BUSHFIRE RISK ASSESSMENT METHODOLOGY

APPROACH

Bushfire risk assessment models were used to test different fuel reduction burning strategies to determine how they would reduce bushfire risk at the Statewide scale. This approach was chosen because it provides an opportunity to compare and analyse scenarios across the entire state, and to determine cost-effective strategies. It also enables more transparent and informed discussions with stakeholders about bushfire risk, with a range of supporting maps, graphs and animations that can be produced. Similar modelling has also occurred in Victoria, South Australia and South West Tasmania.

The bushfire risk and characterisation models that were considered for this report included PHOENIX RapidFire (Phoenix), Prometheus, Pandora and Burn P3, Aurora, FireScape and the Bushfire Risk Assessment Model (BRAM). Each model had a range of strengths and limitations. Phoenix and BRAM were selected as the most appropriate models to use, with a PostgreSQL database established to handle the large quantities of spatial data generated by Phoenix. The following considerations were taken into account to select these systems:

- Their availability and cost, including support and maintenance;
- Stability of the software, and their compatibility with other existing systems;
- Data availability and preparation requirements;
- The amount of time required to prepare and run the systems and to analyse the results;
- The appropriateness of the models to Tasmanian conditions; and
- The accuracy of the models.

BRAM was used in the development of fuel reduction burning scenarios, to prioritise areas for treatment. Both Phoenix and BRAM were used to identify trends in fire behaviour under the different fuel reduction burning scenarios. Each of these models use equations to predict potential fire behaviour. The equations are based on empirical studies, where data was collected in specific vegetation types. The authors acknowledge that the models do not always accurately predict individual fire behaviour for each mapped vegetation type. However this assessment is being undertaken at a landscape scale with multiple ignitions being simultaneously analysed. Given that the primary purpose of the modelling was to compare relative differences between fuel reduction scenarios, rather than to report on absolute fire behaviour values, the models were considered to be appropriate for the purposes of the report. They were also considered the best available tool to objectively and consistently identify current bushfire risk, and potential trends in risk reduction over time, at the Statewide and FMA scale.

DEVELOPMENT OF THE FUEL REDUCTION BURNING SCENARIOS

Seven fuel reduction burning scenarios were developed to determine how different approaches to fuel reduction burning could reduce bushfire impact and fire behaviour. The objectives for developing these scenarios were that they should be based on science-based risk management principles (e.g. the Indicative National Bushfire Principles (Ellis, et al., 2004)) and should be realistic and measurable.

A ‘no fuel treatment’ (NFT) scenario was developed to measure how predicted fire behaviour and bushfire risk would change over time in the absence of any fuel reduction burning activities or bushfires. Each of the remaining fuel reduction burning strategies were developed to the following criteria:

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1) Base the fuel reduction burning strategies on observations and recommendations from scientific literature, bushfire inquiries and strategies used by other jurisdictions, and test them in the Tasmanian context.
2) Prioritise burning, so that high risk areas are treated first. Focus on community risk as the highest priority.
3) Confine fuel reduction burning to vegetation types that are generally known to tolerate fire, referred to as treatable fuels.

Treatable areas were defined by identifying the vegetation types, land use types and land tenures that could be treated by fuel reduction burning under each strategy. In all of the strategies, vegetation types were grouped into two categories based on whether they could generally tolerate fuel reduction burning, using Kitchener and Harris (2013) and Pyrke and Marsden-Smedley (2005) as a guide. A list of vegetation types and their treatability is provided in Appendix 2. Vegetation types categorised in TASVEG 3.0 as 'Agricultural, Urban and Exotic' were excluded as treatable areas, with the exception of areas allocated with a land use type of 'Grazing native vegetation 2.1.0' as defined in the Tasmanian Land Use Summer 2009/2010 spatial dataset (NRM North; Cradle Coast NRM; NRM South; DPIPWE;, 2009). Current fuel age and recommended fire return periods were not used to exclude recently burnt vegetation from treatable areas. It was assumed that the recently burnt areas would have a low fuel hazard, representing a low risk to communities and therefore not being selected immediately for fuel reduction burning. It is important to note that vegetation types grouped into the treatable fuel type category are considered to be tolerant to fire in a general sense. However, true tolerance to fuel reduction burning will depend on factors that have not been taken into account in this report. These include previous fire and disturbance history, tolerable fire return periods, and actual species composition including the presence of sensitive species within the vegetation communities. The authors have identified as an assumption and constraint in this report that while biodiversity should be considered as a part of a strategic fuel reduction burning program, this report has only focussed on community protection. Further work is required to understand potential biodiversity and ecological impacts.

Management Area

A landscape-scale, tenure-blind approach to bushfire risk management is promoted by the SFMC as best practice (State Fire Management Council, 2012). A group of scenarios were therefore developed that involved burning treatable fuels Statewide regardless of land tenure boundaries, which are referred to as Public and Private Land scenarios. A second, tenure-blind approach involved burning treatable fuels within fire management zones, following principles set out in (Ellis, et al., 2004) and used by the Parks and Wildlife Service for strategic fire management planning (Department of Primary Industries, Water and Environment, 2012). These scenarios were referred to as Fire Management Zone scenarios. Finally, a third group of scenarios involved burning treatable fuels on public land only, which was considered to be a realistic approach commonly used by other Australian jurisdictions to implement large-scale fuel reduction burning. The Public Land Only scenarios provided an opportunity to test how the implementation of the Victorian Bushfire Royal Commission recommendation 56 (Teague, et al., 2010) could potentially reduce bushfire impacts and fire behaviour, if implemented in the Tasmanian landscape.

Fire management zones were classified into three categories. Asset Zones were identified as Human Settlement Areas (described in Appendix 3). Asset Protection Zones were defined as the area within 1.05 km of a Human Settlement Area. Strategic Fuel Management Zones (SFMZ) occupied the space between 1.05 km and 6.05 km from a Human Settlement Area. Figure 5 shows an example of fire management zones in the Dolphin Sands area, and Figure 6 shows the treatable vegetation in the Fire Management Zones.

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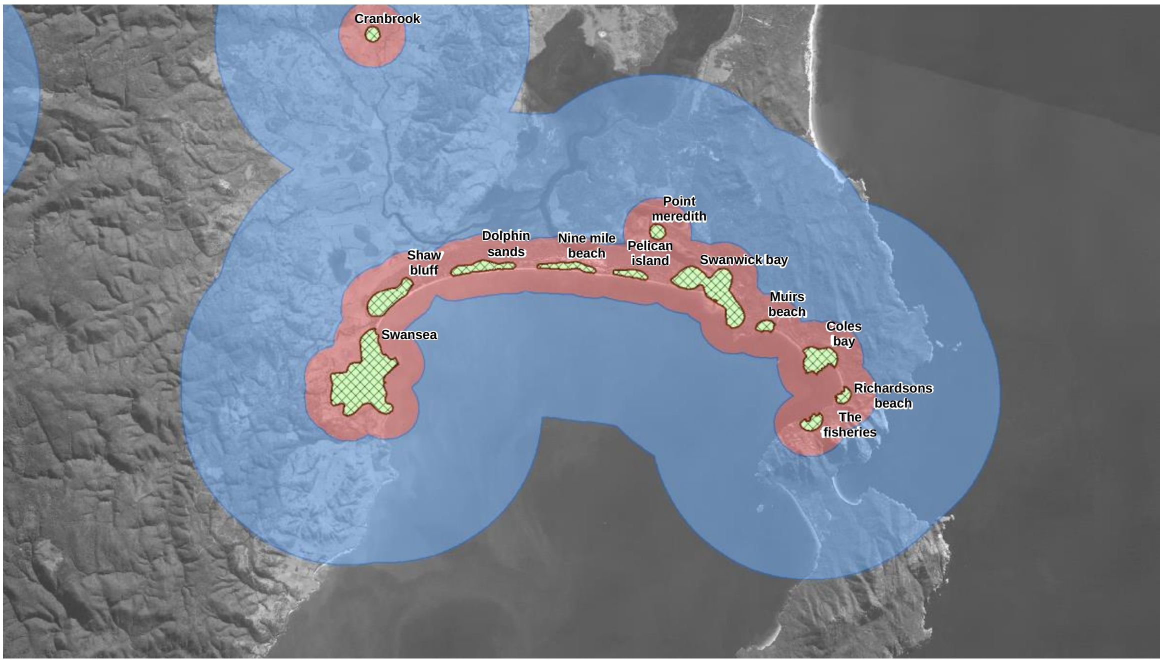

Figure 5: A greyscale orthophoto of the Dolphin Sands area in Tasmania, showing Asset Zones (Human Settlement Areas - green hatch), Asset Protection Zones (APZ - red) and Strategic Fuel Management Zones (SFMZ - blue).

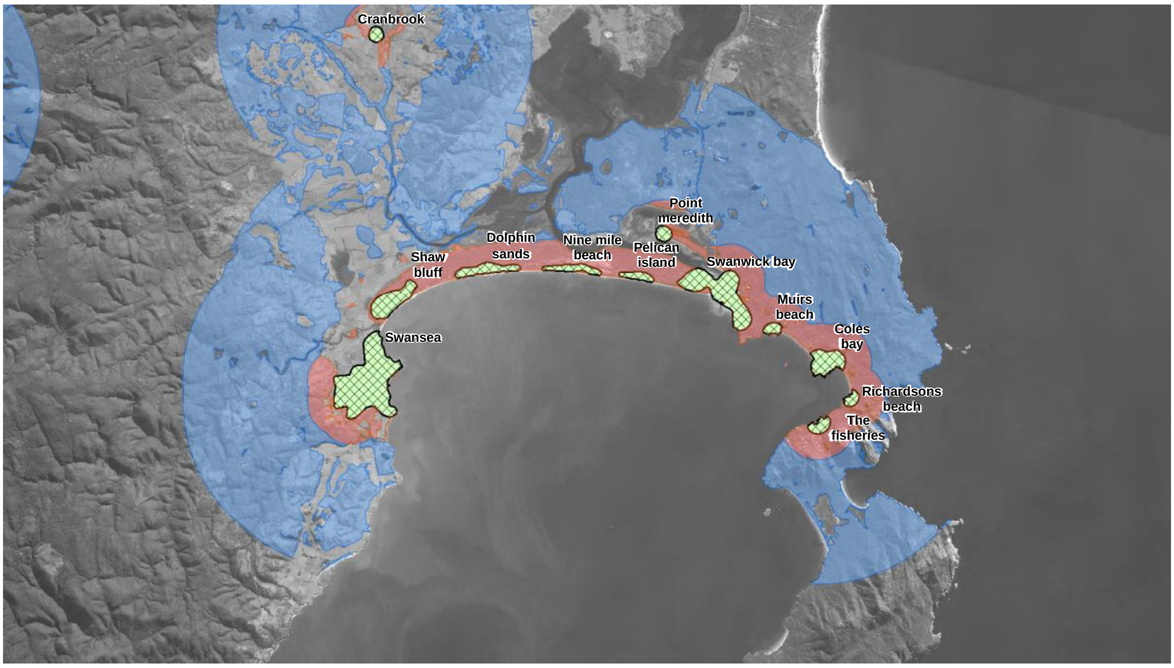

Figure 6: A greyscale orthophoto of the Dolphin Sands area in Tasmania, showing Asset Zones (Human Settlement Areas - green hatch), Asset Protection Zones (APZ - red) and Strategic Fuel Management Zones (SFMZ - blue). Untreatable vegetation types have been excluded from the Fire Management Zones.

Maps were prepared to show the total area of treatable vegetation that could potentially be burnt under each scenario (Figure 7). The total potential land area available for fuel reduction burning under these scenarios, excluding untreatable vegetation types, was approximately:

- 2.5 million hectares for the Public and Private Land scenarios
- 1.45 million hectares for the Public Land Only scenarios
- 878,150 hectares for the Fire Management Zone scenarios

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QUANTITY OF BURNING

Approximately 1% of treatable vegetation on public land is burnt every year in Tasmania, based on the last ten years of fire history records. It is unknown how much burning is undertaken annually on other tenures. Discussion with industry experts in Tasmania indicate that an increase in burning to 5% of treatable fuel would require a considerable increase in resources and effort. Based on these opinions, burning 5%, 2.5% and 1.25% of the target area per year was considered to be realistic targets for the Public Land Only and Public and Private Land scenarios. An estimate of annual burning required under each of the scenarios is shown in Table 2.

Under the Full Fire Management Zone scenario, fuel ages would be maintained at a maximum of five years old within the entire asset protection zone. At the end of the five year burning scenario, approximately 50% of the Strategic Fuel Management Zones would have a mosaic of fuel ages of five years or less. Under the Half Fire Management Zone scenario, approximately 50% of the fuels would have a fire age of five years or less within the Asset Protection Zone, and approximately 25% of the fuels in the Strategic Fuel Management Zone would have a fire age of five years or less.

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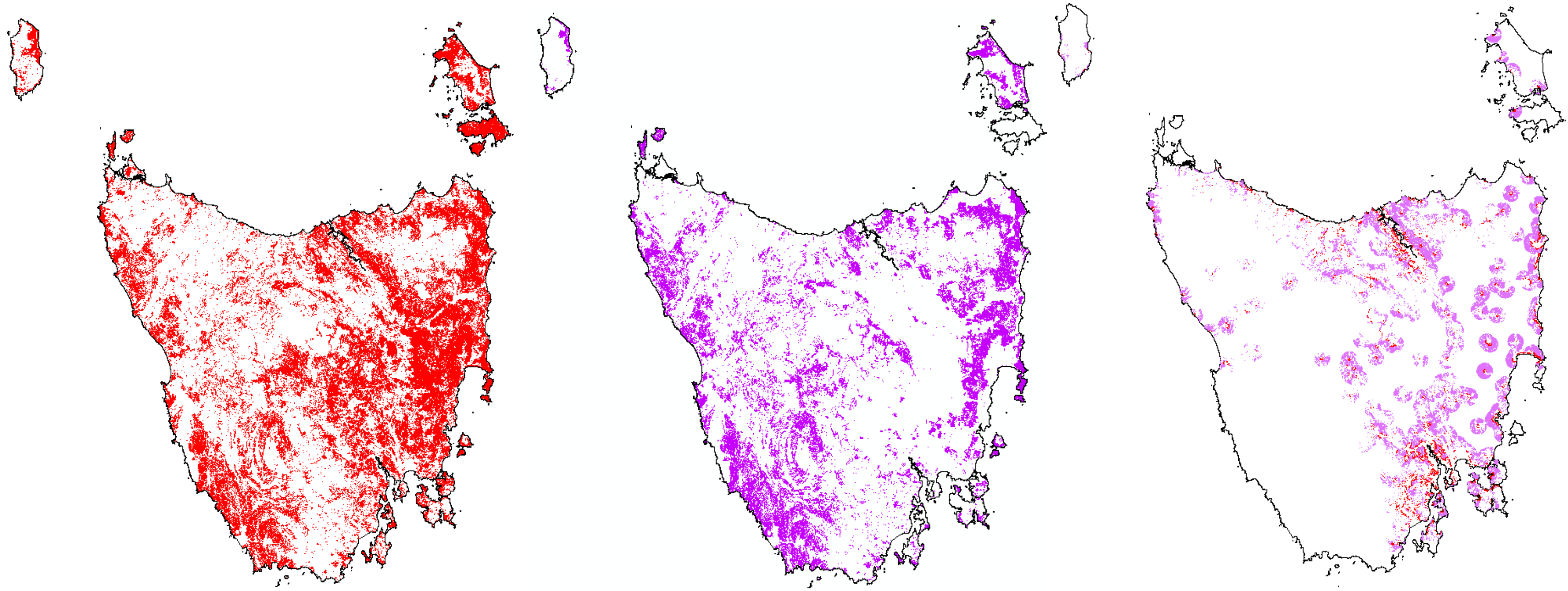

Figure 7: Total Tasmanian land area available for treatment under the Public and Private Land (red, left), Public Land Only (purple, middle) and Fire Management Zone (pink, right) scenarios.

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Table 2: Description of the fuel reduction burning strategies developed for Tasmania, for analysis in the Bushfire Risk Assessment Model and PHOENIX RapidFire.

Scenario Name	Objective	Management Area	Proximity to Communities	Proportion of area treated per annum	Minimum annual area burnt (ha)	Strategic Selection Method
No Fuel Treatment	Allow all fuels to accumulate in the absence of planned burns and bushfires.	N/A	N/A	0%	0	N/A
5% Public Land Only	Strategic fuel reduction burning that replicates VBRC recommendation 56.	Public Land Only	Unrestricted	5%	74,167	BRAM Risk
2.5% Public Land Only	Strategic fuel reduction burning, achieving half of VBRC recommendation 56.	Public Land Only	Unrestricted	2.5%	37,084	BRAM Risk
5% Public and Private Land	Strategic, tenure blind fuel reduction burning at the rate of 5% of the Tasmanian land area per annum.	All land tenures	Unrestricted	5%	123,567	BRAM Risk
2.5% Public and Private Land	Strategic, tenure blind fuel reduction burning at the rate of 2.5% of the Tasmanian land area per annum.	All land tenures	Unrestricted	2.5%	61,784	BRAM Risk
1.25% Public and Private Land	Strategic, tenure blind fuel reduction burning at the rate of 1.25% of the Tasmanian land area per annum.	All land tenures	Unrestricted	1.25%	30,892	BRAM Risk
Fire Management Zone	Maintain fuel ages of < 5 years old within 1.05 km of defined Human Settlement Areas. Maintain a mosaic of fuel ages of <10 year old fuels further out, to 6.05km from defined Human Settlement Areas.	All land tenures	Within 6.05 km of defined Human Settlement Areas.	20% in Asset Protection Zones (APZ), 10% in Strategic Fuel Management Zones (SFMZ)	24,777 (APZ) 74,934 (SFMZ) 99,711 total	BRAM Head Fire Intensity
Half Fire Management Zone	Maintain fuel ages of < 10 years old within 1.05 km of defined Human Settlement Areas. Maintain a mosaic of fuel ages of <20 year old fuels further out, to 6.05km from defined Human Settlement Areas.	All land tenures	Within 6.05 km of defined Human Settlement Areas.	10% in Asset Protection Zones (APZ), 5% in Strategic Fuel Management Zones	12,389 (APZ) 37,467 (SFMZ) 49,855 total	BRAM Head Fire Intensity

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METHODS FOR PRIORITISING FUEL REDUCTION BURNING

A five year hypothetical burning program was developed for each scenario by prioritising burns according to their bushfire risk. A polygon dataset of Analysis Blocks was created using roads, railways, major tracks, watercourses and water bodies, in an attempt to estimate potential burn blocks. Each Analysis Block contained mapped areas of treatable and untreatable vegetation types. Analysis Blocks were erased inside Human Settlement Areas, so that each Analysis Block did not contain any Human Settlement Area. Each Analysis Block recorded the following:

1. Area (ha) of treatable vegetation types
2. Area (ha) of untreatable vegetation types
3. The Analysis Block Risk Score

Analysis Blocks were allocated with an Analysis Block Risk Score. For the Public and Private Land and Public Land Only scenarios, the Analysis Block Risk Score was calculated using Equation 1. For the Fire Management Zone scenarios, the Analysis Block Risk Score was the average head fire intensity (HFI) per hectare, based on BRAM HFI. Both methods used the BRAM version released on 25 February 2014. Analysis Blocks were then sorted in descending order by Analysis Block Risk Score.

$$R_{score} = A_{Moderate}/A_{Area} + (A_{High}/A_{Area} * 5) + (A_{Extreme}/A_{Area} * 10)$$

Where:

$A_{Moderate}$ = Sum of all Moderate Scores in each BRAM output cell in Analysis Block

A_{High} = Sum of all High Scores in each BRAM output cell in Analysis Block

$A_{Extreme}$ = Sum of all Extreme Scores in each BRAM output cell in Analysis Block

A_{Area} = Total Area in hectares

Equation 1: Calculation of Analysis Block Risk Scores (R_{score} for the Public and Private Land and Public Land Only Scenarios.

Two different methods were used to select Analysis Blocks for treatment: the State Selection method and the FMA Selection method. The intent of the State Selection method was to identify bushfire risk – represented by Analysis Block Risk Score – across the entire state, then prioritise and treat the highest risk areas first. This method provides a process for addressing bushfire risk at the Statewide scale. In contrast, the intent of the FMA Selection method was to identify bushfire risk only within the FMA, and then prioritise and treat the highest risk areas. This selection method was considered to be more likely occur, because the FMACs are responsible for identifying and prioritising areas for fuel reduction burning within their FMAs.

STATE SELECTION METHOD

All Analysis Blocks were sorted in descending order by Analysis Block Risk Score. Each Analysis Block was then checked one-by-one from the top of the list. If the block contained treatable vegetation types, it would be 'burnt', i.e. the area of treatable vegetation within the block would be added to the fire history dataset with a date to represent the treatment year, starting in 2014 or 'Year 1'. If the Analysis Block did not contain treatable vegetation types, it would be skipped. The next Analysis Blocks would then be checked in order and treated or ignored until the target area shown in Table 2 was reached for the treatment year. Scoring and treatment was then repeated for each following year up to and including 2018 or 'Year 5'. If the target was over-achieved in a year because the final Analysis Block for that year was very large, the amount of burning in the following year would be reduced to compensate.

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Fire Management Area Selection Method

Within each FMA, Analysis Blocks were sorted in descending order by Analysis Block Risk Score. Each Analysis Block was then checked one-by-one from the top of the list. If the block contained treatable vegetation types, it would be 'burnt', i.e. the area of treatable vegetation within the block would be added to the fire history dataset with a date to represent the treatment year, starting in 'Year 1'. If the Analysis Block did not contain treatable vegetation types, it would be skipped. The next Analysis Blocks would then be checked in order and treated or ignored until the target area was reached for that treatment year (Table 3), where target area for treatment under the FMA Selection method was calculated based on burning the relevant proportions of treatable vegetation within each FMA. Scoring and treatment was then repeated for each following year up to and including 'Year 5'. Due to time constraints, the location of other completed or planned burns could not be incorporated into the analysis. The strategic selection of burns could be improved by incorporating more data and selecting using a number of variables, not just BRAM HFI.

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Table 3: Target Annual Treatment Area for Each Scenario Using the Fire Management Area Selection Method

Scenario Name	FMAC										
	Central North	East Coast	Flinders	Hobart	King Island	Midlands	North East	Southern	Tamar	West Coast	TOTAL
Public Land Only (5%)	3900	5927	2873	551	515	6719	11415	12066	6073	21501	71540
Public Land Only (2.5%)	1950	2964	1437	276	258	3360	5708	6033	3037	10751	35770
Public and Private Land (5%)	5788	12297	6752	1950	1492	21802	15229	14675	20467	23114	123566
Public and Private Land (2.5%)	2894	6149	3376	975	746	10901	7615	7338	10234	11557	61783
Public and Private Land (1.25%)	1447	3074	1688	488	373	5451	3807	3669	5117	5779	30892
Full Fire Management Zone (20% APZ)	1844	2688	268	3919	95	2117	2545	4552	5162	1587	24777
(10% SFMZ)	5640	10181	2440	1916	423	14661	12144	4949	17445	5135	74934
Half Fire Management Zone (10% APZ)	922	1344	134	1960	47	1059	1273	2276	2581	794	12389
(5% SFMZ)	461	672	67	980	24	529	636	1138	1290	397	6194

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Fire History and Fuel Age

A fire history dataset was compiled using fire boundaries provided by the Tasmania Fire Service, Parks and Wildlife Service and Forestry Tasmania up until the end of the 2012-2013 financial year. The dataset includes bushfires attended by all agencies, and planned burns conducted by the Parks and Wildlife Service and Forestry Tasmania. It does not include burns completed by the forest industry for silvicultural purposes, or planned burns conducted by private property owners, councils, Department of Defence or utility companies. The accuracy of the fire boundaries is extremely variable, and there are a considerable number of omissions and overestimates in terms of the actual area burnt by fire. Some fires have been recorded as far back as 1967; however fire boundary records have only consistently been recorded since around 2003.

The fire history dataset was used as an input into Phoenix and the BRAM. The models use fire history to calculate the number of years since the last fire, and they estimate fuel hazard and fuel load using fuel accumulation equations for broad vegetation types. The fuel hazard and fuel load data is then used to calculate fire behaviour characteristics.

A separate, unique fire history dataset was maintained for each scenario, which included the full fire history dataset up to 2013 as well as the treated areas up until 2018. In the results, the treatment years are differentiated from the fire history records by using the terms Year 1, 2, 3, 4 and 5 for the scenario fire history data added for 2014, 2015, 2016, 2017 and 2018 respectively. 2013 is referred to as the 'current' fuel state.

Ignitions

Phoenix is capable of simulating the spread of many individual fires across a landscape. A grid of 11,059 ignition points spaced every 2.5 km across the landscape was chosen, based on a case study comparing 1, 2.5 and 5 km grid spacing. The comparison involved running Phoenix with different grid spacing scenarios in an area between Scottsdale and Fingal that was known for its variability in fire behaviour inputs including fuel types and age, slope, as well as the presence of several communities. In the case study area, 5km spacing (equivalent to 2,765 ignition points Statewide) was found to be too coarse, leaving large areas of unburnt vegetation under current and maximum fuel load scenarios. Spacing using 1km intervals provided the most complete coverage (equivalent to 69,222 ignition points Statewide), but processing time was greatly increased and would not have been achievable within the timeframes of this report. Hence 2.5 km spacing was chosen as it provided good coverage for the objectives of the project, with achievable processing times. It was noted however that 1km spacing would be useful for finer-scale analysis, such as for bushfire mitigation planning around individual communities. A gridded ignition pattern was chosen in preference to a random distribution, or a distribution based on previously observed fire locations. This gridded pattern allowed for results over time and between different fuel treatments to be easily compared, and an even distribution of points provides the most efficient coverage of area while minimising the amount of processing required and the size of potential gaps between fires.

After the 2.5km lattice was created, all points placed in areas where they had no chance of ignition (e.g. in a lake) were moved. The process of moving the point determined using the centroid of the remaining area in the 2.5km grid cell that was suitable to place. If there was no suitable area at all in the 2.5km cell the ignition was not placed at all (i.e. in the lattice across Macquarie Harbour there was ocean that covered the entire cell hence no centroid of remaining area and no ignition point placed.

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SCENARIO WEATHER PROFILES

In Phoenix, each ignition point was allocated a scenario weather profile that was generated using observations from the nearest relevant weather station, shown in Figure 8. The objectives for creating the weather profiles were to represent a typical day of 'bad' fire weather, be realistic in terms of how often the conditions would occur in Tasmania and represent conditions under which 'impacts', for example house damage, could occur.

Tasmania was divided into 45 zones, thought to be the area represented by a local meteorological station (DPIPWE, 2014) (Figure 8). Some of the representative meteorological stations did not have long data records, so close or equivalent stations present in the SILO Patched Point Dataset (SILO-PPD) were used as alternatives.

For each station the archive of daily meteorological data, based on SILO-PPD, were retrieved for the period 1960 to 2012. Daily drought factor, based on the Keetch-Byram Drought Index (KBDI) was calculated for the station record, followed by the daily McArthur Forest Fire Danger Index (FFDI) based on 3pm conditions. The dataset for the station was limited to summer months (December to February). Days representing the 99th to the 99.5th percentile in FFDI values were selected. For each of these days, hourly historical meteorological conditions for the 24 hours of the day were retrieved from the Forecast.IO global archive using the provided application programming interface (API). In cases where observations were missing in this hourly data, that day was excluded from the calculations.

Hourly aggregates of each component meteorological variable were then calculated for the selected station, combining the set of selected days. The 85th percentile was used for temperature, the mean value was used for drought factor and wind speed, while the 15th percentile was used for humidity and the 25th percentile for cloud cover. These values were selected after trial and error, and were found to produce hourly FFDI dynamics that matched closely to 'typical' conditions in which assets would be undefendable without reaching rare *Catastrophic* levels; Moderate FFDI trending towards a peak in mid-afternoon at the *Severe* category, then decline in FFDI towards evening. Hourly wind direction was decomposed into N-S and E-W vectors, averaged and converted back to an angle.

Plots were produced of the synthetic aggregate meteorological variables, as well as FFDI, in comparison to the individual daily records. The aggregated meteorological variables were written to a CSV file. One CSV file was generated per station, and these were then combined into a single CSV file for use in the simulations, with meteorological station recorded for joining with the ignition points (Figure 8). The plots, location map and aggregated meteorological variables for each weather station area are included in Appendix 4.

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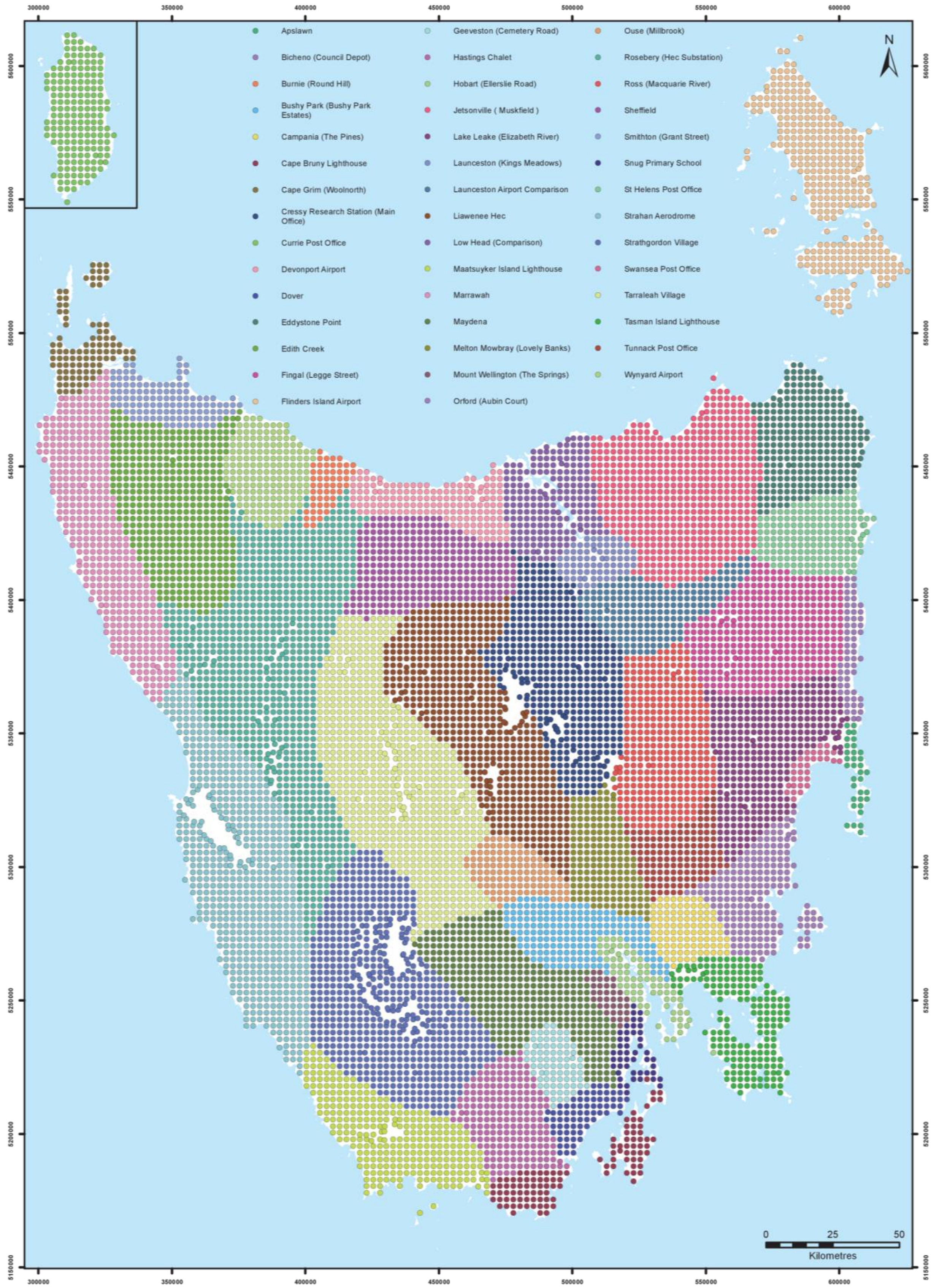

Figure 8: Ignition point and name of corresponding weather station. Weather station areas adapted from Department of Primary Industries, Parks, Water & the Environment (2014).

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PHOENIX RAPIDFIRE SIMULATIONS

Phoenix is a dynamic fire behaviour and characterisation model that responds to changes in the conditions of the fire as well as to changes in fuel, weather and topography as a fire moves across the landscape (Tolhurst, et al., 2008). Fire behaviour calculations are based on the CSIRO southern grassland fire spread model (Cheney & Sullivan, 1997; Cheney, et al., 1998) and the McArthur Mk5 forest fire behaviour model (McArthur, 1962; McArthur, 1967; McArthur, 1973; Noble, et al., 1980). Other models used within Phoenix relate to fuel accumulation rates, fuel moisture, solar radiation, linear disruption to fire behaviour, spot fire ignition, ember transport and distribution, the effects of spot fire induced indraughts at the fire front (Tolhurst, et al., 2008), wind-terrain interactions (Forthofer, 2007), asset impact (Tolhurst & Chong, 2012) and convective plume development (Chong, et al., 2012). Inputs to the model include fuel type, fire history, slope, aspect, weather, ignition point locations, time and date (Figure 10 and Figure 12). Input data grid cell sizes included 25 metres for fuel, elevation, fire history and disruption, 50 metres for road proximity and 100 metres for the wind modifiers data layer.

A 'template' Phoenix project was created that contained all ignition points and their weather profiles (Figure 10 and Figure 11). The Phoenix output grid cell size was set to 200 metres (Figure 9). Phoenix was run for each scenario and fire history/treatment year from 2003 through to 2018 (Year 5) of treatment, simulating the ignition and spread of each fire individually. The model outputs fireline intensity, flame height, flame depth, spotting density and convection. These were captured for each Phoenix output grid cell and related to each ignition point, impacted cell, Human Settlement Area, FMA, fuel reduction burning scenario and fire history/treatment year and saved in a PostgreSQL database. Figure 13 provides an example of how the outputs from the Phoenix model can be viewed for a single fire. See Appendix 6 for further information about the Phoenix system.

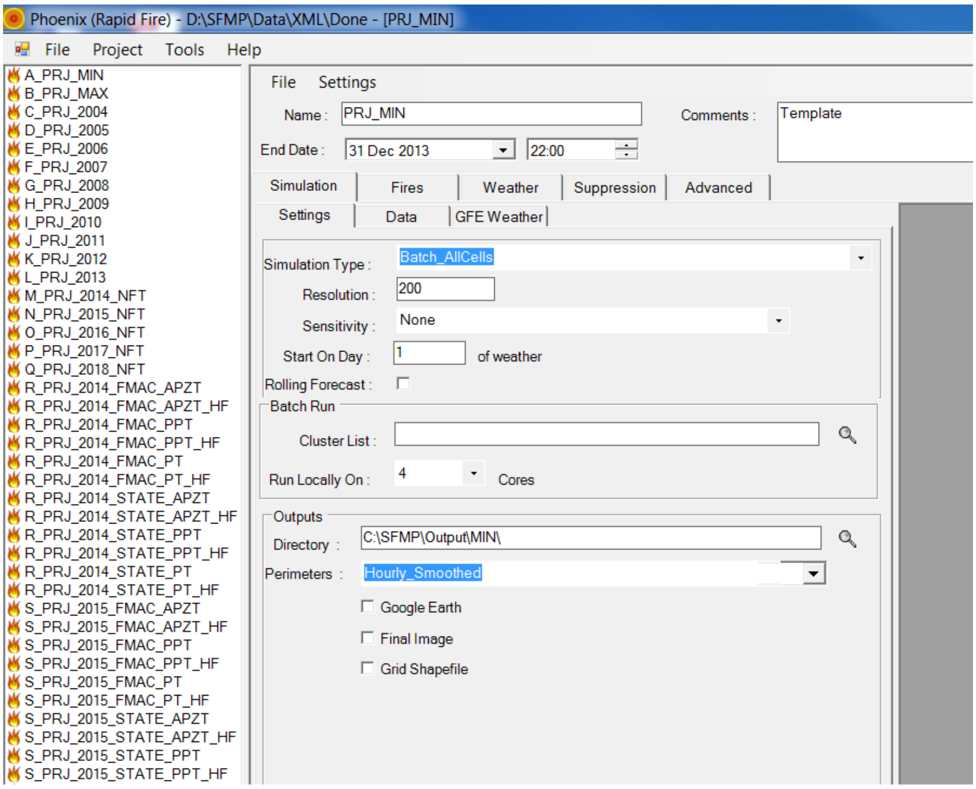

Figure 9: PHOENIX RapidFire project settings used for the Strategic Fuel Management Report.

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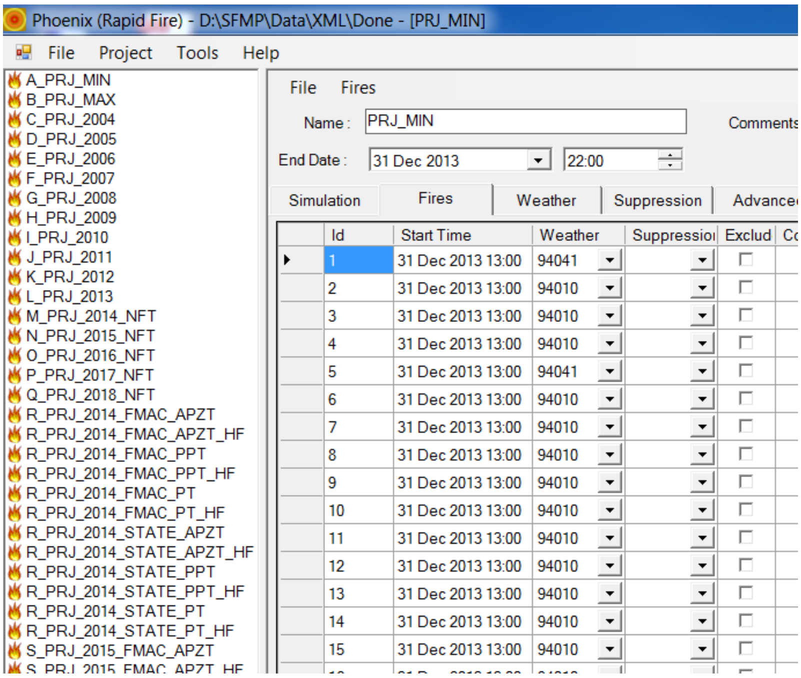

Figure 10: PHOENIX RapidFire settings for the Strategic Fuel Management Report showing a sample of ignition points, their start and end times and their weather profiles.

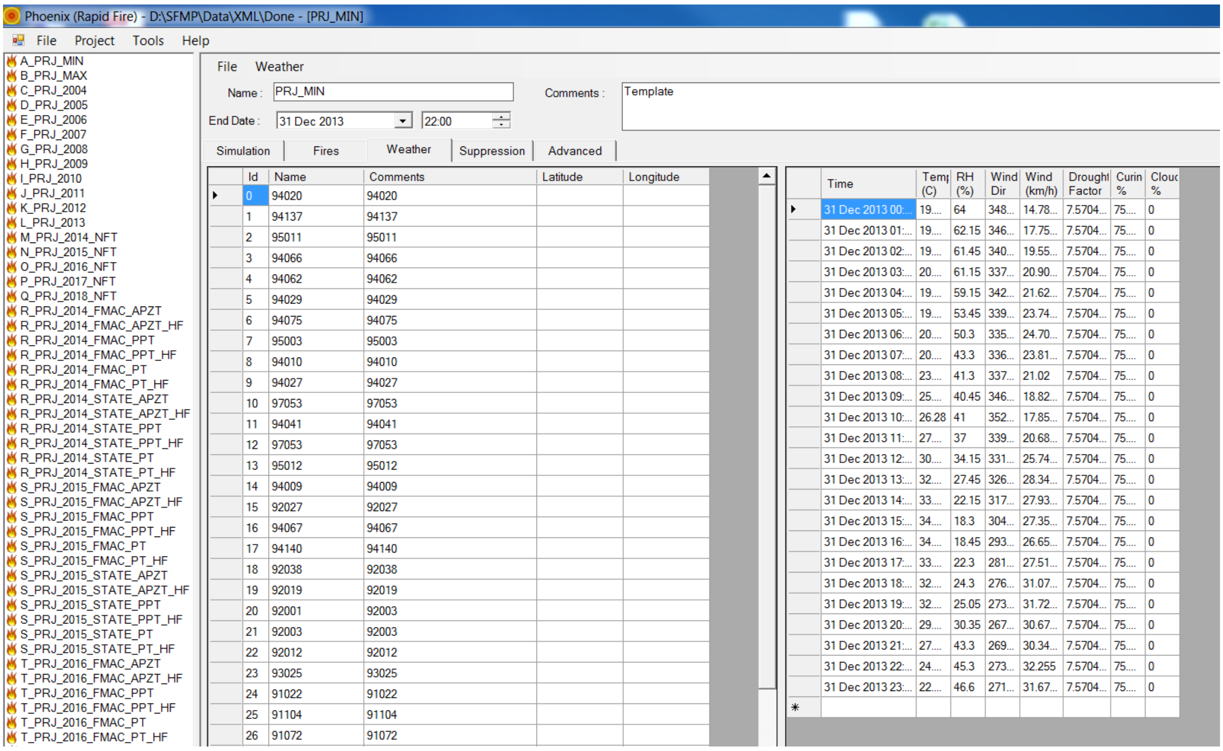

Figure 11: PHOENIX RapidFire settings for the Strategic Fuel Management Report, showing the weather profile for ignition point no. 0 based on data from the Dover weather station (no. 94020).

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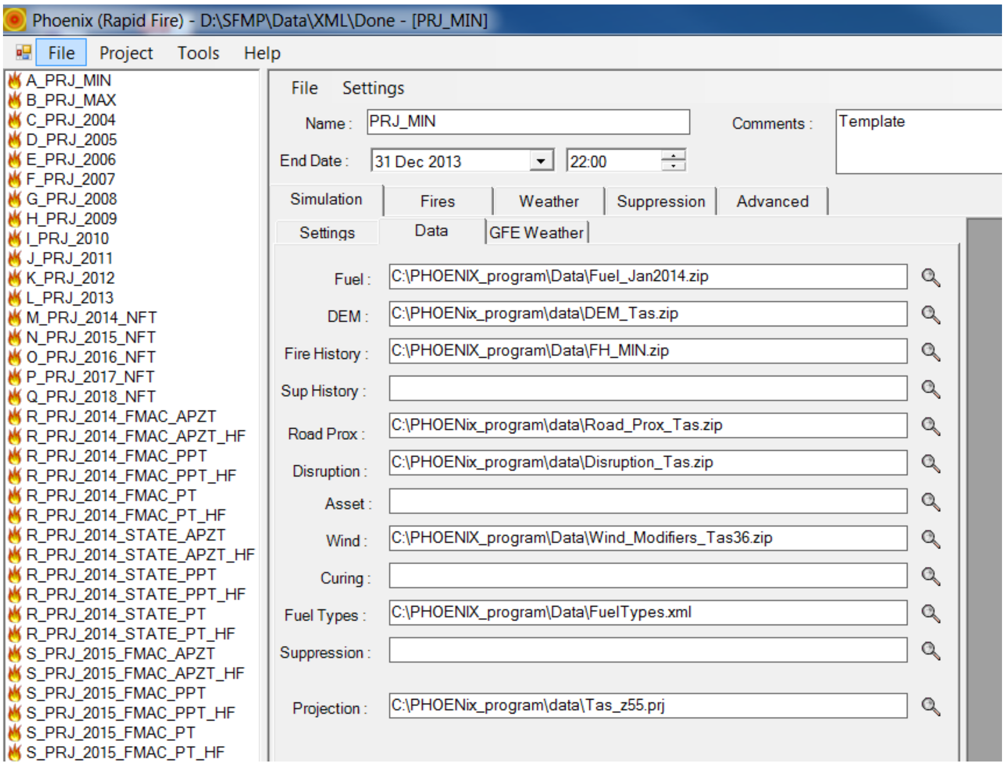

Figure 12: PHOENIX RapidFire RapidFire settings for the Strategic Fuel Management Report showing the data files that were used for all simulations and the fire history file that was used specifically for the minimum treatable fuel load scenario.

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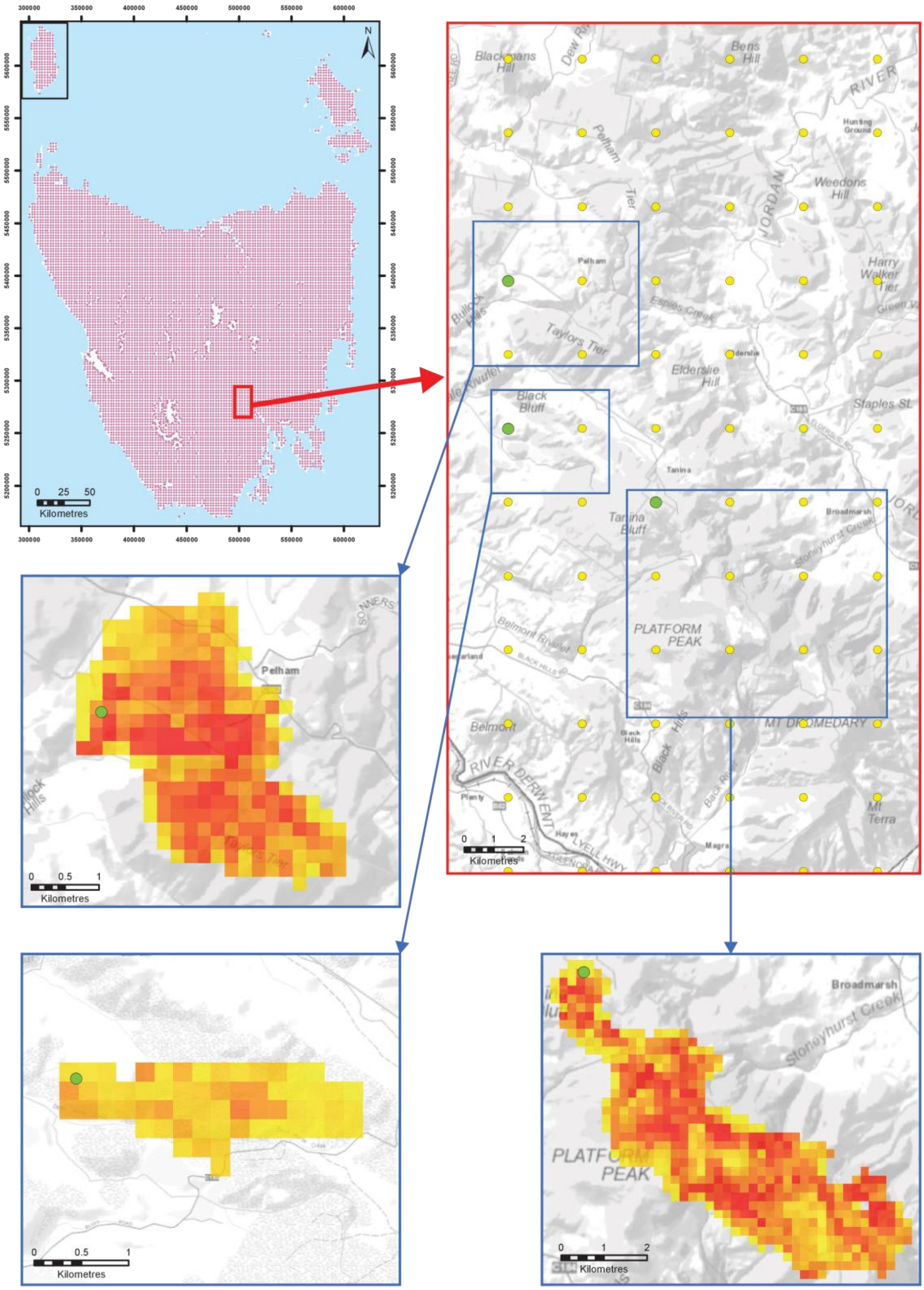

Figure 13: PHOENIX RapidFire simulations running multiple individual fires across the landscape.

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MEASURING POTENTIAL IMPACTS

Building locations, cadastre and ABS data were used to create a Human Settlement Areas (HSA) polygon dataset to define areas where people live and work, including seasonally populated and industrial areas. The accuracy and currency of the datasets on which the HSA dataset were built are questionable in some areas in Tasmania, so the HSA dataset draws from a number of datasets including building locations, cadastre and ABS data, to improve the overall quality and accuracy of the entire dataset. The HSA dataset was not designed to capture every isolated building or home, but is intended to identify higher density areas of buildings and populations, including seasonal populations like shack communities. More information about the methodology used to create the HSA dataset can be found in Appendix 3.

The Phoenix static output grid, consisting of 200m grid cells for the entire state, was overlayed with Human Settlement Areas to determine which grid cells overlapped. If a cell was intersected by the Human Settlement Areas dataset, this was recorded in the static grid as a 'Human Settlement Area' cell, shown in Figure 14. No thresholds were used to determine whether a cell was inside or out, i.e. any overlap of a grid cell with a Human Settlement Area resulted in that grid cell being marked as a Human Settlement Area.

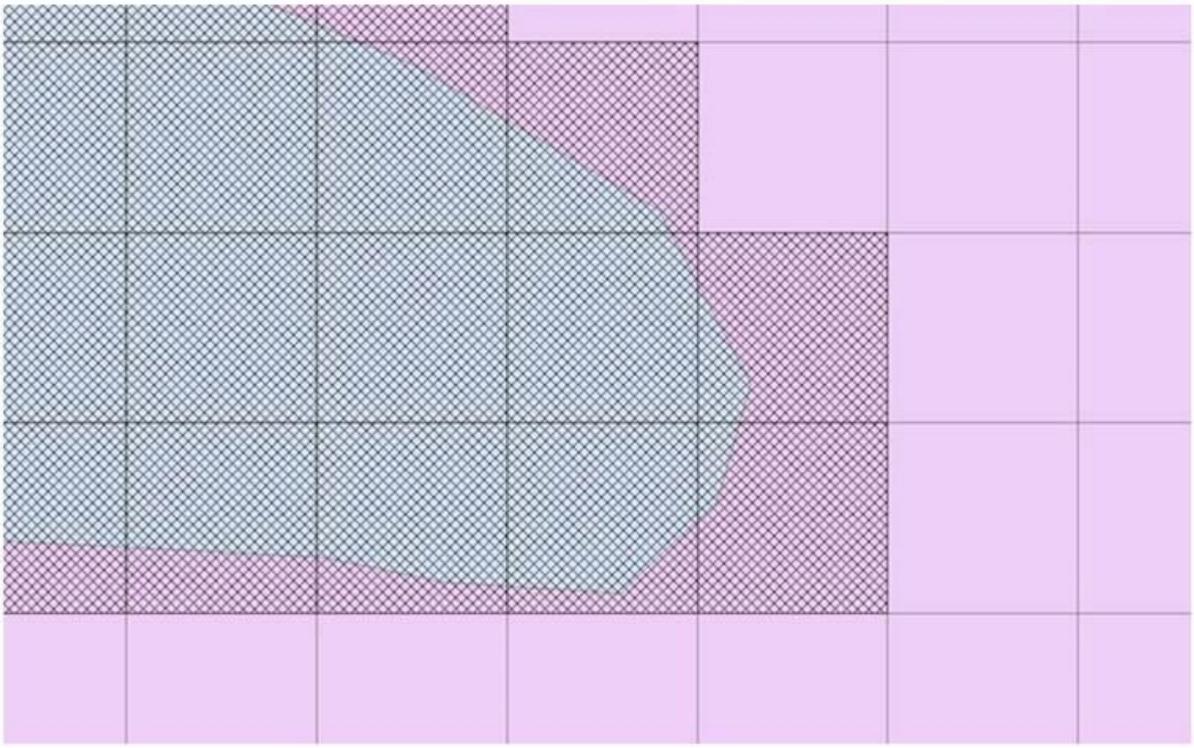

Figure 14: Phoenix static output grid (purple), overlayed with the Human Settlement Area polygon dataset (light blue). The hatched areas are the grid cells that were recorded as Human Settlement Areas in the PostgreSQL database.

An impact on a Human Settlement Area cell was measured when predicted fireline intensity exceeded 10,000kW/m and/or ember density exceeded 2.5 embers/m^2. These thresholds are the same as those used in the House-Loss-Ratio impact type in Phoenix (Tolhurst & Chong, 2012).

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STATISTICAL ANALYSIS

The significance of fuel treatment scenarios in reducing asset impact, fire intensity and fire area was determined using a generalized linear mixed model (GLMM) in the *lme4* (Bates, et al., 2013) package of the statistical language R-3.0.2 (R Core Team, 2013). This statistical methodology was chosen in order to enable some degree of replication and variation to be considered in the fire impacts. Ideally, multiple simulations would be run under varying meteorological conditions, and with stochastically varying ignition locations. However, the computation time for such an analysis was unfeasible for this study. Therefore, individual ignition points within a FMA were regarded as pseudo-replicates within a random effect model, to account for varied model intercept terms across the simulations. For each FMA, counts of number of cells meeting the intensity criteria were calculated for each ignition point, for each fuel treatment scenario in Year 5, along with the no fuel treatment (NFT) scenarios for Years 1 and 5. The cell intensity criteria for each model are as follows:

- Asset Impact - Cell intersecting asset, intensity > 10,000kW/m or ember density > 2.5m^2
- High Intensity - Intensity > 3,000kW/m
- Fire Size – Intensity > 0 kW/m

GLMM models were run with a Poisson error distribution and a log link, and modelled cell count against fuel treatment scenario as a fixed effect, and ignition point as a random effect to control for pseudoreplication.

Cell Count ~ Scenario + (1|Ignition)

95% confidence intervals were plotted for each scenario, and scenarios were regarded as having a significant effect in reducing asset impact, fire intensity or fire size when confidence intervals did not overlap those of the no fuel treatment scenarios. In addition, the three models were run using data from the whole state in addition to each separate FMA.

RELATIVE RISK PROFILES

The modelled impacts on Human Settlement Areas were measured each year from 2003 to Year 5, using the scenario fire history datasets to determine how changes in fuel loads could change potential impacts in response to a combination of bushfire and planned burning. By comparing the impact on HSAs at maximum fuel load with the impact on HSAs in the fire history and treatment scenarios, relative risk graphs were prepared to show how impacts on HSAs change over time in response to past fires and future fuel reduction scenarios. This approach is based on work pioneered by the Strategic Bushfire Risk Assessment Team, Department of Environment and Primary Industries, Victoria (Department of Environment and Primary Industries, 2013).

Relative risk was measured as the ratio of the HSA impact after a certain fuel reduction burning scenario to the impact after No Fuel Treatment, expressed as a percentage as shown in Equation 2.

$$R_{treat} = 100 \times (I_{treat} / I_{max})$$

Where:

R_{treat} is the relative risk.

I_{treat} is the count of HSA cells that exceeded the impact threshold when the bushfires were simulated under a particular fuel modification scenario.

I_{max} is the count of HSA cells that exceeded the impact threshold when the bushfires were simulated under conditions of maximum fuel load, i.e. without any level of fuel modification whatsoever.

Equation 2: Definition of relative risk.

Residual risk graphs were prepared for the entire State of Tasmania, and for each of the 10 FMAs within the State. The risk profile lines were smoothed using the Microsoft Excel 2010 smoothing function.

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SUPPRESSION

All fire spread simulations assume that there is no suppression effort in place. The Phoenix simulations therefore did not use the suppression model that is built into the software.

THE BUSHFIRE RISK ASSESSMENT MODEL (BRAM)

The BRAM was run using each scenario fire history dataset for 2013 (current), Year 1, Year 3 and Year 5. The model outputs HFI (head fire intensity), Fire Behaviour, Likelihood and BRAM Risk were stored for each scenario. Graphs (were prepared to show the area of BRAM $100m^2$ grid cells where HFI exceeded 3,000kW/m. The threshold of 3000kW/m was used to categorise fire, based on fire intensity, to indicate whether the fire was controllable or uncontrollable.

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INFLUENCE OF WEATHER ON A FUEL REDUCTION BURNING PROGRAM

PLANNED BURNING WEATHER WINDOWS

Planned burning guidelines set out by Marsden-Smedley (2009) were used to develop a simple set of weather parameters within which fuel reduction burning could potentially occur, referred to as the 'burning window'. The weather data were compared with the parameters to estimate:

1. the average number of days each year where burning could potentially occur; and
2. the average number of days each year where burning could occur, outside of the peak fire danger period.

The method used to derive the burning window is summarised in Table 4. The final set of weather parameters represent the 'best case scenario', i.e. all planned burning guidelines fall within the weather parameters that represent the burning window. The burning window does not take into account the conditions that affect smoke dispersion.

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Table 4: Weather Parameters used to define the Planned Burning Weather Window

Planned burning guidelines from (Marsden-Smedley, 2009)	Wind speed at 1.7 to 2m (km/h)	Wind speed at 10m (km/h)	Relative humidity (%)	Soil Dryness Index	Temperature (°C)	Days Since Rain (>2mm)	Fire Danger Rating
Dry eucalypt forest planned burning guidelines	-	<30	40 to 80	<126	10 to 25	-	<11 (Forest)
Heathland and dry scrub	5 to 20	-	40 to 80	-	10 to 25	-	<21 (Scrub)
Wet scrub	5 to 20	-	40 to 80	15 to 25	10 to 25	-	<21 (Scrub)
Buttongrass moorland with secure natural boundaries	<21	-	40 to 90	<10	10 to 25	2 to 10	<11 (Moorland)
Buttongrass moorland with mineral earth boundaries	<21	-	40 to 90	<20	10 to 25	4 to 10	<6 (Moorland)
Buttongrass unbounded burning*	<6	-	>60	-	<10	-	-
Native grassland**	<21	-	40 to 80	-	10 to 25	2 to 10	<6 (Grassland)
Gorse	<21	-	50 to 85	<2	10 to 25	<2	<10 (Scrub)
Best case burning windows	-	<30	40 to 90	<126	10 to 25	Rainfall to 9am < 2mm	FFDI < 11 or SFDI < 21 or MFDI < 6

* Forecast rain/dew fall to 09:00 > 0.0mm. Only weather observations will be used to determine burning windows, not forecast weather conditions.

** Curing, and therefore Grassland FDI, has not been captured in the weather observations.

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SUMMARY OF ASSUMPTIONS AND LIMITATIONS

The bushfire risk analysis is based upon modelling, and therefore has a range of assumptions that underpin the analysis. Conclusions based on this bushfire risk analysis must be referenced against the assumptions and limitations of the modelling.

This work provides the foundation for a more strategic and cost-effective approach to fire management by representing bushfire risk spatially and temporally across multiple scales from the state to regional scale, using a combination of models, data and data management systems to characterise bushfire risk. This is the first time that these models and systems have been used in such a way for Tasmania, and so will require ongoing assessment and improvement to further develop robustness and ensure that the outcomes of the risk assessment can be operationalised across all regions of Tasmania.

The BRAM was used as the basis for selecting areas for fuel reduction burning based on bushfire risk. The BRAM is a complex model built on large amounts of spatial data, of varying accuracy and currency. In some cases spatial data is missing, for example where a stakeholder does not have the capacity to provide spatial data in an appropriate format. A considerable amount of time is spent on maintaining the BRAM, but some areas (particularly on private property) do not necessary provide an accurate representation of bushfire risk.

Phoenix is a research tool developed by the University of Melbourne (Kevin Tolhurst and Derek Chong) and the Bushfire Co-operative Research Centre (Bushfire CRC). Phoenix has been used operationally by the Tasmania Fire Service, Parks and Wildlife Service and Forestry Tasmania for incident prediction and in this report for bushfire risk assessment. Phoenix is also used for incident prediction in Victoria, New South Wales and South Australia, and for bushfire risk assessment in Victoria and South Australia. Many of the models, assumptions and settings in BRAM and Phoenix are based on rigorously tested, peer reviewed scientific work. However the systems themselves have not been extensively assessed. As planning tools, they are generally acknowledged by many stakeholders as being at the cutting edge of bushfire risk assessment and critical for helping to reduce risk to life and property. Users of both systems are encouraged to understand their functions, assumptions and limitations.

Phoenix is designed for severe bushfire conditions, i.e. Forest Fire Danger Index (FFDI) > 30. The weather conditions used in this report were based on 99.0 to 99.5th percentile observations from 45 weather stations. In some areas, the maximum FFDI achieved did not exceed an FFDI of 30, and we therefore have lower confidence in the bushfire risk assessment for these areas, shown in red in Figure 15. Under conditions where a major convection column is established, such as the 2013 Forcett-Dunalley fire, Phoenix underestimates spotting and its effect on fire propagation. However such conditions are unlikely to occur under the modelled weather conditions used in this report, because FFDIs used in this report did not exceed 50.

Phoenix was used to simulate bushfires burning in a single day, one-by-one on a 2.5km systematic grid across the whole of Tasmania. A finer scale (1km) grid may be necessary for more detailed analysis of risk in some areas. Each ignition was allocated with a single weather profile representing a typical bad fire weather day in summer. The risk assessment therefore is based on a single weather event and does not reflect the whole distribution of potential weather drivers of fire behaviour, in terms of variations in meteorological components such as wind direction within the selected fire danger level, or the behaviour of fire at more extreme or catastrophic fire danger indices. A more detailed spatially explicit fire weather climatology is required for assessment of risk with a range of potential weather streams. This is being considered as part of future iterations of this report. The 45 weather profiles that were generated, using data from the nearest relevant weather stations (Figure 8), did not account for more localised variations in weather patterns, e.g. those driven by elevation or terrain as shown in Figure 16.

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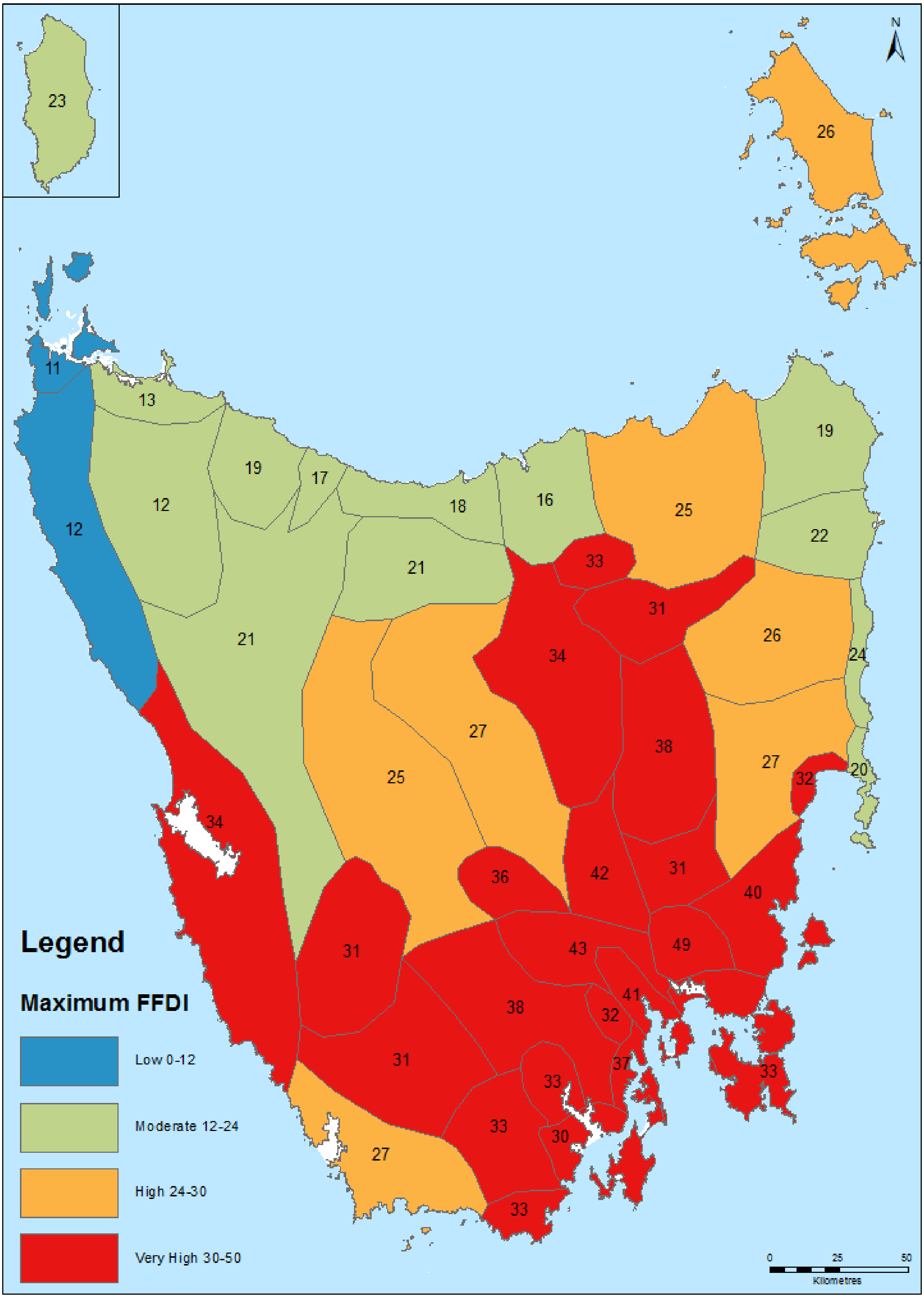

Figure 15: Maximum FFDI in each weather station area based on the 99.0 to 99.5 percentile 10-hour weather profile constructed for the PHOENIX RapidFire modelling.

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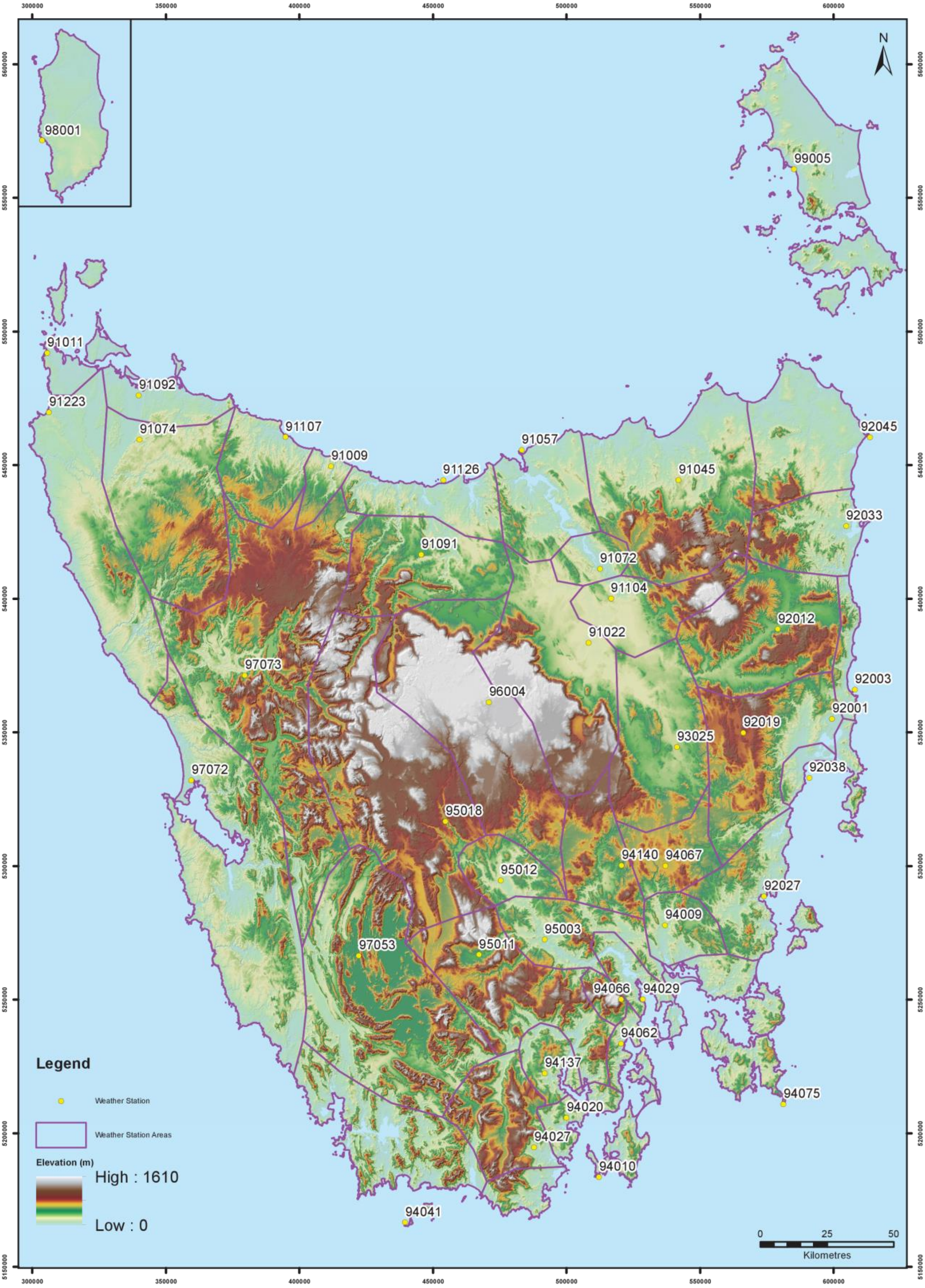

Figure 16. Elevation map, showing weather station locations.

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A Human Settlement Area (HSA) dataset was created for this report to identify the areas in Tasmania where people live and work. The accuracy and currency of the datasets on which the HSA dataset were built are questionable in some areas, which is why the HSA dataset draws from a number of datasets to improve the chances of identifying HSAs in the absence of good data. The HSA dataset was not designed to capture every isolated building or home, but it is intended to identify higher density areas of buildings and populations, including seasonal populations like shack communities. A review of the HSA dataset may result some name changes to existing polygons, and in some changes to better define how smaller and more dispersed communities are included in HSAs.

The priority of this report was to model the risk of bushfires impacting on communities. The property impact metrics used in Phoenix are currently threshold-based and have significant limitations. A shift to a continuous probability of house loss function, incorporating convection, is being investigated by the Phoenix developers as a preferred method for estimating property loss.

Expert opinion has been used to describe treatability of vegetation types, based on work done by Pyrke and Marsden-Smedley (2005). Vegetation types in TASVEG 3.0 (Kitchener & Harris, 2013) were broadly categorised as vegetation that was either treatable or untreatable in relation to fuel reduction burning, based on the typical species composition within each vegetation type and their known sensitivity to fire.

Spatial records of fire history have been used to represent the historical fire disturbance in the landscape. These data have many errors, overestimates and omissions. Future work aims to improve the fire history dataset including burning on council land, privately owned land, burning for silviculture and other burning that is currently not captured. BRAM and Phoenix use different models to calculate fuel quantity and accumulation rates after fire.

Fuel accumulation equations are based on empirical data collected in the field. Fuel accumulation rates and subsequent fire intensity calculations are based on data collected from a range of sites that were burnt under different conditions, from prescribed low intensity fire through to high intensity bushfires. Therefore the fuel accumulation curves are assumed to represent the average fuel accumulation rate, allowing for a variety of fire intensities.

Data used to estimate burning costs provided by FT and HCC show a large variability in the cost of burning. More information could be provided from other agencies such as PWS, councils and other practitioners, and would provide a better data set on which to estimate the potential cost of burning.

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