this approach.

A.3.2 HOUSE LOCATION

This house was located at the tip of the blue arrow in Figure 53.

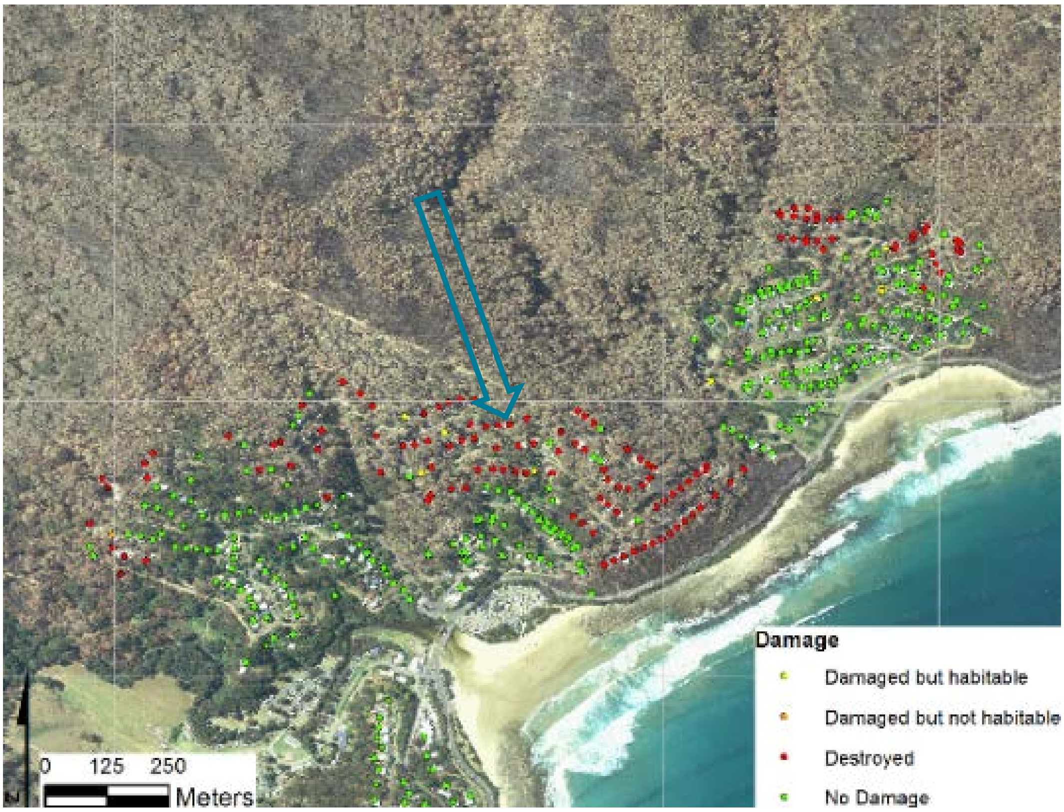

Figure 53: Location of house in Koonya Avenue, Wye River.

A.3.3 HOUSE DESIGN

This house was completed in October 2014, was subject to BAL-40 construction requirements. It comprised steel posts, aluminium framed windows, a non-combustible clad subfloor and cypress pine timber cladding. BAL-40 compliant houses don't not typically have timber cladding due to the inherent ignition risk during a bushfire. This house however was constructed using an approach which consists of timber frame which is then clad in plasterboard in a way that achieves a fire rated construction level for the wall. A cladding of timber (cedar) was then placed over the plasterboard with the assumption that this would not compromise the fire rating of the plasterboard wall system. It appears that this system does meet the compliance requirements of AS3959-2009 [8] but unfortunately is not likely to survive a bushfire given that the combustion of the wall cladding will provide sustained flame contact on all adjoining building elements. At BAL40 these adjoining elements are rated to withstand radiant from a passing bushfire and not this level of sustained flaming. Pre-fire Photo examples of this house could be found at the following links at the time of writing this report:

https://www.facebook.com/tuckerhousewyeriver/ (accessed March 2016)

Combustible elements below the subfloor appeared to consist mainly of treated pine retaining walls and an old tree stump (Figure 54).

Figure 54: House on Koonya Avenue showing an old tree stump under the floor on the right of the picture.

The floor system including the decks was supported by steel piers and major steel beams. Timber minor beams were evident under the non-combustible subfloor cladding (Figure 55). The decking surface was non-combustible.

Figure 55: 17 Subfloor construction.

The predominant ground cover adjacent to the retaining walls was a combination of leaf litter and wood chip mulch. The walls and ground cover extended up to and under the house. There were numerous points of potential interaction between the retaining walls and the combustible facade. The combustible fine fuels in the various crevices would have been readily ignited by embers and surface fire spread. This, in turn, could have readily ignited the retaining wall sleepers and building facade. These two elements would be able to transmit heat to each other and increase the rate of combustion until the facade was burnt through. The fire could then enter the house via the windows, doors roof system and ignite the building contents. If the house was occupied at the time of fire impact it is possible that the house could burn externally with sufficient severity to prevent the occupants from safely leaving the house. As the houses internals ignite, the house may have provided an entrapment for the occupants if they were present. The non-combustible decking surface would have improved the prospects of escape however the combustible cladding and decorative combustible panelling could have provide a life threatening level of heat to those trying to escape.

Observations of the wreckage following the fire offers no definitive clues to the cause of initial fire ignition and spread. It does provide sufficient evidence to rule out other process such as tree impact and vehicle-to-house fire interactions. Figure 56 shows a view of the house following the fire, this view reveals the connection between the combustible building facade and combustible elements at ground level.

Figure 56: Ground to wall interface after the fire.

A.3.4 FIRE ARRIVAL AND IMPACT DESCRIPTION

This house was exposed to a surface fire of flame height approaching 0.4 metres, which followed the slope moving up to and past the building (Figure 37). This location was impacted between 15:30 and 16:45 by a fine fuel burn through. Fine fuels close to, under and against the house mainly consisted of bark mulch, dried grasses and windblown fine litter fuels. This ground fire attack would have provide a likely ignition of combustible elements adjacent to and under the house.

A.4 Case study – Iluka Avenue, Wye River

A.4.1 KEY LEARNINGS

This house contained many design aspects that could resist radiation and ember attack from an approaching bushfire. The actual bushfire approach was a surface fire of less that 0.8 meters that did not directly impact the house. The main threats to house loss would have been presented by the extensive use of timber retaining walls under and adjacent to the house as well as the combustion of the neighbouring house which was less than 3.5 meters away.

A.4.2 HOUSE LOCATION

This house was located at the tip of the blue arrow in Figure 57.

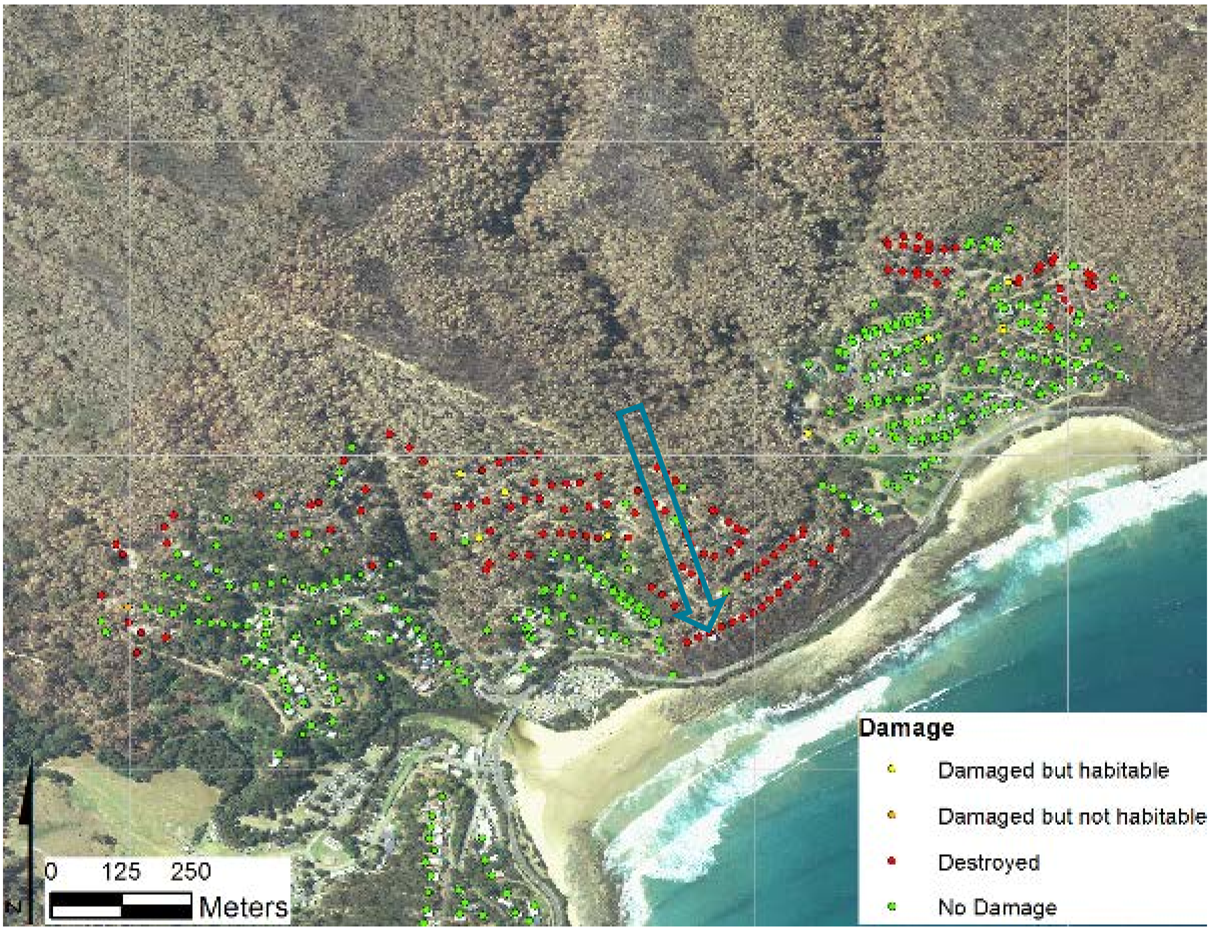

Figure 57: Location of House below Iluka Avenue, Wye River.

A.4.3 HOUSE DESIGN

The house was completed in 2012 and built to BAL40 construction requirements under AS3959-2009 [8]. The house was timber framed and clad in Colorbond steel. The roof was also clad in Colorbond steel. Decks adjacent to windows were supported by timber posts and bearers and clad with a composite decking product. At the driveway entrance a deck comprising of steel bearers and timber cladding was used, this deck was made to support vehicle access to the garage and served as a parking area.

Extensive use of timber retaining wall was evident around and under the building see Figure 58 & 59. A polyethylene water tank was also present under the building immediately adjacent to timber retaining walls (Figure 60). This tank and adjacent retaining walls had collapsed and burnt out. This may have been either a cause or a result of the house fire. If it occurred prior to the house burning it would have present two risks to the building:

- By providing a direct fire impingement to the houses sub floor and wall system
- By providing a direct impact to the facade and windows immediately below the tank as the tank ruptured

The driveway timber deck and adjacent polyethylene water tanks burnt extensively and may have present an egress issue if the house was occupied as it appear that the only way to exit the property onto the street is via to pass over of past these elements Figure 61 & 62.

Figure 58: House on Iluka Avenue Wye River, showing vegetation condition below structure

Figure 59: 23 Location of burnt out timber retaining walls below and beside structure

Figure 60: 23 Burnt out retaining walls and tank adjacent to house.

Figure 61: Rear deck combustion at driveway entrance

Figure 62: 23 Interaction between the timber driveway deck and a polyethylene water tank. It is possible that the rupture water tank split out over the timber driveway and prevent the complete combustion of the deck.

A.4.4 FIRE ARRIVAL AND IMPACT DESCRIPTION

This house may have been subjected to multiple fire approaches. Figure 20 shows a line scan at 16:45 indicating that fire had approached for the east via spotting of surface fire spread along the line of houses below Iluka Avenue. Figure 22 provides a FLIR image which indicated that the coastal scrub below this house was burning at the time the image was taken. This house was also build within 3.5 meters of its nearest neighbour to the west which was a house that also burnt and appear to have been built prior to the period where building or planning requirements for bushfire would have been present.

The coastal scrub below the house showed indications of a surface fire which was sufficient to scorch the foliage but not remove it in the upper portion of the coastal scrub. This suggested a mean flame height of 0.8m arrived in the adjacent vegetation. The maximum distance the fire could run up this slope was 41m being the distance between the road below and the edge of the adjacent vegetation below the house. The estimated separation distance between the continuous vegetation below the house was 3-4 meters.

A.5 Case study – The Boulevarde, Wye River

A.5.1 KEY LEARNINGS

This house had a range of features (Figure 65 to 72) which could have supported ignition and development to totally involve the house. Even though the subfloor area was readily accessible to ember entry and contained elements which were readily ignitable there were no signs of ember arrival in this sub-floor area of immediately adjacent to it. The surface fire present a significant threat of direct ignition of the combustible near ground features, however surface fire spread did not reach the building, most likely because of suppression activities. The relatively flat ground on all sides of the building in combination with a concrete apron around two sides of the building could have provided an area for ground crews to stand and defend the building. There were a number of signs that suppression crews defended this property, indicated by water wash marks and supressed surface fire (Figure 70 & 71).

A.5.2 HOUSE LOCATION

This house is located at the tip of the blue arrow in Figure 63.

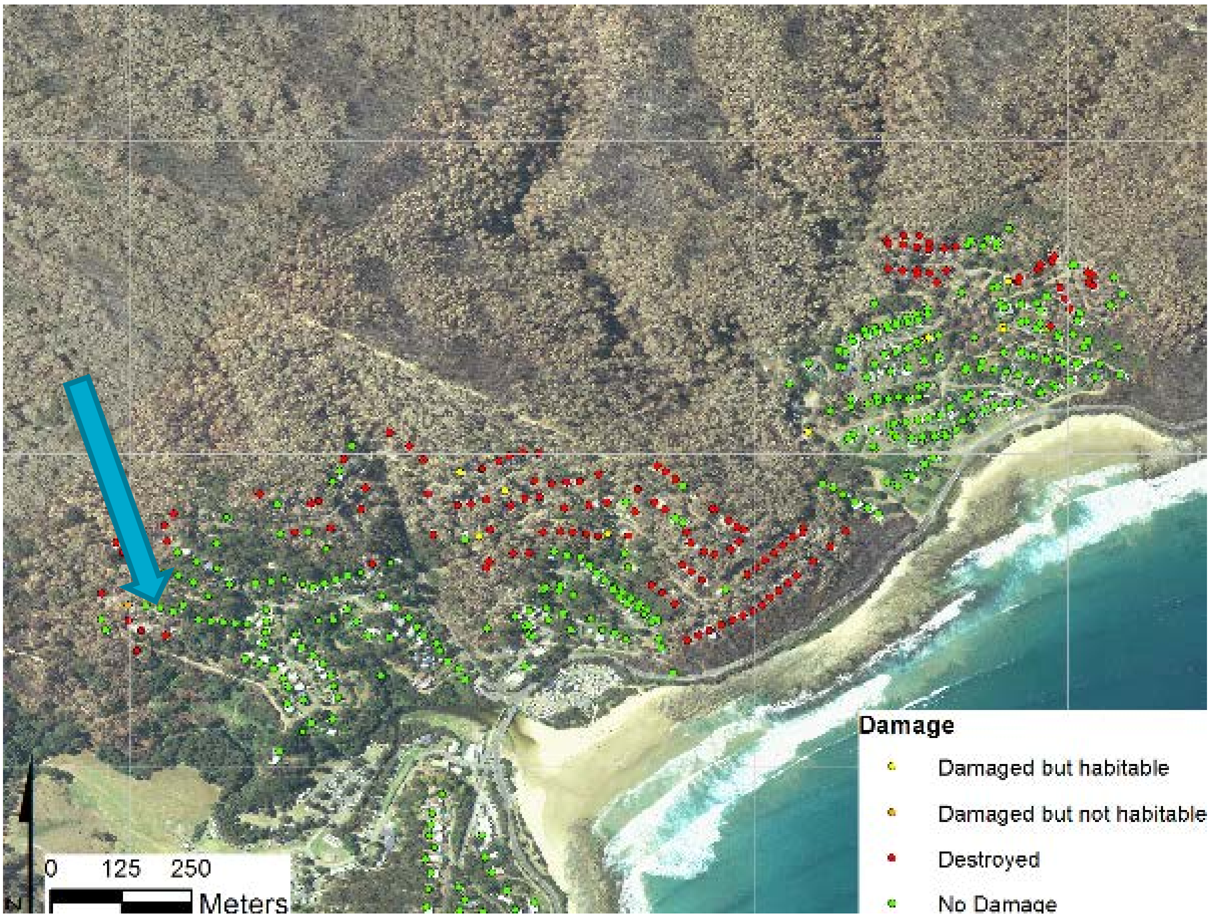

Figure 63: Location of house on The Boulevarde, Wye River.

A.5.3 HOUSE DESIGN AND MANTAINANCE

This house was completed in April 2006 and was categorised as Medium. The building is clad with two different systems, Colorbond steel and painted timber weatherboards. The house has a timber subfloor that is semi enclosed with gapped timber boards (Figure 66 to 68). The gaps between the battens is in excess of 6mm.

Figure 64: Google Street View image of the house some time before the fire event.

Figure 65: Cladding of walls and sub-floor

Figure 66: Concrete apron, house to surface fuel orientation, and surface fuels present after the fire.

Figure 67: Subfloor area and material stored within.

Figure 68: Extensive combustible objects in sub-floor area

Figure 69: House to tank proximity and adjacent combustible elements including rubbish bins and firewood.

Figure 70: Some fire interaction between a burning tree trunk and an adjacent polyethylene water tank. The ground surface and tree bark condition indicate the suppression had occurred in this area.

Figure 71: 33 Bare earth interface adjacent to sub-floor area. The dried earth on the sub-floor boards indicate water suppression in the area.

Figure 72: 33 Elevated deck with no clear signs of radiation or ember attack.

A.5.4 FIRE ARRIVAL AND IMPACT DESCRIPTION

This property allotment experience a surface fire of less than 0.4 meters over the majority of the allotment, there were also extensive patches of unburnt surface fuels most of which appeared to be a result of suppression activities. There were no burnt patches against the house suggesting that the ground crews as well as aerial suppression may have been present.

This location was impacted between 19:00 and 19:32 by a fine fuel burn through.

A.6 Explanation of Thermal Imagery

Airborne thermographic (or infrared) cameras are used operationally by fire agencies to see through smoke to observe and reconnaissance on the fire location, size, path and localised hotspots. Instead of the 400–700 nanometre range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm). The resulting image is greyscale where cooler radiant temperatures are darker and warmer radiant temperatures are lighter (Figure 73). Note that some of the very bright features in the image are not related to the fire. These include heated bare ground such as roads, beaches and breaks in vegetation. Very bright regions that do relate to fire include active flame, smouldering combustibles and heated air.

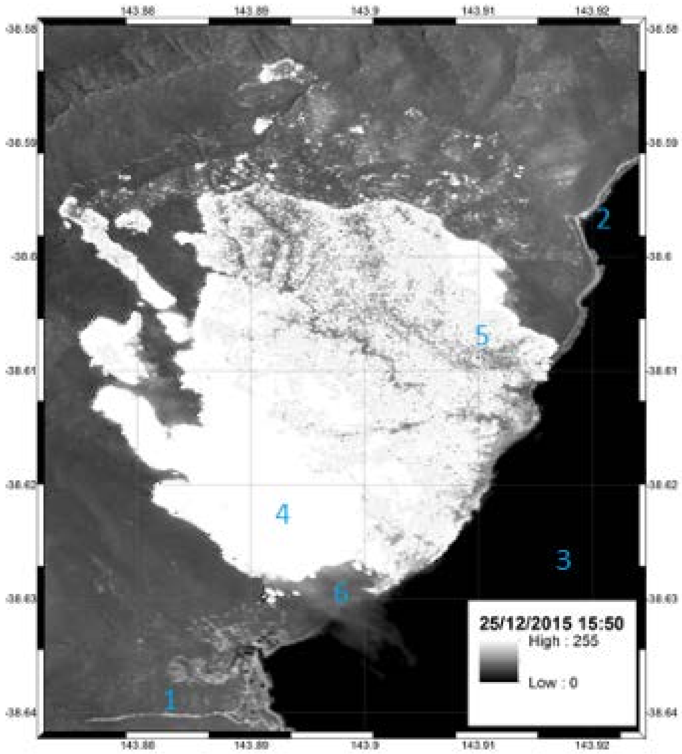

Figure 73: Greyscale example of line scan image 25/12/2015 15:50

Features to note in Figure 73 are:

1. Bare ground, namely a paved road along the back of a ridge
2. A combination of sandy beaches and coastal road
3. Cool radiant temperature - Water
4. Hot radiant temperature – Active fire
5. Warm radiant temperature – Smouldering fire
6. Hot air rising due to convection and travelling in the direction of the prevailing wind

Images are stored in 8-bit format, meaning that values range from 0 to 255. The image values are often referred to as digital numbers. The surface measurement is derived through calibrating an image to radiance values, in this case it would be kilowatts of radiance per meter squared. Calibration of these digital numbers to black body radiant heat (Kw/m^2) values is complicated due to the influence of many environmental effects. The altitude of the aircraft alone has a significant effect on brightness temperature. Radiometric calibration of thermal infrared requires corrections relating to atmospheric absorption and emission (Figure 74) and surface emissivity effects. Regression analysis and field sampling would be ideal for calibrating the radiance received by the sensor and thermal radiance at the surface. The nature of a fire makes it unsafe and impractical to take a representative measurements of surface radiant temperatures at the time that the image is captured.

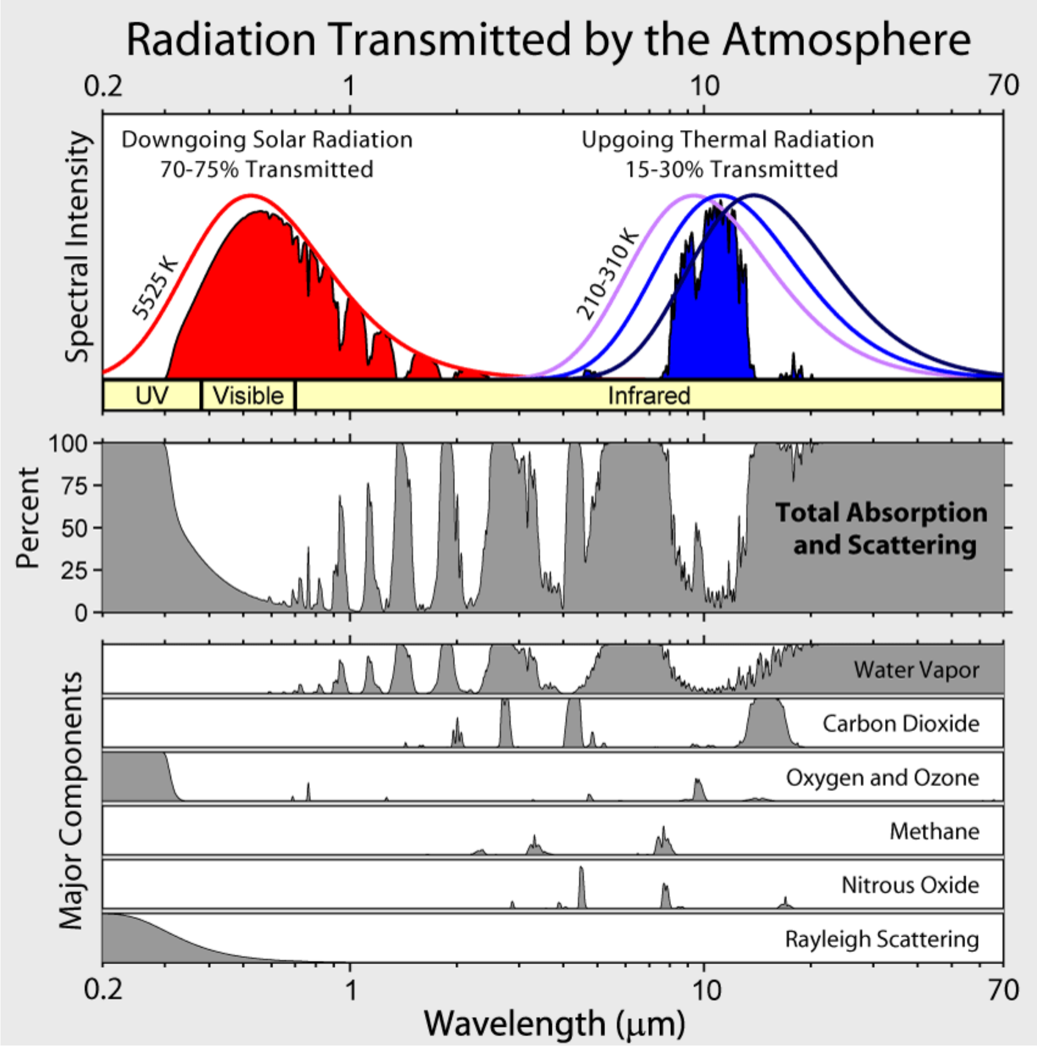

Figure 74: Effects of the atmosphere and some of it components on waves of electromagnetic radiation. Source: http://wattsupwiththat.com/2011/02/28/visualizing-the-greenhouse-effect-atmospheric-windows/

High altitude fire line scan imagery was captured by the Victorian Aviation Services Unit at irregular times to observe the progression and nature of the fire in southern Victoria on 25 December 2015. An analysis of this imagery found that using a colour threshold was the best way to determine the spatial and temporal characteristics and nature of the fire approach on the towns of Separation Creek and Wye River. We found that most information came from the saturated pixels; these indicate a high heat emittance (Figure 75).

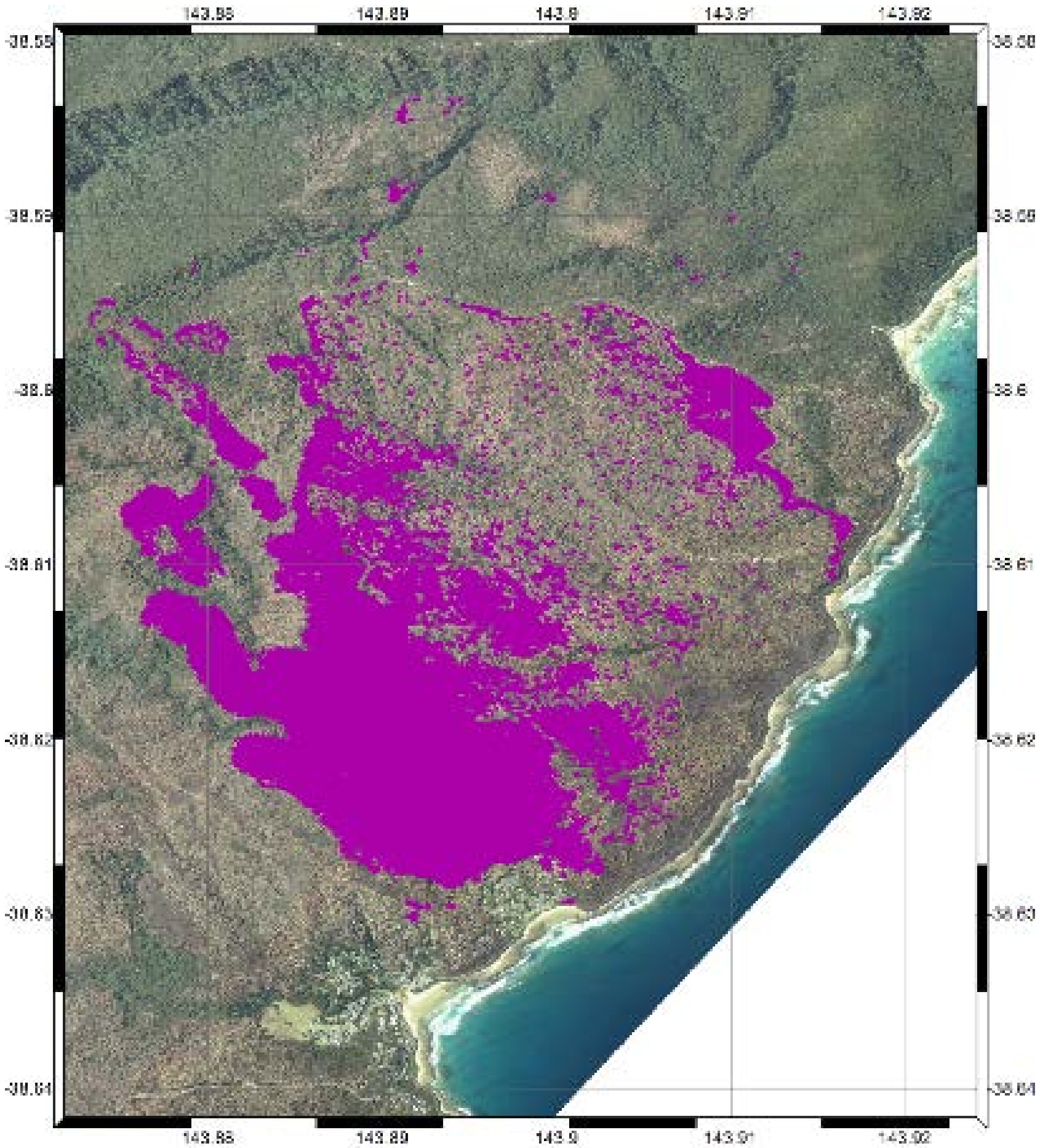

Figure 75: Saturated pixels of a line scan image captured 25/12/2015 15:50 overlayed on a visible colour aerial image.

Artefacts such as smouldering fire and clouds of hot air from convection are eliminated from the image when only saturated pixels are shown. Evidence of this finding is shown in Figure 76, where it is visible where highly combustible elements in the environment (such as houses) continue to burn while the fine fuels have since burnt out.

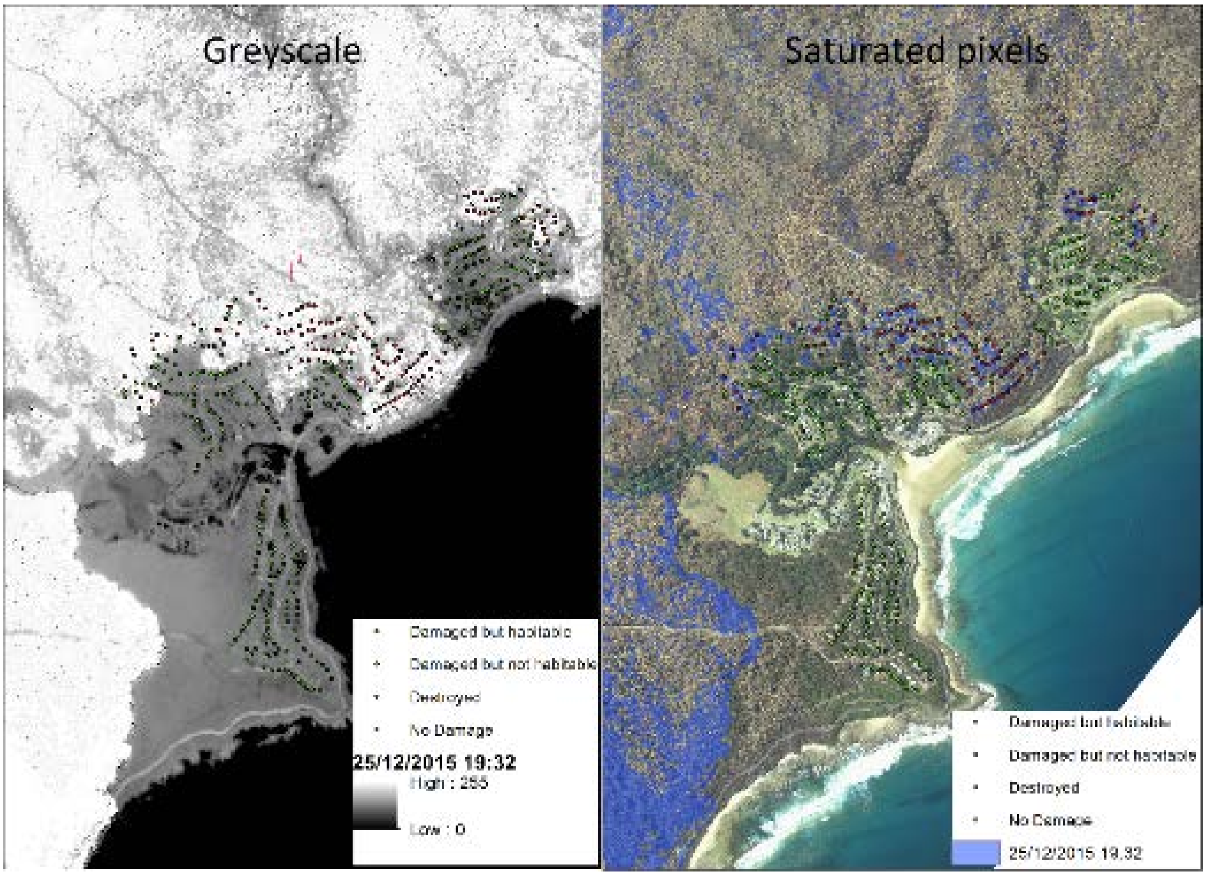

Figure 76: Comparison of greyscale (left) and only the maximum image values (right) overlayed on visible colour aerial imagery

A helicopter mounted fire line infra-red (FLIR) video recorder was also flown during the fire. Frames from this footage were extracted and where possible, georeferenced to observe in detail any footage that captured the progression and nature of the fire. Due to the high resolution of these images it was deemed unnecessary to threshold the colour to saturated pixels. See Figure 77 as an example of a georeferenced frame from the FLIR footage captured.

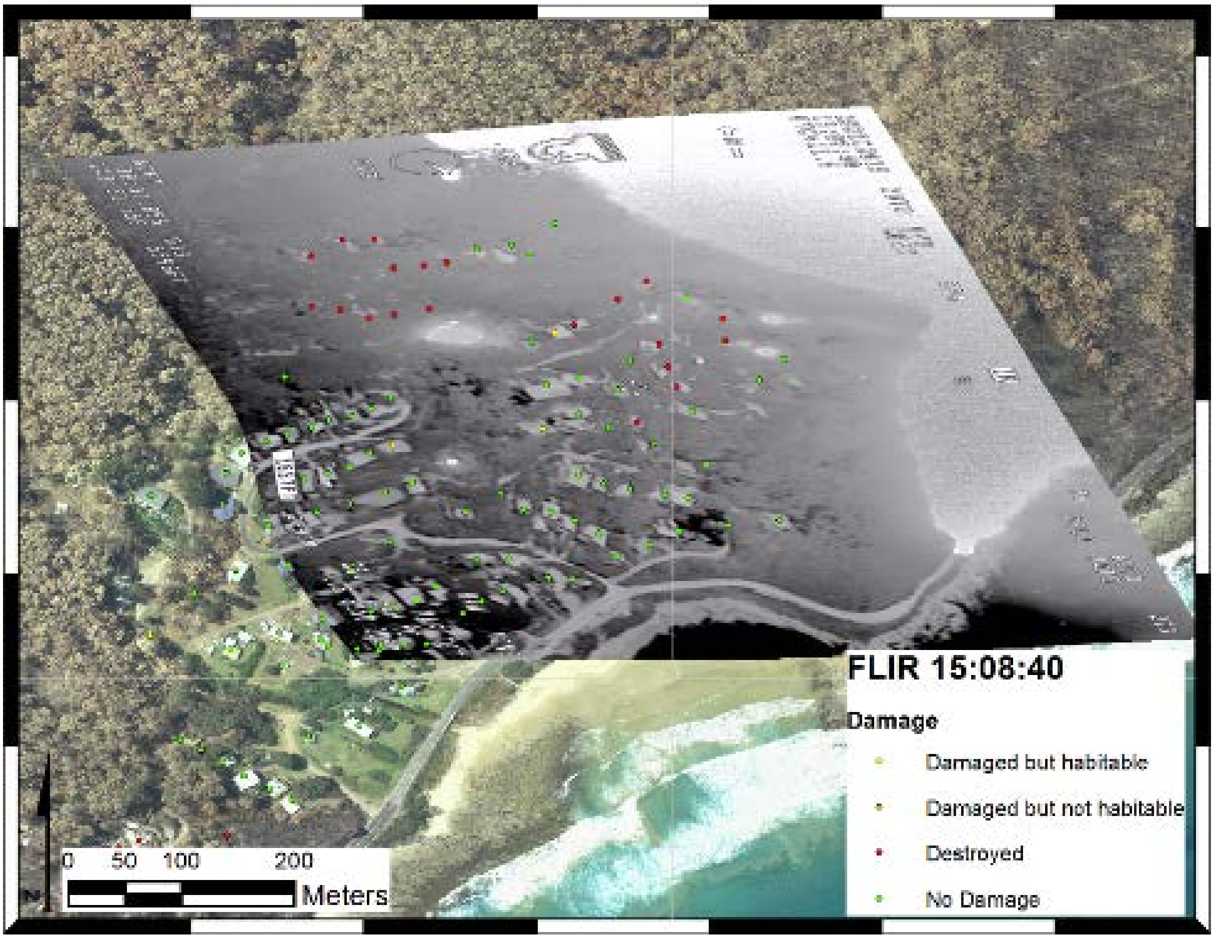

Figure 77: Example of a georeferenced frame from the FLIR footage capturing the entry of the fire into Separation