Mapping Potential Rate of Spread and Intensity of Bushfires using Project Vesta GIS Toolbox

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Abstract
This paper outlines the application of GIS technology to build an operational tool which leverages new fire behaviour prediction models developed from Project Vesta to visually display potential fire rate of spread and potential fire intensity.

GIS technology provides for visual representation of potential rate of spread and intensity of bushfires allowing operational staff to rapidly identify relative risk at the landscape scale. This intelligence is fundamental to risk mitigation, including strategic prescribed burning to reduce fuel loads, and the management of bushfires.

Keywords
GIS, Potential Rate of Spread, Potential Fire Intensity, Project Vesta, Fire Behaviour, Arc Toolbox, ESRI

Introduction
The Department of Environment and Conservation (DEC) is a state government department of Western Australia (WA), who’s primary role is a land manager for government owned lands across WA. DEC and its predecessors have been actively involved in fire science since the mid 1950’s and is recognised in international fire science literature for science based fire management and prescribed burning activities. DEC has strong relationships with countries such as Canada, USA, Spain, South America, and Africa where exchange of fire resources and scientific knowledge have occurred.

DEC is responsible for fire management on 27 million hectares of national parks, marine parks, conservation parks, state forests and timber reserves, regional parks, nature reserves, marine nature reserves and marine management areas. In addition to this DEC is also responsible for fire preparedness on 89 million hectares of unallocated crown land and unmanaged reserves (Figure 1). This combined management area is the equivalent of the total land mass area of South Australia and Tasmania combined and is administered by 9 regional and 19 district jurisdictions.
Forest vegetation in the area of interest (Figure 1 Vesta Broad Vegetation Types) is primarily eucalypt medium open forest type (Anon 2008) and confined to the south-west of Western Australia in the area west of a line between Perth and Albany (Figure 2). Similar eucalypt medium open forest type is widespread in south-eastern Australia and Tasmania (Anon 2008). The south-west of Western Australia has a Mediterranean type climate with cool moist winters and warm dry summers. Forest fuels are dry enough to burn for 6 to 8 months each year during the period from October to May, and occasionally longer if dry weather persists into early winter. Forests accumulate fuels comprised of leaf litter, twigs and understorey shrubs which are capable of supporting intense bushfires under dry summer conditions. Bark also accumulates on the stems of rough-barked eucalypts and other trees, providing firebrands that can propagate several kilometres downwind of a spreading fire by a process known as spotting. The ability to reliably predict the rate of spread, intensity and spotting potential of forest fires is important both in responding to unplanned bushfires, and in using prescribed fire as a tool to reduce fuels and achieve a variety of land management objectives.

![Figure 1. Land Area of Western Australia (WA) managed by DEC, with an enlargement showing the broad vegetation types used to assign Vesta fuel types to the forested area of the south-west.](image-url)
DEC has an active program of fire science within the agency, and also participates in collaborative research with other organizations including the Bushfire Cooperative Research Centre (Bushfire CRC), Commonwealth Scientific Industrial Research Organisation (CSIRO), and universities. DEC was a significant collaborator in Project Vesta that developed fire behaviour models for dry sclerophyll Eucalypt forest.

Two fire behaviour guides (empirical models) are used widely in forest fire operations in Australia to predict forward rate of spread, flame height, spotting and crowning. These are the McArthur Fire Behaviour Tables incorporated in the Forest Fire Danger Meter (FFDM) (McArthur, 1967 and McArthur, 1973) and later formatted as equations by Noble et al. (1980); and the Forest Fire Behaviour Tables for Western Australia (FFBT) (Sneeuwjagt and Peet, 1985) formatted as equations by Beck (1995). The FFDM and FFBT were developed independently from measurements of small experimental fires in dry eucalypt forest fuels comprised of leaf, bark and twig litter and occasional low shrubs (Peet, 1965 and McArthur, 1962). Both guides were designed primarily to predict the behaviour of low-intensity fires for prescribed burning operations, but have been extrapolated to predict the full range of expected fire behaviour based on limited data from low to moderate-intensity experimental fires (<2500 kW m\(^{-1}\)) and observational reports on the spread of wildfires. (Cheney et al., 2012)

The Project Vesta studies were primarily conducted in response to preliminary analysis of the behaviour of high-intensity experimental fires in dry eucalypt forest on a scale of 50–100 ha burnt during Project Aquarius (Gould et al., 1996), and work by Burrows, 1994 and Burrows, 1999 which suggested that both the FFDM and FFBT consistently under-predict the rate of spread of fires burning under dry summer conditions by a factor of 2 or more. Conclusions from case studies of wildfires burning under more extreme conditions such as on Ash Wednesday in 1983 (Rawson et al., 1983) were the same. Experimental fires in Project Vesta (Gould et al.,
Project Vesta was a comprehensive research project to investigate the behaviour and spread of moderate to high-intensity bushfires in dry eucalypt forests with different fuel ages and understorey vegetation structures. More than 100 experimental fires were conducted in southwestern Australia during the summers of 1998, 1999 and 2001 at two sites in eucalypt forest comprised of jarrah (Eucalyptus marginata) and marri (Corymbia calophylla) with top height of 25-30 m. The two sites had contrasting understorey fuel structures of tall and low shrubs that had developed over 2 to 22 years since last fire. Fires were conducted under dry summer conditions of moderate to high forest fire danger, and were lit from a line 120 m long to achieve rates of spread close to the potential for the prevailing conditions. The design and conduction of these experiments are described in Gould et al. (2007a); the methods of fuel sampling and numerical ratings to describe the structure of the fuel at different ages are presented in Gould et al. (2011); and the significance of fuel and wind variables in describing fire behaviour are presented in McCaw et al. (2012). The Vesta fire spread model is made available to users in the form of a nomogram (Gould et al. 2007a), a series of fire behaviour tables in the format of a field guide (Gould et al. 2007b), and as equations (Cheney et al. 2012).

Fire behaviour estimates from the Project Vesta models depend on current fire weather and observed fuel conditions and topography inputs for a particular site. To enable the fire behaviour model to be utilised as a decision support tool associated with bushfire response and bushfire risk mitigation planning the forests of the southwest of WA was classified into standard Vesta fuel descriptions (Figure 1.) based on known spatial distribution of fuel age and estimates of Vesta fuel characteristics applicable to the forest type and the fuel age (Appendix 3).

This paper describes a GIS Toolbox developed by DEC Fire Management Services Branch to leverage the Project Vesta fire spread algorithms and apply them in a simple to use Arc GIS toolbox. The toolbox combines many complex GIS processes into a single integrated process linking GIS data such as vegetation, fuel age, weather, and digital elevation derived slope to calculate a potential fire rate of spread and a potential fire intensity output that is adjusted for slope and fuel moisture content.

The GIS Toolbox has been designed to assist operational staff get a better understanding of areas in the landscape with high potential fire behaviour. This intelligence across the landscape facilitates appropriate fire response management and supports decision making associated with bushfire risk mitigation. This information is fundamental to implementing strategic prescribed burning to reduce fuel loads, and consequently potential rates of spread and potential fire intensity associated with bushfires.

Methodology
The Project Vesta GIS Toolbox contains a variety of tools to create potential rate of spread (ROS) and fire intensity. The toolbox consists of two primary tools (Pre Processing, Post Processing), and three supplementary tools (Post Processing with Real Slope Data, Study Area Clip, Slope Raster Creation). The primary tools have been developed for operational use and require a minimal level of software licensing (ESRI Arcview). The secondary tools have been targeted at data administrators who have access to a higher level of licensing (ESRI Spatial Analyst extension).
Potential rate of spread is calculated using wind speed, fuel moisture content and hazard scores that described the amount and condition of fine fuel in the surface and near-surface fuel layers. Potential fire intensity is calculated from the rate of spread and fine fuel load, and potential flame height from the rate of spread and the height of the elevated fuel layer. The sequence of data inputs, model predictions and data outputs is shown in Figure 3.

Figure 3. Vesta GIS Toolbox Flow
Pre Processing Tool
The pre processing tool is specifically designed to create a vector dataset of the Vesta fuel hazard scores and the indicative fuel load. Please refer to Appendix 1-2 for a screen shot of the tool and processing steps outlined by the model design.

Vesta Fuel Hazard Score Classification:
Fuel Hazard Scores (FHS) are determined by visual assessment of the fuel with the aid of visual guides in the Vesta Field Guide (Gould et.al., 2007b) to classify the four main structural layers (surface, near-surface, elevated, and intermediate and overstorey bark fuels). Broadly similar vegetation structural types are defined based on the forest ecosystems defined for the Western Australian Regional Forest Agreement (Bradshaw and Mattiske 1997). Default hazard scores are provided for fuels (Jarrah East, Jarrah North-West, Jarrah South, Jarrah-Karri Mosaic) in the five age classes post-fire: 0-2 years, 3-4 years, 5-9 years, 10-20 years, 20+ years. Fire history and fuel age data is maintained for DEC managed lands on a 6 monthly timeframe based around burning cycles and bushfire season (Hamilton et al., 2009). Default values are based on fuel accumulation curves determined by Gould et al. (2007a) supplemented by experienced judgement. Appendix 3 provides the classification matrix for FHS using vegetation structure and fuel age, and examples of typical vegetation structures are illustrated in Figures 7 and 8. The FHS classification process is the main purpose of the pre process model which is achieved by overlapping (union analysis) the broad vegetation structure type and fuel age. A series of field calculations are run to populate the appropriate FHS rating (refer to Appendix 3) to the appropriate combinations of broad vegetation structure type and fuel age. This process is also used to assign indicative fuel loads to the various combinations of vegetation type and fuel age. Indicative fuel load values are applied to the Surface Fuel, Near Surface Fuel, and Elevated Fuel at the various fuel age categories. Summing these values provides a total indicative fuel load, which can be used to calculate potential fire intensity.

Post Processing Tool
The post processing tool is designed to take the results of the pre processing tool and union them with standardised weather inputs and a user defined slope class value to calculate a potential ROS and intensity. Appendix 4-5 illustrate screen shots of the tool and the processing steps outlined by the model design.

Weather Information:
The weather variables used in the Vesta fire behaviour models are wind speed recorded at a height of 10m (U10), relative humidity (RH), and temperature (T). The other primary variable is Fuel Moisture Content (FMC) which is calculated using the methodology described by Matthews et. al (2010) with the appropriate model being selected to reflect peak of day conditions:

- FMC Model 1 : November – February from 1300-1700 (daylight savings time) or 1200-1600 (standard time)
  - FMC = (2.76 - (0.0187 * T)) + (0.124 * RH)

The following weather parameters were chosen to reflect a standard summertime condition in the South West of Western Australia:

- Wind Speed (U10) : 30 km/hr
- Temperature (T) : 34 degrees celcius
- Relative Humidity (RH) : 20 %
- FMC Model : 1
Topography:
Terrain has a large impact on fire behaviour. The McArthur forest meter predicts that a slope of 10° will double the spread rate of a forest fire, and a slope of 20° will quadruple the spread rate (McArthur, 1973). However on downhill slopes the effects of eddy winds can complicate fire behaviour (Cheney and Sullivan, 1997). Project Vesta and the Vesta GIS toolbox only model the affects of fire behaviour increasing when moving up slope (Cheney et al., 2012).

The post processing tool has been simplified to allow users with Arcview to nominate a single slope value which is applied across the landscape for calculation of Vesta outputs. A more detailed slope analysis is included in later tools and require a Spatial Analyst extension to run.

Post Processing with Real Slope Data Tool
The post processing with the real slope data tool is designed to use real slope data in combination with FMC to calculate potential ROS and potential fire intensity adjusted for slope. This tool requires a Spatial Analyst extension given the raster nature of the data and hence is targeted at data administrators who have access to higher levels of ESRI licensing. Appendix 6-7 illustrates a screen shot of the tool and the processing steps outlined by the model design.

The Shuttle Radar Topography Mission (SRTM) derived 1 second Digital Elevation Model (DEM) as sourced from Geoscience Australia is used to calculate slope classes. The slope data is then used to calculate the slope correction factor for ROS. Note any slope > 20° has been restricted to 20° to align with McArthur’s upper slope limit (McArthur, 1967). This upper slope limit is also used in both the vesta nomogram and the vesta field guide.

The other three data inputs (ROS on flat ground with 7% FMC, moisture correction factor, and indicative total fuel load) is sourced from the post processing vector data which is converted to raster using the same pixel resolution (~29m pixel size) as the SRTM DEM data.

The model first calculates the adjusted potential ROS and then uses this value to calculate the potential fire intensity using the methodology described by Burrows (1984). Both of these values are then converted into an integer and the 0 values are converted to “null”.

Results
Thirteen sample sites (Table 1) were compared using 3 different methods, Vesta field guide tables, Vesta nomogram, and Vesta GIS toolbox; to calculate the potential Vesta ROS. Sites were selected to provide a good representation of the various broad vegetation types, fuel age, and slope. Variance in site parameters can be observed in tables 1-3 (Table 1 – fuel age and broad vegetation type, Table 2 – FHS’s, Table 3 – slope inputs). In addition the geographical location of the sites can be observed in Figure 7 and 8.
Table 1. Sample site input variables

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Site Name</th>
<th>Weather Inputs</th>
<th>Fuel Assessment</th>
<th>Vesta Broad Vegetation Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BOM Weather District</td>
<td>U10 Temp</td>
<td>RH</td>
</tr>
<tr>
<td>1</td>
<td>Rate</td>
<td>Stirling-Coastal</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>2</td>
<td>Weld</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>3</td>
<td>Yeagarup</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>4</td>
<td>Torrens</td>
<td>Lower West-Inland</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>5</td>
<td>Happy Valley</td>
<td>Geographe</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>6</td>
<td>Chester</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>7</td>
<td>Dee Vee</td>
<td>Nelson</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>8</td>
<td>Shotts</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>9</td>
<td>Flynn</td>
<td>Avon</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>10</td>
<td>Shotts</td>
<td>Nelson</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>11</td>
<td>Collins</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>12</td>
<td>Toodyay</td>
<td>Metropolitan-Inland</td>
<td>30.0</td>
<td>34.0</td>
</tr>
<tr>
<td>13</td>
<td>Mooralup</td>
<td>Leeuwin</td>
<td>30.0</td>
<td>34.0</td>
</tr>
</tbody>
</table>

Table 2. Sample site allocation of Indicative Vesta Hazard Scores and the Indicative Fuel Loads (Pre Process model)

- **SF_FHS** – Surface Fuel Hazard Score
- **SF_Fuel** – Surface Fuel Load (tonnes/hectare)
- **NSF_FHS** – Near Surface Fuel Hazard Score
- **NSF_Fuel** – Near Surface Fuel Load (tonnes/hectare)
- **NSF_Ht** – Near Surface Height (cm)
- **EF_Ht** – Elevated Fuel Height (m)
- **EF_Fuel** – Elevated Fuel Fuel Load (tonnes/hectare)
- **BK_FHS** – Bark Fuel Hazard Score
- **BK_Fuel** – Bark Fuel Load (tonnes/hectare)
- **Fuel_Total** – Total Fuel Load (tonnes/hectare)
Table 3. Calculated results of Post Process and Post Process Raster models for sample sites

- FMC_Calc – Fuel Moisture Content calculated using the methodology described by Matthews et. al (2010) using FMC Model 1
- OMf – Moisture Correction Factor
- O – User Defined Slope (degrees)
- Rad – Potential Rate of Spread on Flat Ground at 7% FMC
- OSf – Slope Correction Factor
- Intens_Rad – Potential Intensity using Rad
- FlmHt_Rad – Potential Flame Height using Rad
- ROS – Potential Rate of Spread adjusted from Slope and FMC
- INT – Potential Intensity using ROS
- DEM_SLOPE – Slope derived from 1 Second SRTM DEM, any slope > 20° has been restricted to 20° to align with McArthur’s upper slope limit

The Vesta field guide tables and nomogram have some inherent rounding errors. These are responsible for the higher ROS values at most sites compared to the Vesta GIS toolbox. Given this limitation the results of the 3 methods produce similar results at most of the sample sites (Figure 4). There is a divergence in the figures at Shotts, Collins, and Toodyay sites. These sites have been impacted by a slope restriction to 20° to comply with McArthur’s slope upper limit of 20° (Shotts = 37.8°, Collins = 34.3°, Toodyay = 21.1°). McArthurs’s 20° slope limitation has also been applied in the Vesta field guide and nomogram (McArthur, 1967).
Figure 4. Comparative results for the three ROS prediction methodologies for each of the 13 sample sites.

A scatter plot of the rate of spread results displays a strong linear relationship between the 3 methods to calculate Vesta rate of spread. This strong correlation can be seen in Figures 5 and 6 by the tightly distributed points around the linear line of best fit. This is also represented by the high $R^2$ value (0.9909) which is almost equal to 1.
Table 4. Rate of spread results from the 3 methodologies

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Site Name</th>
<th>Vesta GIS Toolbox ROS (m/hr)</th>
<th>Vesta Field Guide ROS (m/hr)</th>
<th>Vesta Nomogram ROS (m/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rate</td>
<td>2,364</td>
<td>3,080</td>
<td>2,900</td>
</tr>
<tr>
<td>2</td>
<td>Weld</td>
<td>5,157</td>
<td>6,510</td>
<td>6,500</td>
</tr>
<tr>
<td>3</td>
<td>Yeagarup</td>
<td>247</td>
<td>445</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>Torrens</td>
<td>2,288</td>
<td>2,220</td>
<td>2,500</td>
</tr>
<tr>
<td>5</td>
<td>Happy Valley</td>
<td>2,894</td>
<td>3,600</td>
<td>3,650</td>
</tr>
<tr>
<td>6</td>
<td>Chester</td>
<td>3,091</td>
<td>4,320</td>
<td>3,650</td>
</tr>
<tr>
<td>7</td>
<td>Dee Vee</td>
<td>550</td>
<td>600</td>
<td>500</td>
</tr>
<tr>
<td>8</td>
<td>McCorkhill</td>
<td>1,963</td>
<td>2,640</td>
<td>2,100</td>
</tr>
<tr>
<td>9</td>
<td>Flynn</td>
<td>164</td>
<td>490</td>
<td>250</td>
</tr>
<tr>
<td>10</td>
<td>Shotts</td>
<td>7,204</td>
<td>8,800</td>
<td>8,500</td>
</tr>
<tr>
<td>11</td>
<td>Collins</td>
<td>10,467</td>
<td>14,400</td>
<td>14,500</td>
</tr>
<tr>
<td>12</td>
<td>Toodyay</td>
<td>7,397</td>
<td>9,800</td>
<td>7,500</td>
</tr>
<tr>
<td>13</td>
<td>Mooralup</td>
<td>1,616</td>
<td>1,490</td>
<td>1,500</td>
</tr>
</tbody>
</table>

Figure 5. Scatter plot of Vesta GIS vs Vesta Field Guide rate of spread calculations

\[ y = 1.3395x - 186.17 \]
\[ R^2 = 0.9909 \]
The output layers have been symbolized based on operational use of the data. Potential Vesta ROS is visually presented as 11x categories (0-500, 500-1,000, 1,000-1,500, 1,500-2,000, 2,000-2,500, 2,500-3,000, 3,000-3,500, 3,500-4,000, 4,000-4,500, 4,500-5,000, >5,000 m/hr). Potential fire intensity is presented as 4x categories which reflect the limits of fire intensity where various response strategies are most appropriate (<2,000 kW/m = direct attack, 2,000 – 3,000 = parallel attack, 3,000 – 5,000 = indirect attack, >5,000 = no attack). Examples of the output and the symbology categories are presented in Figure 7 and 8.
Figure 7. Potential Rate of Spread Output
Potential Fire Intensity
(December 2012)

Legend
- Townsites
- Validation Sites

Vesta Forest Type
- Jarrah North-west
- Jarrah East
- Jarrah South
- Jarrah-Karri Mosaic

Potential Intensity (kW/m)
- < 2,000
- 2,000 - 4,000
- 4,000 - 10,000
- > 10,000

Slope
- High : 69
- Low : 0
Conclusion
The Vesta GIS Toolbox has shown a strong correlation with the results of other Vesta calculation methods. The Vesta GIS Toolbox produced lower potential rates of spread particularly for fuels with high hazard scores, and this difference was further magnified on steep slopes e.g. slope correction factor of x4 was applied. The reason for this difference is the Vesta GIS Toolbox uses modified Vesta equations of Cheney et al. 2012 which are a slightly different form than was used in the creation of the Vesta field guide and nomogram.

The reliability of the ROS predictions is dependent on the ability of the indicative Vesta fuel hazard score matrix to accurately reflect observed field conditions. Ensuring a valid relationship between fuel age and Vesta fuel hazard scores and their spatial distribution requires detailed knowledge of vegetation structure distribution, the spatial distribution of fuel age, and fuel accumulation rates for each vegetation type supported by sufficient sampling to ensure a confident relationship between fuel age and hazard scores. The reliability of this information is the primary determinate of the accuracy and reliability of the mapped potential ROS outputs.

Given the limitations of the relationship between Vesta fuel hazard scores and fuel age and the accuracy with which this information can be spatially determined, the Vesta GIS toolbox outputs provide useful decision support for strategic fire management planning. The indicative rate of spread and indicative fire intensity layers are very useful in identifying areas in the landscape which have unacceptable bushfire risk potential. The Vesta GIS Toolbox can also be used to examine how various weather scenarios impact upon potential rate of spread and intensity. For example weather conditions from an extreme summer or mild spring day can be used to examine the impacts to potential fire behaviour. DEC plan to update the potential rate of spread and potential intensity layers every 6 months to align with burn planning timeframes. This intelligence across the landscape facilitates appropriate fire response management and supports decision making associated with bushfire risk mitigation.
References


Bradshaw J., and Mattiske E. (1997) Forest ecosystem mapping for the Western Australian RFA. Commonwealth and Western Australian Regional Forest Agreement Steering Committee, Canberra.


SSSI Conference 2013


Peet, G.B. (1965) *A Fire Danger Rating and Controlled Burning Guide for Northern Jarrah Forest of Western Australia.* Forest Department Western Australia Bulletin No. 74


Appendix 1 – Pre Process Model Interface

Broad Vesta Forest Type

Reflects the 4 primary forest types in the South West Forest Regions which consist of:
- Jarrah East
- Jarrah North West
- Jarrah South
- Jarrah - Karri Mosaic

Each Broad Forest Type when unioned with the Fuel Age can derive the Fuel Hazard Scores (FHS) for each Fuel Layer. A diagram below displays the Vesta Fuel Layers.

Users are recommended to use the Broad Forest Types input as defined by Dr Lachie McCaw.
Appendix 2 – Pre Process Model
## Appendix 3 – Fuel Hazard Score and Indicative Fuel Load Matrix

### Forest Type: Jarrah East

<table>
<thead>
<tr>
<th>Fuel Age (years)</th>
<th>SF FHS</th>
<th>SF Fuel Load (T/ha)</th>
<th>NSF FHS</th>
<th>NSF Fuel Load (T/ha)</th>
<th>NSF Ht (cm)</th>
<th>EF Ht (m)</th>
<th>EF Fuel Load (T/ha)</th>
<th>BK FHS</th>
<th>BK Fuel Load (T/ha)</th>
<th>Total Fuel Load (SF, NSF, EF) (T/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2</td>
<td>0.5</td>
<td>1.0</td>
<td>1</td>
<td>0.5</td>
<td>5</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>1.5</td>
</tr>
<tr>
<td>3 - 4</td>
<td>1.5</td>
<td>3.0</td>
<td>1.0</td>
<td>1.0</td>
<td>10</td>
<td>0.3</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>5.0</td>
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<tr>
<td>5 - 9</td>
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<td>5.0</td>
<td>2.0</td>
<td>2.0</td>
<td>15</td>
<td>0.5</td>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
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<tr>
<td>10 - 20</td>
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<td>2.5</td>
<td>3.0</td>
<td>20</td>
<td>0.5</td>
<td>1.5</td>
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<tr>
<td>20 +</td>
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<td>8.0</td>
<td>3.0</td>
<td>3.5</td>
<td>20</td>
<td>0.5</td>
<td>1.5</td>
<td>3.0</td>
<td>5.0</td>
<td>13.0</td>
</tr>
</tbody>
</table>

### Forest Type: Jarrah North West

<table>
<thead>
<tr>
<th>Fuel Age (years)</th>
<th>SF FHS</th>
<th>SF Fuel Load (T/ha)</th>
<th>NSF FHS</th>
<th>NSF Fuel Load (T/ha)</th>
<th>NSF Ht (cm)</th>
<th>EF Ht (m)</th>
<th>EF Fuel Load (T/ha)</th>
<th>BK FHS</th>
<th>BK Fuel Load (T/ha)</th>
<th>Total Fuel Load (SF, NSF, EF) (T/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2</td>
<td>1</td>
<td>2.0</td>
<td>1.0</td>
<td>0.5</td>
<td>5</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>2.5</td>
</tr>
<tr>
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<td>10</td>
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### Forest Type: Jarrah South

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<th>NSF Fuel Load (T/ha)</th>
<th>NSF Ht (cm)</th>
<th>EF Ht (m)</th>
<th>EF Fuel Load (T/ha)</th>
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<th>BK Fuel Load (T/ha)</th>
<th>Total Fuel Load (SF, NSF, EF) (T/ha)</th>
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### Forest Type: Jarrah - Karri Mosaic

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Appendix 4 – Post Process Model Interface

BOM Fire Weather Districts Data

The weather data template allows the user to input the following for each BOM forecast district:

- **Wind Speed**
  - Column needs to be called "U10" and be measured in km/hr at 10m
- **Temperature**
  - Temperature column called "Temp" measure in Degrees Celsius
- **Relative Humidity**
  - Relative Humidity column called "RH" measured in %
- **FMC Model**
  - FMC Model relates to the 3 available models in the Vesta Handbook:
    - Model 1: To be used from November - February from 1200-1600 with cloud cover less than 4/8
    - Model 2: For all other times during the day
    - Model 3: Use at night time (accuracy of this model is uncertain and should be used with caution)
  - If dew has fallen overnight then the models will under-predict moisture until the dew has evaporated

Users are recommended to modify the template BOM forecast dataset when inputting Temperature, Wind Speed, and Relative Humidity.
Appendix 5 – Post Process Model
Appendix 6 – Post Process with Real Slope Data Model Interface
Appendix 7 – Post Process with Real Slope Data Model