Bushfire Risk Model Framework Standard

Findings Report

Department of Environment, Land, Water and Planning

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→ **The Power of Commitment**

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The Power of Commitment

Executive Summary

In response to recommendations made by the Victorian Bushfires Royal Commission (VBRC) following the 2009 Black Saturday bushfires, the Victorian Government, in partnership with the private sector, supported a program of significant investment in upgrading Victoria's electricity distribution network, with the major objective of reducing bushfire risks arising from electricity infrastructure. This work has been enabled and overseen by the Powerline Bushfire Safety Program (PBSP) which sits within the Energy Program of Victoria's Department of Environment, Land, Water and Planning (DELWP).

To promote cross-organisation modelling consistency, DELWP has engaged GHD to assist with the development of a stakeholder-driven strategic overhead powerline bushfire risk modelling framework through consultation with DNSPs.

This engagement involves the following:

1. Review of the current state of the powerline bushfire risk modelling in Victoria
2. Review of how quantitative bushfire risk modelling is used by Victorian distribution businesses to inform planning decisions and to identify risk mitigation priorities
3. Identification of strengths, gaps, and opportunities for improvement for consideration by the PBSP and DNSPs

This was done through a series of consequence and likelihood workshops with stakeholders to collect an extensive database of information.

At an industry level this review has identified several wider opportunities that could be realized through the coordination and cooperation of the DNSPs and DELWP and ESV. These include:

– Establishment of a review group consisting of the DNSPs, DELWP and ESV to consider the effectiveness of current Victorian regulations and legislation in minimizing bushfire risk. All stakeholders agree to the minimum requirements and acceptable risk-based assessment methodologies.
– Further definition on data, approaches to modelling, data structures and data architecture. This could cover areas such as calculations, data sets, GIS mapping methodology, asset classes, data collected relating to faults, 3rd party data used for consequence modelling. Consistent language, titles and descriptions would make the data sharing more efficient. Principles on data sets (formats, titles and descriptions) could be established. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.
– Establishment of a bushfire modelling practice group between the DSNPs to better share knowledge and approaches to improve bushfire risk modelling and relevant asset information. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.
– Development of risk cost elements based on the risk models which can be incorporated into the asset replacement business cases for DNSP for future review submissions considering the guidance already provided in the AER practice note.
– Using the opportunities and principles from this exercise in conjunction with the DNSPs and ESV to agree on the framework for various levels of modelling requirements for the range of risk profiles that the DNSPs face. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.

The DNSPs have achieved good development of bushfire risk modelling to date on a forward path of continuous improvement.

After several interviews with NSPs, it was also established that developing a risk modelling framework and common approach to modelling derives the following benefits:

– DNSP assets may have long-time spans between planning to the delivery or replacement of assets. Managing these lifecycle risks is done through inspections, maintenance, and capital remediation programs. Better modelling supports decision making and supports funding submissions to the AER
– It allows for the sharing of information, data and lessons learnt

– It allows for a common approach for investment decision-making, both internal and external to NSP organisations
– It allows for a more efficient process to agree common approaches for those considerations: climate change impacts, energy security, transparency and reporting to customers and stakeholders and bushfire management operational measures
– It promotes the use of common terminology for communications, preventing confusion between stakeholders

In terms of overall risk modelling, as part of validation and verification process of a model, sensitivity analysis should be undertaken.

As with any program of continuous improvement, the incremental benefit and costs will need to be considered to determine which will better inform DNSP decision making. It is observed that there is a lack of consistency in consequence modelling.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.4 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

The management of bushfire risk exposures is becoming increasingly complex, with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) recently publishing that climate change has resulted in an increase of bushfires in Australia [1]. Understanding trends and evolving risk factors is necessary to inform Distribution Network Service Providers' (DNSP) bushfire management programs. This is particularly important to Victorian DNSPs as they are responsible for maintaining and operating large networks comprised of millions of overhead assets, in the most bushfire disaster-prone State in Australia. For example, Powercor has greater than 79,000 line route kilometres while AusNet Services has greater than 43,000 line route kilometres.

In response to recommendations made by the Victorian Bushfires Royal Commission (VBRC) following the 2009 Black Saturday bushfires, the Victorian Government, in partnership with the private sector, supported a program of significant investment in upgrading Victoria's electricity distribution network, with the major objective of reducing bushfire risks arising from electricity infrastructure. This work has been enabled and overseen by the Powerline Bushfire Safety Program (PBSP) which sits within the Energy Program of Victoria's Department of Environment, Land, Water and Planning (DELWP).

Enabled by advances in spatial bushfire spread, impact modelling, and simulation technology over the last decade or so and utilising the data modelling and analytics capability of CSIRO (within the Data 61 business unit), the PBSP invested in the development of a Bushfire - Risk Reduction Model (RRM) to facilitate informed decision making regarding the following:

- Implementation of recommendations 27 and 32 made by the VBRC following the 2009 Black Saturday bushfire
- Prioritisation of bushfire safety infrastructure investments
- Legislative and regulatory reforms to mandate new safety standards for electricity safety
- Provide a basis for measuring the benefits of safety improvements

To promote cross-organisation modelling consistency, DELWP has engaged GHD to assist with the development of a stakeholder-driven strategic powerline bushfire risk modelling framework through consultation with DNSPs. This will enable the PBSP to ultimately design the data structures / architectures and consistent risk modelling framework for powerline bushfire risk modelling that will enhance the current Bushfire Risk Models (BRM) utilised in industry.

This engagement involves the following:

- Review of the current state of the powerline bushfire risk modelling in Victoria.
  Review of how quantitative bushfire risk modelling is used by Victorian distribution businesses to inform planning decisions and to identify risk mitigation priorities. This was done through a series of consequence and likelihood workshops with stakeholders to collect an extensive database of information.
- Identification of strengths, gaps, and opportunities for improvement for consideration by the PBSP and DNSPs.

1.2 Purpose of this report

The purpose of this engagement is to assist the PBSP to create an informed, stakeholder-driven bushfire risk modelling framework. This report summarises GHD's findings from:

- A review of the current powerline bushfire risk modelling employed in Victoria
- Interview sessions with DELWP and DNSPs ascertaining how the bushfire risk modelling is used in the planning of bushfire mitigation programs and, if applicable, how the resultant data is used to update and further inform the BRM

- Interview sessions with other relevant stakeholders identifying how these parties currently use, or could potentially use, bushfire risk modelling to support decision making with respect to prioritisation of investments and implementation of regulatory changes
- Comparison of stakeholder responses identifying strengths, gaps and potential areas for improvement within the BRM

From these findings, this report articulates the elements needed within a framework and their respective functions, as well as recommendations to promote consistency and useability across multiple stakeholders.

1.3 Scope

The scope of this project is to:

- Interview and document how DELWP use bushfire risk modelling in the planning of bushfire mitigation programs and how their programs result in data that can be used to update the BRM profiling
- Interview and document how DNSPs use bushfire risk modelling in the planning of bushfire mitigation programs and how their programs result in data that can be used to update the BRM profiling
- Interview and document how other parties use, or could potentially use, bushfire risk modelling to support decision making with respect to investment priorities and regulatory changes
- Develop recommendations to support the effectiveness of the PBSP and to inform the design of the data structures / architecture and risk modelling framework for powerline bushfire risk modelling that will enable an enhanced BRM to be developed and implemented
- Present the findings from the above into a report

As detailed by the PBSP, there are multiple core data categories which form part of the BRM, including the *bushfire consequence* data and *the ignition likelihood* data. To determine how DNSPs capture and approach these elements, GHD developed consequence- and likelihood-based interview questions / discussion points (refer to Appendix C).

The DNSPs approached for interviews include:

- Jemena
- AusNet Services
- Powercor Australia (Powercor)
- United Energy

The other parties approached for interviews include:

- Energy Safe Victoria (ESV)
- DELWP (including Forest, Fire and Regions Group (FFRG))

The following is excluded from the scope of this engagement:

- A *bushfire risk modelling framework* is different to a *bushfire risk management framework*. The latter encompasses broader elements such as bushfire risk policies, organisational mandates, commitment, and governance arrangements for risk management, as well as the design of whole-of-business risk management framework (not just the bushfire risk assessment process). Accordingly, reference to the term *bushfire risk modelling framework* as used in this report is in relation to a framework for a spatial modelling process used for bushfire risk assessment. Additionally, this engagement is to assist with the development of a bushfire risk assessment framework, not a bushfire risk *reduction* framework.
- Design of the data structures / architecture and risk modelling framework for powerline bushfire risk modelling. As specified by DELWP in the provided Request for Quotation, this will be developed following the completion of this project as the findings from this work will inform the subsequent design and framework requirements. However, in order to undertake an assessment of the strengths and gaps of the BRMs reviewed, and assist with the identification of opportunities, GHD has proposed a high-level conceptual reference BRM (Section 5.1). Utilising this reference model for comparative analysis and discussion addresses some key elements which need to be considered within the risk modelling framework; it does not, however, represent a completed risk modelling framework.

- Discussion of controls and mitigations as part of the DNSP interviews as this would form part of the organisation specific bushfire management plans.
- Engagement with third party consultants commissioned by DNSPs to undertake aspects of bushfire risk assessment or modelling (e.g., ENEA Consulting Pty Ltd (ENEA) consulting).
- Other bushfire risk factors that are outside the responsibility of DNSPs.

1.4 Limitations and disclaimers

This report: has been prepared by GHD for Department of Environment, Land, Water and Planning and may only be used and relied on by Department of Environment, Land, Water and Planning for the purpose agreed between GHD and Department of Environment, Land, Water and Planning as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Department of Environment, Land, Water and Planning arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.4, of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

1.5 Assumptions

The following assumptions were made as part of this project:

- Interviews and consultations
  - As part of this engagement, a number of interviews and consultations are required with the DELWP, DNSPs and other stakeholders listed in Section 1.3. In order to effectively liaise with each, it was necessary for DELWP to assist GHD with identifying then reaching out to the appropriate personnel and organise required meetings
  - In addition to the above, it was assumed that the stakeholders contacted would cooperate with GHD in participating in interviews and providing responses to follow-up questions. In preparation for these interviews, GHD created a discussion proforma (refer to Appendix C). In instances where the questions were not addressed adequately during the discussion, these questions were sent to the interviewees for responses. Notes were also sent to interviewees for verification/validation
- Information provided
  - That DNSPs collect, collate, and assess the information they utilise in an appropriate fashion (i.e., outages, fires, and related meta data)
  - That DNSPs have provided all information they use to assess bushfire risk, including data sets, processes, methodologies and uses
  - It was assumed that fire causes are correctly attributed by DNSPs (i.e., due to power line failure, asset failure, or other network events). Events that are attributed to bushfire risk which are not network related have not been covered.

2. Interview & workshop process

DELWP, DNSPs, and other relevant stakeholders were consulted to determine how these organisations and / or authorities:

– Utilise the PBSP RRM; specifically, how bushfire risk modelling has evolved and is currently used to inform planning and risk mitigation decision making
– Identify the methodology DNSPs use to assess bushfire risk
– How DNSPs use data and information to quantitatively assess bushfire risk
– Identify data and / or risk management elements they believe could be improved on or is currently missing from their current bushfire risk modelling. Further, if there are any unclear areas or elements associated with their respective BRMs
– Determine probability of ignition (as part of likelihood modelling) and the elements which form the consequence modelling

These consultation sessions were held in an interview-style arrangement, with GHD subject matter specialists facilitating the interview. As described in Section 1.3, the consequence modelling and likelihood modelling interviews were conducted separately.

The stakeholders interviewed as part of this engagement and their jurisdictions are summarised in Table 1.

Table 1 Stakeholders consulted

Stakeholder	Interview conducted	
	Likelihood discussion	Consequence discussion
AusNet Services	●	●
Jemena	●	
Powercor	●	●
United Energy	●	
DELWP	●	●
ESV		●

The interview questions / discussions points used to facilitate these sessions are provided in Appendix C. Further, the unedited notes are provided in Appendix D for reference. Answers which the GHD team deemed common across both likelihood and consequence discussion points are annotated in red text in the unedited version of the meeting minutes.

3. Current process & initial findings

3.1 Consequence findings

3.1.1 Recent and current approaches to modelling bushfire consequence

Bushfire consequence modelling, as an input for bushfire risk assessment, has been evolving over the past decade since the early consequence modelling work commissioned in 2010/11 as part of the Victorian Powerline Bushfire Safety Taskforce's (PBST) investigations in response to the findings and recommendations of the VBRC. Driven by the need to implement the resultant recommendations to reduce fire ignition potential for Single Wire Earth Return (SWER) and 22kV overhead lines, bushfire consequence modelling was initially used to inform decisions about mandating the deployment of Rapid Earth Fault Current Limiter (REFCL) and SWER Automatic Circuit Recloser (ACR) technologies, and prioritising other engineering solutions applied through declaring Electric Line Construction Areas (ELCA).

The potential bushfire consequence mapping output from the modelling for the PBST was, by intent, a coarse, state-wide map depicting relative levels of potential consequence in a simple 'heat map' style format. This is useful for differentiating regions / landscape areas with high potential consequence from those with lower degrees of potential consequence. The PBST used the modelled potential bushfire consequence results to inform its recommendations [2].

This early Victoria-wide modelling work used bushfire simulation software (Phoenix RapidFire) to simulate bushfire ignitions from Victoria's power supply network modelling a nine-hour run to identify impacted property addresses and derive a quantitative modelled output of house loss for each modelled bushfire. A single 'worst-case' weather scenario based on Ash Wednesday[1] conditions was used in the modelling and applied state-wide. The modelling was undertaken by the University of Melbourne which developed the Phoenix RapidFire system.

Victorian and other electricity distribution business (e.g., in Tasmania and NSW) recognised the potential for more refined application of bushfire consequence modelling undertaken using Phoenix Rapidfire; through the use of improved input assumptions (such as improved weather scenario inputs) and extending consequence assessment beyond house-loss, to determine potential consequences for their own network areas.

Since the early modelling work undertaken for the PBST, alternative bushfire simulation software systems have become available, most notably the 'Spark' system developed by CSIRO. AusNet Services, United Energy and Powercor have commissioned their own bushfire consequence modelling approaches, with AusNet Services using Phoenix Rapidfire, and Powercor and United Energy using Spark. Both bushfire modelling systems adopt similar modelling processes utilising fuel, slope, and weather variable input data to determine fire rate of spread and intensity from which modelled fire area perimeters and potential impacts are derived.

There are a number of differences in the fire behaviour models used. However, the main differences between the consequence modelling work currently undertaken are the number and variety of weather scenarios used and the range of impact types which are assessed.

Based on current processes, a general bushfire consequence modelling process is depicted in Figure 1. The general modelling approach / process applied by AusNet Services, Powercor and United Energy is similar. The main differences are in weather inputs used for fire modelling and the range of asset classes / values assessed in the impact modelling component. Different valuation systems have also been used.

[1] Which occurred on 16 February 1983

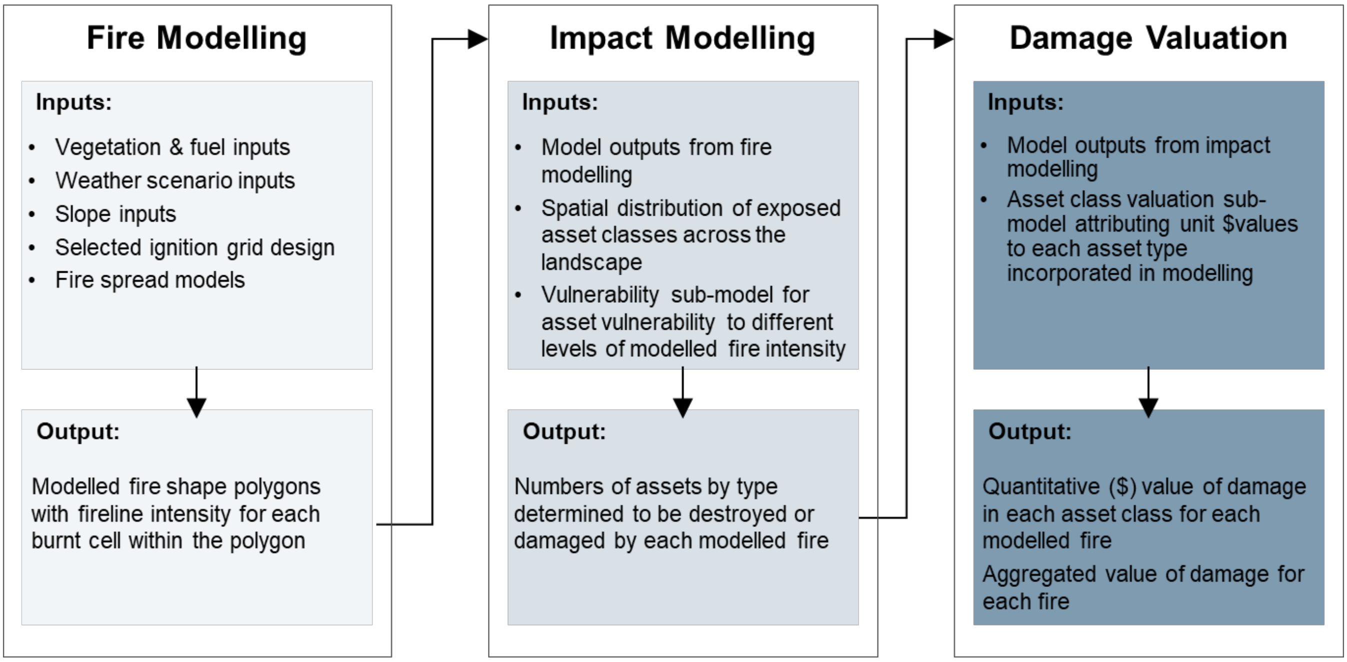

Figure 1 Victorian DNSP bushfire consequence modelling process

In general, with regard to modelling potential bushfire consequences, model input assumptions are very important and substantially influence the model outputs:

– **Bushfire fuel inputs**

The quantity, arrangement, and condition of fuels is a critical input value influencing bushfire dynamics, in particular:

- How far a fire can spread over the model run period
- How intense the fire will be during its spread
- Consequently, the degree of destruction / loss the fire can cause

The fuel attributes which determine fire dynamics and behaviour vary significantly between different vegetation types, different vegetation states and conditions. Modelling can be undertaken using ‘average’ fuel assumptions for broad vegetation groups (e.g., forests, woodlands, shrublands, grass). However, to the extent local conditions in specific vegetation types vary from the assumed ‘average’ values for broader vegetation groupings, the modelling results will have inherent inaccuracies. Accordingly, modelling using more refined fuel inputs to take better account of different fuel attributes in different vegetation types will be inherently more accurate.

– **Weather variable inputs**

Historically, some bushfire consequence modelling has been undertaken using a single ‘worst-case’ weather scenario, assuming a selected wind direction, speed, air temperature, relative humidity, and drought index. This means the model outputs do not account for any potential fire impacts associated with other potentially serious weather conditions. A relatively minor difference in wind direction can make a very large difference in what a fire impacts. Accordingly, modelling which uses a variety of different credible weather scenarios will better identify potential fire consequences from selected ignition locations than single or limited scenarios.

All models use the Forest Fire Danger Index (FFDI) which was developed in the 1960s by CSIRO scientist A. G. McArthur to measure the degree of danger of fire in Australian forests [3]. The index combines a record of dryness, based on rainfall and evaporation, with meteorological variables for wind speed, temperature, and humidity. In continuous use for around 60 years, the FFDI is calculated daily by the Bureau of Meteorology and provides the basis for determining daily Fire Danger Ratings (FDR) communicated via media weather bulletins, FDR signage in rural areas and via digital platforms. While the FFDI has remained constant since its inception in the 1960’s, changes were made to the FDR categories following the Victorian Black Saturday (2009) fires when the Extreme category was subdivided into Severe, Extreme and Catastrophic (Code Red) categories.

On 1 September 2022, a new Australian Fire Danger Rating System (AFDRS) which is based on a new Fire Behaviour Index (FBI) was introduced across all Australian States and Territories, replacing the FFDI, and previous FDR categories [4]. The new FBI is calculated from modelled fire behaviour characteristics using contemporary fire behaviour models whereas the FFDI was based on weather variables only. Future work on bushfire risk models will need to align with the new FBI.

– **Slope inputs**

  The availability of slope data is not generally a limitation for bushfire modelling. However, if modelling is intended to determine potential impacts at individual property scales (e.g. to determine impacts on particular asset classes like houses) then a 10 metre or better resolution digital elevation model is desirable.

– **Impacted values data**

  Bushfires can impact widely across rural lands and naturally occurring vegetation and extend into urban areas where fuel continuity allows. The area impacted by a fire can contain a multitude of tangible and intangible assets including people, houses and other buildings, critical infrastructure / essential services, various agricultural commodities, forestry assets, public infrastructure, tourism generating features/landscapes, and a variety of environmental values, among others. Determining the potential impacts of a fire requires spatially explicit data regarding the locations and attributes of a wide range of asset classes as well as understanding of how they are impacted by fires. The availability of such data is commonly a constraint for fire consequence modelling.

If the intended use of consequence assessment is limited to understanding relatively coarse differences in the spatial distribution of fire damage / loss potential across whole network areas, then coarsely scaled, relative assessments using a limited number of major asset classes as a proxy of overall damage may be suitable. However, if the intent of modelling is to undertake quantitative assessments, and to understand differences on the impact profile across different asset classes / values in specific localities or at finer scales (such as the feeder level), then a finer resolution of modelling effort will be required.

3.1.2 Interview findings – consequence

The interviews were used as a mechanism to determine how different organisations, in particular DNSPs, approach modelling the likelihood and consequences of fires assumed to start at selected locations around their network. Table 2 provides a summary of the responses provided by the DNSPs interviewed. Note that Powercor and AusNet Services were the only stakeholders interviewed for the consequence discussions and the summary for United Energy has been distilled from the documentation provided.

From the interviews conducted and review of the available documentation, the way DNSPs approach bushfire risk assessment is, to an extent, proportional to a networks' general risk profile, as well as what a particular DNSP seeks to use the consequence and subsequent risk assessment for.

At a coarse network level, Victoria has a binary system of bushfire risk identification; this being the Hazardous Bushfire Risk Area (HBRA) and Low Bushfire Risk Area (LBRA) designations. For further background on bushfire risk area designations, refer to Appendix E. For DNSPs which have a relatively small proportion of the network situated in HBRA areas, they may choose simply to apply high levels of bushfire risk control across their small HBRA areas, thus dispensing with any need to conduct more refined bushfire risk assessment within the HBRA area. However, for those DNSPs which have a high proportion of their network area in HBRA designated areas, for the purpose of prioritising and optimising bushfire risk mitigation investments, they will typically seek to conduct substantially more refined bushfire risk assessment.

Only those DNSPs with a substantial bushfire risk profile, as indicated by the proportion of each DNSP's network falls in HBRA, engage in quantitative modelling of bushfire consequence for their network – specifically AusNet Services and Powercor and, to a lesser extent, United Energy. As CitiPower and United Energy are under the same ownership and risk governance systems as Powercor, to an extent risk assessment is integrated for these businesses.

Powercor & AusNet Services

The current modelled consequence inputs for bushfire risk assessment undertaken by AusNet and Powercor differ most in the resolution associated with the weather scenario inputs for modelling and the range of asset classes and value attribution for modelling impacts. AusNet Services' consequence modelling assumes a single FFDI 140 weather scenario, and then derives different consequences for two less severe weather scenarios by applying a fractional multiplier value to the single FFDI 140 scenario modelled results. Powercor's consequence modelling is based in 24 different weather scenarios; with six adverse scenarios generated for each of the four highest fire danger rating categories (assuming that fires starting in the lowest two categories will be suppressed without significant damage occurring).

In terms of assessment of fire impacts, AusNet Services' modelling incorporates house loss, and loss of human life as a derivative of house loss, and assigns economic values to the modelled outputs. Other costs added include response costs and budgeted government-funded recovery costs based on VBRC assessments for the Black Saturday fires. Powercor's modelling incorporates a range of 'major consequence' categories including statistical life loss, property (residential, commercial, and industrial) loss, agricultural losses, tourism losses, and powerline damage. Recently, data relating to school losses have been incorporated. Recent 'proof-of-concept' consequence modelling work undertaken for Energy Networks Australia (ENA) as part of 'Project Ignis' (which included two Victorian districts – Mt Macedon and Otway Ranges) extended impact assessment to include human health and injury impacts, environmental impacts, and some additional essential services impacts including hospitals and water catchment damage[2] [5].

An additional consideration is the selection of thresholds for modelled consequence scales (often used for combination with likelihood to determine risk). Care needs to be taken to set category thresholds which align with historical loss context, in this case in Victoria. GHD notes for example that in the house loss consequence mapping undertaken for AusNet Services, the thresholds are set at:

1. 2000+
2. 1,000 – 2,000
3. 500 – 1,000
4. 100 to 500
5. 0-100

However, no fire in Australian history has ever burnt more than 2,000 houses; only one fire in Victoria's bushfire history has ever burnt more than 1,000 houses (Kilmore East fire of 2009); and even fires which burn 500 – 1,000 houses are rare. This means that all but a very small number of Victoria's worst-ever bushfires fall within the lowest two consequence categories for modelled house loss.

The following provides a high-level summary of the findings from the DNSPs interviewed.

[2] This is in addition to those assessed in Powercor's modelling

Table 2 Summary of stakeholder consequence interview findings

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy (from documentation provided)**
Proportion of network in Hazardous Bushfire Risk Area (HBRA) [3]	**55%**	**55%**	**5%**	**Estimate of 20%**
	Notes: The HBRA percentage estimate is based on pole locations only. Because span lengths are longer, on average, in rural areas a substantially higher proportion of conductor length is in HBRA areas, and this also extends to network asset classes such as distribution transformers which in the case of AusNet Services 81% are in HBRA areas. The pertinent point is that both Powercor and AusNet Services have a high proportion and large number of network assets located in HBRA areas (generally considered high risk profile areas) whilst Jemena and CitiPower have a low proportion of their networks in HBRA, with United Energy also having a relatively lower risk profile taking account of its network area size in relation to Powercor and AusNet Services. CitiPower are excluded from separate assessment and covered at a high level as part of interviews with Powercor.			
Is spatially explicit consequence modelling undertaken as part of DNSP bushfire risk assessment?	**Yes** Modelling undertaken using CSIRO's 'Spark' bushfire simulation system.	**Yes** Modelling undertaken using University of Melbourne's Phoenix RapidFire bushfire simulation system.	**No** HBRA designation is relied on to define the higher bushfire risk network areas, noting the small proportion of the network subject to bushfire risk	**No** UE network principally serves urban areas in southeast Melbourne but has HBRA network areas on the Mornington Peninsula
What bushfire risk control/ mitigation program application or design decisions (and/or asset design/inspection/ management regime decisions) are based (in whole or in part) on bushfire risk or consequence assessment?	Presently, investment decisions about REFCL installation (other than mandated changes), prioritising replacement of conductors, and other asset replacement prioritisation decisions are informed by bushfire risk assessment. Currently vegetation management prioritisation is largely driven by HBRA/LBRA designation and codified area (ELCA) designation. Also used for supporting business cases as part of the Electricity Distribution Price Review (EDPR) process.	General estimation of bushfire risk variation across the network. Network asset management planning and investment decision making. Inspections and corrective maintenance are driven by HBRA / LBRA designation. In areas designated as ELCA, bushfire safety project / initiatives receive higher priority and construction of line assets conform to the regulatory mandate (underground or insulated). Hazard Tree Program prioritisation.	**NA** Bushfire mitigation decisions largely driven by HRBA/LBRA designation.	As specified within the United Energy report [6], the asset baseline includes the mitigation measures implemented by Powercor since the beginning of bushfire works in 2016.

[3] Used as an indicative measure of the DNSP risk profile

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy (from documentation provided)**
For the purpose of evaluating the outputs of bushfire consequence modelling, what qualitative (or quantitative) scale for consequences is used, and how are the thresholds between consequence categories determined?	Risk (which is a function of modelled consequence ($) and likelihood) is expressed as an annualised loss value ($) with a dimensionless scale. Current annualised risk for the network is $42.3M, with spatial variation in results presented on a map interface using a colour coded scale from 0 to $50M. The only 'categorisation of consequence at outcome level is differentiation between "Minor Consequences" and "Major Consequences". Minor consequences are a result of two sources: – F-factor penalties – Insurance claims from customers affected by fire Major consequences is the aggregated potential loss estimated from the $ value lost in the burning for the following categories: – Agricultural losses – Property damage (residential, commercial and industrial) – Damage to powerlines – Tourism loss – Statistical life loss	Consequence is expressed as a potential fire cost ($) using a five-tier scale: – $0-$20K – $20K – $100K – $100K – $300K – $300K – $700K – > $700K Note that the monetary thresholds may be determined by a user and are adjusted to suit the results being presented. Cost benefit analysis is performed using the exact amount and the 1 to 5 scale is used for presentation only.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	Similar to Powercor in that the only categorisation of consequence at outcome level is differentiation between "Minor Consequences" and "Major Consequences". Major consequences are estimated from the value lost in the burning for the following categories: – Agricultural land – Buildings – Life loss Minor consequence costs are F-Factor penalty value and insurance claims costs.
What, if any, analysis/assessment process has been undertaken to evaluate actual DNSP bushfire consequence historical data alignment with the	Modelling results compared with major historical loss events (Black Saturday and St Patricks day fires) and against results from Project Ignis modelling for Mount Macedon and Otway Ranges areas (undertaken by Energy Networks	No modelling evaluation against major historical fire events to GHD's knowledge. ENA did not model any areas in AusNet Services' network area.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire	As for Powercor

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy (from documentation provided)**
modelled consequence category triggers used?	Australia). Commentary documented on Section 3.4 of Energy Networks Consulting Pty Ltd (ENEA) bushfire risk modelling report [7]		behaviour and impact modelling is not undertaken by Jemena.	
Noting that vegetation types and their attendant fuel hazards vary widely across Victoria, what system is used for determining the vegetation-based bushfire fuel assumptions to be used in bushfire consequence modelling?	Spark modelling utilises DELWP vegetation classifications and mapping.	Phoenix RapidFire modelling utilises DELWP vegetation classifications and mapping.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	As for Powercor
	Note: DNSPs rely on the expertise of their bushfire modelling service provider to select appropriate spatial vegetation and fuel data for modelling, and to undertake any customisation of fuel input data that may be required to run the fire behaviour models.			
Noting that the range of weather conditions to which a bushfire could be exposed to can vary greatly at any one location, and is variable between locations, what system is used for selecting the weather variables and values used in bushfire consequence modelling?	Bushfire consequence modelling is based on 24 separate weather scenarios (six in each of the *Very High, Severe, Extreme and Catastrophic* fire danger rating categories). The modelling thus incorporates scenarios involving a range of wind directions and other weather variables and is thus less prone to omitting potentially high-consequence fire scenarios than single or limited scenario methodologies.	Bushfire consequence modelling is based on a single catastrophic scenario for a FFDI of 140 (based on Ash Wednesday conditions). The impacts of less severe weather conditions (FFDI 100 and FFDI 70) are assessed by applying fractional multipliers for house impact to the FFDI 140 scenario, so these are not truly additional weather scenarios incorporated in fire modelling.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	As for Powercor
	Notes: DNSPs rely on the expertise of their bushfire modelling service provider to select appropriate weather scenarios for modelling, noting that the weather extremes experienced at different locations across a network area vary depending on such factors as elevation, topography, and proximity to coastlines. To optimise the relevance of selected weather scenarios to different weather districts, it is prudent to base weather scenario selection on local climatological analysis.			

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy (from documentation provided)**
What system is used for determining the slope data to be used in bushfire consequence modelling?	Spark modelling utilises a digital elevation model deemed by the fire modelling service provider to be fit-for-purpose for fire modelling.	Phoenix RapidFire modelling utilises a digital elevation model deemed by the fire modelling service provider to be fit-for-purpose for fire modelling, and as used by DELWP in their operational use of fire modelling.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	As for Powercor
What types of bushfire fire impact are modelled (e.g., loss of human life, house loss, other asset class loss etc) and how are these quantified (and/or classified into qualitative categories)?	Major consequence impact categories including: – Human fatalities – Property/building loss (Residential, commercial, industrial) – Agricultural losses (crops, pastures, livestock, feedlots) – Forestry losses (plantations) – Powerline damage – Tourism revenue losses Minor consequence costs are F-Factor penalty value and insurance claims costs.	As a proxy for total damage, relative consequence assessment is based on modelling of: – House loss – Human fatalities as a derivative of modelled house loss	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	Major consequences are estimated from the value lost in the burning for the following categories: – Agricultural land – Buildings – Life loss Minor consequence costs are F-Factor penalty value and insurance claims costs.
Where multiple weather scenarios are used in bushfire consequence modelling, how are the modelled impact results of the multiple scenarios aggregated or otherwise combined to provide a single modelled consequence output?	The results of the bushfire simulations give the probability of being impacted by one of four fire intensities (FI) on a grid of 30 metre cell size and are averaged over the six weather scenarios. FIs are mutually exclusive, which means that if a cell has a 60% chance of being hit by a FI 3, the sum of the probabilities for the three other FIs can only add up to 40%.	**NA**	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	As for Powercor
Where multiple weather scenarios are used in modelling, is weather	The probability of weather scenario occurrence (based on FDI) is not incorporated in the consequence	The probability of FDI 140, FDI 100 and FDI 70 scenario occurrence is factored in at consequence	Jemena not interviewed for consequence. Current documentation provided does not	As for Powercor

Prompts	Organisation			
	Powercor	AusNet Services	Jemena	United Energy (from documentation provided)
scenario occurrence probability used in any part of the bushfire risk modelling process?	modelling stage but is incorporated at the overall risk value calculation stage, using the probability of FFDI occurrence at the asset where the modelled fire is ignited.	modelling stage, as a function of annual occurrence probability and daily occurrence/persistence period.	detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	
What evaluation or validation process do you apply to the modelled bushfire consequence outputs to assess for errors or significant variances from other relevant sources of risk assessment?	Modelling results compared with major historical loss events (Black Saturday and St Patricks day fires) and against results from Project Ignis modelling for Mount Macedon and Otway Ranges areas (undertaken by ENA). Commentary documented on Section 3.4 of ENEA bushfire risk modelling report [7]	No modelling evaluation against major historical fire events to GHD's knowledge. ENA did not model any areas in AusNet Services' network area to facilitate comparison.	Jemena not interviewed for consequence. Current documentation provided does not detail responses to this prompt. It is understood that detailed bushfire consequence modelling using fire behaviour and impact modelling is not undertaken by Jemena.	As for Powercor
	Notes: A form of modelling validation can be done (potentially as part of the risk modelling process) by modelling the impacts of selected historical major fires known to have started from powerlines and undertaking comparative analysis with the actual burnt area and fire-caused losses associated with the selected fire event.			

3.2 Likelihood findings

3.2.1 Approach to determining ignition likelihood (PBSP model)

As described in the *PBSP Risk Reduction Model – Overview and Technical Details* report [8] the evolution of faults and fire conditions in the PBSP RRM follows a "chain of escalation" process which is illustrated in Figure 2.

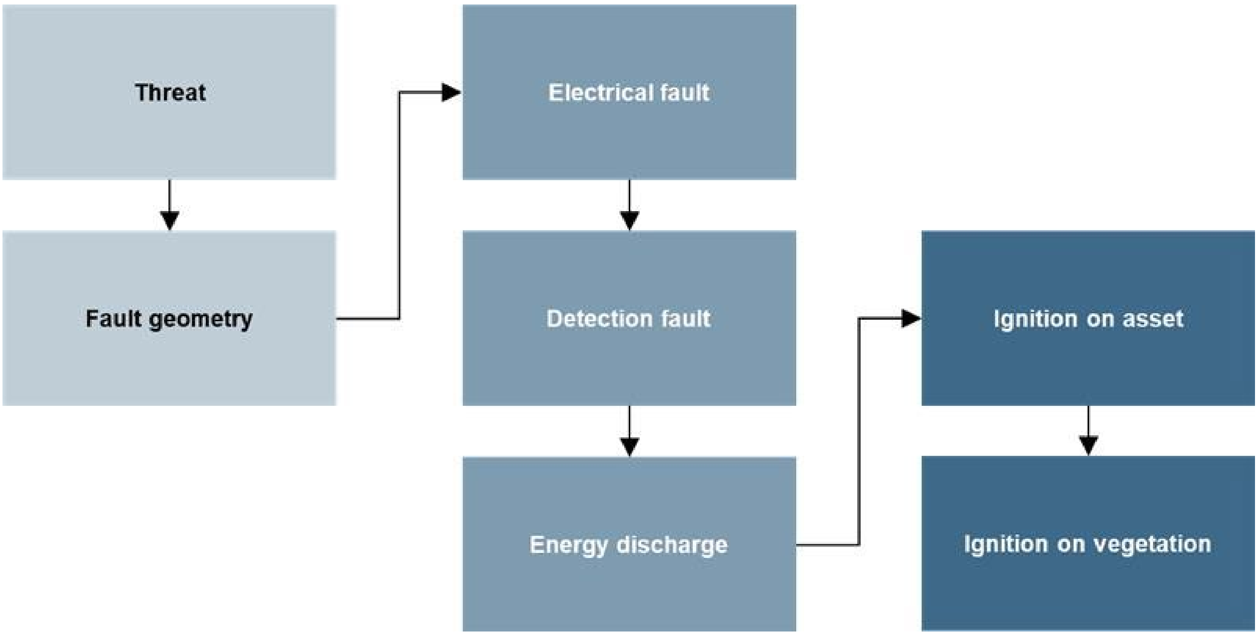

Figure 2 Chain of escalation leading to bushfire ignition (Figure 1 in ref [8])

The "chain of escalation" process is utilised for the ignition likelihood model. Dunstall et al. [8] assume that fault detection is a "stage in the evolution towards detection" rather than assuming that all faults are detected in the model.

There are several data inputs which feed into the determination of the technology ignition likelihood reduction and network ignition likelihood reduction as shown in Figure 3. Network asset data, both spatial and asset based, and network fault data provided by DNSPs are required to provide a representative quantification of risk. Although the aim of this RRM is to quantify the risk of ignitions, it is recognised that insufficient ignition data is available; thus, utilising datasets available for faults and applying a fault-to-ignition conversion (a transition step in Figure 2) allows for the development of an informed RRM.

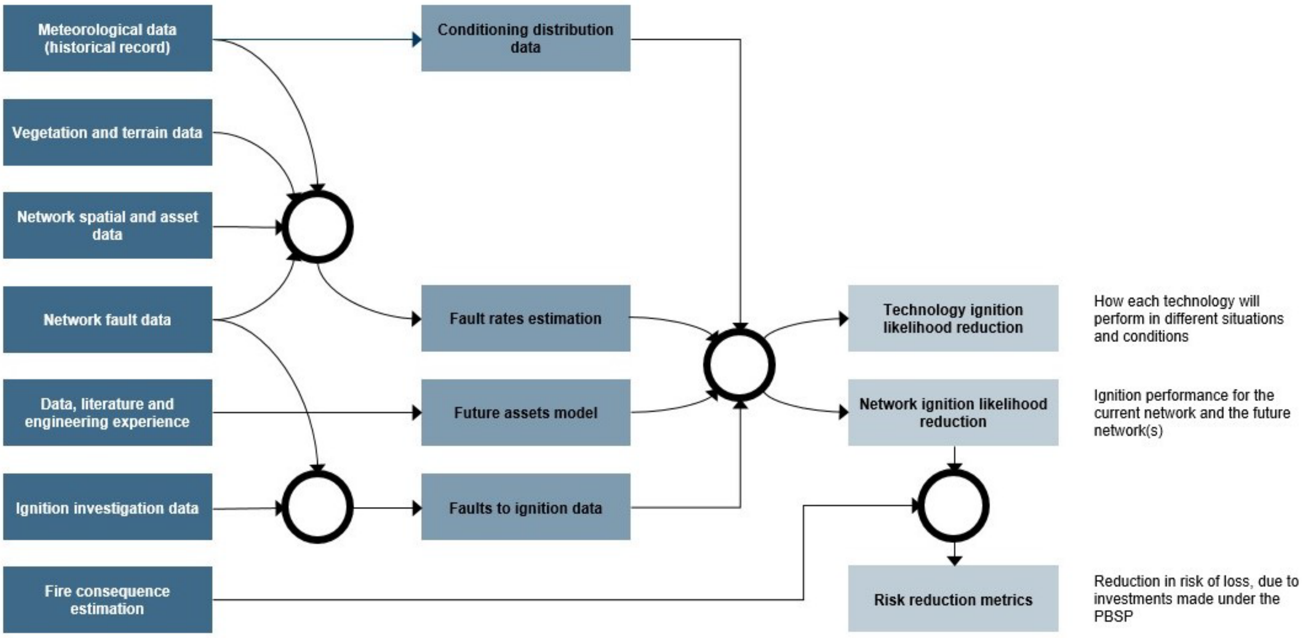

Figure 3 Data, models and outputs relevant to the likelihood and risk modelling approach (Figure 2 in ref [8])

3.2.2 Interview findings - Likelihood

The interviews were used as a mechanism to determine how different organisations, in particular DNSPs, approach calculating the fault and fire ignition likelihood of which is required for the quantification of risk. Table 3 provides a summary of the responses provided by the DNSPs interviewed, with more detailed responses in Appendix D.

The way DNSPs described the approach for calculating the likelihood of asset failure, thus feeding into calculation of ignition likelihood, is proportional to the network's risk profile. By using the proportion of each DNSP's network falls in HBRA as an indicative measure, it was found that DNSPs which have a greater of their network in HBRAs have a more detailed risk analysis approach and have explored the potential to use more advanced computational tools and data sources (e.g., leveraging artificial intelligence and asset management data to identify at risk assets).

It was found that all DNSPs use historical fault and fire start data as a prediction of current likelihood. This is a justifiable method for assessing risk of future fire start events. It was emphasised that the historical fire start data set is important; a long history is required, as well as relevant / recent data, data quality and volume of events. As bushfire risk likelihood models are (optimally) updated yearly, relevance of data is eroded with time. DNSPs have indicated that fire starts are not as frequent (potentially due to the increase in bushfire mitigation programs), so that recent fire start history may not carry as much weight due to lower statistical significance. These considerations have influenced opportunities referenced in section 5.4.

The following provides a high-level summary of the findings from the DNSPs interviewed.

AusNet Services

AusNet Services currently use different data sources to assess likelihood of asset fault / failure and likelihood of ignition:

– Asset failures that have translated into fire start (providing a static ignition likelihood), plus HBRA / LBRA with respect to probability of ignition
– Use of unassisted failure data and weight the probability of future fault based on location [9]. Recently, AusNet Services have moved to a machine learning model which provides more granularity to the determination of asset failure as it allows a weighting to be applied based on history, manufacturing, construction features (and other conditions) and location. A report from McKinsey [9] provides further detail about this process.

A concluding remark made by the interviewees was that there is a need to improve data quality. The use of data from other networks may be useful if the environment and ignition sources are similar to AusNet Services' networks. The continuous reduction in network caused fires, albeit positive, means that historical data points which inform the calculations are becoming scarce.

Jemena

Five percent (5%) of Jemena's networks are in HBRA. As a result, the organisation is more focused on mitigation programs to remove risks entirely rather than completing quantitative likelihood modelling at an asset level. Quantifying risk to the level of detail of other DNSPs may not be justifiable in terms of effort or benefit.

Powercor

Based on the information provided and the responses by the interviewees, Powercor have a comparatively advanced ignition likelihood model. Powercor engaged ENEA to undertake modelling on likelihood on their behalf [7] using the PBSP's CSIRO RRM to assess ignition likelihood based on asset types and failure rates.

The asset fault model is based on the historical distribution of fault on Powercor and AusNet Services' networks between 2009 and 2013. This allows Powercor to form a statistical understanding of fault occurrence rate based on the asset properties (cable type), asset situation (vegetation, terrain), asset condition (cumulative weather exposure) and fire weather variables. Aggregates at each pole location (half spans are also aggregated to pole).

The Powercor model is the only one which has a Geographic Information System (GIS) model of bushfire risk and considers climate change in a way that allows for projections / scenario modelling, using FDR as an influencer of risk.

Interviewees also stated in their concluding remarks to include fire suppression in the likelihood calculations (i.e., after ignition, what is the likelihood of that fire being suppressed?). This would further refine the model.

United Energy

It is estimated that approximately 20% of United Energy's assets are in HBRAs.

United Energy utilise Powercor's methodology and data, having recently updated their methodology to align with Powercor [6]. However, the methodology differs as:

- Fault data does not include asset location weather conditions, or vegetation
- There is reduced spatial granularity
- Unlike the other DNSPs interviewed, United Energy's model includes all asset ignitions, not just ground ignitions

It was noted, however, that United Energy's failure rates of assets are a network-wide count and are therefore independent of the asset location. An issue identified by interviewees is that United Energy cannot distinguish parts of the United Energy's network with a higher bushfire likelihood with the current model. It is also currently biased towards asset type and not asset location.

As part of stakeholder consultations, GHD also interviewed DELWP representatives to gain an understanding of how likelihood assessments are conducted.

DELWP

FFRG are currently utilising Phoenix RapidFire modelling for bushfire consequence. There are plans to implement the University of Melbourne's model to assess likelihood in 2023 [10].The model determines the probability of fire ignitions across Victoria via examination of the key drivers of both anthropogenic and lightning-caused fire ignitions. A range of ignition causes were examined, including:

- Lightning
- Deliberate ignition (e.g., via arson)
- Accidental ignition caused by humans (e.g., campfires, escaped burn-offs or vehicle ignitions)

Data obtained was reclassified into anthropogenic and lightning ignited fires. Due to the lack of data available for anthropogenic ignited fires, the model generates a random set of points within the date range of the available ignition data. This was not required for the lightning ignition component of the model. The random forests statistical model was utilised, which, according to the McKinsey report provided by AusNet Services, is “robust…with good predictive power.” [9]

This is used for planning and operational practices. This includes ‘human’ ignitions and models the probability of fire ignitions across Victoria for a range of different ignition causes, including powerlines.

Table 3 Summary of stakeholder likelihood interview findings

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy**
Proportion of network in Hazardous Bushfire Risk Area (HBRA).[4]	**55%**	**55%**	**5%**	**Estimate of 20%**
Is likelihood modelling at an asset level (quantitative risk) undertaken?	**Yes**	**Yes**	**No** The likelihood modelling is complete at a network level	**Yes** The likelihood model combines United Energy's historical asset failures with ignition rates extracted from the PBSP's BRM [8]
Are separate assessments of likelihood of asset fault and likelihood of ignition undertaken?	**Yes** The model estimates the fault likelihood in the first step and the fault to ignition rate in the second step. There are two different data sources: – Fire starts database – Historical faults database The likelihood of ignition is calculated based on historical data of electrical faults and characteristics of poles, wires and fuses. Ignition rates and fault likelihood are specific to location and asset condition. Only includes ground ignitions	**Yes** There are two different data sources: - Asset failures that have translated into fire start (unassisted only), weighted based on location 'area' (e.g. HBRA / LBRA or spatial area analysis coast/inland) [9] - Probability of ignition is assessed separately	**No** No quantitative modelling is completed at the asset level. Instead, Jemena aim to eliminate the risk through mitigation activities, based on 'good practice' and modelling from other NSPs. Fault data is distinguished from ignitions data. Use ignitions data for consequence calculations.	**Yes** Data sources include: – Network-wide, per-asset class failure rates and failure modes for all asset classes – Per-span failure probability for conductors Condition Based Risk Methodology (CBRM) models). Includes all asset ignitions (not just ground).
How is asset failure likelihood calculated?	The asset fault model is based on the **historical distribution of fault on Powercor and AusNet Services' networks between 2009 and 2013**. The following information is needed for the fault model:	GHD believes that AusNet Services appear to only use unassisted failures (not assisted) in their likelihood assessment. They cleanse the data to	**Not applicable**	The asset failure likelihood has been estimated **using datasets readily available to United Energy**, mostly derived from historical failures of assets averaged across the United Energy (UE) network. The following datasets were used:

[4] Used as an indicative measure of the DNSP risk profile

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy**
	– The network type (22kV or SWER) at the fault – The fault cause (e.g., animal, tree branch, etc.) and impact (e.g., broken conductor) – Asset's situation (terrain and vegetation) – Locate the fault to: • Determine the local meteorological conditions at the time of the fault • Determine the total exposure of the asset to meteorological conditions over time Other conditions considered in the likelihood model are provided in Appendix 3 of the ENEA report [7]. This allows Powercor to form a statistical understanding of fault occurrence rate based on the asset properties (cable type), asset situation (vegetation, terrain), asset condition (cumulative weather exposure) and fire weather variables. Aggregates at each pole location (half spans are also aggregated to pole).	remove assisted (i.e., faults due to lightning, debris)[5]. The total likelihood = *Probability of asset failure (not based on location*) **x** *Probability of ignition* Probability of fault is weighted using spatial areas, i.e., more failures near the coast. More recently AusNet Services has moved to a machine learning model – which takes into account location and features [9]. Only includes ground ignitions.		– Network-wide, per-asset class failure rates and failure modes for all asset classes – Per-span failure probability for conductors Condition Based Risk Management (CBRM models) These are aggregated at each pole location. Note United Energy failures rates of assets are a count network-wide, thus are agnostic to the location of the asset.
Is ignition likelihood based on past fire start events (fault leading to a fire start)?	**Yes** Through the use of the PBSP BRM. The conversion rate is estimated by assessing the proportion of detected faults that transition to ignition on asset (see Figure 5). The asset ignition rates are asset location and conditions specific.	**Yes** Ignition likelihood is based on past fire start events. However, in most cases there is not enough data to be so granular as to split as asset class into High Voltage (HV) / Low Voltage (LV), HBRA / LBRA, or different types, models or manufacturers.	**Yes** Through the use of known industry history.	**Yes** Region-wide averages were extracted from PBSP BRM, and rates were determined by assessing proportion of detected faults that transition to ignition. Thus enabling the determination of ignition of each asset at a pole location.

[5] For the machine learning models, AusNet Services only want to consider the unassisted failures for predicting probability of failure. This is appropriate if AusNet Services intend to remove the bushfire risk posted by unassisted failures, such as asset replacement. Like-for-like replacement will not prevent an assisted failure and hence does not reduce this component of the risk

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy**
	Biased toward asset location more than asset class? All faults are 'aggregated' to a conductor/pole.			Biased towards urban assets due to UE's network locations. A methodology per asset is used to aggregate this network wide data to a location
What is your BRM used for?	The BRM is used for investment decision-making, both internally and externally, for the EDPR process.	The BRM is used for: – Insurance premiums – Investment decision-making – Estimation of annual risk	The BRM is used for: – Insurance premiums – Reporting requirements (e.g., to ESV) – Investment decision making and risk mitigation / elimination programs	The BRM is used for investment decision-making, both internally and externally, for the EDPR process.
Do you have a GIS model of bushfire risk?	**Yes**	**No**	**No**	**No**
Are individual assets assigned likelihood ratings?	**Partially** This is not completed for many asset types. Asset likelihood ratings are aggregated to a conductor/pole, where 'type of pole' takes into account assets related to that pole	**Yes** For fault likelihood estimates. The assets assigned individual likelihood ratings include fuses, conductor, crossarms, protection devices, poles (for geolocation)	**No** However, HBRA / LBRA are treated differently	**Yes** For fault likelihood estimates. The assets assigned individual likelihood ratings include poles, substation, crossarms, conductors, and isolating devices
Does likelihood change with weather conditions?	**No** Fire danger rating is qualitatively noted in fire start database. Weather conditions are used for likelihood based on location of fault history to determine influence of weather on likelihood. Historical weather data is used to create six weather scenarios at the asset for the four highest FFDIs	**Yes** Probability of three FFDI scenarios are considered in consequence assessment. However, AusNet Services noted that this consideration has minimal impact to the outcome as there are currently few data points (as extreme and catastrophic conditions are rare). Also record fire index and weather for qualitative reporting purposes.	**Not appliable** Jemena puts an emphasis on eliminating risk rather than quantifying risk reduction. Minimal data on fire starts (noted that there have been 7 minor fire start over past 5 years)	**Partially** No, for asset failures Yes, for ignition probability based on PBSP ignition rate model (using Powercor data)
Are there any external factors that	**Yes**	**For consequence only**	**Yes** For mitigation programs	**Yes**

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy**
remove or reduce risk? Does the modelling account for this?	Identified 'unburn-able areas' which reduces risk on poles to zero. Likelihood modelling does take into account conditions (e.g., vegetation, terrain) at the time of fault to determine influencing factors.	Proximity to vegetation and ground fuel is taken into account for consequence only		Yes, for ignition probability based on PBSP ignition rate model (using Powercor data)
Do you consider climate change impacts?	**Yes** Climate change impacts are considered for longer-term projections. It is considered that in the future there will be a higher likelihood of higher FDR days, which consequently increase the probability of fire starts. As per the ENEA report the main assumption made is that climate change will only impact the bushfire likelihood [7]	**No**	**No**	**No**
Do you consider asset condition information?	**Partially** Only in terms of 'cumulative weather exposure' such that fault history is location-specific and can influence risk likelihood in terms of network type at a higher level (e.g., using 'corrosivity area'). Asset condition is documented in Asset Management database.	**Partially** Yes, for fault likelihood. Corrosivity area (or similar) is considered in likelihood of an asset failure. Also Condition of conductor - assigned a rating of 1-5 and is used is probability of failure.	**Partially** Qualitatively. work to manage condition in HBRA areas more proactively based on condition assessment and assigned a priority	**No**
How do you consider faults where there is no information?	It is possible to aggregate data into areas / feeders / regions if no data is available. Wait until the model is refreshed.	**Use of external references**	**Use of HBRA / LBRA differentiation**	**Wait until historical data captures rates of failure for that new asset**
Do you consider network improvements in your likelihood assessment?	**Yes – for asset replacements, new asset types and new / modified network (based on GIS)** Only when model is refreshed with latest history and latest network GIS data. At the moment the model is static	**Yes – for new asset types or asset replacements** Take into account asset condition in asset failure likelihood (via a 'expert applied' weighting factor).	**Yes – for overall network risk** For assessing overall risk. Jemena focus on risk elimination including, for example, – Removal of SWER lines – Elimination of staked poles	**Yes – for new asset types or asset replacements** When the ENEA report is refreshed

Prompts	Organisation			
	Powercor	**AusNet Services**	**Jemena**	**United Energy**
	with a refresh every 2-3 years. Not used in operational decision-making.	Changes in pole material and conductor type also change the likelihood assessment. The model needs to be rerun on an as needed or ad hoc basis. Pulls data from Asset database (via SAP).	– Replacement of timber poles with concrete poles (new poles are all concrete unless new design calls for underground construction) – Remove bare Low Voltage (LV) mains – REFCL	
Is all of your likelihood data sourced internally?	**No** External data is used as well as internally-supplied asset data, network data, faults data, fire starts data	**No** The externally sourced likelihood data is with respect to safety risk (likelihood of an asset failing and injuring someone), not bushfire risk. Also uses 'area' analysis for likelihood of asset failure which uses information sourced externally, as well as their own faults and fire starts data.	**NA** Other than network -wide assessment of risk likelihood after controls have been applied	**No** Ignition likelihood is not internal. United Energy obtain 3rd party data for ignition risk modelling
What evaluation / verification / validation processes do you apply to likelihood-related data?	Powercor have **used models to assess the effectiveness of BRM initiatives** (back-casting). They also use **F-Factor report** to track risk profile and validate control measure effectiveness Data cleansing is undertaken for fire start database, cross referencing with faults data.	**There is no method of evaluation / verification / validation currently used.** However, they also use **F-Factor report** to track risk profile and validate control measure effectiveness AusNet Services expressed that it is hard to evaluate risk as there are a variety of influencing factors which determine the severity of bushfire consequence	Jemena use **F-Factor report** to track risk profile and effectiveness of mitigation measures	**There is no method of evaluation / verification / validation currently used.** However, they also use **F-Factor report** to track risk profile and validate control measure effectiveness Obtaining 3rd party data for ignition risk modelling improves overall result of United Energy's risk estimation

3.3 Determination of bushfire risk

Traditional, qualitative methodologies for risk assessment typically involve determination of a risk level as a function of likelihood and consequence assessments. This approach often uses a simple matrix (which considers safety / environmental / reputational / legal / financial implications etc.) to combine the qualitative likelihood and consequence ratings into an overall qualitative risk rating. Historically, such an approach has been challenging for DNSPs due to difficulties quantifying (or qualitatively assessing) the likelihood subcomponents, often due to paucity of accurate data relating to the many fire-causing fault occurrence components, escalation probabilities, and transition to a major event.

However, factors such as those listed below[6] have all enabled the quantification of likelihood and subsequently bushfire risk:

– The technological advancements through the enablement of asset location data capture in GIS mapping
– Better equipment availability and diversity, and digital systems for equipment condition reporting/monitoring
– Ability to store more data and conduct analytics
– The improved sophistication of asset management approaches
– Evolution of bushfire mitigation for residential and commercial infrastructure
– Change in organisational and societal risk appetite
– Better understanding of forest, agricultural, urban, peri-urban, and rural built environment fire behaviours
– Desire to better understand the risk reduction benefit implications of investments in fire prevention/mitigation technologies
– The computational/analytical capability due to advances in network data availability and network visibility

Currently, likelihood quantification relies on data gathered from distribution network operators about assets, faults and ignitions. Endeavours to accurately quantify the likelihood of ground fire ignition at different locations around a network have been relatively recent, noting the progress made in this regard by the work of the Victorian PBSP (CSIRO) [8] focussed on developing a suitable methodology for determining the likelihood of fire ignition by powerline network infrastructure.

In considering ‘risk’, consequence modelling / assessment is principally concerned with quantifying the damage that a fire is capable of causing under the fuel and weather assumptions incorporated in the fire modelling process. Conceptually, the consequence modelling component does not consider either the likelihood that the assumed weather conditions will occur, nor the likelihood of network faults occurring which result in ignition of a ground fire. These elements need to be considered in the likelihood assessment process. Advancements in bushfire consequence modelling have enabled quantitative assessment of the potential impacts of bushfires starting from powerlines. Such modelling can provide DNSPs with a much more granular understanding of network locations where the highest potential consequence bushfires could start, and where they would be most likely to impact under the vegetation cover and weather conditions assumed in the modelling. This enables the spatial evaluation of bushfire risk when combined with spatially explicit ignition likelihood modelling.

The bushfire risk model applied by Powercor [7] and United Energy [6] is depicted by Figure 4. It combines both likelihood and consequence assessments (using an algorithm) to quantify risk at an asset scale, which can then be aggregated as required to quantify risk at different spatial scales, including the overall network scale.

[6] Note that this is not an exhaustive list

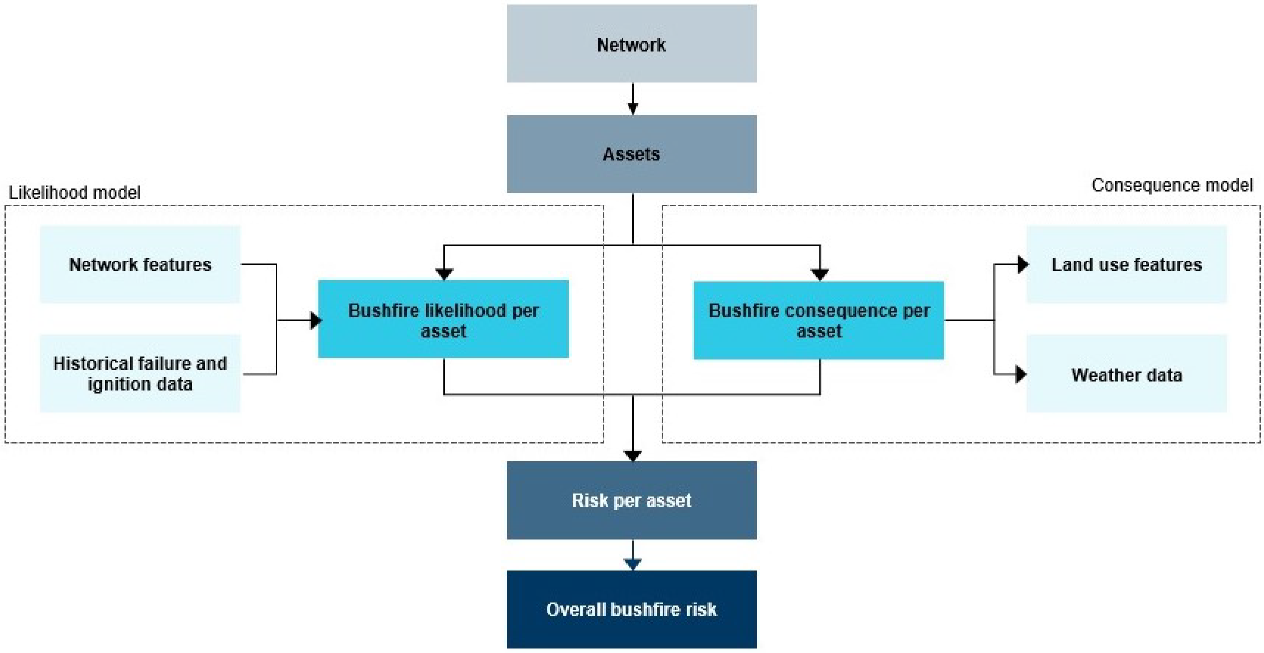

Figure 4 Outline of the Powercor and United Energy bushfire risk model (Figure 3 in ref [7] and [6])

GHD's consultation with Victorian DNSPs (and analysis of recent bushfire risk modelling work undertaken as part of the Project Ignis work undertaken by ENA) demonstrate that DNSPs are moving away from qualitative assessment methodologies. The move is toward quantitative assessment methods where risk is expressed as an aggregated cost, at different spatial scales ranging from individual fire to local scales such as a feeder level, regional scales such as for part of a network, or at network level as an annualised cost.

GHD reviewed the Project Ignis modelling work commissioned by ENA, which is titled "Quantifying Catastrophic Bushfire Consequence". The Project Ignis modelling methodology seeks to take account of uncertainties arising from historical FDI occurrence frequencies through the application of Bayesian modelling. However, the Project Ignis modelling work does not incorporate modelling elements addressing the influence of network fault occurrence on bushfire ignition likelihood. Accordingly, as the title of the Project Ignis modelling work suggests, effectively it is a bushfire consequence model and not truly a bushfire risk model.

Similarly, AusNet Services' bushfire risk methodology incorporates a component for quantifying the probability of weather scenario occurrence, and quantifies the risk of an asset failure, but does not separately calculate or objectively quantify the risk of ignition (in the event of an asset failure) of a ground fire. The outputs of applying AusNet Services' Bushfire Risk Methodology are a "Final Bushfire Consequence Outcome" map, and "Return Period" maps for the three different FFDI scenarios considered in the consequence assessment.

The only Victorian bushfire risk modelling work to-date which incorporates a method of combining separately modelled bushfire consequence and likelihood results was delivered by ENEA for United Energy and Powercor titled "Bushfire Risk Modelling" [6], [7]. The bushfire risk modelling undertaken by Powercor and United Energy integrates the consequences of modelled bushfires with major and minor fire occurrence likelihood for each asset assessed [7]. It does this by multiplying the likelihood of ignition by the consequence value for each modelled fire (separate calculations for minor and major fires). The multiplication is done for each FFDI and averaged by weighting with FFDI probability to get the overall result. In Powercor and United Energy's bushfire risk modelling methodology, overall risk is calculated for each asset using the following algorithm [6], [7]:

$$Risk_a = \sum_a \sum_{FFDI} [P_{FFDI,a} \cdot \left(P(I|FFDI)_a \cdot MinC_{FFDI,a} + P(US|FFDI)_a \cdot MajC_{FFDI,a}\right)]$$

Where:

- *Risk* is the overall risk at the asset *a*
- $P_{FFDI,a}$ is the probability of the *FFDI* at the asset
- $P(I|FFDI)_a$ is the probability of ignition at the asset given a *FFDI*
- $P(US|FFDI)_a$ is the probability of unsuppressed fire at the asset given a *FFDI* (it is considered that for *FFDI*s strictly less than 3 this probability is zero)
- $MinC_{FFDI,a}$ is the asset's minor consequence given a *FFDI*
- $MajC_{FFDI,a}$ is the asset's major consequence given a *FFDI*

In Powercor's and United Energy's case, the modelling work has been integrated into a customised 'bushfire risk tool' which integrates both likelihood and consequence data to determine and display risk and can be used to assess the impact on risk (at different scales) of investing in different risk control options by varying the likelihood assumptions associated with different risk controls.

Conceptually this model has the elements needed for analysis. With most models, the analysis is dependent on the level of detail of the data and the attributes of quality and representativity etc. Recent work with clients on more detailed asset condition for reliability of networks for operational purposes could be used to generate better quality probability data for driving this model. Weibull curves based on inspection, general wear and tear from local and broader environmental conditions, as well as asset class, condition, age, and inspection data could all contribute to better quality probability input. This was evidenced in the Powercor ENEA report provided [7].

While DNSPs are currently undertaking bushfire risk modelling, the use of their respective BRMs for decision making is currently largely limited to prioritising the roll-out of new risk controls and asset replacement programs (where populations of assets are being phased out and more bushfire risk-effective assets are introduced to replace them). However, it was noted that bushfire risk modelling has been used as a mechanism to determine where it is necessary to invest in relatively high capital cost engineering controls to reduce bushfire risk in the highest potential consequence locations. In some jurisdictions, the consequence component of the modelling may also inform selection of more intensive vegetation management treatments such as clear-to-sky application and / or prioritisation of hazard tree removal programs.

For many asset and vegetation inspection and maintenance related risk controls, BRMs are currently not well embedded in decision-making about risk controls, and triggers such as HBRA / LBRA designation are still being utilised. Opportunities exist to use the outputs from the BRM in decision-making for risk control application, but this would likely need to have greater and more formal acceptance by safety regulators before DNSPs are able to benefit from such an approach.

3.4 Other findings

3.4.1 ESV interview findings

In addition to the DNSPs consulted, the GHD team also interviewed ESV to understand what they would like to see within a bushfire risk model. ESV communicated that they receive annual Bushfire Mitigation Plans (BMPs) from DNSPs in a format prescribed by ESV for their review and acceptance.

If shortcomings are identified in the BMP, resubmission is required.

The differing BRMs used by DNSPs does not have a defined structure or process and ESV recognises that standardisation of the process would be beneficial, both from their perspective as well as for the DNSPs.

ESV would like to understand the things that DNSPs can do to reduce risk at different levels of fire danger. Further, they would like to understand what DNSPs are doing (of those things that can be done) and what they are choosing not to do, and why. An observation made by ESV was that the respective BRMs of the DNSPs interviewed are at different stages of maturity / development (perhaps due to network risk profile) and are utilised in different ways.

3.4.2 Standardised framework

The interview sessions were also used to gauge if stakeholders believe there is a need for a common powerline bushfire risk framework. Representatives from AusNet Services, Jemena, Powercor, and United Energy agreed that a common framework would result in a “standard” procedure, thus enabling a consistent approach to be adopted across different States. The development of a standard framework would also:

– Look to implementing / using a procedure which is currently the leading practice modelling techniques
– Promote the use of common terminology for communications, preventing confusion between stakeholders
– Promote the understanding of how risk is determined and quantified
– Support investment decision-making, including consideration of new technologies
– Support the EDPR process and justification regarding expenditure
– Streamlining of vegetation management and bushfire management operational measures

From the information provided and the interviews with various DNSPs it was found that not all stakeholders use the PBSP RRM developed by CSIRO. Rather, some (as listed below) utilise a modified version, or use other models which have subsequently been developed:

– Powercor’s likelihood model builds on the PBSP BRM to “better capture Powercor’s asset characteristics and their long-term exposure to weather conditions.” [7]
– Both AusNet Services, Powercor and United Energy have commissioned their own bushfire consequence modelling approaches, with AusNet Services using Phoenix Rapidfire, and Powercor and United Energy using CSIRO’s Spark model [7], [6]

Additionally, AusNet Services are looking to incorporate machine learning within their BRM which would represent a step-change in the way bushfire modelling is completed by DNSPs. As such, this is an evolving field, where model back-testing and model training are required for validation and verification activities associated with assurance and general advancements.

From our reviews, a greater emphasis is required for the data framework and management of the models. There are currently being developed by International Standards Organisations [11]. The standardisation of bushfire risk modelling presents an opportunity which will be discussed in latter sections of this report.

A key requirement for an effective framework is a strong focus on the practicality and useability of models and tools that are developed. Such tools will need to utilise the level of asset information and condition available from the DNSPs. It is important to recognise that some distribution assets are low value high volume assets and as such detailed condition information is not always available for such assets.

4. Use of quantitative bushfire risk modelling

As discussed in Section 3.3, DNSP's BRMs are largely used for:

- Prioritisation of the implementation of new risk controls and asset replacement programs and for use in cost/benefit analysis (where populations of assets are being phased out and more bushfire risk-effective assets are introduced to replace them)
- Investment decision-making, both internally and externally, for the EDPR process

While the more bushfire risk-exposed DNSPs have integrated bushfire risk modelling within their organisations, elements of the regulatory framework they operate under establish other, prescriptive threshold criteria for the application of particular aspects of bushfire risk management. These include the HBRA, LBRA, ELCAs and Total Fire Ban (TFB) declarations. These concepts are explained in Appendix E. Thus, a DNSP's ability to utilise BRM to inform bushfire risk mitigation decisions is constrained by the extent to which they have regulatory requirements to comply with mitigation measures linked with these other regulatory criteria (statutory bushfire hazard or danger-related systems).

For DNSPs with very limited network exposure to heightened risk areas (no ELCAs, and very limited HBRA exposure) such as Jemena, there may be little advantage in undertaking detailed bushfire risk modelling. Instead, these DNSPs with limited HBRA exposure may choose to apply high levels of bushfire risk mitigation in areas of their network which are within HBRAs, and quantify risk at a less granular level. However, for those DNSPs which have very large network areas extending across expansive HBRA areas, bushfire risk across such network areas is not uniform. To determine risk-based investment strategies for bushfire risk mitigation, the adoption of common and in some cases sophisticated bushfire risk modelling processes can provide DNSPs with risk-based decision support systems for optimising investment in bushfire risk mitigation.

The current state of the BRMs utilised by the DNSPs approached as part of this engagement has been outlined in Section 3 of this report.

4.1 Bushfire risk modelling for bushfire risk mitigation decisions

It is relevant to note that a significant proportion of DNSP network assets are legacy assets which were constructed or installed over previous decades; some existing assets are more than 50 years old and are in locations which were deemed sensible under the laws, regulations, and technical capabilities of the time.

Generally, the asset strategy applied by Victorian DNSPs involves a reliability centred maintenance philosophy whereby the condition and performance of assets are monitored, and asset replacements or upgrades are timed to occur before the onset of specified performance declines and failures. Such an approach is generally considered to be conservative relative to the setting of mandated timeframes for asset replacement or upgrade. Network fire cause and performance data is also analysed to identify specific asset classes, types, makes and / or models which may be more prone to fire ignition. This analysis is used to inform bushfire mitigation programs, including elements such as new and replacement asset design; asset condition inspection and maintenance program design standards and specifications; vegetation management program design standards and specifications; quality assurance and audit specifications; network operation standards and specifications; and bushfire risk mitigations performance monitoring, analysis and evaluation systems.

4.1.1 New and replacement asset design

Some new and replacement asset programs are mandated outside of any DNSP process for bushfire risk modelling. As discussed with the DNSPs (refer to Table 1) examples include REFCL systems installation and operation and installation of SWER ACR systems mandated in designated network areas by the Victorian Government through ESV. Others include requirements for new network assets and replacement network assets to be of underground or insulated line design types in designated ELCAs.

However, it is open to DNSPs to extend such programs beyond mandated areas, on the basis of their own BRM and asset strategies. An issue for DNSPs is whether these additional proposals will be approved for funding as these are beyond the mandated regulatory requirements and may not be considered necessary and efficient by the economic regulator. A suitably nuanced and quantitative BRM potentially offers DNSPs a mechanism to justify whether a proposed bushfire safety enhancement is necessary, through cost estimation for implementation relative to the quantum of risk reduction (i.e. risk based cost benefit analysis) achieved applied through an As Far As Possible (AFAP) process. An example might be installation of REFCLs or undergrounding of powerline sections in modelled high risk areas outside of mandated areas.

4.1.2 Asset inspection and maintenance standards and specifications

Victorian DNSPs, in particular Powercor and Ausnet Services, have very large overhead network asset populations to manage, and vegetation management programs to undertake. To implement reliability centred maintenance, asset inspections are conducted on a cyclic basis across the network. Various factors can affect the frequency of the asset inspection cycle such as asset type, condition class or age, as well as the HBRA / LBRA designation. For some asset classes, such as wooden poles, the use of HBRA / LBRA designation comes with specific regulatory requirements regardless of the actual bushfire risk for that asset. For example, the regulations prescribe maximum inspection intervals of 3 and 5 years for HBRA and LBRA respectively, regardless of overhead asset class. Therefore, despite using their respective BRMs to model risk, this may not be used for setting inspection cycles even though this may provide more detailed risk profiles than HBRA / LBRA designation. Prescribed inspection intervals are only one element of a DNSPs asset inspection and condition monitoring. However, BRM may be used to inform other forms of asset condition monitoring and risk mitigation as inspection does not detect all latent defects.

For some asset classes, there may be no HBRA / LBRA triggered differentiation in inspection or maintenance standard, and it is open to DNSPs to vary standards on the basis of assessed risk. However, noting that BRMs are not yet subject to any standard framework, the use of BRM to drive asset inspection and maintenance cycles and standards may not gain traction until BRM systems are more mature and accepted by regulators.

4.1.3 Vegetation management

The HBRA / LBRA designation may trigger different maintenance standards. For example, there are different minimum line clearance distance requirements for vegetation in HBRA and LBRA for certain line types. Again, the regulatory requirements are linked explicitly to HBRA / LBRA designation, with standard clearances established across HBRA areas regardless of what level of bushfire risk has been modelled for a span. Another example is the triggering of ‘clear-to-sky’ clearance specification for bare high voltage lines. Clear to sky requirements apply for all bare conductors in HBRA, however vegetation overhang above bare wires (with exception of 66kV) is permitted in LBRA.

4.1.4 Quality assurance and audit specifications

For auditing compliance of contractors’ work, HBRA / LBRA designation may be used to differentiate sampling effort in audit planning (e.g., higher proportion of audited spans in HBRA relative to LBRA). Thus, future decision making associated with audit planning is another area where bushfire risk modelling may be useful.

4.1.5 Network operation

While HBRA / LBRA designation has long been a spatial differentiator of fuel hazard[7], for bushfire risk management the weather-based differentiator is the Total Fire Ban (TFB) declaration. Decisions such as ACR settings are triggered by TFB. For areas deemed to be highest risk category by the BRM, it may be appropriate to trigger network operation risk controls at fire danger levels below those used for triggering TFB. This is particularly important in areas with expansive forest cover where fires may be difficult to control even at ‘High’ fire danger (equivalent to Very High FDR prior to commencement of the AFDRS). This is another example of where the BRM could be used to drive more focussed implementation of risk controls to identified highest risk areas.

It is relevant that DNSPs are not unconstrained in what they can do to reduce bushfire risk. Firstly, DNSP capital and operating expenditure programs and funding are regulated by the Australian Energy Regulator (AER). The

[7] Whereby fire ignition and spread is possible in HBRA, but unlikely in LBRA)

AER applies revenue and pricing assessment principles which require DNSPs to demonstrate that their expenditure forecasts, including forecasts associated with bushfire risk mitigation, are well informed and efficient. Secondly, bushfire risk mitigation programs are subject to other laws including environmental laws which, for example, constrain the degree to which DNSPs can clear trees and other vegetation near powerlines.

Historically, some bushfire risk mitigation programs have been applied at asset type population level (e.g., replacement of particular fuse types, other pole-top hardware and protection system devices). More refined bushfire risk modelling, enabled by improved spatial data availability and the ability to now run complex spatial modelling processes, has provided opportunities to prioritise risk mitigation investments based on risk. More detailed understanding of bushfire risk can generally be of greater benefit to DNSPs than coarse, binary systems such as HBRA / LBRA classifications as it facilitates more informed decision-making for risk management.

The major improvements to bushfire risk modelling over the past decade present an opportunity to modernise the bushfire risk related triggers in safety regulations. As discussed, DNSPs must justify investments in bushfire risk mitigation programs to safety and economic regulators to obtain funding for such safety improvements. However, DNSPs report that it can be difficult to provide such justification without recognition of BRMs in regulatory frameworks. The future introduction and adoption of a bushfire risk modelling framework presents an opportunity to improve risk-related elements in regulatory frameworks to drive improved outcomes in bushfire risk mitigation.

In the future, there is the potential that the more sophisticated systems which have been developing for modelling bushfire risk could replace the current legacy systems (such as the HBRA / LBRA designations, TFB and ELCA) noting that would be a matter for consideration by appropriate regulators.

The AER in January 2019 released an Industry Practice Application Note on Asset Replacement Planning that provides guidance upon network replacement expenditure including those related to bushfire risk reduction. The practice note recommends the use of Net Present Value analysis to demonstrate proportionality for ALARP justification. The methodology recommended incorporates the Probability of Failure (PoF), Likelihood of Consequence (LoC) and Cost of Consequence (CoC) that can include property damage and safety risks to public and workers based upon the Statistical Value of Life (SVL) and the application of Disproportionality Factors (DF) to account for wider societal impacts.

Whilst this provides guidance on the analysis required to support funding submissions it provides no guidance on the identification of risks that cannot demonstrate ALARP, which is the primary role of BRMs.

4.2 Aspatial risk assessments

In addition to the spatial bushfire risk modelling process outlined in Section 3, DNSPs use other risk management processes, such as bow-tie analyses and conceptually similar threat barrier analyses. These aspatial risk assessments are typically focussed on:

– Identifying potential sources and causes and consequences of bushfire ignition on the network
– Identification of risk controls to prevent or reduce the likelihood of loss of control (unsuppressed high impact bushfire) and mitigate the impacts of such an event

Typically, they consider asset types and failure modes, often at asset population or sub-population level. Further, these risk assessments identify asset design, maintenance, and operational controls (among others) to reduce fault occurrence and transition to fire ignition potential. DNSPs may use such techniques when considering what mix of risk controls they will select to apply for the reduction of bushfire risk.

5. Strengths, gaps and opportunities in current bushfire risk modelling

GHD considers it necessary to clarify terminology, specifically the term bushfire risk modelling framework, to clearly identify what the bushfire risk modelling process is intended to achieve.

In the context of the bushfire risk modelling systems currently used by Victorian DNSPs and used by the PBSP and ESV in their work, the bushfire risk modelling process is a method of bushfire *risk assessment*. BRMs are used to quantitatively assess a DNSPs bushfire risk exposure as well as its spatial distribution across the network. *Risk assessment* is a component of *risk management* and does not constitute the whole process.

As described in Section 1.3, reference to the term *bushfire risk modelling framework* as used in this report is in relation to a framework for a spatial modelling process used for bushfire risk assessment.

5.1 Bushfire risk modelling process – A reference model

In order to undertake an assessment of the strengths and gaps in a BRM, the key components of the model, both essential and desirable, need to be identified at a conceptual level. The resultant conceptual reference model provides a baseline to complete the strengths and gap analysis. A high-level conceptual reference model is provided in Figure 5 whereby the key elements which form the basis of the likelihood model and consequence model are provided.

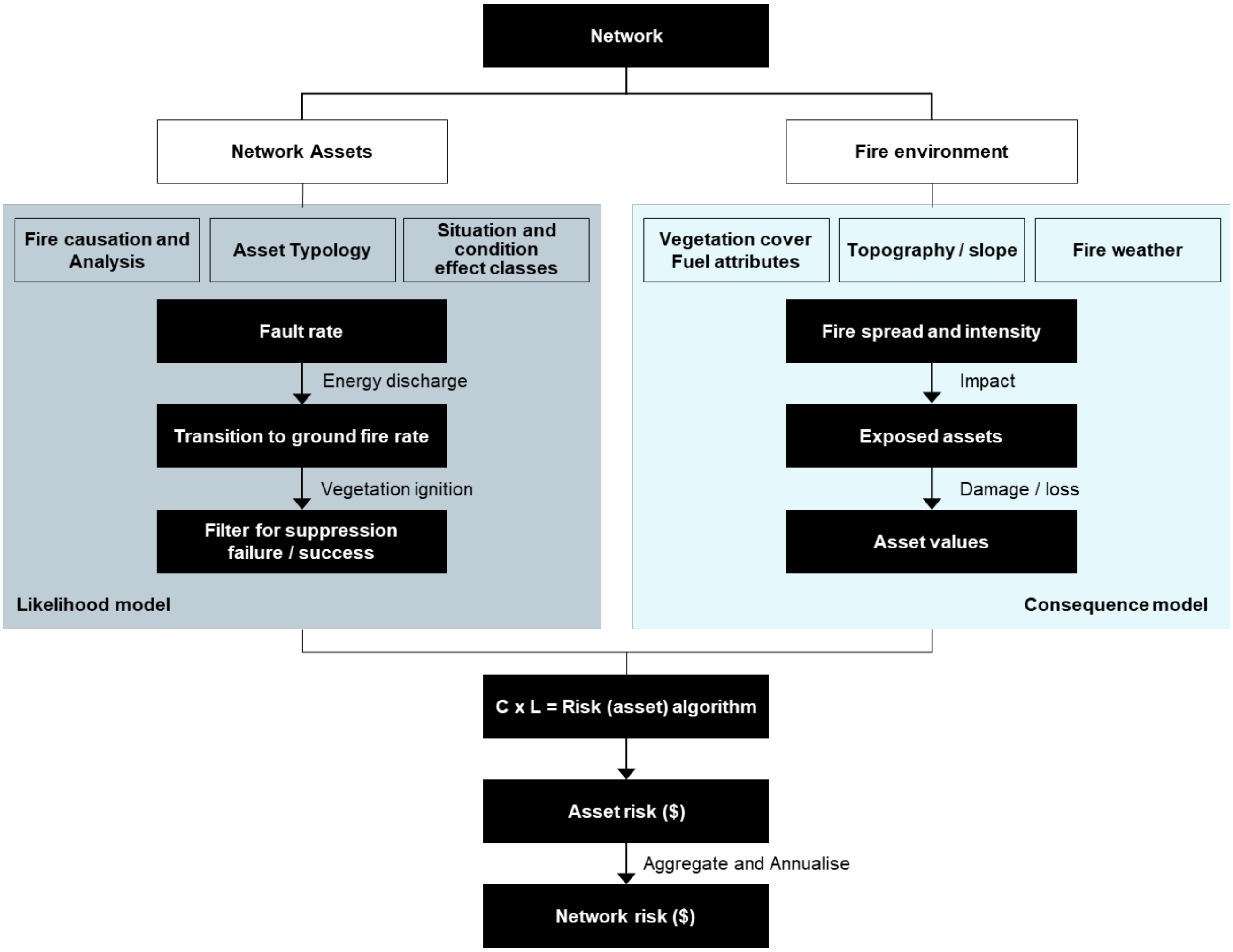

Figure 5 Bushfire Risk Modelling Process – Overview Level

A summary of the definitions of each category presented in Figure 5 is discussed in Section 5.2 (for consequence modelling) and Section 5.4 (for likelihood modelling).

5.2 Bushfire consequence – reference model overview

For the purpose of conducting the strengths and gaps analysis, each of the sub-models in the consequence modelling reference model provided as Figure 6 are detailed within Appendix F.

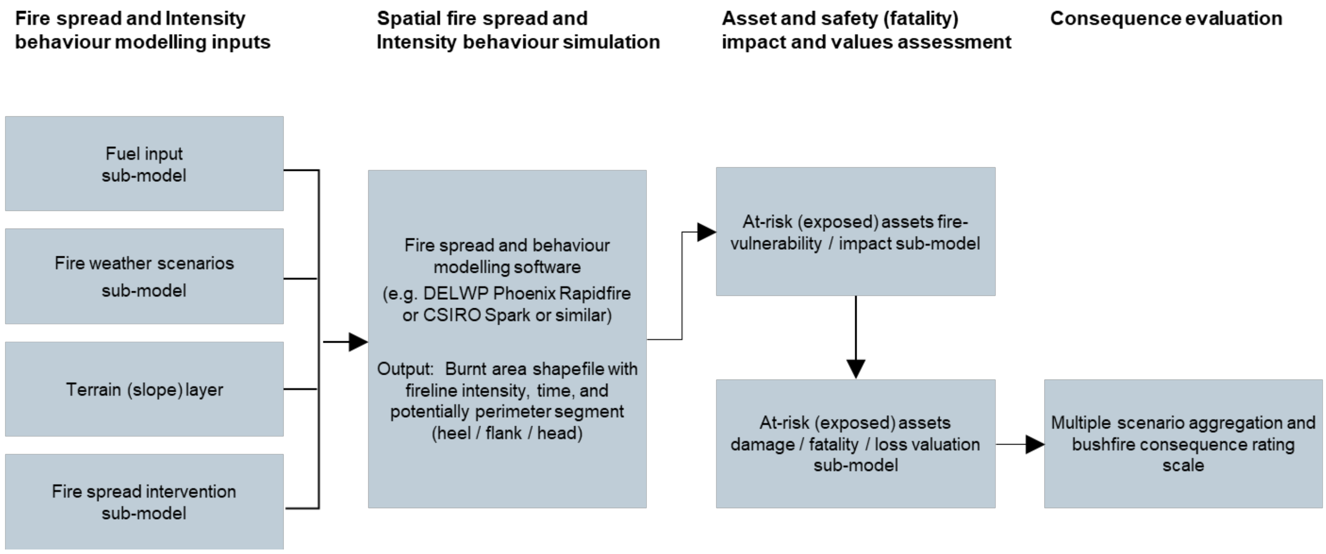

Figure 6 Consequence model components

There is a need for consistent language across all stakeholders involved with the development, utilisation, and subsequent use of the evolving BRM. By implementing consistency, the likelihood of cross-organisational understanding increases, facilitating modelling congruency. Terminology has been used in the next sections that are typically utilised.

5.2.1 Fire spread and intensity modelling step

Spatial modelling of fire spread and intensity requires a suite of fire behaviour models covering the various different vegetation types which occur across the landscape where bushfires can burn. All fire behaviour models require:

- Fuel input values (derived from a suite of vegetation types), noting that for grass, condition (curing state and grazing state) is also required
- Weather input values (typically air temperature, relative humidity, wind direction and speed, and drought index) for all weather scenarios used in the modelling
- Slope input values (usually derived from digital elevation models)

Thus, all fire spread and intensity modelling will require a minimum of three sub-models:

- Fuel sub-model
- Weather scenario sub-model
- Slope sub-model

Consequence sub-model design detail and input data attributes are discussed in more detail at Appendix F.

In terms of modelled fire behaviour outputs, all fire behaviour models provide a measure of rate of forward fire spread while some may provide derived values for spotting distance, flame height / length, or fireline intensity. When spatial fire modelling is run over a defined fire run period, polygons representing the area impacted by the modelled fire are produced, with fire intensity attributes derived for each pixel within the polygon.

Fire spread and impact modelling is sensitive to all model inputs, and to the run period selected for modelling. Accordingly, if an objective of developing a standardised bushfire risk modelling framework is to facilitate comparability of modelled results, then standardisation of the fire modelling input data and model run period will be required.

Opportunities for improvement in fire spread and intensity modelling (see section 5.3) are principally directed to attaining consistency in fire behaviour model selection and data standards for each of the sub-models.

5.2.2 Impacted assets and fatalities modelling step

After modelling fire spread and intensity, the second stage of consequence modelling is determining what exposed assets and population centres are impacted by the modelled fire, and what proportion of fire-impacted assets incur loss or damage. Different asset types have varying vulnerability to bushfire damage and loss. Assets which are made from or have exposed combustible materials, and are themselves considered a fire hazard, can have a high degree of vulnerability to bushfire damage and loss. Other assets may be resilient to damage from low intensity fires but vulnerable to high intensity fires, and there may be assets highly resilient to bushfire impact. Some natural resource assets such as cured pre-harvest cereal crops, pine plantations and other combustible crop types may be highly vulnerable to fire loss and damage.

Fire impact modelling requires:

– Multiple spatial data layers pertaining to the location and spatial extent of asset classes and populations across the landscape where fires can impact
– Consideration of asset vulnerability to bushfire impact

Accordingly, to achieve consistency in bushfire consequence modelling, the following is required:

– A standardised exposed asset classification system, so modelling undertaken considers the same range of assets
– A standardised vulnerability sub-model (covering human populations and all selected asset classes) so that assumptions about fire losses are consistent between different modelling projects

In the absence of a fire vulnerability sub-model, whereby there is an assumption that fire impact is destructive, fire spread, and potential impact modelling may tend to overstate the potential fire consequences.

Opportunities for improvement in bushfire impact modelling (see section 5.3) are principally directed to attaining consistency in asset class inclusions for impact modelling and vulnerability assumptions for determining modelled losses.

5.2.3 Fatalities and asset loss valuation step

The final stage in bushfire consequence modelling is quantifying losses. This is essentially a process of assigning economic values ($) to the human lives and assets lost or damaged. This requires a consistent approach to human life and asset valuation.

Opportunities for improvement in bushfire impact quantification (see section 5.3) are principally directed to establishing a standardised valuation system for application to all asset classes and loss of human life.

5.3 Consequence modelling strengths and gap analysis

Using the powerline bushfire consequence modelling reference framework (Figure 6) as a frame of reference, GHD has assessed the strengths, gaps, and opportunities for improvement for powerline bushfire modelling methodologies in current use in Victoria.

5.3.1 Consequence modelling logic and structure

Powerline bushfire consequence modelling undertaken by the Victorian DNSPs consulted as part of this engagement adopt a process logic and workflow that is generally consistent with spatial bushfire risk modelling processes applied by DELWP, which undertakes regionally scaled bushfire risk assessment processes as a component of DELWP's strategic bushfire risk management planning process. Whilst there are significant differences in the detail incorporated in each DNSP's bushfire consequence modelling, the general modelling process is similar. Similarities include:

- Powercor, United Energy and AusNet Services consequence models all used a spatially explicit modelling methodology.
- Powercor, United Energy and AusNet consequence models all use fire simulation tools (Powercor and United Energy – SPARK; AusNet Services – Phoenix RapidFire) which are recognised and utilised by Australian fire and emergency services for bushfire spread and behaviour modelling.
- All consequence models reviewed used sub-models (of varying content and detail) for the following inputs: vegetation / fuel, weather scenario variables, slope, at-risk asset layer, vulnerability sub-models for house loss, loss of human life assumptions as a derivative of house loss sub-model, and incorporated an economic sub-model for attributing economic values to impacted asset classes.
- None of the models applied a fire intervention sub-model, noting that weather scenarios were restricted to weather scenarios when fire intervention (attempted suppression) would most likely be unsuccessful. In Powercor's and United Energy's modelling [6] [7], fire escalation and suppression considerations are addressed in a binary manner (either a fire is assumed suppressed without escalating to major consequences or it is not) within the likelihood modelling component, after the statistical fire suppression analysis is undertaken.
- All current models' express consequences in economic terms (dollar value of loss / damage per modelled fire), though the at-risk asset classes considered in impact assessment varies substantially (Powercor's and United Energy's impact modelling incorporates a wider range of asset types than AusNet Service's impact modelling process).

Accordingly, at the model logic and structure level, there are no significant structural gaps in the consequence modelling processes reviewed, however there are several opportunities for improvement in the modelling inclusions. These are addressed at 'sub-model' level in proceeding sections.

5.3.2 Fuel sub-model

Metadata and technical details of the vegetation layers and associated fuel assumptions for each model are not currently specified in consequence modelling methodology documentation. GHD considers for consequence modelling undertaken by DNSPs, it is likely that assumed fuel attributes for each vegetation category used in fire spread modelling may differ for some vegetation categories (noting that different simulation systems are used, and each can be configured differently, for example using different fire spread models for forest or other vegetation groups). This means that the results of modelling would not be directly comparable.

Principle C1: *To ensure transparency of consequence modelling processes, documented modelling methodologies should include metadata for all model inputs.*

Improvement Opportunity: Vegetation metadata and fuel attribute assumptions could be documented in all powerline bushfire consequence modelling methodology descriptions.

Fire behavior model specifications used in the modelling process are not currently specified in bushfire consequence modelling methodology descriptions. It is possible that different fire behaviour models are being used, particularly for forests where there are different model options to choose from.

Principle C2: *To facilitate comparability of consequence modelling results between NSPs, a consistent suite of fire behaviour models should be used.*

Improvement Opportunity: Pursuant to achieving fire behaviour modelling consistency, the bushfire risk modelling framework could specify that fire behaviour model selection should be in alignment with the fire behaviour models specified in the AFDRS [4].

5.3.3 Weather scenario sub-model

Bushfire consequence modelling is particularly sensitive to the weather scenario assumptions used. It is not valid to assume that fire impacts (e.g. in terms of house loss and human fatalities) at different fire danger indices will be directly proportional to the impacts for a single reference scenario (e.g. a FFDI 140 scenario). Further, relatively small variations in weather variable inputs (particularly wind direction) can have a major influence on modelled consequence. Accordingly, if the intended uses of the bushfire consequence modelling extend beyond simple, coarsely-scaled relative impact potential mapping, then modelling based on multiple weather scenarios – at least representative of the range of adverse weather scenarios known to occur – will be prudent.

Principle C3: *To facilitate that bushfire consequence modelling is representative of the range of adverse weather scenarios known to occur in network areas, a suitably representative range of weather scenarios should be used in multiple scenario modelling (including one or more scenarios which consider climate change projections).*

Improvement Opportunity: The bushfire risk modelling framework could specify weather scenario development for use in bushfire consequence modelling and:

- Use a sufficient range of weather scenarios, representative of the range of adverse fire weather scenarios (those for which it is probable that fire behaviour would exceed suppression thresholds)
- Weather scenarios used could reflect typical diurnal variability in weather variables
- Weather scenario selection could be based on appropriate regional climatology assessment
- One or more weather scenarios which account for climate change scenarios could be incorporated
- Model run-times should also be standardised.

5.3.4 Slope sub-model

Slope models are generally not a constraint for bushfire consequence modelling. The resolution of digital elevation models used on modeling should be commensurate with the resolution of impact assessment sought in the modelling. As this is typically at least to individual property impact scale, a minimum 30 m model resolution will be required, and 10 m resolution would be desirable.

5.3.5 Fire spread intervention sub-model

Victoria maintains substantial bushfire response capabilities through fire response agencies and networked organisations including the Country Fire Authority (CFA), Fire Rescue Victoria (FRV) and Forest Fire Management Victoria. When bushfires are reported, fire response agencies dispatch local resources (potentially supplemented by regionally based aerial waterbombing resources) to contain and extinguish fires as early as possible. A range of factors influence the likelihood of early fire containment success, including (among other factors) the vegetation/fuel types and terrain in the ignition location, accessibility of the fire ignition location, the severity of the fire weather influencing the fire, the severity of local drought conditions, the extent and connectivity of bushfire-prone vegetation cover in the landscape, and the timeliness and weight of fire response able to be mobilized. A high proportion of bushfires are contained early before they can cause significant damage, but those which escape early control efforts can quickly grow to uncontrollable proportions, particularly where adverse fuel and weather conditions are influencing fire growth. Other response measures which influence fire impacts include life protection measures such as the early issue of bushfire warnings, evacuation of communities in the fire path, traffic control measures on at-risk road networks, and property defence tactics by fire responders and property owners/occupiers.

While the suite of response actions taken by fire and emergency response agencies serve to mitigate fire impacts, it is very challenging to accurately model the multi-factorial effects of such actions on fire suppression success and on life and property loss reduction in fire-impacted areas. Modelling some aspects of fire spread intervention has been attempted but is yet to develop to a degree suitably reliable for incorporation into BRM by NSPs. This remains an aspirational modelling element requiring further development by Victorian fire response agencies before it could be incorporated into future BRM versions. The reference consequence model at Figure 6 can accommodate fire spread intervention models in the future, however, at the current time, a suitably reliable and peer-reviewed sub-model is unlikely to be available.

5.3.6 At-risk asset sub-model

A major difference evident between the Victorian DNSP bushfire consequence models reviewed is the extent to which different asset classes are incorporated in impact modelling. The earliest bushfire consequence modelling commissioned by the PBST in 2011 [2] was limited to assessing impacts on ‘property’ in the form of habitable buildings, primarily residential dwellings but also non-residential buildings. Later modelling processes, including modelling commissioned by AusNet Services[8] (2014) extended potential impact consideration to include loss of human life, as well as making allowance for suppression costs. The most recent consequence modelling work undertaken in 2021 (for Powercor [7] and United Energy [6]) extends potential impact assessment further to include a range of other asset classes. These include different types of agricultural and timber plantation asset classes, powerline losses, tourism losses, loss of human life, with schools added more recently. The different inclusions in potential asset impact modelling leads to different quantitative modelled consequence results.

If it is desirable to improve modelled bushfire consequence results comparability, then it will be useful to standardise inclusions in the impact modelling process in powerline bushfire consequence modelling.

Principle C4: *To facilitate comparability of consequence modelling results between DNSPs, a standard suite of asset and human fatalities/health impacts classes should be established for consequence modelling*

Improvement Opportunity: The powerline bushfire risk modelling framework could specify standard asset class inclusions for powerline bushfire consequence modelling.

Just because an asset is impacted by bushfire does not necessarily mean it will be destroyed or even damaged. Different asset classes have different levels of vulnerability to bushfire damage. Some may incur a total loss even if the fire intensity is not at high levels (e.g., cured cereal crops). Some asset classes may incur total loss at high fire intensities but only partial or no loss at low fire intensities. For some other asset classes there will be some asset survival and some asset loss at the same intensity of fire impact (e.g., residential dwellings) due to unforeseeable differences in immediate site or asset condition or design. Accounting for these loss potential differences requires incorporation of an asset vulnerability sub-model.

Principle C5: *To maximise accuracy of consequence modelling, vulnerability sub-models based on peer-reviewed studies should be used to account for variability in asset vulnerability to varying levels of fire severity.*

Improvement Opportunity: The powerline bushfire risk modelling framework could specify requirements for a vulnerability sub-model to be used in powerline bushfire consequence modelling. All elements of the sub-model could be based on peer-reviewed studies.

5.3.7 Asset economic valuation sub-model

Quantitative modelling of bushfire consequence typically requires expression of results in economic terms ($). This requires incorporation of an economic valuation sub-model in the consequence modelling process. If different valuation models are used in different modelling methodologies, then modelled results can be expected to differ. If it is desirable to improve modelled bushfire consequence results comparability, then it will be useful to standardize economic valuation sub-models used in powerline bushfire consequence modelling.

Principle C6: *To maximise comparability of consequence modelling results between DNSPs, a harmonised system of economic valuation for human life and asset classes incorporated in modelling should be used*

Improvement Opportunity: The powerline bushfire risk modelling framework could specify requirements for a harmonised economic valuation sub-model to be used in powerline bushfire consequence modelling.

5.3.8 Consequence aggregation process

For bushfire consequence modelling frameworks which require modelling using multiple weather scenarios, there will typically be a requirement to aggregate the results of the multiple simulations into a single consequence value which can later be combined with modelled likelihood to determine risk. The modelled fire consequences from each weather scenario can be expected to vary significantly. There are numerous methodology options for determining the single modelled consequence result from the multiple weather scenario modelling process. For example, the mean or median value could be used, or the worst case could be used, or a value representing a selected percentile (e.g., 95th percentile) could be used, among other options.

[8] PowerPoint presentation provided by AusNet Services at the beginning of this engagement

Principle C7: *To maximise comparability of consequence modelling results, a standardised methodology for determining consequence values from the outcomes of multiple weather scenario modelling is required.*

Improvement Opportunity: The powerline bushfire risk modelling framework could specify a standard methodology for determining the modelled consequence value from the outcomes of multiple weather scenario modelling.

5.4 Likelihood modelling strengths and gap analysis

A likelihood model will require three key sub-models; probability of fault occurrence, ignition rate and filter for suppression as shown in Figure 7 below. The key elements of each of these models are discussed in the following sections.

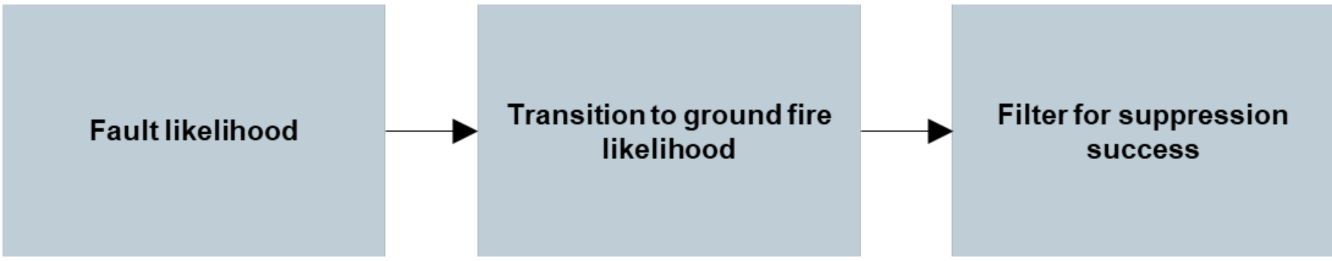

Figure 7 Likelihood sub-models

There are a number of key attributes that an effective model should contain which include:

- Use of readily available asset data (including asset condition) from DNSP's asset management systems
- Use of readily available environmental condition data (such as vegetation, topology)
- Differentiated fault occurrence frequencies for relevant asset types
- Geospatial likelihood mapping
- The ability of the DNSP to update the model readily for new fault data, assets, environmental conditions or expected climate changes
- Ease of use and understanding of the model by DNSP's teams
- Verification and validation features to ensure confidence in the model

5.4.1 Fault likelihood

There are a number of elements that can be used to determine the probability of a fault occurring including:

- The asset type that causes the fault
- The failure mode that causes the fault
- Relevant asset conditions that impact a fault causing failure mode
- Past fault history
- The fault probability (or rate) associated with the above three elements

Only certain DNSP assets have the potential to cause faults that may result in fire starts, such as bare conductors. These asset types can be further broken down by the voltage levels, type of asset (e.g. conductor or fuse), and relevant categories such as steel or aluminium conductors.

Principle L1: *Asset categories that have the potential to cause faults should align with the categories in the DNSP's asset management system.*

The model needs to identify and only consider failure modes which may cause both the asset to failure but also has some probability of creating a fire start.

Principle L2: *The failure modes should be related to the failure of individual asset types and be consistent with the asset failure modes in DNSP's asset management systems.*

The condition of assets, especially corrosion, may impact the probability of an asset failure.

Principle L3: *Asset condition is an important element in determining the probability of fault occurrence*

One of the challenges for a DNSP is that detailed condition data (sufficient for prediction of future asset failure) is not available for all distribution assets. This is due to a large number of wires, insulators and associated electrical and structural components related to poles and towers (i.e., low individual asset value components) geographically dispersed across the state. The cost of detailed and frequent inspections for the purpose of accurate asset failure prediction is likely to be cost prohibitive for low-cost items such as cross-arms or stay wires. Often networks will have only an approximate idea of the condition of asset types in particular areas, such as greater corrosion in coastal areas.

The fault rate would need to account for the asset types, their failure modes and their relevant conditions to determine how likely each fault is for each asset type based on historical data.

Principle L4: *The model needs to include condition parameters that are consistent with the condition information that the networks have in their asset management systems.*

Principle L5: *Asset data (including asset types, failure modes and conditions) will need to be updated at regular intervals, ideally from both internal and equivalent external data sources.*

Asset situation data is useful in determining the effect of geographic location on an asset and can be used to model risk from a geospatial standpoint. This is useful in extrapolating the risk profile of assets spatially. Historical fault data can be used to: determine the local meteorological conditions at the time of the fault and estimate the total exposure of the asset to meteorological conditions over time.

Fault history and asset failure history is a reasonable indicator of future asset performance, particularly if coupled with conditions data and failure mode analysis. Situation data such as geographical location, vegetation and terrain can also support a spatial risk mapping of asset failure likelihood.

Principle L6: *Faults data should include meta-data such as geographical location, asset type, weather (FDI, meteorological conditions) at the time of the event.*

Principle L7 (stretch target): *Historical data can be used to predict asset failure likelihood, but the best use of historic asset failure data is for verification and validation purposes.*

With the exception of REFCLs the primary objective of protective devices is not to reduce probability of ignition which leads to fire starts. The primary purpose of protective devices such as fuses and relays are to protect people and equipment by minimising the magnitude and duration of faults and by isolating the faulted section of the network.

However, protection sequencing and operation can impact probability of fire start. Where mitigation programs are undertaken to alter operation or setting of protective devices, the impact will be understood via historical firestart data.

Due to the hesitation in relying on accurate settings information, and the potential of protection not operating in a correct or timely fashion, and not being available depending on operational needs, protection settings are not considered an important distinction when referring to protection devices as an asset class.

Principle L8: *Protection settings are at this time not considered in order to quantify bushfire start probability, however protection devices as an asset class should be considered with respect to mitigation technologies such as REFCL and programs which lead to alteration of sequencing and operation.*

The opportunities identified have been categorised into high-, medium- and low-risk profile networks as it is recognised that certain opportunities may not be required or applicable for certain DNSPs.

Opportunities (high-risk profile networks)

- Begin to collect an agreed sub-set for information relating to faults (geographic location, situation, meteorological information)
- A computational or machine learning model is required, and, if possible, is able to be owned and operated by the DNSP
- Utilise historic faults data and perform a statistical analysis considering the different components of the assets to determine a spatial fault occurrence probability, aggregated to nearest pole. This includes, but is not limited to voltage, age, asset type to determine aggregated asset complexity (at a minimum: consider conductors and fuses), material, and geographic location as a proxy for corrosion / temperature / wind loading
- Utilise conditions data from asset management / maintenance databases to further weight / rate likelihood of fault
- Share data on fault probability per asset type or aggregated asset complexity (ag a pole with a conductor alone vs a pole with a conductor plus ACR or fuse)
- Use data from other networks or share data on how geographical location (including applied bushfire mitigation technologies or programs) impacts fault probability
- Determine a quantified bushfire risk likelihood score aggregated to each pole, thereby creating a GIS model of asset failure risk
- Incorporate climate change impacts for longer term projections where there is an increased frequency of FDR days or using relative change of FFDI

Opportunities (medium-risk profile networks)

- Begin to collect an agreed sub-set for information relating to faults (geographic location, situation, meteorological information)
- Utilise historic faults data and perform a statistical analysis considering the different components of the assets to determine a spatial fault occurrence probability. This includes asset type/complexity and geographic location as a proxy for corrosion / temperature / wind loading
- Gather data from other networks on how geographical location (including applied bushfire mitigation technologies or programs) impacts fault probability
- Determine a quantified bushfire risk likelihood score aggregated to each pole, thereby creating a GIS model of asset failure risk

Opportunities (low-risk profile networks)

- Begin to collect an agreed sub-set for information relating to faults (geographic location, situation, meteorological information)
- Gather data from other networks on fault probability per asset type
- Gather data from other networks on how geographical location (including applied bushfire mitigation technologies or programs) impacts fault probability
- Determine a quantified bushfire risk likelihood score aggregated to each pole, thereby creating a GIS model of asset failure risk

Future opportunities or further considerations:

- Include asset, condition, and situation information to build a bottom-up likelihood rating (condition, age, type/complexity related to pole) and then utilise historical faults to verify/validate the fault likelihood GIS model.

– Move to an DNSP managed model to reduce reliance on 3rd party management. Asset failure likelihood would be ideally suited in-house, and ignition likelihood could be mixture of in house and external. Those DNSPs with jurisdiction over higher risk profile networks could look to moving bushfire risk likelihood modelling internally for greater control and more frequent updates and would encourage greater alignment with asset management approaches plus make it easier to model bushfire risk likelihood via GIS. Medium and low risk profile DNSP's could look to external consultants.

5.4.2 Transition to ground fire likelihood

Not all faults will lead to ignition. Therefore, a sub-model is required to determine the rate of conversion of faults to ignition. The elements that determine the rate of ignition include:

– Location specific information such as the terrain and slope
– Vegetation type, current growth, and proximity to vegetation
– Meteorological conditions such as wind speed, temperature, environmental dryness and relative humidity

Location specific elements of terrain and slope are static elements which will (largely) not change over time.

Principle L9: *The ignition likelihood model should have sufficiently granular location information to be predictive. For these elements it is less important that this information is updated as frequently.*

Vegetation type is usually relatively static however may change if there is a change in the land use (e.g., a forested area becomes farmland). The growth rate and the proximity of vegetation to the overhead assets are subject to change and will require more frequent updating of information in the model. Vegetation type is valuable in understanding fall-in and blow-out risks due to debris.

Particularly important with meteorological conditions will be the ability to easily adjust individual parameters such as humidity and wind speed to enable sufficient scenario analysis. This will enable better understanding of the sensitivity of areas to changes in weather as well to model how the likelihood may change with climate change.

Principle L10: *Vegetation type is useful in determining ignition likelihood, particularly for blow-in risk.*

Principle L11: *Vegetation proximity is valuable information but is not essential given the requirement for appropriate vegetation clearances. If vegetation proximity is possible to considered in future ignition risk assessment, annual updates would be beneficial*

Principle L12: *The meteorological conditions can significantly influence the likelihood of ignition.*

Historical data can also be used to determine a statistical relationship between fault and ignition (the probability of an asset ignition converting to ground fire) to derive a fault to ignition rate. Ignition probabilities can also be derived subjectively through sharing of information and data between NSPs.

The opportunities identified have been categorised into high-, medium- and low-risk profile networks as it is recognised that certain opportunities may not be required or applicable for certain DNSPs.

Principle L13: *It is reasonable that ignition rate is estimated by assessing the proportion of detected faults that transition to ignition on asset, as long as asset situation and location is considered.*

Opportunities (high-risk profile networks)

– Use and share ignitions data to form a GIS model for ignition likelihood. Ignitions must be analysed for the corresponding fault (or estimated). Vegetation type and terrain are inputs
– Alternatively, region-wide averages can be extracted from the PBSP RRM ignition rates. The asset type is used, and the failure mode must first be estimated

Opportunities (medium-risk profile networks)

– Gather ignitions data from other NSPs to form a GIS model for ignition likelihood based on terrain and vegetation type, or region-wide averages can be extracted from the PBSP RRM ignition rates

Opportunities (low-risk profile networks)

– Use information from other NSPs to determine a GIS model for ignition likelihood, based on terrain and vegetation type

Future opportunities or further considerations

– Location-specific information (geography), vegetation clearances and vegetation type could be used in the future to develop a bottom-up GIS model of ignition likelihood, and then utilise historical fire starts to verify/validate the ignition likelihood GIS model
– Real time weather data (or at least Fire Danger Ratings) could be input into the ignition likelihood model for dynamic risk model updates. Eventually, a dynamic model could be used for operational decision-making

5.4.3 Filter for suppression success

The last step of the likelihood model can be to estimate the probability of fire suppression after the initial asset ignition… note in this case we are not referring to 'suppression through intervention' but 'suppression through barrier' (eg insufficient flammable material). The rationale for this step is to determine whether the asset ignition progresses to a ground fire, then whether the ground fire progresses to the next stages.

This can be determined through fire footprint simulations. A suppression rate can then be estimated for each fire simulation by comparing historical distribution of fire areas to the distribution given by the set of simulations, weighted by their likelihood of occurrence.

Ignition suppression is difficult to accurately quantify and may inadvertently reduce risk disproportionately through subjective analysis.

At this stage, the way most NSPs accommodate suppression is to take into account ground fires only from their historical fire start database. This is a reasonable proxy for whether a fire will progress or not. However, a more conservative approach would be to take all fire starts into account, or understand (through qualitative analysis) the proportion of reported fire starts that are not ground fires, that progress to ground.

Principle L14: *A conservative position on suppression likelihood is best. This would assume that all fire starts will not be suppressed, or take a proportion of non-ground fire starts that are assumed to progress to ground*

As completed for the sub-models discussed in Section 5.4, the opportunities identified have been categorised into high, medium and low risk profile networks as it is recognised that certain opportunities may not be required or applicable for certain DNSPs.

Opportunities (high risk-profile networks)

– Fire start suppression could be estimated and used to determine the reduction in likelihood of bushfire risk. In the same way it is suggested that a GIS model can be created for ignition likelihood, the likelihood of suppression can also be used, based on location, terrain and vegetation type
– Alternatively, use ground fire starts historical data only probability assessments, plus a proportion of non-ground fire starts that will likely progress to ground (based on history)

Opportunities (medium risk-profile networks)

– Fire start suppression probability is possibly not beneficial at this point in time. Assume all fire starts will not be supressed.
– Alternatively, use ground fire starts historical data only probability assessments, plus a proportion of non-ground fire starts that will likely progress to ground (based on history)

Opportunities (low risk-profile networks)

– Fire start suppression probability is possibly not beneficial at this point in time. Assume all fire starts will not be supressed.

5.5 Powerline bushfire risk determination methods

As discussed in Section 3.3, not all current bushfire risk modelling systems (and none of the past bushfire risk modelling work used for targeting of major network bushfire safety upgrades in response to VBRC recommendations) are true bushfire risk modelling systems. All but the recent (2021) Powercor and United Energy bushfire risk modelling systems were effectively bushfire consequence modelling systems. This is because development and application of bushfire ignition likelihood methodologies, and methods for combining likelihood and consequence to determine risk, have only emerged recently.

The likelihood modelling methodology development process, developed by CSIRO/Data 61, has been subject to a systematic and consultative development process with DNSP fault and fire start data used to build and test the likelihood model.

The risk determination algorithm [8] has not been subject to the same degree of testing and validation as either the likelihood or consequence modelling. Accordingly, the risk determination methodology (computational method for combining likelihood and consequence) can be considered the least tested and validated component of powerline bushfire risk modelling. Typically, in qualitative likelihood, consequence and risk matrix-based risk assessment systems (such as used in National Emergency Risk Assessment Guidelines (NERAG)), where catastrophic or major levels of consequence have been assessed, the effect upon risk of reducing likelihood by one or even two categories can be no change in risk, or at most a one category reduction. It is not known if the powerline risk determination methodology has been subject to sensitivity analysis to ascertain the proportional effects that reducing likelihood has on risk. This could be an opportunity for further work on the path to developing a powerline bushfire risk modelling framework.

Principle R1: *As part of validation and verification process of a model, sensitivity analysis should be undertaken.*

As seen in this document, the various DNSPs have utilised approaches and developed models that have relevance for the nature of their assets and the bushfire related risks that they have, consistent with the current legislation. The natural evolution of such approaches and models is driven by societal expectations, organisational objectives, and by regulatory impetus.

Therefore, one model of a certain level of detail as a benchmark may not necessarily be the most practicable for another DNSP. In some instances, basic prescriptive approaches may be suitable.

Therefore, a modelling framework needs to take into account the bushfire risk context of an organisation, and the societal risks their operations may have (i.e., there need to be a range of risk modelling tools of choice within a framework).

– Are they using the right tools for the level of risk that they have. Jemena is more focused on mitigation programs to remove risks entirely rather than undertaking detailed modelling at an asset level. Quantifying risk may not be justifiable in terms of effort or benefit due to the network risk profile.
– Moved beyond the prescriptive level as a natural evolution. DNSPs are doing capital improvements and operational activities that comply with the current legislative and regulatory requirements but also have worked on BRM.

An important risk principle relevant to any organisation with a range of uncertainties, is to use tools and approaches relevant to the level of their risk, to be approximately right for key decision making.

6. Datasets and architecture

Bushfire risk modelling is a data-intensive process utilising a multitude of spatial and aspatial datasets. Only the likelihood modelling input data is produced and managed by DNSPs. The consequence modelling makes extensive use of spatial data sets as it is necessary to model the spatial footprint of fires and quantify the impacts on various asset classes within the fire footprint. The various spatial datasets used are sourced from a multitude of sources.

Spatial data used for the modelling of fire spread and intensity is principally vegetation type and associated fuel attribute data (covering the entire land surface across each network area), gridded data for weather variables for each of the weather scenarios used (noting that to reflect that weather is not static these change at different timepoints over the course of the model run), and digital elevation data.

During the stakeholder consultations, DNSPs agreed there would be significant merit in achieving standardisation around the datasets used for fire modelling components. DELWP also conducts spatial modelling of bushfire spread and impact across Victoria (for risk planning and operational purposes) and maintains spatial datasets relevant to all the bushfire spread modelling inputs.

Accordingly, in the development of a standardised bushfire modelling framework, it should be possible to develop data standards for the bushfire modelling component, based on DELWP's own standards for the bushfire modelling work it routinely undertakes.

The bushfire impact modelling component also involves extensive use of spatial data pertaining to the spatial distribution of different asset classes across the landscape, these include:

- Built assets
- Critical infrastructure
- Natural resource and agricultural assets
- Other location-based economic values such as tourism values

While the asset mix present in different network areas may vary, the fundamental asset classes for modelling are the same and thus there is good potential for standardisation around the spatial datasets used in impact modelling.

A consultative working group comprised of Victorian DNSPs, DELWP and ESV could reach a consensus on what asset classes should be incorporated in modelling (noting that by agreement it is feasible to add asset classes as appropriate as they become available in the future). This is an achievable aim for a standardised bushfire risk modelling framework to incorporate data standards for bushfire impact modelling components. Similarly, agreement could cover economic valuation systems applied for asset classes.

Likelihood modelling is the component where data is collected and managed by each DNSP. Data pertains to different component assets within the network and their potential to fail plus their fire ignition potential (which is typically based on historical fire incident data), fire start and causation data. Various opportunities relating to data have been proposed in section 5.4.

It is important to agree on defined datasets (including naming terminology, units, frequency of update), so that data can be shared efficiently and effectively between NSPs. Even that data which is managed by NSPs is useful to share, given the disparity between network size and risk profile between electricity networks in Victoria.

The agreement on defined datasets and architecture could be an important next step in harmonising risk modelling approaches and developing an agreed bushfire risk modelling framework.

7. Conclusions

At its core, bushfire risk modelling involves three distinct elements:

1. Modelling of potential bushfire consequence
2. Modelling of bushfire ignition likelihood
3. Combining of modelled consequence and likelihood to generate modelled bushfire risk (quantitative)

Of the above elements, modelling systems maturity is greatest for the bushfire consequence element which has been evolving over a period of more than 10 years. Likelihood modelling is a much more recent area of endeavour, with concept development advancing significantly in 2016, and application at network scale only recently being undertaken for the first time in 2021. Combining of modelled likelihood and consequence into modelled risk has also only been undertaken for the first time in 2021.

Given the maturing state of bushfire consequence modelling and the recently emergent state of bushfire likelihood and risk modelling, it is very timely now to pursue standardisation of a bushfire risk modelling framework. This will enable further innovation in model development to have an aligned direction, and also enhance comparability of modelled risk outputs.

There is potential for the current bushfire hazard-based concepts currently embedded in electricity network bushfire mitigation regulatory systems to be updated with modelled bushfire risk-based systems (conforming to a standardised bushfire risk modelling framework). This will enable delivery of better targeted and more efficient bushfire risk mitigation outcomes for Victorian communities and DNSPs.

Many principles and opportunities were identified as part of this engagement. These can be reviewed in Sections 5.3 and 5.4.

There are 14 principles and associated opportunities for a consistent / common modelling of asset failure and ignition likelihood determination for the range of areas of concern for the DNSPs. These focus on improving accuracy and provide a common approach to quantitative analysis of the likelihood of an ignition event, through a more objective 'bottom-up' approach that can be applied across Victorian electricity networks. In addition, efficiencies can be gained by sharing data and analytical modelling approaches / outputs to improve risk quantification with respect to the likelihood of a bushfire developing from powerlines.

There are 6 principles and associated opportunities for improving consistency in bushfire consequence modelling and improving modelled consequence accuracy. These cover:

1. Measures to achieve greater transparency and consistency of data inputs for modelling
2. Improving the range and resolution of weather scenarios used in modelling
3. Standardising selection of bushfire behaviour models used in bushfire spread simulation systems
4. Standardising asset class inclusions in impact modelling
5. Measures to improve consistency of approach in accounting for asset vulnerability to varying levels of fire severity
6. Harmonisation of economic valuation methods applied to quantify losses.

In terms of overall risk modelling, as part of validation and verification process of a model, sensitivity analysis should be undertaken.

The market and safety regulators need to be actively engaged throughout the evolution of the powerline bushfire risk modelling framework so that there is agreement on risk, agreed approaches and tolerance thresholds that are practical and relevant for each organisation.

7.1 Next steps

At an industry level this review has identified several wider opportunities that could be realised through the coordination and cooperation of the DNSPs and DELWP and ESV. These include:

- Establishment of a review group consisting of the DNSPs, DELWP and ESV to consider the effectiveness of current Victorian regulations and legislation in minimizing bushfire risk. All stakeholders agree to the minimum requirements and acceptable risk-based assessment methodologies.
- Further definition on data, approaches to modelling, data structures and data architecture. This could cover areas such as calculations, data sets, GIS mapping methodology, asset classes, data collected relating to faults, 3rd party data used for consequence modelling. Consistent language, titles and descriptions would make the data sharing more efficient. Principles on data sets (formats, titles and descriptions) could be established. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.
- Establishment of a bushfire modelling practice group between the DSNPs to better share knowledge and approaches to improve bushfire risk modelling and relevant asset information. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.
- Development of risk cost elements based on the risk models which can be incorporated into the asset replacement business cases for DNSP for future review submissions considering the guidance already provided in the AER practice note.
- Using the opportunities and principles from this exercise in conjunction with the DNSPs and ESV to agree on the framework for various levels of modelling requirements for the range of risk profiles that the DNSPs face. This would be best facilitated by meetings organised by DELWP with the DNSP's and ESV.

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Appendices

Appendix A

Abbreviations

Table A.1 Abbreviations table

Term	Definition
AER	Australian Energy Regulator
AFAP	As Far As Possible
AFDRS	Australian Fire Danger Rating System
ALARP	As Low As Reasonably Practicable
BRM	Bushfire Risk Model
CBRM	Condition Based Risk Methodology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning
DNSP	Distribution Network Service Providers
EDPR	Electricity Distribution Price Review
ELCA	Electric Line Construction Area
ENA	Energy Networks Australia
ENEA	ENEA Consulting Pty Ltd
ESV	Energy Safe Victoria
FDR	Fire Danger Ratings
FDI	Fire Danger Index
FFDI	Forest Fire Danger Index
FFRG	Forest, Fire and Regions Group
GIS	Geographic Information System
HBRA	Hazardous Bushfire Risk Area
HV	High Voltage
LBRA	Low Bushfire Risk Area
LV	Low Voltage
NA	Not applicable
PBSP	Powerline Bushfire Safety Program
PBST	Victorian Powerline Bushfire Safety Taskforce
Phoenix Rapidfire	A bushfire simulation system developed by the University of Melbourne
Powercor	Powercor Australia
REFCL	Rapid Earth Fault Current Limiter
RRM	Risk Reduction Modelling
'SPARK'	A bushfire simulation system developed by CSIRO and Data 61
SWER	Single Wire Earth Return
TFB	Total Fire Ban
VBRC	Victorian Bushfires Royal Commission

Appendix B

Reference documentation

Table B.1 Information supplied by stakeholders regarding the bushfire BRM

	Document title	Details	Provided by
1	*PBSP Risk Reduction Model: Overview and Technical Details*	Dunstall S, Towns G, Huston C and Stephenson A (2016) PBSP Risk Reduction Model. CSIRO Data61, Australia. CSIRO Data 61. Completed draft awaiting final technical review. Prepared for the Victorian Government Powerline Bushfire Safety Program	DELWP
2	*PBSP Risk Reduction Model: Mathematics and Computation*	Simon Dunstall, Carolyn Huston, Gary Towns and Alec Stephenson Completed draft awaiting final technical review. Report dated June 27, 2016	CSIRO
3	*Risk Reduction Model Refresh: ESV perspective*	Presentation slide pack	ESV
4	*Jemena Risk Reduction Model* *Powerline Bushfire Safety Program*	Presentation slide pack dated 6 April 2022	Jemena
5	*Quantifying catastrophic bushfire consequences*	Dr Kate Parkins[1], Mr Brett Cirulis[1], Dr Veronique Florec[2], Associate Professor Trent Penman[1]. 1. School of Ecosystem and Forest Sciences, University of Melbourne, Victoria 2. School of Agriculture and Environment, University of Western Australia, Western Australia Version 1.0 dated 31 January 2020	
6	*Bushfire risk model roadmap*	Presentation slide pack dated 10 August 2022 Draft for comment	DELWP
7	*Tranche 4 REFCL Assessment*	Presentation slide pack, Revision 1 dated 3 June 2022	Powercor
8	*A journey through recent bushfire risk modelling improvements – The Risk 2.0 project*	Presentation slide pack, titled with the date 7 July 2022	DELWP
9	*As Far As Practicable analysis – Catastrophic bushfire risk*	Presentation slide pack, revision and date unknown	Powercor
10	*Bushfire risk modelling*	This document describes the bushfire risk work conducted by ENEA and CSIRO for CitiPower and Powercor. It covers the modelling methodology and a discussion of the main limitations and results as well as some recommendations to improve bushfire safety Revision 2 dated December 2021	Powercor
11	*Bushfire risk model overview*	DELWP-hosted industry workshop Presentation slide pack, dated 6 April 2022	Powercor
12	"Bushfire Consequence Methodology_AusNet.pptx"	Presentation slide pack, revision and date unknown	AusNet
13	*Modelling ignition probability and the drivers of anthropogenic and lightning-caused fire ignitions in Victoria*	Annalie Dorph, Dr Kate Parkins, Prof Trent Penman Dated 2021	The University of Melbourne
14	*Advanced Analytics applied to asset health modelling – workshop supporting document*	Presentation slide pack dated November 2020 Slide pack from McKinsey & Company	AusNet
15	*Bushfire risk modelling*	This document describes the bushfire risk work conducted by ENEA and CSIRO for United Energy. It covers the modelling methodology and a discussion of the main limitations and results as well as some recommendations to improve bushfire safety Revision 1 dated January 2021	United Energy

Appendix C

Bushfire BRM interview questions / discussion items

C-1 Likelihood discussions

The following questions / discussion items were used by the GHD team to discuss likelihood modelling aspects with the relevant stakeholders:

1. What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?
2. Does your NSP commission or undertake asset-related fault likelihood modelling as part of network bushfire risk assessment?
3. How does your likelihood of fire start get determined?
4. Is a fault likelihood determined first and then a second calculation performed to translate a fault into a bush fire start
    a. Do you include or exclude particular faults in your fault/bush fire start likelihood
    b. Do you include or exclude particular assets in your fault/bush fire start likelihood
    c. Do you consider previous faults or other history that have led to bushfires in your likelihood determination?
5. Are all fire starts treated equally – for example do you consider pole fires vs ground fires and how likely they are to start bushfires
6. What factors do you consider in the likelihood of a failure/fire start occurring that leads to a fire and what are the sources it is derived from
7. Do you consider weather – in what way? Conditions relate to risk of ignition, risk of fault, what else? Is climate considered? How? How are weather forecasts used (if at all). What are the limitations in how date is obtained and used? What assumptions are used? How is probability of weather occurrence taken into account?
8. Do you consider location, topology proximity to vegetation, is asset in a corrosion area, type of fuel on ground etc. What data is used, and what are the assumptions and limitations? Is weather data used to forecast future topology, and how is this used?
    a. Do you consider asset information
        i. Do you only model conductors or do you consider other assets
        ii. Types of conductors
        iii. Age
        iv. Condition
        v. Material
        vi. Voltage
        vii. Number of phases
9. Protection system in place (REFCL, ACR's, Fuses etc).
10. Where is this data limited, and what could be further considered in order to improve quality of this data and/or outcomes of the likelihood assessment?
    a. Do you consider historical data with respect to faults and their weather, location / topology and asset information
11. If you do consider faults or other history, how do you consider it for assets where there are no records of faults, or the fault data is too poor
    a. please provide details regarding data source(s), data fields collated and used
    b. Do you consider improvements to the network that reduce fire risk in your modelling? How?
    c. Do you consider changes to the network that increase likelihood of bushfire start in your modelling? How?
    d. Is all of your data sourced internally or does some come from third parties?
12. Will there be any issues if the third parties stop providing all of the data that you currently get or change the format, for example if Fire danger rating changes to a completely new model
    a. Are there any other things not listed above that you consider in determining the likelihood of an asset starting a fire

13. If you could do anything to improve your likelihood process in your model, what would it be?
14. What factors have you introduced recently in your bushfire risk modelling that you believe have improved likelihood determinations?
15. What evaluation or validation process do you apply to the modelled bushfire risk likelihood outputs to assess for errors or significant variances?
16. Are there any key deficiencies or limitations in the bushfire risk likelihood modelling that you consider require further work or improved data for use in next generation modelling? If so what and why?
17. What do you think a successful bushfire risk framework looks like? How could it be used? How could network location be used to determine how prescriptive the framework needs to be?

The raw notes taken by GHD during these interviews, with corresponding responses for each of the questions above, is provided within D-1. Refer to Section 3.2.2 of the report above to review distilled elements of each discussion and comparison between the how stakeholders engaged as part of this framework development differ in their approach to likelihood determination.

C-2 Consequence discussions

The following questions / discussion items were used by the GHD team to discuss consequence modelling aspects with the relevant stakeholders.

1. Does your NSP collect and collate historical data on the consequences of bushfires attributed to network faults – if so, please provide details regarding data source(s), data fields collated.
2. What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?
3. What proportion of your network falls within Electric Line Construction Declared Energy mapped areas?
4. Does your NSP commission or undertake spatially explicit bushfire consequence modelling (fire ignition, spread and impact modelling) as part of network bushfire risk assessment?
   If NOT, please identify the system by which potential bushfire consequence is assessed (and skip questions 6 to 19)
5. What bushfire risk control/mitigation program application or design decisions (and/or asset design/inspection/management regime decisions) are based (in whole or in part) on bushfire risk or consequence assessment?
6. For the purpose of evaluating the outputs of bushfire consequence modelling, what qualitative (or quantitative) scale for consequences is used, and how are the thresholds between consequence categories determined?
7. What, if any, analysis/assessment process has been undertaken to evaluate actual NSP bushfire consequence historical data alignment with the modelled consequence category triggers used?
8. Noting that vegetation types and their attendant fuel hazards vary widely across Victoria, what system is used for determining the vegetation-based bushfire fuel assumptions to be used in bushfire consequence modelling?
9. What assessment process has been undertaken to evaluate the suitability and limitations of the vegetation-based fuel assumptions used in consequence modelling?
10. Noting that the range of weather conditions to which a bushfire could be exposed to can vary greatly at any one location, and is variable between locations, what system is used for selecting the weather variables and values used in bushfire consequence modelling?
11. What assessment process has been undertaken to evaluate the suitability and limitations of the selected weather scenario(s) and input value(s) assumptions used in consequence modelling?
12. What system is used for determining the slope data to be used in bushfire consequence modelling?
13. What assessment process has been undertaken to evaluate the suitability and limitations of the selected slope data used in consequence modelling?
14. What modelled fire behaviour attributes are generated in the fire behaviour modelling and how are these categorised?
15. What assessment process has been undertaken to evaluate the suitability and limitations of the modelled fire behaviour outputs for determining the impacts of a modelled fire?
16. What types of bushfire fire impact are modelled (e.g., loss of human life, house loss, other asset class loss etc) and how are these quantified (and/or classified into qualitative categories)?
17. Where multiple weather scenarios are used in bushfire consequence modelling, how are the modelled impact results of the multiple scenarios aggregated or otherwise combined to provide a single modelled consequence output?
18. Where multiple weather scenarios are used in modelling, is weather scenario occurrence probability used in any part of the bushfire risk modelling process?
19. What evaluation or validation process do you apply to the modelled bushfire consequence outputs to assess for errors or significant variances from other relevant sources of risk assessment?
20. Are there any key deficiencies or limitations in the bushfire consequence modelling that you consider require further work or improved data for use in next generation modelling?
    If so what and why?

Appendix D

Responses to bushfire BRM interview questions / discussion items

D-1 Likelihood discussions

D-1-1 AusNet (Interview One & Two)

Table D.1 AusNet likelihood meeting summary

Author	Claire Cass, GHD	**Project no.**	12586987
Attendees	**Meeting One:** Jensen Lai, AusNet Services Shen Cardosa, AusNet Services Claire Cass, GHD Michael Schulzer, GHD **Meeting Two:** Jensen Lai, AusNet Services Claire Cass, GHD Michael Schulzer, GHD	**Meeting time**	**Meeting One:** 19/09/2022, 2:00pm **Meeting Two:** 10/10/2022, 4:00pm
Subject	Questions/Discussion items for bushfire BRM – Likelihood component discussion		

General notes:

– Discussion of how to model the likelihood of ignition
– CSIRO model used as example - All data feeds in to determine conditions, fault rates, future assets (for reduction) and faults to ignition. AusNet uses all 4 data types, on an asset by asset basis. New assets that have been introduced to reduce/eliminate risk are assumed to have very low risk, otherwise current design asset types are assumed to have average ignition risk to similar type assets.

AusNet was asked the following relevant questions on the likelihood modelling component (red = common across likelihood/consequence):

– Use fault rates and ignitions data, not so much conditions (more for consequence)
– Future assets - go assets by assets. Depends on asset that has been introduced. New technologies assume negligible. Use average based on any actual data on that new asset

1. *What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?*

   Approximately 55% of poles are in HBRA.

2. *Does your NSP commission or undertake asset-related fault likelihood modelling as part of network bushfire risk assessment?*

   Yes

3. *How does your likelihood of fire start get determined?*
   a. *Is a fault likelihood determined first and then a second calculation performed to translate a fault into a bush fire start?*
   Take historical data in terms of asset failures that translate into fire start, use reportable fire data, use historical data to translate. If enough data, yes take into account where located. Just split into HBRA and LBRA with respect to prob ignition. At least for conductors.
   b. *Do you include or exclude particular faults in your fault/bush fire start likelihood?*
   Use of failures rather than faults. What is failure mechanism? Conductors = deterioration or external influence. Unassisted or assisted 'failure'. E.g., assisted (vegetation) more likely to start fire. All are counted as fire starts. Think there is value in analysing separately. Probability of unassisted failures for likelihood. Asset failure one cause.
   c. *Do you include or exclude particular assets in your fault/bush fire start likelihood?*
   Fuses (not as rigorous), conductor (highest cost), poles also, but get replaced when considered likely (and impacts reliability), (not transformers; since 2009 replacement program and close to zero bushfire starts).

d. *Do you consider previous faults or other history that have led to bushfires in your likelihood determination?*
   Attribute an ignition likelihood based on historical fire starts.
e. *Are all fire starts treated equally – for example do you consider pole fires vs ground fires and how likely they are to start bushfires*
   Use ground fires only. These are the ones which can develop into a significant bushfire. A Pole fire by definition means that a bushfire did not occur / was not ignited.

4. *What factors do you consider in the likelihood of a failure / fire start occurring that leads to a fire and what are the sources it is derived from?*
   a. *Do you consider weather – in what way? Conditions relate to risk of ignition, risk of fault, what else? Is climate considered? How? How are weather forecasts used (if at all). What are the limitations in how date is obtained and used? What assumptions are used? How is probability of weather occurrence taken into account?*
      Weather gets taken into account when considering consequence. Likelihood is the same irrespective of the weather. Extreme and catastrophic conditions are rare and bushfires caused by assets in these conditions are even rarer so it's not appropriate to derive a weather specific rate from so few data points.
   b. *Do you consider location, topology proximity to vegetation, is asset in a corrosion area, type of fuel on ground etc. What data is used, and what are the assumptions and limitations? Is weather data used to forecast future topology, and how is this used?*
      Proximity to vegetation and ground fuel is taken into account in the consequence modelling data that we receive. Corrosivity area is considered in likelihood of a failure / fault. Neither is taken into account in probability of ignition.
   c. Do you consider asset information
      i. *Do you only model conductors or do you consider other assets?* Other assets as well
      ii. *Types of conductor?* Yes – probability of failure for steel conductors
      iii. *Age?* Probability of failure Yes, probability of ignition no.
      iv. *Condition?* Yes – steel look for signs of rust and score from 1-5. This rating is used in the probability of failure analysis.
      v. *Material?* Yes for probability of failure, no for probability of ignition.
      vi. *Voltage?* Yes HV or LV
      vii. *Number of phases?* No
      viii. *Protection system in place (REFCL, ACR's, Fuses etc)?*

         Should take into account REFCL in the future regarding probability of ignition. HV fuse candling. Improvement in ignition likelihood in REFCL areas? Not enough data available.

         Voltage used LV/HV (including 22 and 66kV bare conductors), covered conductor has had some problems with partial discharge, risk assessment: probability of failure, probability of ignition, consequence. For some assets (steel conductor) score between 1-5. Wooden pole given a condition rating. When the amount of remaining sound wood reaches specified thresholds, action is taken on the pole to mitigate the risk of failure. Crossarms and hardware (aerial photos). Insulators get replaced if found defective. The severity of a defect determines the time allowed for replacement.

      Where is this data limited, and what could be further considered in order to improve quality of this data and/or outcomes of the likelihood assessment?
      Using machine learning models to identify most at-risk assets. Not enough data to be too specific. Need enough data points. Can't be too categorical. For insufficient data, use generic data form external references.
   d. *Do you consider historical data wrt faults and their weather, location/topology and asset information*
      Fires – record fire index, qualitative reporting, e.g., "windy day".
      i. *If you do consider faults or other history, how do you consider it for assets where there are no records of faults or the fault data is too poor?*
         Find external standard, reference, usually UK records.
      ii. *Please provide details regarding data source(s), data fields collated and used*

e. *Do you consider improvements to the network that reduce fire risk in your modelling? How?*
Introduce covered conductor, or underground to reduce risk.

f. *Do you consider changes to the network that increase likelihood of bushfire start in your modelling? How?*
Take into account deteriorating condition of critical assets.

g. *Is all of your data sourced internally or does some come from third parties?*
Externally If likelihood data isn't known. Bushfire consequence data is provided by DELWP.

   i. *Will there be any issues if the third parties stop providing all of the data that you currently get or change the format, for example if Fire danger rating changes to a completely new model*?
   We have existing data sets from 2012-2017 with no requirement for continual supply of updated versions. Other datasets we use in probability of failure modelling have the ability to be interchanged with data from multiple sources which mitigates the risk of relying on a single supplier.

   ii. Are there any other things not listed above that you consider in determining the likelihood of an asset starting a fire?
   No. Workers that have been dispatched into the field (welding and grinding in high-risk days) not yet considered.

5. *If you could do anything to improve your likelihood process in your model what would it be?*
Extend machine learning on fire data. However, once fire data is split over different assets, areas, or weather conditions, there may not be sufficient data points available for a reliable machine learning model.

6. *What factors have you introduced recently in your bushfire risk modelling that you believe have improved likelihood determinations?*
Machine learning to estimate the probability of asset failure. Mainly focused on reliability which automatically improves risk of fires.

7. *What evaluation or validation process do you apply to the modelled bushfire risk likelihood outputs to assess for errors or significant variances?*
The estimate of annual risk is considered by our governance department who need to consider what level of insurance to take out. However, it is hard to evaluate the risk against actual damage as there are a variety of influencing factors which determine the severity of bushfire consequence. Also, we are often talking about 1 in 100-year events so a large event can skew any 5, 10 or 20 year averages of bushfire consequence.

8. *Are there any key deficiencies or limitations in the bushfire risk likelihood modelling that you consider require further work or improved data for use in next generation modelling? If so what and why?*
Need to improve quality of data. Currently there are lots of quality issues that can result in misinformation. Identify and report hazards which is captured. More data from overseas might be useful if the environmental / ignition conditions are similar.

9. *What do you think a successful bushfire risk framework looks like? How could it be used? How could network location be used to determine how prescriptive the framework needs to be?*
Continuous reduction in network caused fires. Reduce the incidence of fuse candling which is a contributing factor to ignition rates.

D-1-2 Jemena

Table D.2 Jemena likelihood meeting summary

Author	Claire Cass, GHD	**Project no.**	12586987
Attendees	Tom Ruzeu, Jemena Davis Speairs, Jemena Claire Cass, GHD Michael Schulzer, GHD	**Meeting time**	19/09/2022, 12:00pm
Subject	Questions/Discussion items for bushfire BRM – Likelihood component discussion		

1. *What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?*

   Approximately 5% of our network is in the HBRA.

2. *Does your NSP commission or undertake asset-related fault likelihood modelling as part of network bushfire risk assessment?*

   Yes – use data, and also industry knowledge (in terms of asset management, mitigation programs)

3. *How does your likelihood of fire start get determined?*

   a. *Is a fault likelihood determined first and then a second calculation performed to translate a fault into a bush fire start?*
   Fault data is distinguished from ignitions data. Use Asset System risk modelling. Fire ignitions data is used for consequence. OMS – contains both fault and consequence (e.g., fire ensues). If fire is ignited but not originated from a fault (outage) this is notified in SAP. Use both combined. Used for F-Factor reporting. GIS data – fault is recorded geolocated.

   b. *Do you include or exclude particular faults in your fault/bush fire start likelihood?*
   Exclude faults that cannot cause a fire (e.g., metal to metal arcing) but will record burning plastic causing grass fire, e.g. LV switches.

   c. *Do you include or exclude particular assets in your fault/bush fire start likelihood?*
   No asset classes are excluded from asset-based fire ignition risk assessment. We include everything from poles and transformers to conductor and connectors, including above ground portions of underground networks.

   d. *Do you consider previous faults or other history that have led to bushfires in your likelihood determination?*
   Yes, since JEN specific history is scant or non-existent, Jemena uses known history from around Victoria and around Australia

   e. *Are all fire starts treated equally – for example do you consider pole fires vs ground fires and how likely they are to start bushfire*
   Yes between asset fires and ground fires (pole fires are assessed across network)

4. *What factors do you consider in the likelihood of a failure / fire start occurring that leads to a fire and what are the sources it is derived from?*

   a. *Do you consider weather – in what way? Conditions relate to risk of ignition, risk of fault, what else? Is climate considered? How? How are weather forecasts used (if at all). What are the limitations in how date is obtained and used? What assumptions are used? How is probability of weather occurrence taken into account?*

      Yes – pole top fires linked to weather condition, e.g. in HBRA replaced all HV timber crossarms with HV steel crossarms. Use weather for mitigation measures (operations). Produce Bushfire Mitigation Index – ESV require reporting. No GIS model of bushfire risk. Report has been produced for insurance assessor to get insurance cover at minimum premium (including mitigating risk of not being able to purchase insurance at all). Report included bushfire risk, how low the risk was, no forest, all rural areas are easily accessible, initiatives and focus are to remove risk and not just to ameliorate (this assists their insurance broker secure cover, i.e. justify insurance). HBRA / LBRA is treated differently. Focus on risk elimination including for example, removal of SWER lines, eliminate staked poles, replace timber poles with concrete poles, new poles are all concrete (unless new design calls for underground construction), remove bare LV mains. Bushfire mitigation plan being updated with REFCL.

b. *Do you consider location, topology proximity to vegetation, is asset in a corrosion area, type of fuel on ground etc. What data is used, and what are the assumptions and limitations? Is weather data used to forecast future topology, and how is this used?*
   Yes, at a holistic level. Vegetation clearance. Use HBRA (compliance at all times). Based on historic data (particular incident – originated in Jemena area but not by Jemena assets; Mickleham Rd fire, 9 Feb 2014) introduced dedicated hazard tree management program.

c. Do you consider asset information
   i. *Do you only model conductors or do you consider other assets?* See statement for c. above
   ii. *Types of conductor?* See statement for c. above
   iii. *Age?* See statement for c. above
   iv. *Condition?* In HBRA inspect assets (generally) once every 3 years (as per legislation). E.g., made decisions on mitigation initiatives. Not geographic class. Defects are reported by exception. In HBRA manage more proactively based on condition priority.
   v. *Material?* Considered in our Materials Standards, i.e., risk to fire ignition and risk to fire sustainment
   vi. *Voltage?* Considered in our Materials Standards, i.e., risk to fire ignition and risk to fire sustainment.
   vii. *Number of phases?* considered in our Design Standards, e.g., <u>all</u> SWER replaced with multi-phase by 2013.
   viii. Protection system in place (REFCL, ACR's, Fuses etc)?
   Yes. For example, installing/operating a REFCL is mandated in Coolaroo supply area. Voluntarily Jemena is working towards protecting all HBRA feeders with REFCL technology. Control of auto reclose on TFB days is above requirements, i.e. Jemena employs zero re-closes compared with the one allowed. All fuses in the HBRA are cool discharge (Boric Acid technology) or zero discharge (Power filled technology) or discharge contained (utilizing flame arrestor technology). ACR's are used for fast sectionalization to aid supply restoration / fault isolation.

d. Where is this data limited, and what could be further considered in order to improve quality of this data and/or outcomes of the likelihood assessment?

   In general data quality is not an issue. For Jemena the overwhelming limitation is lack of faults to enable meaningful trending to be established. As an example, it's impossible to justify asset conclusions/recommendations based on 7 minor fire start in the HBRA over the past 5 years

e. *Do you consider historical data with respect to faults and their weather, location/topology and asset information*
   i. *If you do consider faults or other history, how do you consider it for assets where there are no records of faults or the fault data is too poor?*

      Yes, see response to 4.c. above.
   ii. Please provide details regarding data source(s), data fields collated and used
   Sources – GIS, SAP, OMS, OSIRIS (this is an online register administered by ESV), F-Factor register. Fields vary based on asset from the GIS. The F-Factor is a regulated template, and Jemena capture all fields contained. The OMS, Outage Management System is historical and captures many "events" based fields. SAP captures all condition based and works management-based information (including cost/expenditure capture).

f. *Do you consider improvements to the network that reduce fire risk in your modelling? How?*
   Qualitatively – reduction in ignition risk unit has reduced, and also IRU (Ignition Risk Unit) target has reduced. Use F-Factor report to track risk profile and effectiveness of mitigation measures

g. *Do you consider changes to the network that increase likelihood of bushfire start in your modelling? How?*
   Yes, this is assessed by the Standards department whenever a new component/asset/material is contemplated for introduction to JEN.

h. *Is all of your data sourced internally or does some come from third parties?*
   Yes, see response to 4.c. above
   i. Will there be any issues if the third parties stop providing all of the data that you currently get or change the format, for example if Fire danger rating changes to a completely new model?
      Yes, albeit minor until systems/spreadsheet are modified to cater to the change/amendment.

i. Are there any other things not listed above that you consider in determining the likelihood of an asset starting a fire?
   Yes. Human intervention, internal/public deliberate and accidental.

5. *If you could do anything to improve your likelihood process in your model what would it be?*
   Quantifying risk may not be justifiable in terms of effort / benefit
6. *What factors have you introduced recently in your bushfire risk modelling that you believe have improved likelihood determinations?*
   Risk modelling is at asset class level and not at each pole location, for example. As stated earlier our focus is on risk elimination rather than amelioration by prioritization via risk modelling.
7. *What evaluation or validation process do you apply to the modelled bushfire risk likelihood outputs to assess for errors or significant variances?*
   Reduction in ignition risk
8. *Are there any key deficiencies or limitations in the bushfire risk likelihood modelling that you consider require further work or improved data for use in next generation modelling? If so what and why?*
   Nil
9. *What do you think a successful bushfire risk framework looks like? How could it be used? How could network location be used to determine how prescriptive the framework needs to be?*
   Model should be based on thresholds of acceptable risk. In terms of investigations, the modelling framework needs to recognize the sophistication of modelling required based on risk profile and need. Also, the model needs to recognize investment based on risk determination vs investment in risk reduction. Mitigation shouldn't be based purely on what the modelling results, qualitative assessment is also needed. The model should be calibrated to needs of the network.

D-1-3 Powercor

Table D.3 Powercor likelihood meeting summary

Author	Claire Cass, GHD	**Project no.**	12586987
Attendees	Dene Ward, Powercor Claire Cass, GHD	**Meeting time**	27/09/2022 10am
Subject	Questions/Discussion items for bushfire BRM – Likelihood component discussion		

General notes:

How risk likelihood and ignition risk is determined at PAL:

– Against each pole – 6 probs against each pole, probability of asset failure (fault history) fault that leads to fire = fire start. Through investigation, found what asset on that pole would have led to the fault – conductor condition. Across every pole likelihood of fault. SWER poles lower likelihood of fault. Identified fuse pole, higher likelihood of fault. Use proportion of faults that led to fire start as a fire start… but take into account TFB day. Where was the fault, what type of pole (e.g., fuse pole), which fire district, what was fire danger rating at the time. Higher conversion rate of fault to fire when FDR extreme. Came up with ignition likelihood specific to that pole and FDR. Fault data (likelihood of fault) is also location specific. This is because fault rates are related to condition, maintenance, the way things were built, reliability initiatives etc. Location /area. Fuse pole is treated differently or a non-fuse pole. Conductor is linked to a pole. Conductor likelihood of failure is also related to condition, type, location (coast etc), age, where it sits in corrosion map. 'Top down' quantitative approach. 3 asset classes – basic conditional stuff – pole itself, concrete/wood and age, fuses (type, age), conductor (age, type, where is it located in corrosion map). THEN use all the faults data / historical. Projected influence of conditions. ENEA and CSIRO then used the above to come up with a overall map of fault data and ignition likelihood.

– Powercor was asked the following relevant questions on the likelihood modelling component (red = common across likelihood/consequence):

1. *What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?*

   2. Quantify risk profile – past history (area severely impacted), quantify (simple: length of network in HBRA and LBRA, but how defined? CFA determine the boundaries – predominantly based on fuel content, density and topography of the area) 55% poles HBRA (80% from sq km)

   3. Conditions: climate and environmental, asset condition

4. *Does your NSP commission or undertake asset-related fault likelihood modelling as part of network bushfire risk assessment?*

   Currently don't take into account condition of asset but wish to. To do this successfully Powercor will need to understand the condition of all elements on a pole, and the condition of conductor between poles

5. *How does your likelihood of fire start get determined?*

   a. *Is a fault likelihood determined first and then a second calculation performed to translate a fault into a bush fire start?*
   Currently model likelihood on past performance (faults and fire starts per pole plus qualitative info used for cataloguing and for mitigation measures). BUT if could use health score of assets, existing 'likelihood of past performance' could be further improved. Dene: thinks using past data is robust. As improve network, likelihood reduced. Gives conservative starting point. Uses absolute data relevant. Moving towards asset condition, need every element on the pole with a condition scope prior to using in likelihood assessment. Only having pole and crossarm isn't giving full picture of everything that could fail, and influence on fire start. Need individual assets to get a true health score.

   Current approach captures ALL asset failures and external factors that start fires e.g., LV fires starts, 3rd party contact fire starts, vegetation contact fire starts etc.

b. *Do you include or exclude particular faults in your fault/bush fire start likelihood?*
Maintain 2 databases:

– faults (outage management system) i.e., what was the fault?

– fire starts database. Firestart is geolocated to a pole.

5-10 years of data on faults and 5-10 years of fire starts, fully correlated (F-Factor scheme has seen a step-increase in accuracy of fire reporting). The pole is the primary location (report conductor faults against nearest pole).

c. *Do you include or exclude particular assets in your fault/bush fire start likelihood?*
If conductor starts the fire, location = pole. All assets are covered based on history.

d. *Do you consider previous faults or other history that have led to bushfires in your likelihood determination?*
Yes

e. *Are all fire starts treated equally – for example do you consider pole fires vs ground fires and how likely they are to start bushfires*
Yes. Distinguish if ground fire or not. The risk model accounts for this conversion rate of fire starts to ground fires as only fires that come to ground will cause a material consequence

6. *What factors do you consider in the likelihood of a failure / fire start occurring that leads to a fire and what are the sources it is derived from?*

a. *Do you consider weather – in what way? Conditions relate to risk of ignition, risk of fault, what else? Is climate considered? How? How are weather forecasts used (if at all). What are the limitations in how date is obtained and used? What assumptions are used? How is probability of weather occurrence taken into account?*
Yes, it does. Fire is started with a measured location e.g., northern regions are prone to higher fire danger ratings more frequently but possibly less ignitions due to fuel load e.g., Mallee = desert and salt plains. These are factored into future. Powercor use historic fire danger ratings at time of fire starts. Fire danger ratings account for climate and weather. Too onerous to break down further into temp / wind speed / fuel moisture content etc. The FDR is a reasonable indicator of these factors.

b. *Do you consider location, topology proximity to vegetation, is asset in a corrosion area, type of fuel on ground etc. What data is used, and what are the assumptions and limitations? Is weather data used to forecast future topology, and how is this used?*
Yes, the Powercor model has identified "unburnable" areas so not all poles have a risk factor assigned to them. Where poles are located in burnable areas, Powercor currently do not take into account proximity of vegetation to powerlines when modelling likelihood. This is a future pathway for us. Trees in vicinity of line or trees that could blow into line – maybe future? Integrate vegetation management with bushfire risk model so state of vegetation would also scale up or down likelihood. Powercor know where all trees are relative, know clearance, density may contribute? aspect (north side of the line etc), higher likelihood inadvertent contact. Also, if know you have trees inside of clearance, higher likelihood (temporarily). Species of trees (those that are more likely to shed / fall).

c. Do you consider asset information

i. *Do you only model conductors or do you consider other assets?*

ii. *Types of conductor?* Not yet – starting to profile conductor condition in asset management system, not yet integrated into bushfire management system. Covered vs non covered conductor is accounted for in fault/fire history, and whenever the asset model is updated, the status of conductor updated. Potential to include a likelihood factor for covered conductor in future model. Do take into account covered conductor for likelihood for future business cases

iii. *Age?* Future

iv. *Condition?* Future

v. *Material?* Future

vi. *Voltage?* Yes

vii. *Number of phases?* Yes (poly or SWER)

viii. *Protection system in place (REFCL, ACR's, Fuses etc)?*
Don't in context of risk modelling – controls / mitigation. Increase these controls on TFB days.

Where is this data limited, and what could be further considered in order to improve quality of this data and/or outcomes of the likelihood assessment?
Consider condition of all assets related to particular pole (and conductor of course). Powercor have good asset data but not yet integrated. Waiting for asset management team to have a prob of failure score for every pole (includes all components on that pole). E.g. some poles are more complex than others and pole condition doesn't relate properly. This is under progress. At least 1 year away. Data quality can also be a challenge. Use as multiplier. Then could use a likelihood only geospatial map. Could use for climate resilience.

Potential to have a likelihood de-rating factor once a health score is provided for every pole. Thus, likelihood is firstly determined using previous history (faults/fires/location/FDR) and then an asset condition (and veg condition) multiplier is applied to increase the likelihood if condition is projected to increase PoF.

d. Do you consider historical data wrt faults and their weather, location/topology and asset information
   i. *If you do consider faults or other history, how do you consider it for assets where there are no records of faults or the fault data is too poor?* Poles without fault or fire start history are still in the model. Applying the model is more areas / regions / feeders
   ii. *Please provide details regarding data source(s), data fields collated and used*

e. *Do you consider improvements to the network that reduce fire risk in your modelling? How?*
Yes – refresh likelihood data annually could be undertaken (or regularly) based on current network and based on last e.g.: 5 years of fire history ('likelihood data'). It's a static model which needs refreshing. Reflection of a given point in time as model is used for longer term planning & investment decisions, not real-time operational decisions. IF e.g. a bushfire mitigation program is undertaken (e.g. undergrounding), calculate effectiveness of covered/underground, and apply that to that section of that feeder. Calculate risk retired based on that bushfire improvement program. BUT not reliability programs e.g. ACRs. These will feed back when the network model is updated.

f. *Do you consider changes to the network that increase likelihood of bushfire start in your modelling? How?*
Yes – if a new line was built (e.g.) that would be reflected in the next network model update and a risk would be assigned to that new line.

g. *Is all of your data sourced internally or does some come from third parties?*
All network data, faults and fires come from PAL.
   i. *Will there be any issues if the third parties stop providing all of the data that you currently get or change the format, for example if Fire danger rating changes to a completely new model*?
   CSIRO get data from BoM etc for situational data.
   ii. Are there any other things not listed above that you consider in determining the likelihood of an asset starting a fire?
   More granular weather data for every fire start, 'best practice' would be capturing wind speed and temp in fire start data. But weather data depends on closest AWS so currently not granular enough to be useful.

7. *If you could do anything to improve your likelihood process in your model what would it be?*
See above.

8. *What factors have you introduced recently in your bushfire risk modelling that you believe have improved likelihood determinations?*
Climate change impacts…scenarios which scale up result based on projections. Built into risk model. More frequent high fire danger rating days. We have used RCP4.5 and 8.5… The Intergovernmental Panel on Climate Change (IPCC) represents possible future climate scenarios by various Representative Concentration Pathways (RCP), which are greenhouse gas concentrations trajectories resulting of socio-economic and public policy hypotheses. The data source provides projections of the number of days of FFDI in various locations around Victoria. We have used two pathways: RCP4.5 and RCP8.5

9. *What evaluation or validation process do you apply to the modelled bushfire risk likelihood outputs to assess for errors or significant variances?*

Project back… what benefits have occurred based on REFCL etc? What is the effectiveness of bushfire mitigation initiatives? What is the risk reduction, what would it have been without initiatives. AFAP review of network – risk model was a major input to review all of the mitigation options, how much would it reduce risk, what cost i.e. cost benefit. Provide bushfire contribution to risk

10. *Are there any key deficiencies or limitations in the bushfire risk likelihood modelling that you consider require further work or improved data for use in next generation modelling? If so what and why?*
    See above
11. *What do you think a successful bushfire risk framework looks like? How could it be used? How could network location be used to determine how prescriptive the framework needs to be?*
    Determine investment decisions. Use for AER purposes… compare like for like, understand how risk is determined. 'Standard recipe'. Consistent and justifiable e.g. past history is a good indicator of current performance, but relevance is important (recent data, length of history). Climate change data should be used. Project back… what benefits have occurred based on REFCL etc? What is the effectiveness of bushfire mitigation initiatives? Veg risk profiling. Asset condition risk profiling. Dynamic risk model (real time) – make operational decisions based on current conditions and risk profiles

D-1-4 United Energy

Table D.4 United Energy likelihood meeting summary

Author	Claire Cass, GHD	**Project no.**	12586987
Attendees	Justin Lau, United Energy Claire Cass, GHD	**Meeting time**	27/10/2022 11:30am
Subject	Questions/Discussion items for bushfire BRM – Likelihood component discussion		

1. *What proportion of your network falls within the Hazardous Bushfire Risk Area (HBRA)?*

   2. Not answered

3. *Does your NSP commission or undertake asset-related fault likelihood modelling as part of network bushfire risk assessment?*

   Yes – asset failures, asset classes, fire ignition rates. Engaged ENEA to conduct analysis. Fire ignition was so low that UE use Powercor/AusNet data for ignition. Asset failure x ignition likelihood – likelihood of fire start.

4. *How does your likelihood of fire start get determined?*

   a. *Is a fault likelihood determined first and then a second calculation performed to translate a fault into a bush fire start?*
   Internal standard defines asset failure vs fault. Assessment today se failures, historical data uses fault data. Database of outages. 2012-2017. Now use more recent data (past 5 years). Refresh model every 2 years. No platform… a report is produced. Report was produced in 2020, next scheduled for 2023

   b. *Do you include or exclude particular faults in your fault/bush fire start likelihood?*
   LV assets are excluded (HV only), also 66kV but no failure data.

   c. *Do you include or exclude particular assets in your fault/bush fire start likelihood?*
   HV conductor, LV conductor, poles. Geographic location = functional location based on nearest pole.

   d. *Do you consider previous faults or other history that have led to bushfires in your likelihood determination?*

   e. *Are all fire starts treated equally – for example do you consider pole fires vs ground fires and how likely they are to start bushfires*
   Yes – Ffactor reporting. Use AusNet/Powercor data.

5. *What factors do you consider in the likelihood of a failure / fire start occurring that leads to a fire and what are the sources it is derived from?*

   a. *Do you consider weather – in what way? Conditions relate to risk of ignition, risk of fault, what else? Is climate considered? How? How are weather forecasts used (if at all). What are the limitations in how date is obtained and used? What assumptions are used? How is probability of weather occurrence taken into account?*
   Not for asset failures, but for fire risk modelling (fire danger rating days, AWS). Not a large bushfire risk profile. AWS data was used for likelihood too. **High fire danger rating days**.

   b. *Do you consider location, topology proximity to vegetation, is asset in a corrosion area, type of fuel on ground etc. What data is used, and what are the assumptions and limitations? Is weather data used to forecast future topology, and how is this used?*
   Yes – classifications of veg (at pole level) is taken into account in terms of probability. Veg – generally clear to reduce risk

   c. Do you consider asset information

      i. *Do you only model conductors or do you consider other assets?*

      ii. *Types of conductor?* HV ABC

      iii. *Age?* No

iv. *Condition?* Not yet but need model to tie into probability

v. *Material?* No – covered conductor too new, underground also not included

vi. *Voltage?* Yes

vii. *Number of phases?* No

viii. *Protection system in place (REFCL, ACR's, Fuses etc)?*

Where is this data limited, and what could be further considered in order to improve quality of this data and/or outcomes of the likelihood assessment?

.

d. Do you consider historical data wrt faults and their weather, location/topology and asset information

i. *If you do consider faults or other history, how do you consider it for assets where there are no records of faults or the fault data is too poor?* E.g. covered conductor, wait for historical data to capture

ii. *Please provide details regarding data source(s), data fields collated and used*

e. *Do you consider improvements to the network that reduce fire risk in your modelling? How?*
When report is refreshed, new network topology.

f. *Do you consider changes to the network that increase likelihood of bushfire start in your modelling? How?*

.

g. *Is all of your data sourced internally or does some come from third parties?*

i. Will there be any issues if the third parties stop providing all of the data that you currently get or change the format, for example if Fire danger rating changes to a completely new model?
Powercor / AusNet. Report – look at source table

ii. Are there any other things not listed above that you consider in determining the likelihood of an asset starting a fire?
More granular weather data for every fire start, 'best practice' would be capturing wind speed and temp in fire start data. But weather data depends on closest AWS so currently not granular enough to be useful.

6. *If you could do anything to improve your likelihood process in your model what would it be?*
Suppression – likelihood?.

7. *What factors have you introduced recently in your bushfire risk modelling that you believe have improved likelihood determinations?*
AusNet / Powercor ignitions data

8. *What evaluation or validation process do you apply to the modelled bushfire risk likelihood outputs to assess for errors or significant variances?*
3rd party data take as is. QC, but no validation

9. *Are there any key deficiencies or limitations in the bushfire risk likelihood modelling that you consider require further work or improved data for use in next generation modelling? If so what and why?*
See above

10. *What do you think a successful bushfire risk framework looks like? How could it be used? How could network location be used to determine how prescriptive the framework needs to be?*
Networks have specific needs and requirements… start high level, anything additional based on… condition data, geography, extent of rural network, population density, HBRA/LBRA, BCA

D-1-5 DELWP

Table D.5 DELWP likelihood meeting summary

Author	Claire Cass, GHD	**Project no.**	12586987
Attendees	Sarah Loveday, DELWP Estrella, DELWP Josie, DELWP Claire Cass, GHD	**Meeting time**	28/09/2022 10am
Subject	Questions/Discussion items for bushfire BRM – Likelihood component discussion		

General discussion:

- Consistency across the state
- Backed by science and modelling
- More overlap b/w bushfire line safety program (reduce risk from assets) and FFR (operational and field management, property, environment) (DELWP) – in the same dept
- Uni of Melb – statistical model of prob of fire start – use historical ignitions events, next predict future(based on external data, asset data) – use to predict probability of future.
- Statistical approach

Appendix E

Bushfire hazard and risk concepts incorporated in current regulatory frameworks

E-1 Bushfire hazard and risk concepts incorporated in current regulatory frameworks

Bushfire risk controls (many of which are also for control of reliability risks) implemented by DNSPs use a range of quasi-risk (bushfire risk) concepts which operate independently of Bushfire Risk Models. These include:

E-1-1 Bushfire Risk Area designation

Under Section 80 of the *Electricity Safety Act 1998* (ES Act), a 'fire control authority' [the Victorian Country Fire Authority (CFA)] assigns land areas in Victoria to either a low or high fire hazard rating for the purpose of applying the ES Act and Regulations. These ratings are used in conjunction with the *Electricity Safety (Electric Line Clearance) Regulations 2020*, the *Electricity Safety (Installations) Regulations 2019* and the *Electricity Safety (Bushfire Mitigation) Regulations 2013*, to prescribe low or hazardous bushfire risk areas (known by DNSPs and regulators as the HBRA and the LBRA). Although the word 'risk' is used in the naming of these areas, the way such areas are designated is not based on any true or detailed assessment of bushfire risk. Rather, it is a binary presence / absence assessment of vegetation able to support the ignition and spread of bushfires.

Councils that fall entirely within the former Metropolitan Fire Brigade (MFB) area have been rated as LBRAs. LBRAs are usually restricted to irrigated areas and towns where block sizes are small and well maintained. Examples of these include:

- High density residential areas (i.e., property sizes of up to 0.25 hectare (ha));
- Industrial and commercial urban areas;
- High moisture crops (i.e., market gardens);
- Irrigated farmland (but not seasonally irrigated as it must remain irrigated over summer);
- Vineyards;
- Golf courses and sporting ovals (permanently green)

HBRAs are defined as any areas not categorised as LBRAs. These areas are said to contain sufficient fuel on the ground to carry a fire. Regional and municipal scale bushfire risk assessments undertaken by Victoria's principal fire management agencies[9] identify areas within designated HBRA areas with assessed bushfire risk levels ranging from low to extreme. Thus, the HBRA designation does not equate with high bushfire risk – it denotes areas where it is possible for bushfires to start and spread.

The HBRA and LBRA designations influence a range of bushfire risk controls implemented by DNSPs. Noting that bushfire risk control practices vary between DNSPs, which are dependent on their bushfire risk profiles, HBRA or LBRA designation may influence such risk control decisions as:

- Cyclic inspection frequency. This includes vegetation clearance and specified asset class inspections such as pole condition;
- The timing of cyclic vegetation clearance and asset inspections (e.g., before commencement of the fire risk period in HBRA areas);
- Additional non-cyclic pre-summer vegetation / asset inspections in selected HBRA areas;
- Defect rectification prioritisation for vegetation and asset defects;
- Hazardous tree program design and application;
- Tree overhang management and clear-to-sky clearance specifications;
- Electric Line Clearance Audit regimes

Linking of bushfire risk control practices with HBRA and LBRA designations is a long-standing historical practice.

[9] Forest Fire Management Victoria in DELWP and CFA

E-1-2 Electric Line Construction Area designation

Electric Line Construction Areas (ELCAs)[10] were derived in part from catastrophic bushfire consequence modelling work undertaken for PBSP by the University of Melbourne for the principal purpose of identifying priority areas for electricity network bushfire safety upgrade programs and investments. ELCAs represent network areas where fire ignitions have the greatest potential to spread and cause potentially catastrophic impacts to Victorian communities under adverse fire weather conditions. The bushfire consequence modelling from which ELCAs are derived (based on worst case fuel load and fire weather scenarios) may be different from bushfire consequence modelling subsequently undertaken by some DNSPs, although it is expected that there would be a high degree of overlap. ELCAs are based on potential bushfire consequence and do not explicitly incorporate assessment of bushfire likelihood.

ELCA designation may influence such risk control decisions as:

– Selection of network areas for Victorian government mandated REFCL systems installation and operation and installation of SWER ACR systems
– Regulatory requirements to replace overhead bare conductor systems with lower bushfire risk assets such as underground or insulated conductors
– DNSP prioritisation of specific bushfire risk mitigation programs such as Hazard Tree identification and removal programs
– DNSP bushfire risk mitigation performance indicator evaluation

E-1-3 Catastrophic and Total Fire Ban declarations

The CFA may, at the discretion of the CFA Chief Officer or delegate, declare Total Fire Bans (TFB) across all or parts of Victoria. This is based on assessments of adverse fire weather forecasts indicating heightened potential for bushfires to ignite, spread, and become uncontrollable and destructive. Historically, TFB days are declared when Fire Danger Indices in the Severe to Code Red Fire Danger Rating categories; TFB days are principally, but not exclusively, during the declared fire danger period. This has subsequently been replaced by Extreme and Catastrophic Fire Behaviour Index categories under the Australian National Fire Danger Rating System (AFDRS) which are forecast by the Bureau of Meteorology along with consideration of other factors such as fire activity. TFB declarations are intended for public warning about the onset of adverse fire weather conditions and to provide a framework for bushfire prevention systems, including the prohibition of high fire risk activities.

The TFB designation provides a framework for DNSPs to implement fire risk likelihood (and therefore risk) reducing actions. This includes actions such as altering protection system settings, increasing priority for actioning certain asset or vegetation defects, and in certain circumstances disconnecting customers with outstanding Private Electric Line defects. DNSPs must specifically document system operation and maintenance arrangements on TFB days in their statutory Bushfire Mitigation Plans prepared as required by the *Electricity Safety (Bushfire Mitigation) Regulations 2013.*

[10] As designated in Schedule 2 of the *Electricity Safety (Bushfire Mitigation Duties) Regulations 2017*

Appendix F

Consequence modelling sub-model design and data

For the purpose of conducting the strengths and gaps analysis associated with the bushfire consequence modelling component of the BRM, sub-models in the reference model provided as Figure 6 are further articulated in the proceeding sections.

F-1 Fuel sub-model

Figure F.1 Fuel sub-model

Generally, all fire behaviour models require fuel inputs. Fuel input requirements are derived from the vegetation type in which a fire may ignite. Some fire behaviour models require a single fuel input value (such as vegetation height for shrublands) whereas others may require multiple fuel inputs (such as condition and degree of curing for grass; and multiple fuel strata characteristics and values for forests). As modelled outputs, all fire behaviour models provide a measure of rate of forward spread while some may provide derived values for spotting distance, flame height / length, or fireline intensity.

Some vegetated areas are highly modified by land use and ongoing maintenance activities such that they have an inherently low fuel hazard. These areas are excluded from fire spread modelling.

F-1-1 Fire behaviour models

It is important that current, peer-reviewed scientific research-based fire spread models are used in the fire spread modelling process, noting that the selected models will determine the fuel data requirements. Fire spread model selection should be consistent with the fire spread models used in the AFDRS [4].[11] used in all Australian States and Territories. The AFDRS fire spread models are used to determine the forecast Fire Behaviour Index (FBI) which is used for public warning about daily fire danger. Further, the FBI is or can be used operationally by fire and emergency services for fire spread and behaviour prediction of actual fire events. The fire spread models used in the AFDRS which are relevant for use in Victoria [4] include:

1. *Forest*: The Dry Eucalypt Forest Fire Model (DEFFM) also known as the Vesta model [12]

   Forest is prevalent across more than 75% of Victorian fire weather areas, and therefore has a significant influence on the fire behaviour and associated risk [4].

   The DEFFM has replaced the previously used McArthur Forest Fire Behaviour tables.[12] [3] which scientific research revealed had a significant under prediction bias. Thus, it is important to utilise the DEFFM in preference to the McArthur Mark 5 forest model to avoid the under prediction issues.
2. *Pine plantation*: The Pine Plantation Pyrometrics (PPPY) model [13]

   Pine plantations occur in various parts of Victoria, with the major plantation areas occurring in South-Western Victoria (Green Triangle), South-Gippsland, and North-East Victoria..
3. *Temperate Shrublands*: The Shrubland Mode [14], being a generic, empirical model applicable for a range of temperate heath and shrubland types.
4. *Mallee*: The Mallee Heath Model [15] for semi-arid shrublands with a mallee-form eucalypt canopy and shrubby understory. Occurrence in Victoria is limited to the Mallee and Wimmera weather districts.
5. *Grassland*: The CSIRO Grassland Model [16], being a generic grassland model applicable for native and exotic grassland areas across Victoria.

[11] Launched nationally on 1 September 2022
[12] McArthur [3]on the Mark 5 FFDI. This was converted to equations by Noble et. al. [21]

The CSIRO Grassland model is applicable for a variety of grassland fuels including continuous and tussock grasslands, pastures, and grassy cereal crops. The grassland model is also used for temperate grassy woodlands with a sparse overstory of trees, as the model applies a wind reduction factor to account for open woodland tree cover.

6. *Low threat vegetation exclusions*: Fire spread is not modelled for a range of 'low threat vegetation' exclusions. This is where land use and / or recurrent vegetation management activities result in highly modified and low fuel hazard levels including irrigated crops / horticulture; sports fields; managed (slashed / mowed) recreation reserves; golf courses; and maintained lawns / gardens). Embers may transport fire across these low threat vegetation areas, however sustained surface fire spread is stopped or strongly inhibited.

F-1-2 Vegetation and fuel data requirements

For the selection of fire behaviour models relevant to Victoria, the fuel data listed below will be required. Given the individual property scale of impact assessment required, continuous spatial fuel data to a resolution of 30 metre pixel size or better will be appropriate.

1. Grassland
   - Grassland fuel sub-type:
     - Grass
     - Grassy woodland
   - Grass condition[13]:
     - "Natural"
     - "Grazed"
     - "Eaten Out"
   - Grass curing (%)[14]
2. Forest
   - Forest sub-type:
     - Dry forest (default)
     - Wet forest
   - Fuel state / attribute:
     - Surface fuel stratum (load or hazard rating)
     - Near surface fuel stratum (load or hazard rating)
     - Near surface fuel height
   - Years elapsed since last fire (actual or assumed)
   - Overall fuel load (used for calculation of fire intensity)
3. Pine plantation
   - Surface fuel:
     - Fuel model
     - Fuel load and fuel bed height and size class distribution
   - Canopy fuel
     - Stand height
     - Height of canopy base
     - Canopy bulk density
4. Shrubland
   - Structural type sub-model

[13] Grassland condition varies spatially and temporally, therefore condition will often need to be assumed, typically with 'grazed' condition applied for agricultural production areas and 'natural' condition assumed for cereal crops and land tenures not subject to livestock grazing
[14] Grassland curing varies spatially and temporally, therefore is typically assumed to be fully cured or in a worst-case curing state.

    - Short heath
    - Shrublands
  - Vegetation height (m)
  - Fuel load (used for calculation of fire intensity)
5. Mallee
  - Overstorey cover (%)
  - Overstorey height
  - Fuel load (used for calculation of fire intensity)
6. Low threat vegetation exclusions
  - Irrigated crops / horticulture
  - Sports fields
  - Managed rec reserves
  - Golf courses
  - Maintained lawns / gardens

Fire behaviour modelling is sensitive to fuel value inputs. In general, particularly for forests, doubling the fuel input values can increase fire intensity four-fold, noting that fire impacts are directly influenced by fire intensity. Equally, reductions in fire intensity (and impact) occur where fuel input values are reduced.

Forest fuels are highly variable, varying significantly between forest vegetation types, and also vary with time after fuel reducing disturbances such as planned burning and wildfire. If a single set of fuel input values is assumed for all forests / shrubby woodlands, then fire intensity will be over-modelled for some forest types (such as many inland grassy open forests/woodlands) and significantly under-modelled for others (such as wet sclerophyll forest types such as ash and some montane forests).

Areas with grass cover are also variable in fuel input values. Grass fuel hazard is very responsive to seasonal rainfall conditions, particularly in late winter and spring. Areas subject to recurrent livestock grazing have reduced fuel input values relative to areas not grazed by livestock. Well-grazed (or eaten out) pastures may not support fire spread under moderate and even high fire danger conditions. The degree of grass curing is highly variable in response to seasonal conditions. Accordingly, for risk modelling applications it is common to assume a standard set of grass conditions and curing.

The accuracy of fire spread and behaviour modelling has a strong dependency on the resolution and degree of validation of fuel assumptions associated with vegetation classification. For risk modelling purposes where it is sought to model impacts to individual property scale, spatial fuel input resolution of 30 metres or better is desirable[15].

F-1-3 Fuel model design for low relative bushfire risk networks

It can be acceptable to apply a single fuel model for the major vegetation classes for which fire spread models exist[16] within relatively low bushfire risk networks (e.g., those principally servicing urban areas).

F-1-4 Fuel model design for high relative bushfire risk networks

It will be appropriate to use a wider range of fuel model inputs for bushfire consequence modelling for higher bushfire risk profile networks such as those principally servicing rural areas.

Worst-case fire risk modelling can typically use highest decile level fuel assumptions for each vegetation type and assume that the full fuel profile is available for combustion (full drought effect on fuel availability). However, where modelling seeks to take account of annual changes in fuels arising from recent bushfires and / or fuel reduction works (e.g., planned burns), fuel assumptions based on time-since-fire fuel accumulation curves or assessed

[15] Coarsely scaled and grouped vegetation type mapping with a single set of standardised fuel hazard assumptions can be expected to generate relatively low accuracy modelling results (potentially with significant errors) relative to modelling based on fuel inputs which take account of the different fuel profiles associated with different forest and other vegetation types.
[16] Fire spread models exist for forest (including woodland), grassland and heath / shrublands

values will be necessary. If dynamic bushfire risk assessment seeks to take account of current seasonal dryness effects, then fuel availability will need to be taken into account as a function of drought indices.

F-2 Fire weather scenarios sub-model

Weather variables have a substantial influence on fire behaviour and resultant impact, as well as on the ability to control the fire. The key weather variables influencing fire behaviour include:

- Wind speed and direction
- Air temperature
- Relative humidity
- Drought severity

Except for drought severity, these factors are highly variable, with the ability to change over the course of a day. Worst case conditions are characterised by very hot days where there are very strong winds and very low relative humidity conditions during severe drought periods. Also known as *highest decile range* fire conditions, these conditions represent a small fraction of the prevailing weather conditions. It is important to note that other conditions which deviate from the worst-case conditions can also result in high consequence fires. Thus, bushfire consequence modelling undertaken using multiple weather scenarios can overcome potential shortcomings associated with single scenario modelling. Therefore, for networks situated in potentially higher bushfire hazard and risk profile rural landscapes, it is important to model a range of credible fire weather scenarios at which uncontrollable high impact fires could occur. When multiple weather scenarios are used, a method for combining the modelled results into a single consequence output are usually required.

Local climatology varies across Victoria, with some areas experiencing significantly more severe and more frequent fire conditions. Local rainfall patterns, elevation and coastal influence are three key drivers of local weather variability affecting fire danger. Accordingly, if a single set of weather variable input values were assumed across Victoria, then fire intensity will be over-modelled in some areas (such as high elevations and potentially also areas subject to higher rainfall) and significantly under-modelled for others (such as inland, drier low elevation areas with topography which channels adverse fire weather winds). Gridded weather data can facilitate more nuanced modelling which takes account of meso-scale weather effects.

DELWP has undertaken historical fire weather analyses across a range of Victorian weather districts, identifying weather conditions occurring during the ten (10) worst recorded fire events in Victoria. The weather scenarios developed by DELWP could be a useful resource for multiple weather scenario bushfire risk modelling undertaken by DNSPs.

Figure F.2 Weather scenario model design for low relative bushfire risk networks

It can be acceptable to apply a single or limited number of reasonable worst case weather scenarios for modelling within relatively low bushfire risk networks (e.g., those principally servicing urban areas)

F-2-1 Weather scenario model design for high relative bushfire risk networks

Multiple weather scenarios, which take into account a range of weather conditions (and not just worst-case scenarios) that can generate uncontrollable bushfire behaviour and high bushfire impact, are needed when undertaking modelling of networks which have a relatively high bushfire risk. This includes areas which are principally servicing rural areas. Such an approach may involve:

- Developing multiple weather scenarios in the form of spatially gridded weather variable values across the subject area based on:
  - Use of regionally based weather scenarios which are derived from historically adverse fires in the region. An example of this is what has been developed by DELWP for bushfire risk modelling in Victoria; or
  - Climatological assessment of historical weather data to establish weather conditions representing different levels of fire weather severity, such as by using percentiles (e.g., the 95th, 70th and 50th percentile fire danger index conditions) or mid-range conditions for different fire danger categories, ensuring multiple scenarios for the upper fire danger category.

Scenarios which use a single time-point static weather scenario for modelling over a sustained period (e.g., a nine-to-12-hour fire run period) should be avoided in preference for dynamic scenarios incorporating hourly, spatially gridded scenarios. These account for natural, diurnal temporal variation of weather during the fire run modelling period and spatial variability across the subject area.

F-3 Terrain sub-model

Topography significantly influences fire behaviour and impact, particularly in hilly terrain and steep areas. As a general rule, for every 10 degree increase in slope, uphill fire spread rate and fireline intensity will double, and the reverse for downhill spread. Thus, fire spreading up a 20 degree slope will spread four times as fast as a far spreading across level terrain, with fireline intensity also four times higher. The main issue with terrain inputs in fire behaviour modelling is taking into account the fire spread direction relative to the slope as this is important for establishing if fire is spreading uphill or downhill.

Data input requirements for the terrain sub-model include:

– Digital elevation model (30 m spatial resolution)
– Slope direction (relative to the modelled fire spread direction)

F-4 Fire spread intervention sub-model

Victoria maintains a substantial fire response capability, enabling rapid deployment of response resources across the State in an attempt to contain or extinguish fires before they reach their full potential fire behaviour. The extent to which response efforts are successful is highly variable and is dependent on a range of factors.

These include the prevailing weather conditions; the fuel type; accessibility to the area and consequently how long it takes for responders to get to the fire; the extent of the response mobilisation[17]; and the extent to which natural and human features[18] which can assist or impede the fire. In extreme weather conditions (i.e., the worst case scenarios), intervention success likelihood may be very low, but in milder to moderate weather conditions and / or with a prompt robust, multi-mode response, intervention success likelihood is typically high.

Incorporation of a fire spread intervention sub-model within the overall bushfire consequence derivation is a feature of more advanced bushfire risk modelling capability, generally absent from first generation modelling systems.

Where fire consequence modelling is focused on worst case and near worst case scenarios – where fire behaviour from point ignitions can rapidly escalate to uncontrollable proportions – fire suppression probability is low and response action is prioritised to saving life and defending property. Therefore, it may be reasonable to assume fires are unable to be suppressed for these modelled scenarios. Conversely, for landscapes where livestock grazing is a dominant land use and pastures are in an eaten-out condition across a high proportion of dryland grazing areas, there may be a valid case for applying a fire intervention sub-model.

Additionally, when examining the risk profile of networks, it may be acceptable to undertake basic modelling which does not account for fire suppression capability or effects for low bushfire risk networks. However, in higher risk profile rural network areas, greater modelling accuracy can be achieved where typical/likely fire intervention actions are taken account of in modelling. More generally, greater consequence results are expected from a model which does not take into account active or passive fire spread intervention methods and factors.

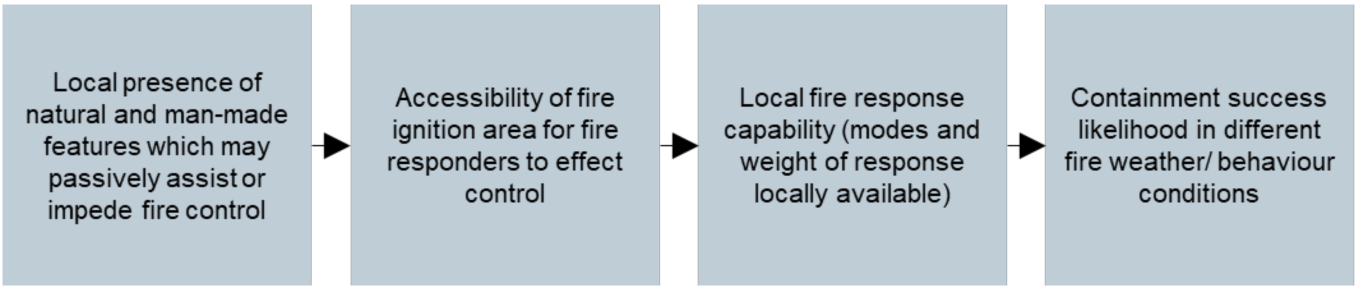

Figure F.3 Fire intervention sub-model

[17] Larger scale multi-shift suppression operations are typically applied to large fires which were unable to be contained during first response shift operations.
[18] Natural features which can impede fire spread include lakes, rivers, and in some conditions, vegetation maintained or naturally in a green fire-resistant state. Human-made features such as major roads, fire breaks, non-fire prone land-use areas and the like can impede fire spread.

F-5 Asset impact and values assessment

F-5-1 Vulnerability to fire loss and damage

Different asset types have varying vulnerability to bushfire damage and loss. Assets which are made from or have exposed combustible materials, and are themselves considered a fire hazard, can have a high degree of vulnerability to bushfire damage and loss. Other assets may be resilient to damage from low intensity fires but vulnerable to high intensity fires, and there may be assets highly resilient to bushfire impact. Some natural resource assets such as cured pre-harvest cereal crops, pine plantations and other combustible crop types may be highly vulnerable to fire damage.

Historically houses have been used as a proxy for quantifying bushfire impact. However, there can be high variability in house loss during bushfires – one house may survive unscathed while the house next door is burnt to the ground. The following factors can contribute to this[19]: separation distance between houses; fire hazard house design; the construction materials used for the houses in the area; general maintenance and preparedness; garden type / condition and proximity to house/widows; presence of combustible materials / goods on decks and verandahs; and various other factors. It is not feasible to have data available for predictive impact modelling in relation to the range of such factors affecting fire loss. However, more generic historical data regarding house loss can be used to develop reasonable assumptions about proportional loss likelihood relative to the level of modelled fire intensity to which houses are exposed.

Loss of human life is comparatively more difficult to account for in bushfire consequence modelling due to the variability of human behaviour during highly uncertain fire threat situations (i.e., human factors). Therefore, loss of human life from bushfire is not simply directly proportional to house loss. In addition to fire danger conditions (in which a fire is burning), there are other factors which can contribute to heightened risk of human fatalities. These include: the degree of settlement exposure and proximity to fuel hazard; limited options or low capacity for safe emergency evacuation routes[20]; limited local options for emergency shelter in the absence of safe emergency exits; and low fire awareness / preparedness. Although difficult due to the various elements mentioned here, there are predictive loss of human life models which have been developed in Australia [17], [18]. The Harris et. al. model [17] and Blanchi et. al. model [18] can be used subject to their limitations.

In the absence of a fire vulnerability sub-model, whereby there is an assumption that fire impact is destructive, fire spread, and potential impact modelling may tend to overstate the potential fire consequences.

For low bushfire risk networks it may be acceptable to undertake basic modelling which adopts a single measure such as modelled house loss as a proxy for bushfire loss potential (particularly in areas where fire vulnerable natural resource assets such as timber plantations and commercial agriculture are limited). However, in higher risk profile rural network areas, greater impact modelling accuracy can be achieved; where bushfire impact modelling seeks to broaden the range of asset classes considered in impact assessment to include human life and other regionally significant economic / agricultural asset classes.

F-5-2 Fire loss / damage potential value

Not all asset classes have equal value; not all assets within an asset class have equal value; and some assets, particularly natural assets, are problematic to place an economic value on. Nevertheless, potential financial / economic loss in terms of asset value is a very common criterion for consequence assessments as part of risk management in commercial enterprises.

Impacted asset values can be assigned using accepted / statistical economic valuation data for asset classes being assessed:

– Human lives: The Government of Australia uses the value of a statistical life (VSL) for economic analyses of reducing loss of life
– Residential dwellings and buildings: Using reconstruction cost data compiled in the Australian Exposure Information Platform developed by Geoscience Australia

[19] The list provided is not exhaustive
[20] Typically, one road in / out towards the fire hazard

– Agricultural asset classes: Using dollar per hectare value data derived from the Australian Bureau of Statistics catalogue "Value of Agricultural Commodities Produced" for Australia [19]
– Other using statistical valuation data applied by economists

Entry level or low maturity bushfire consequence modelling typically does not express losses in financial terms, limiting loss expression to numbers of impacted assets[21].

Further developed or 'mature' bushfire modelling seek to apply economic values to the range of asset classes selected for impact modelling, potentially predicting a potential modelled economic cost of the modelled fire.

F-5-3 Asset impact and values sub-model design for low relative bushfire risk networks

Use of a single asset class as a proxy for establishing relative levels of fire impact (e.g., Using house loss as a proxy for fire impact) may be suitable.

F-5-4 Asset impact and values sub-model design for high relative bushfire risk networks

Bushfire consequence modelling for higher bushfire risk networks (e.g., principally servicing rural areas) should, as far as data availability allows, seek to:

– Use multiple asset classes of tangible assets including:
  - Loss of human life
  - House loss
  - Other significant built asset classes as data:
    – Critical infrastructure assets classes
    – Agricultural and forestry asset classes
    – Regionally important economic activity classes (e.g. tourism)
– Apply economic value assumptions to each asset class enabling calculation of a total economic value of fire impact for each modelled fire

The impacts on environmental damage and reduced capacity for ecosystems to provide services, such as water supply and carbon storage, may be desirable additional analyses of value.

F-6 Consequence scales

The principal output of bushfire consequence modelling – be it basic modelling such as house loss used as a proxy for relative consequence, or more sophisticated quantitative economic consequence modelling – is a quantitative consequence output which is often categorised into different levels[22]. In risk assessment, these consequence categories are often then combined with assessed likelihood using a risk matrix to determine a level of risk. As the assessed level of consequence will influence the level of risk, and consequently the scope and degree of risk reduction works, it is important that bushfire consequence scales are well designed and reflect historical consequences arising from network fires.

If consequence scales are set at inappropriate levels, this can either lead to an under- or over-assessment of the risks.

1. *Under-assessment of the risk*:
   The upper consequence category thresholds are scaled at levels which are beyond those which have occurred historically, or covering a disproportionately small proportion of historical events

[21] Typically limited to modelled house loss
[22] The consequence levels typically range from insignificant to catastrophic or severe. However, it varies between organisations.

2. Over-assessment of the risk
   The consequence scales are set such that a disproportionately high proportion of modelled consequence is categorised to upper levels of the consequence scale

Over-assessment of the risk can potentially lead to an inefficient high risk control program application. Thus, it is very important to design consequence scales such that they reasonably and proportionately reflect bushfire risk impacts which have historically occurred in Victoria.

Consequence scales which relate directly to assessed risk can be useful. For example, the extreme risk levels might be areas where modelled consequence is in the top decile of modelled consequence outcomes. Very high consequence might be areas in the 8th and 9th deciles. High might be within the 4th to 7th deciles. Low might be in the 2nd and 3rd deciles and Very Low in the lowest decile.