Building Fire Behavior Analyst (FBAN) Capability and Capacity: Lessons Learned From Victoria, Australia's Bushfire Behavior Predictive Services Strategy

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Abstract—*Wildland fire managers must frequently make meaning from chaos in order to protect communities and infrastructure from the negative impacts of fire. Fire management personnel are increasingly turning to science to support their experience-based decision-making processes and to provide clear, confident leadership for communities frequently exposed to risk from wildfire. The inclusion of science into their thought processes helps these decisions to be more consistent, accurate, reliable and defendable in an environment where the risk and impact of incidents continues to increase.*

Based on a combination of personal bushfire experience and knowledge of academically reviewed scientific principles, Fire Behavior Analysts (FBANs) provide advice before and during emergencies. The FBAN role has been widely used in North America for many years but was not formally used in Victoria prior to 2006. In Victoria, the program developed rapidly and produced a cadre of highly skilled analysts whose products and services quickly become vital in everyday bushfire management for quantifying risk to communities and infrastructure.

This paper presents the history of the development of the FBAN program in Victoria along with examples of predictive services products regularly accessed during the fire danger period. In order to mature beyond its initial start-up state, fire control agencies in Victoria reviewed past successes and weaknesses and consulted with invested stakeholders in order to produce a strategic document that aims to embed predictive services into emergency management decision-making of the future.

The Bushfire Behavior Predictive Services Strategy sets out future direction under three main goals: 1) provide clear governance; 2) create a unified approach; and 3) develop fit-for-purpose and sustainable products and services. A series of ten lessons learned are also presented as reflection of this strategic analysis process to create knowledge through the translation of previous experience in support of other agencies working to build FBAN capability.

The evolution of fire behavior prediction tools and services in Victoria provides an interesting account of lessons learned, success stories and rapid innovation in response to increasing demand in the emergency sector for more consistent, accurate, reliable and defendable decisions during emergencies.

Introduction

The management and control of bushfires in the Victorian landscape involves making decisions in a complex and rapidly changing spatial and temporal environment. Today's bushfire manager must make the most of his/her background experience and combine it with a team of others' knowledge and skills to maximize the protection of life and property. However, when fire management decision making is largely based on personal experience, the result varies greatly across individuals and fire danger is estimated rather than accurately quantified. Predicting the spread and behavior of a going fire is a complicated task; however, recent advances in technology and scientific research have provided additional tools to facilitate the diverse decision-making process. Models have been designed and tested for use in predicting rates of spread, head-fire intensities, flame heights and spotting potential all of which are key behavior components on which to base operational and tactical decisions.

Recent critical analyses of devastating fires in south-eastern Australia heralded the need for improvements in bushfire behavior prediction. Specifically, the Victorian Bushfires Royal Commission (VBRC) following the Black Saturday fires of February 2009 stressed the need to "provide regular training to IMT staff, highlighting the importance of information and reinforcing the support available from specialists within the State Control Centre" (Recommendation 15, Victorian Bushfires Royal Commission 2009a). Historically, Victoria has had to

In: Keane, Robert E.; Jolly, Matt; Parsons, Russell; Riley, Karin. 2015. Proceedings of the large wildland fires conference; May 19-23, 2014; Missoula, MT. Proc. RMRS-P-73. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 345 p.

Figure 1—Victorian FBAN Tim Wells (Country Fire Authority) with a Phoenix fire growth simulator output in the background (CFA 2012).

haphazardly draw on experts from scientific agencies during days with multiple ignitions and threatening fires. International experts were also used to fill the need for technical fire behavior advice during busy seasons.

In 2006, the need for a Fire Behavior Analyst (FBAN) role[1] was identified by Alen Slijepcevic and Liam Fogarty from the then named Department of Sustainability and Environment (DSE). This led to an agreement by multiple fire and land management agencies and a national course was designed to train in-house experts in the physical behavior of bushfire in the landscape. Since its inception, multiple personnel across all agencies have attended the courses and the state has produced a team of highly skilled technical specialists for use. The FBAN is a key link between the abilities of the scientific community to use mathematics and experimental fire data to predict the impact of fires on people and their communities (Slijepcevic and others 2008). It is their role to communicate the complicated principles to operational staff in a way that informs and improves their suite of complex decision-making activities (Figure 1).

History and Development of the FBAN Program

Southeastern Australia suffers a history of high loss of life and property related to heavy forest fuel loads and extreme fire weather (Blanchi and others 2011) (Figure 2). The capital cities of both Victoria (Melbourne eastern suburbs- 2009 Black Saturday Fires) and Australia itself (Canberra- Duffy Fires 2003) have experienced destructive fire loss in their fringes in recent history. In 2006, following successive seasons of large destructive bushfires and related inquests and inquiries, the Fire Behavior Analyst (FBAN) response role was formally initiated in the state of Victoria. Since its inception, Victoria has rapidly developed a cadre of highly skilled FBANs whose products and services have become integrated into everyday bushfire management activities by identifying and analysing risks to communities and infrastructure. Response personnel use this information to evaluate these risks and determine options to mitigate them. The Victorian FBAN program evolved quickly and on an as needed basis, making it essential that any obstacles to

Figure 2—An example of Victorian fire behaviour (photo credit: Nicolas Bauer, Department of Environment and Primary Industry).

[1] The Australasian Fire and Emergency Service Authorities Council (AFAC) defines a Fire Behaviour Anaylst (FBAN) as the "person responsible for developing fire behaviour predictions based on fire history, fuel, weather and topography" (AFAC 2012).

growth be met and overcome efficiently. The evolution of FBAN capability and capacity in Victoria offers insight for those attempting to build or review predictive services skills within their own organizations elsewhere.

Training and Recruitment

Initially when fire behavior expertise was required during a going fire in Victoria, individuals were requested from academic and research organizations as there was no state or national capability for specialized fire behavior prediction services. The arrangements were informal with limited individuals called upon to provide support only during times of urgency, which was not sustainable. Following a multi-agency workshop targeted at identifying end-user needs for scientific applications by the Bushfire Cooperative Research Center (Bushfire CRC) in Wollongong in 2006, it was deemed necessary to develop a National Fire Behavior Training Course to develop personnel with specific technical fire behavior skills. The contents of this course grew from collaboration with experts from the University of Melbourne, the Bureau of Meteorology (BOM), the Commonwealth Scientific and Industrial Research Organization (CSIRO), the University of Tasmania and the Australian Defence Force Academy (ADFA) within the University of New South Wales.

Two individuals within the former Department of Sustainability and Environment (DSE) of Victoria (now the Department of Environment and Primary Industry or DEPI) managed to establish national arrangements with lead fire behavior scientists and most land, fire and emergency agencies in 2006. With the forecast for an approaching busy fire season, DSE and the Country Fire Authority (CFA) signed an agreement with the fire management agency in British Columbia, Canada, to provide additional resources (including FBANs) if needed. The forecast for a severe fire season became reality with the Great Divide Fires which burned over a million hectares of land across more than 65 days (Smith 2007). Canadian FBANs arrived on request to assist with the fire behavior predictions, and the international FBAN cell consisting of Australian, New Zealand, Canadian and American personnel highlighted the importance of predicting fire extent and used it to raise government and community awareness of the pending mega-fire (Figure 3). The estimates of impact potential supported strategy setting including construction of fireguard, back-burning and the deployment of national and international support.

The operational review of the previous season's Great Divide Fires supported the growing need for specialized fire behavior expertise (Smith 2007). The debrief concluded that a requirement for fire behavior specialists existed,

Figure 3—An original Victorian FBAN, Andy Ackland installs a portable weather station during the 2006/2007 Ensay fires.

with a primary need at the incident management team (IMT) level to communicate likely fire spread under forecast conditions. The need was also recognized at the state level to provide a strategic overview of potential fire spread and impact across all districts. In a timely manner, the first nationally recognised FBAN training course was attended by individuals from all across southeastern Australia in July of 2007.

The program continued to grow through the 2007/2008 season with a total of four courses delivered with sixty-two attendees across twelve different agencies. During this time, Australian FBANs were deployed to fires in Tasmania, Victoria and South Australia. They demonstrated the value of their expertise by providing predictions to support fire control decisions that significantly reduced the potential area burnt as well as providing early warnings to communities about to be affected. FBANs were even eventually requested by Canadian fire control agencies with four individuals sent over to assist with the busy fire season in British Columbia. Canadian fire officials were impressed with the quality of FBAN services and the speed with which skills had been developed and the program matured.

Early Operational Impacts

Pre-season fire risk assessment for the 2008/2009 fire season provided warnings for the onset of a catastrophic fire season. Melbourne's urban fringe was identified as a particular risk zone related to the lack of spring rainfall and long-term drought effects. An FBAN team was initiated by Alen Slijepcevic, Assistant Chief Fire Officer Capability, and worked at producing a range of predictive and risk communications tools as the conditions continued to build and support a serious fire risk. When the Black Saturday fires broke out in early February 2009 (Victorian Bushfires Royal Commission 2009b) FBAN products and services were in place and supported critical decision-making related to resource deployment and management strategies amongst the tragic losses of life and property of the first twenty-four hours. Although the services were relatively new to most operational staff, the available FBAN resources were used heavily to produce estimates of impact zones[2] along with escaped fire scenarios which contributed to management of this complex event (Gibos 2013a).

As the 2010 fire season approached, Victoria prepared its trained cadre of FBANs through a mentoring program in which trainees were tutored by fire behavior scientists from local universities and research agencies, as well as by visiting American and Canadian FBANs. Across the following years, FBANs continued to prove their value by their performance during deployments to other states as well as their contributions to the control of several large fires in Victoria including the 2011 Tostaree Fire, the 2013 Aberfeldy Fire and the 2013 Alpine Fires (Kelsy Gibos, personal observation 2011 to 2013).

[2] In Victoria, an impact zone refers to areas expected to be impacted by smoke and ember attack.

History reveals that although developed somewhat haphazardly and to meet emergent demand, FBAN products and services in Victoria have proven to be invaluable in incident management decision-making. Operational personnel on the fireline and those on IMTs continue to seek support from FBANs and are requesting services and products at an increasing rate.

Examples of Victorian FBAN Products and Services

FBANs in Victoria produce a range of products and services in order to communicate the risk of bushfire. The first product developed in Victoria was based on a paper from Canada by Beck and others (2002) which outlined simple graphs that could be calculated and displayed in relation to diurnal head-fire intensity and then related firefighter safety. Since then, predictive services products have been developed across all preparedness and response activities. FBANs in Victoria make use of a multitude of tools to make these predictions including a range of fire spread models in various fuel types, gridded forecast weather data, ground observations, fire spread modelling software and smoke modelling (Gibos 2013a).

Preparedness products

FBANs create products in advance of going fires to support preparedness planning and prepositioning of resources. In Victoria, FBANs regularly produce spatial renderings of bushfire hazard by calculating head-fire intensity, in kilowatts per metre (kW/m), and elapsed time in minutes (min) required for the fire to grow to 5.0 hectares (ha) in size (Figure 4).

The head-fire intensity map uses a rate of spread model based on the broad fuel type group (dry or wet forest, grassland, heath, etc.) and the fine fuel load from a spatial fuel layer (including the effects of burn history) along with the gridded forecast weather to produce a spatial illustration of variation in intensity across the state. Intensity can be linked to ease of suppression and resource allocation (Alexander and Cole 1995); as intensity approaches 4,000 kW/m, the upper limits of direct attack using ground crews is approached (intermittent crown fire behavior can be expected). Fire intensities greater than 10,000 kW/m represent 'explosive' fire conditions with rapid rates of spread, continuous crowning activity, fire whirls and convective fire spread. The head-fire intensity map represents the magnitude of the destructive potential of a fire and the likelihood of suppression success; the elapsed time (min) to reach 5.0 ha in size map also represents and element of suppression difficulty by indicating how fast a fire is likely to expand. The use of predicted area burnt helps to indicate to fire managers how quickly their suppression resources must mobilise before the fire approaches an equilibrium rate of spread and may become more difficult to suppress, with 5.0 ha being an agency agreed upon assumption across Victoria's fuel types. Each map product is produced in hourly steps six days in advance so managers can review variations over time and determine the duration

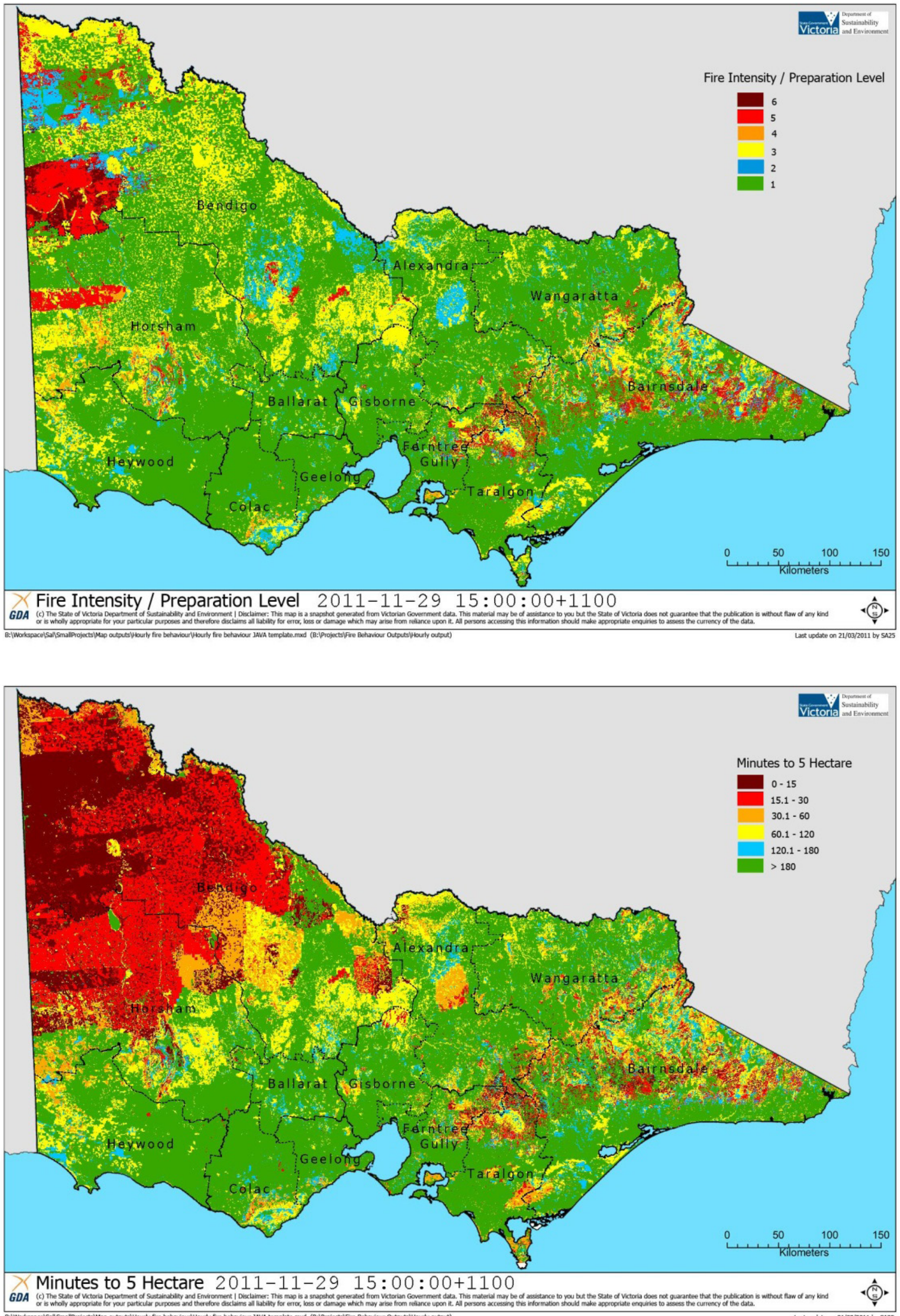

Figure 4—a) Head-fire intensity map for 1500 hrs for the state of Victoria, Australia. Fire intensity Level 1 corresponds to 0–500 kW/m, Level 2 to 501–1,000 kW/m, Level 3 to 1,001–5,000 kW/m, Level 4 to 5,001–10,000 kW/m, Level 5 to 10,001–30,000 kW/m and Level 6 to 30,001–200,000 kW/m. b) Map showing the estimated minutes it will take for a fire to reach 5.0 hectares in size for the state of Victoria.

and magnitude of the threat. Fire management personnel can use these two products together to inform decisions on the location and configuration of resource positioning and allocation. The elapsed time to 5.0 ha in size map (Figure 4) indicates areas with rapid rates of spread across the Bendigo district of Victoria (center of the map); however, after referencing the head-fire intensity map it shows those areas are likely within a suppressible limit by direct attack. So these areas will escalate quickly in fire size, but the flame heights and intensities should be controllable by hand crews. In this case, the maps indicate that quick turn-out times and smart tactical manoeuvers may assist firefighters in controlling the fire. In another example, the fire may be slow moving (longer time to grow to 5.0 ha) but the fuel load and dryness may support a high intensity fire that it would be difficult for ground crews to approach and air support may be required. Fire behavior based preparedness products make it simpler to compare hazard across districts. Quantification of fire behavior can be paralleled across all climatic and fuel conditions. This makes it easier for fire fighters and incident

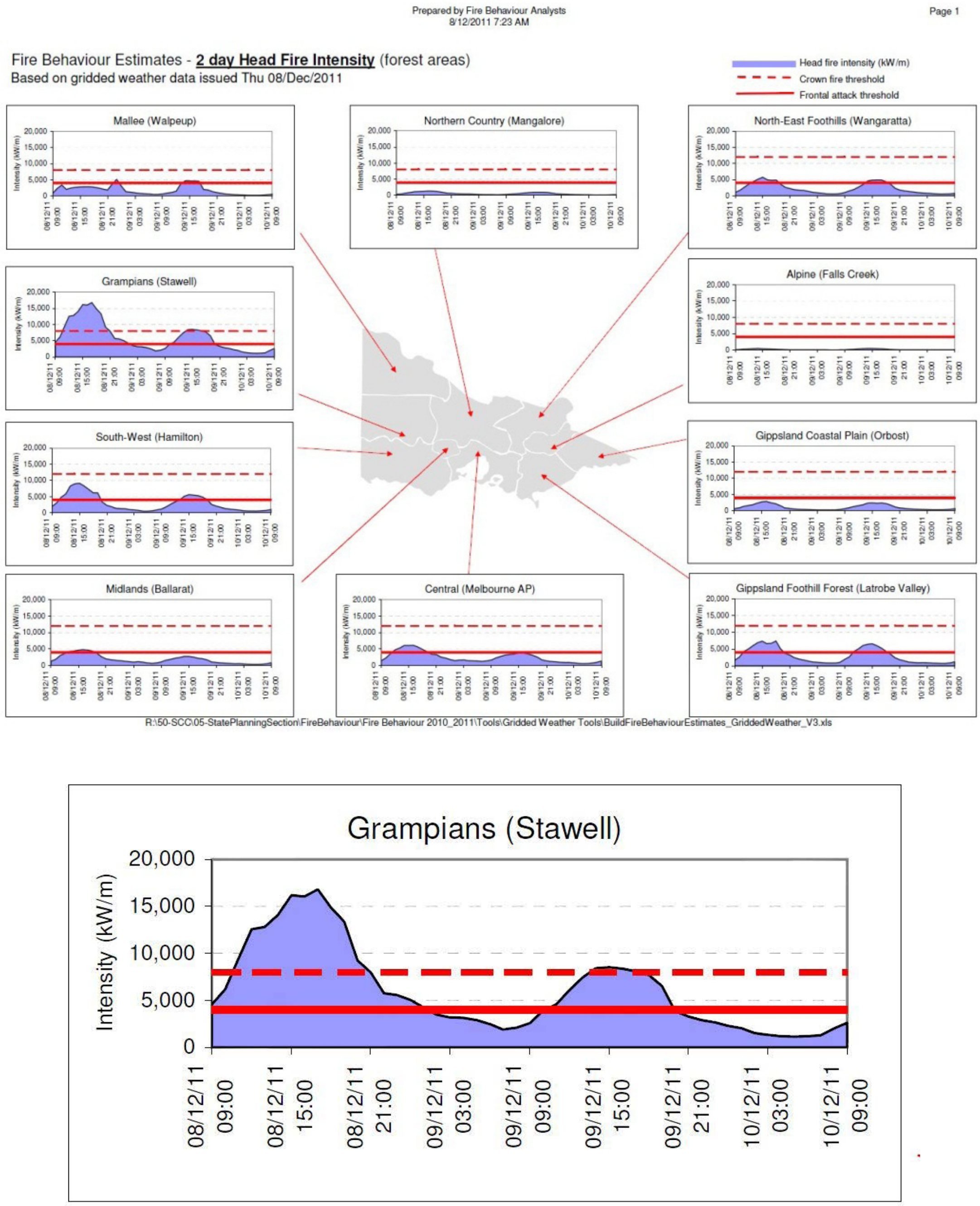

Figure 5—a) An example of the daily fire behaviour estimates (also known as "camel hump" diagrams) produced by FBANs in Victoria. The image shows a collection of state-wide predictions of head-fire intensity across a two day prediction period. b) Close up of a "camel hump" diagram showing head-fire intensity (kW/m) across a two day period for the Grampians district. The solid red line indicates the agreed threshold for direct attack (4,000 kW/m) and the dashed red line indicates potential for crown fire activity in this district's designated fuel type. The diurnal trend in fire behaviour is important for tactical decision making as well as firefighter safety.

management staff deployed intrastate to communicate and understand local fire risks and conditions.

A series of graphs colloquially referred to as "camel-hump" diagrams are created daily during the operational fire season to demonstrate the variation in fire behavior outputs across the prediction or burning period. Information on fire behavior characteristics such as rate of spread and head-fire intensity provide fire management personnel with additional information about damage potential and the success of frontal attack in adding to that determined from fire weather indices. Communicated information on fire behavior potential can provide the on-the-ground firefighter and general public with an improved state of situational awareness; forecasting where the fire will be and whether it is likely to be suppressible provides information about potentially dangerous situations that could occur during the forecast period.

The daily produced fire behavior estimates show forecasted head-fire intensity in forested areas across two days for each district in the state (Figure 5). The predictions are made using gridded forecast weather produced that morning and calculated for an established fire (considered greater than 10 ha in size) that is burning in a standard fuel type (i.e., unburned for at least 20 years) assigned for each region. The graphic includes agency agreed upon estimated thresholds for crowning as well as frontal attack[3]. Direct suppression of a fire is assumed difficult when the fire intensity exceeds 4,000 kW/m as suppression tactics may only be successful early on in the development of the fire (Alexander and Cole 1995). For the duration of the period when the potential head-fire intensity exceeds 4,000 kW/m, direct fire suppression will be limited to the flanks and back of the fire. While indirect fire suppression tactics may be employed, it is unlikely that backburning will be successful during the period. It is expected that when there is no period of time overnight where the head-fire intensity is predicted to drop below 4,000 kW/m, a going fire is likely to become very large over the next 24 hours.

If the head-fire intensity is forecasted to be above the agreed upon frontal attack threshold (refer to Footnote 3) of 4,000 kW/m, an additional page of graphics provides details about key fire behavior variables for each district (Figure 6).The duration (number of hours) that the intensity is above the threshold in the next 24 hours is represented by a number in a black box as well as the percentage filled of a rectangle. The average perimeter growth rate (km/h) is also included and if that value exceeds 2 km/h it is coloured red to emphasize the estimated potential for greater loss. The maximum rate of spread (km/h) in the next 24 hours is also shown, with values greater than 1.5 km/h emphasized as a useful threshold recognized by firefighters on the ground.

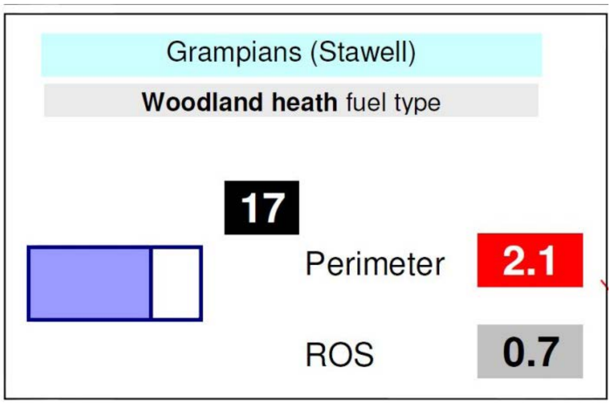

Figure 6—An example of an additional visual aid provided with the daily fire behaviour estimates (Figure 2). This image shows the hours of today that the head-fire intensity is predicted to be above 4,000 kW/m in a black box with white text. This is represented visually by the blue bar on the left. The estimated perimeter rate of spread (km/h) and forward rate of spread (km/h) are given on the right.

The daily fire behavior estimates also include a seven day forecast of forest and grassland Fire Danger Index (FDI) (Cheney and others 1998, McArthur 1962, Noble and others 1980) (Figure 7). The FDIs are calculated using gridded weather data[4] and the grassland values using curing percentages based on the Day 0 curing map provided by CFA (Country Fire Authority 2014). A red line in the diagram represents agency designated "severe" FDI levels which result in high levels of suppression difficulty except for very early in the development of a fire or in very low fuels.

A similar product showing head-fire intensity and upcoming forecasted fire danger is also produced during the prescribed burning periods during the year. FBANs can use these tools to better recognize upcoming windows of opportunity that would generally support prescribed burn objectives. All of the above products can also be personally adjusted by the FBAN; some practicing FBANs produce the "camel hump" diagrams specific to their area of responsibility to focus in from the coarseness of the state-wide resolution.

Response products

During a going fire, the role of an FBAN in Victoria is to provide analysis and advice through the Planning Section of the IMT to the State Controller, the Chief Officers and other government executives about the medium and longer term potential fire spread, risk and priorities, operational options, resource requirements and potential fire impact zones. In addition to this, FBANs can also provide advice about potential planned burning strategies and options including back-burning and burning out operations. The FBAN must also inform the State Duty Officer and Planning Officer within the relevant emergency coordination centre about strategic risks and priorities for communication to strategic Regional Coordination level, IMTs and the general public via the Information Unit.

FBANs produce a large menu of items during a going fire. There are standard products produced immediately following a reported ignition as well as the ability to cater the products specifically to the incident upon request (Table 1). There are two main product types that FBANs can develop during a going fire (Slijepcevic and others 2008). The first is a series of maps indicating potential fire impact zones. The maps indicate all areas that will be possibly affected by fire or ember attack in the defined forecast period. The information includes a 'use-by' date and time, and the map often includes an indication of the area beyond the current projection where

[3] The thresholds chosen for head-fire intensity in the diagrams are based on research data in fuel types different from that in Victoria (Alexander and Cole 1995), but were deemed acceptable by agency managers due to a lack of similar research in Australian fuel types. Using a single value of head-fire intensity across multiple fuel types and conditions is not ideal; a firefighter or fire manager must still combine their experience and "gut feel" along with the mathematical determination of measures such as intensity. These values are meant to provide a rough "rank" or "heads-up" to flag conditions that could be potentially dangerous and difficult for crews on the fireground, and are not meant to be used in isolation. One must calibrate their experience to the science and personally decide when the measure is effective and what conditions might cause it to be inaccurate.

[4] Similar to all forecasts, the accuracy of the gridded weather products decreases as one moves forward from Day 0. Caution must be used when using a seven day outlook; the graph is meant to highlight "spike" weather days and indicate upward or downward trends. The absolute values calculated seven days out will be limited by the accuracy of the weather prediction models.

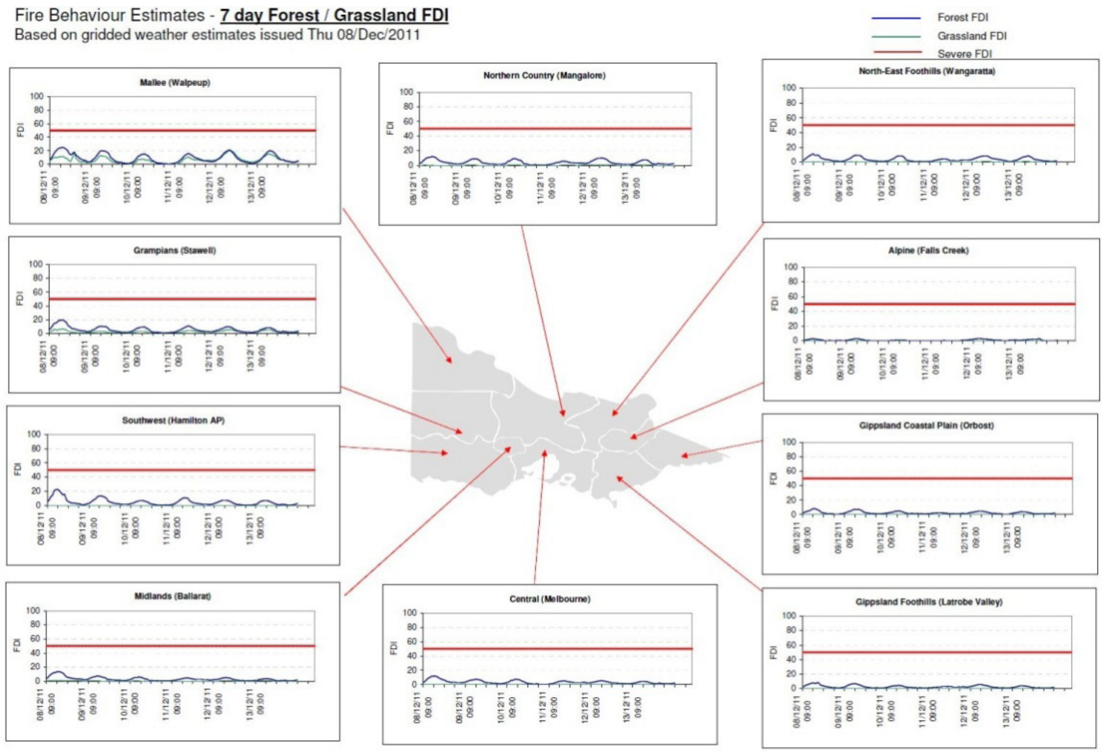

Figure 7—Seven day Forest Fire Danger Index (FFDI) in blue and Grassland Fire Danger Index (GFDI) in green forecast based on gridded weather. The red line represents the agency agreed upon threshold for severe levels of FDI.

Table 1—Activities to be conducted by FBANS in Victoria during a fire incident.

Category	Detail
Data gathering	Develop fire weather profiles for fire area based on spot weather forecasts and weather models for up to seven days ahead
	Assimilate fire history, fuel and topographic information in the fire area
	Analyse fire intelligence from situation reports, linescans and satellite hotspot data
Fire behaviour prediction	Prepare best estimate fire spread and growth predictions for areas where fire activity is likely. Predictions are to be typically based on daily growth to midnight but shorter time intervals may be used if necessary
	Prepare a map of the potential fire impact zone to show the possible extent of the fire, spotfires and burning embers within a specified period
Strategic planning	Provide advice on efficiency of fire suppression strategies including backburning and methods of direct attack
	Indentify aspects of incident management that require post-incident improvement
Safety and warnings	Issue safety warnings of severe potential fire behaviour or fire weather to the operations officer and incident controller
	Monitor fire and weather to assess if or when fire danger is likely to suddenly increase

future potential impact areas may be located. These maps show a general overview of the predicted impact area which is useful for providing warnings to inform the public about the impending fire potential.

The second is a fire spread prediction. It represents the best estimate of the fire spread at specified times across the forecast period; the prediction can span from six hours to six days. The predictions are adjusted as new weather information solidifies and fire intelligence is gathered from the fireline. These predictions are accompanied by a detailed report and are best used for internal strategic planning.

Originally, FBAN fire behavior predictions were only done by hand (Figure 8). Fire spread isochrones (i.e., contours of fire perimeter mapped as occurring at the same time) were drawn based on calculations from the McArthur Forest Fire Danger Meter (McArthur 1967) and the CSIRO Grassland Spread Meter (Cheney 1998). These maps included up-to-date weather information direct from BOM

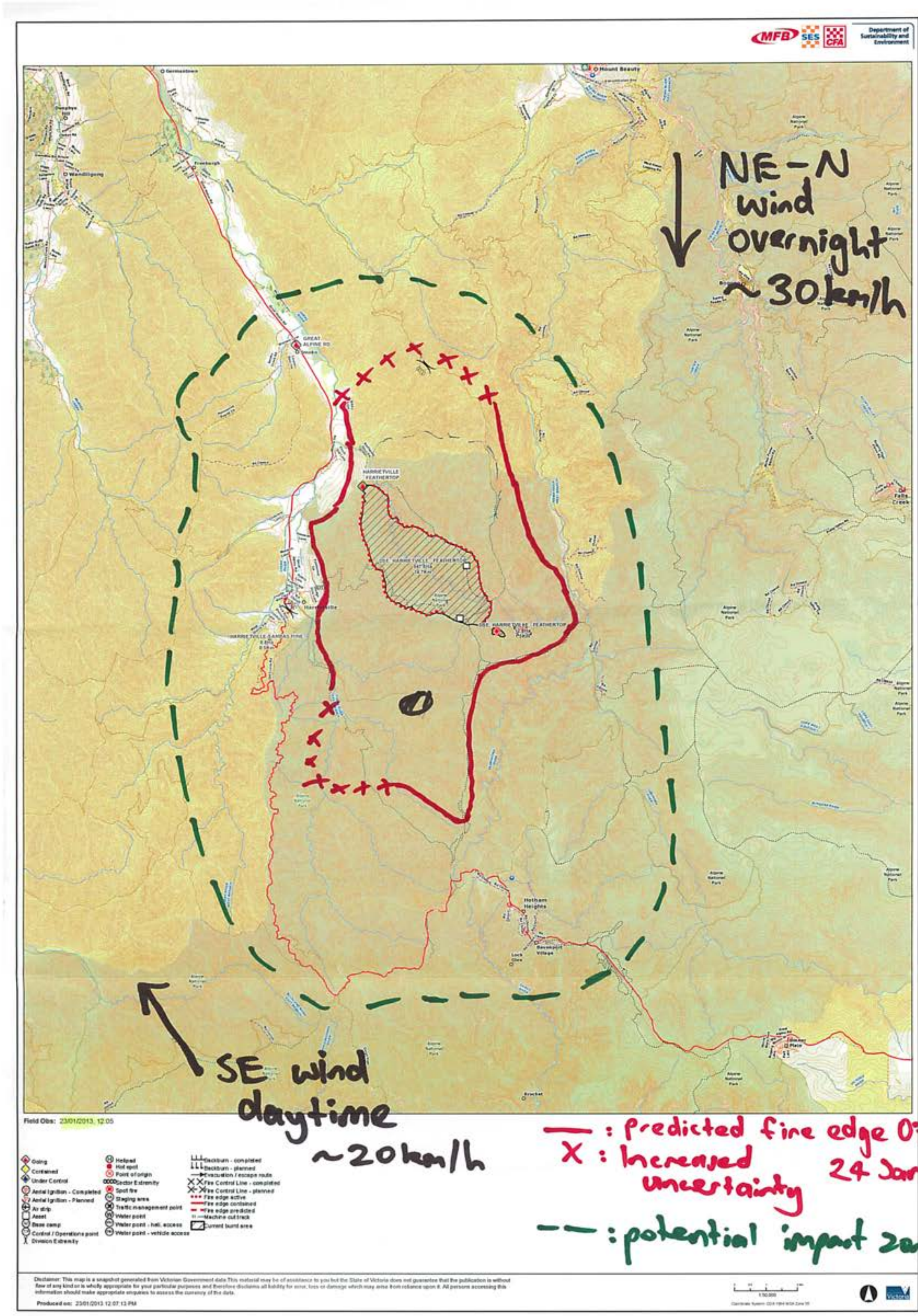

Figure 8—Rough hand drawn prediction map created for a going fire in northeastern Victoria.

and areas of potential ember impact. These maps are still regularly produced today, but can also be supplemented by computer generated fire growth prediction maps.

The introduction and use of the Phoenix fire growth modelling software (Tolhurst and others 2008) allowed FBANs to quickly produce graphically represented views of fire spread and behavior that are more easily viewed and analysed in various formats. Phoenix is a dynamic fire growth simulator that runs in a computerised environment where it can respond to changes in fuel, weather and topography as the fire moves across the landscape (Figure 9). It contains various underlying simplifying assumptions. Phoenix incorporates models to characterize spotting and ember storms, fuel accumulation curves for Victorian fuel types, a fuel moisture function across space and time as well as a function for including the effects of suppression.

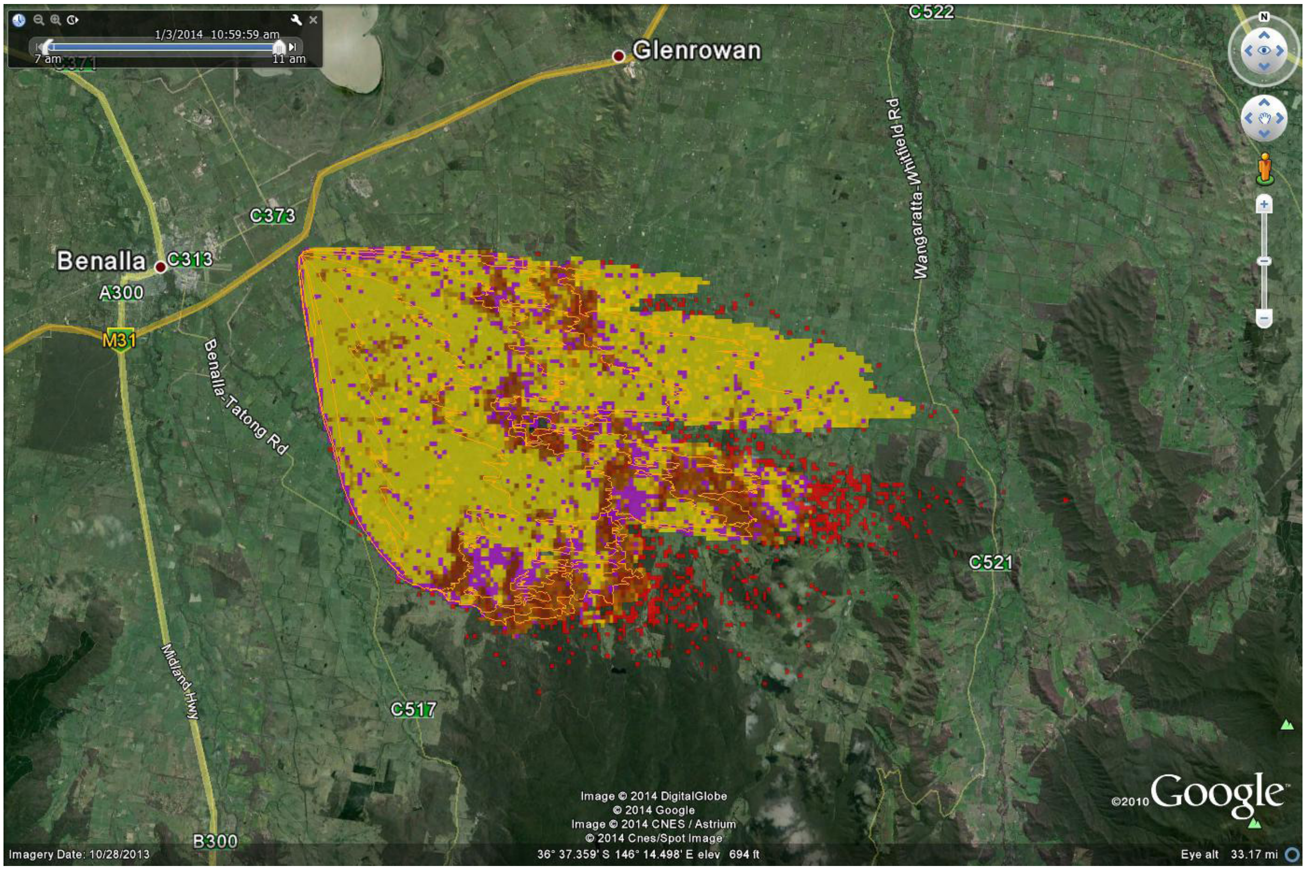

Figure 9—Fire behaviour prediction created by the Phoenix fire growth simulator shown in Google Earth. The orange lines indicate fire spread isochrones. The red to orange color ramp indicates flame height increasing from yellow to orange to red. The purple squares indicate prediction of self-extinguishment. The red squares indicate spotting activity.

Phoenix RapidFire is an automated version of the Phoenix fire growth simulator that is used to produce quick initial predictions based on an ignition point. As soon as a fire is detected and reported, Phoenix RapidFire produces a six hour fire growth prediction and loads it to a universally accessible internet platform known as FireWeb. The prediction uses the forecast gridded weather and state-wide fuel type layer. All personnel with appropriate access can view the predictions once they have been uploaded. FBANs can open the predictions and check their validity by reviewing local weather information and any fireline observations about fire behavior and fuel condition.

Embedding Predictive Services Into Emergency Management Decision Making

The advance of Victoria's FBAN program has to be largely credited to a few key individuals and a lot of formally unrecognized personal time and commitment. As a result, in 2013, it was acknowledged that these previous arrangements were not sustainable and that the state needed a strategy to deal with some of the resulting symptoms of the hurried developments led to the FBAN program in the first place. Initiated by the Country Fire Authority (CFA) in mid-2013, the Bushfire Behavior Predictive Services Strategy (BBPSS) was developed by an operational FBAN in consultation with FBAN peers as well as incident and emergency managers from various emergency response agencies (Gibos 2013b). The multi-agency strategy combined experiences from previous fire seasons with stakeholder preference to produce a series of long term goals and interventions for the state.

Embedding predictive services into emergency management decision-making requires lasting change to provide for a sustainable, trusted and innovative predictive service model in Victoria. To support the FBAN program into the future, the end-user agencies will need to change the way they make decisions regarding workforce planning, technological research and the delivery of predictive services.

The BBPSS contains a range of initiatives under three goals:

1. **Clear governance** for bushfire predictive services and the FBAN role through the introduction of a new model to lead the management and development of the program into the future.
2. **Unified approach** through the development of common standards to improve consistency.

3. **Fit-for-purpose and sustainable resources, products and services** that are delivered efficiently and are designed to meet the collective changing needs of fire agencies and communities.

The state will seek to institute clear accountability for the sustainability of bushfire predictive services through the establishment of a new governance framework to set priorities and oversee joint planning and investment, and to ensure state capability and capacity is development and maintained. A single, authorized and central point of governance will allow for the setting of common goals and standards whilst still providing agencies with the flexibility to meet the particular requirements of their business. The proposed governance model promotes a hierarchy for decision-making focussed on common standards related to people, technology and processes.

The strategy also stresses the need to drive interoperability, improve performance and reduce duplication through the development of a predictive services model that is focused on achieving common standards for people, technology and process with support from agency participation. Agencies share many common goals and needs and the specialized nature of bushfire predictive services, which means that a more unified approach will benefit emergency managers and agencies. Instituting a series of common standards related to accreditation, certification and role specification will work to secure and improve the quality of FBAN human resources. The state must assign authority to prioritize and coordinate maintenance and improvement to existing technology platforms along with providing common control for data management and feedback reporting systems. Developing a forecast doctrine process will ensure that uncertainty and model accuracy are communicated appropriately to end-users. The key to implementing these standards will be in educating emergency managers to facilitate uptake and adoption of these products and services in line with individual policies and operations.

The third goal within the BBPSS outlines the need to keep pace with the changing needs of the community and fire managers in order to ensure that resourcing, products and services are all secure, reliable, adaptable and benchmarked against good practice. FBANs must be able to operate across the incident, regional and state-wide levels and withstand a constantly changing physical, political and economic environment. The agencies must clearly identify their priorities and objectives for evolving predictive service capability and capacity. Bushfire behavior predictive services must also keep pace with technological and scientific advances in order to remain current and relevant. This means that agencies must look to the future and plan for changes in FBAN workforce requirements as well as maximise investment in research and development to achieve shared objectives. Encouraging innovation and excellence in the predictive services field will help to ensure that predictive services are meeting the shifting needs of emergency managers.

The BBPSS was completed in December 2013 and implementation across the state has begun. The strategy provides an implementation plan to help achieve the identified goals across the next five years. Recently, the strategy has been reviewed by national research bodies and it is intended that it will be used to help guide the development of a national FBAN and predictive services approach for Australia.

Lessons Learned

The BBPSS in Victoria was informed by an intensive stakeholder engagement analysis. Operational personnel from various management levels and locations across the state were interviewed and surveyed in relation to their preferences and previous experience with FBANs and predictive service outputs. Functioning FBANs were also engaged in a workshop using a strengths, weaknesses, opportunities and threats (SWOT) analysis in order to evaluate the predictive services program.

From these interactions and across the development of the BBPSS, ten simple targets became emergently important in relation to forming and maintaining effective capability and capacity for specialized fire behavior prediction. They are:

1. **Quality over quantity:** Nominate personalities and backgrounds who are most likely to succeed and carry forward knowledge gained from training. Investing time into specific individuals will produce the best results.
2. **Maintain flexibility**: Be ready to adapt to the changing emergency response environment. Updates to technology, shifting demographics and increasingly complex fire behavior must be regularly addressed.
3. **Measure success**: Gain support from those who do not interact with the role directly by quantifying the impact of including predictive science in decision-making. Science can support positive reporting (e.g., area saved instead of lost, contribution of prescribed burning to forest fire control, etc.).
4. **Good governance**: Identify a program champion(s) whose role it is to strive for identified strategic goals, to maintain training schedules, to facilitate new product development and to update overhead staff of ongoing advancements.
5. **Fit for purpose**: Build FBAN products and services to suit end-user needs. Consultation with those on the fireline will ensure outputs are adapted easily and are well used in the field.
6. **Skills maintenance**: Allocate FBANs enough time annually to maintain their skills and to keep up-to-date on advances in the research and modeling realm. This IMT role requires substantial time additional to that allocated to regular duties.
7. **Technical support**: Deal with technical support issues as soon as they arise. Although FBANs are trained to function entirely separate from modern technology, certain tools assist their ability to provide timely advice especially when there are multiple ignitions to triage.
8. **Unified front**: Keep products standardized for delivery across all involved fire control agencies. Uniform prod-

ucts will help decisions be more consistent, accurate, reliable and defendable under scrutiny.

9. End-user education: Continually educate those who regularly use and interpret FBAN products. New products and services should be accompanied by a form of technical transfer outlining intended uses and applications.

10. Urgency: Build FBAN capability and capacity with the future in mind. Increasing public expectation and rising risk of liability means that fire management decisions must be defendable and accountable. Do not get caught undersupplied.

Applications and Conclusion

The development of the Victorian predictive services capability is truly a story of learning by doing. It is a strong example of the power of a few committed individuals and the strength of scientifically based decision support tools. By reflecting on the outcome of the SWOT analysis, learning becomes a process whereby knowledge is created through the transformation of experience (Healey and Jenkins 2000).

The key lessons from the Victorian experience as described in this paper indicate that in order to build new capability in an organization, it is important to have champions high enough in the hierarchy to be able to continue promoting and investing in the development of a new service. There must be an individual capable of explaining and frequently providing proof of the value of the new capability to those decision-makers with the power to promote or cull the program.

The agencies involved also need a number of individuals who are willing to learn and be flexible enough while exploring new options and optimal solutions. There needs to be a willingness to persevere even when new capability is not understood within the organization and individuals must continue to educate end-users until those new products and services become business as usual. A lack of recognition tends to plague early generations of new capability, but case studies and evidence of ongoing adoption and success can fuel recruitment of additional willing individuals.

Given the above, it is clear that training alone will not deliver appropriate results when implementing the strategic plan. The Victorian fire agencies have adopted the "10:20:70 model" for capability development (Figure 10) (Slijepcevic and others 2012). This is borrowed from Lombardo and Eichinger (1987) who explain the learning process as:

- 10% gained from courses that provide specific material to support knowledge and tools for a leadership toolbox;
- 20% acquired from others from coaching, feedback, mentoring and reviewing lessons learned; and
- 70% attained on-the-job through practice, simulations and actually doing the job.

In closing, the history of the advancement of the FBAN capability in Victoria demonstrates the highs and lows of developing a program on an as needed basis using experience-based learning to guide the evolution of a program. Collecting lessons learned from past experience and engaging end-users in the thinking for a future approach has helped to produce an adaptable and easily adoptable series of strategic interventions; these actions will guide the program forward and allow it to flex through anticipated changes in the emergency management environment while providing objectives on which to evaluate ongoing success.

For Further Information

The process as described in this paper produced a series of four documents that are available upon request from the authors. They include:

1. "*History of the Development of Fire Behavior Analysts in Victoria"* provides a full history of Victoria's FBANs along with case studies of their work.
2. "*Initial stakeholder analysis report"* summarises extensive stakeholder consultation undertaken to capture future

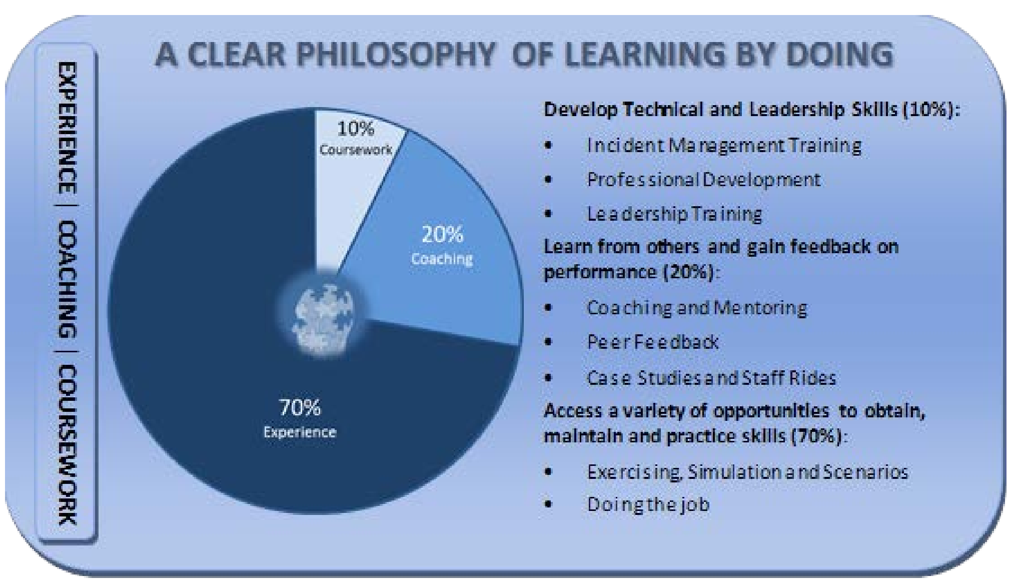

Figure 10—The 10:20:70 model (adapted from Lombardo and Eichinger 1987) which emphasises the value of on-the-job training versus coursework and coaching programs.

expectations of both practicing FBANs and incident management personnel.

3. "*Predictive Services Strategy discussion paper"* presents key themes identified in the background document and initial stakeholder analysis. It is paired with a stakeholder survey.
4. "*Embedding predictive services in emergency management decision-making- Victoria's Predictive Services Strategy"* is the final document which pulls together solutions and strategic interventions for issues identified in the first three documents.

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.