Determining Threshold Conditions for Extreme Fire Behaviour

Alex Filkov
Tom Duff
Trent Penman

Research Advisory Forum - Canberra 2016

Layout

- Project overview
- Database compiling
- Future research

Project overview

Most operational fire spread models assume that fires will burn at an approximately constant (quasi-steady) rate of spread under a specific set of environmental conditions:

- VESTA dry eucalypt forest fire behaviour model
- McArthur Mk5 forest fire behaviour
- CSIRO Grassland fire behaviour
- CSIRO Mallee-Heath fire model
- and others…

Objectives of the project

- Compile a database of extreme fire behaviours within Australian wildfires
- Investigate the conditions and processes under which bushfire behaviour undergoes major transitions
- Identify if threshold conditions occur that could allow for the prediction of extreme fire behaviour from environmental conditions

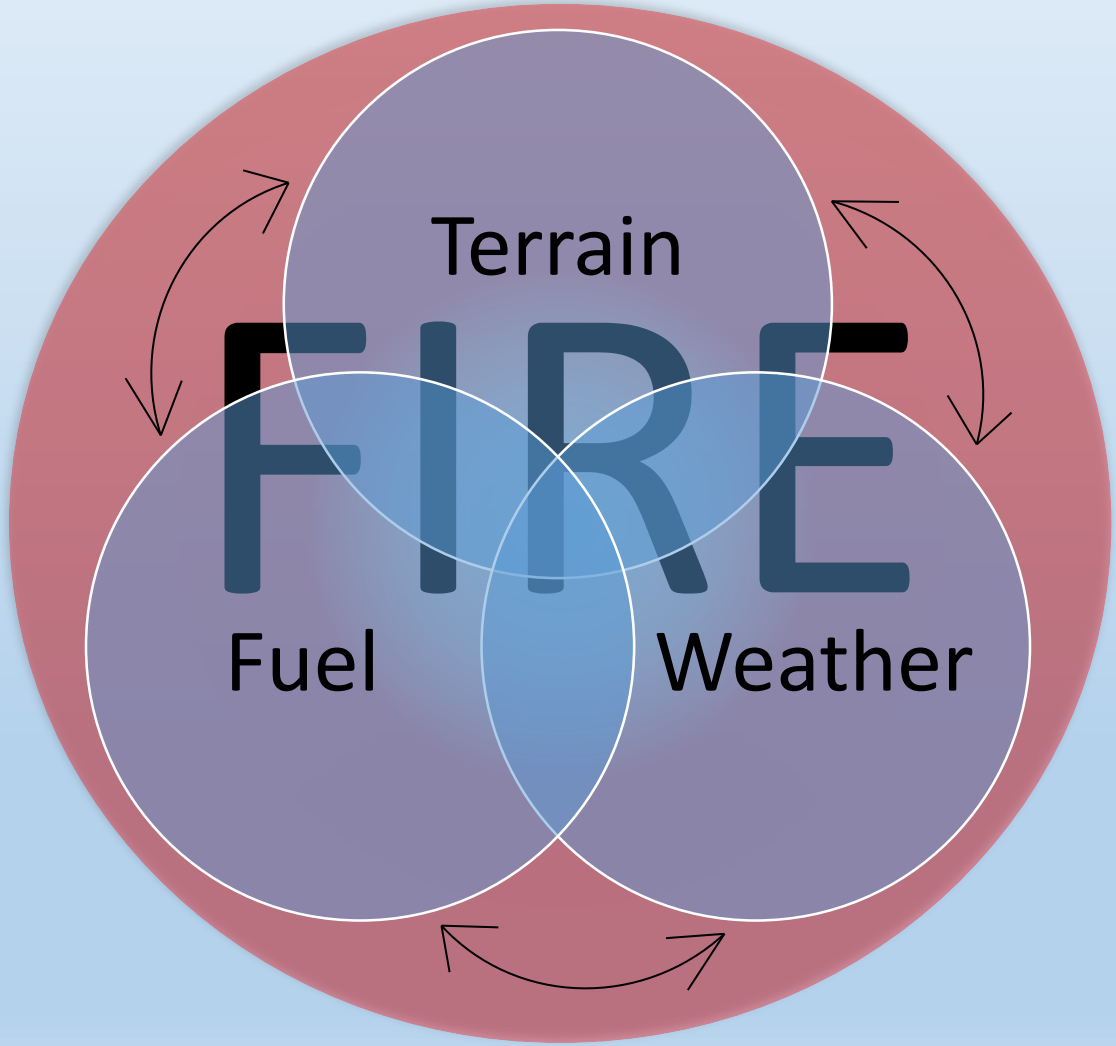
Definition

Extreme fire:

"Fire spread other than steady surface spread, especially when it involves rapid increases"

Werth et al. 2011, 2016. Synthesis of knowledge of extreme fire behavior: volume 1 and 2. Gen. Tech. Rep. PNW-GTR-854, 891. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Extreme Fire



Extreme fire behaviours

- Spotting/Fire storm
- Fire tornado/whirls
- Lateral vortices
- Junction zones (Jump fires)
- Eruptive fires
- Crown fires
- Conflagrations
- Downbursts
- Pyro-convective events

Spotting/fire storm

Byram (1959) considered spotting "the worst behavior characteristic, both from the standpoint of fire suppression and the effect on fire intensity."

- Short-distance spotting (up to 750 m)
- Medium-distance spotting (1000–5000 m)
- Long-distance spotting (>5000 m)

Examples include Strathewan, Narbethong, Marysville 2009

Fire tornado/whirls

- Combination heat and winds

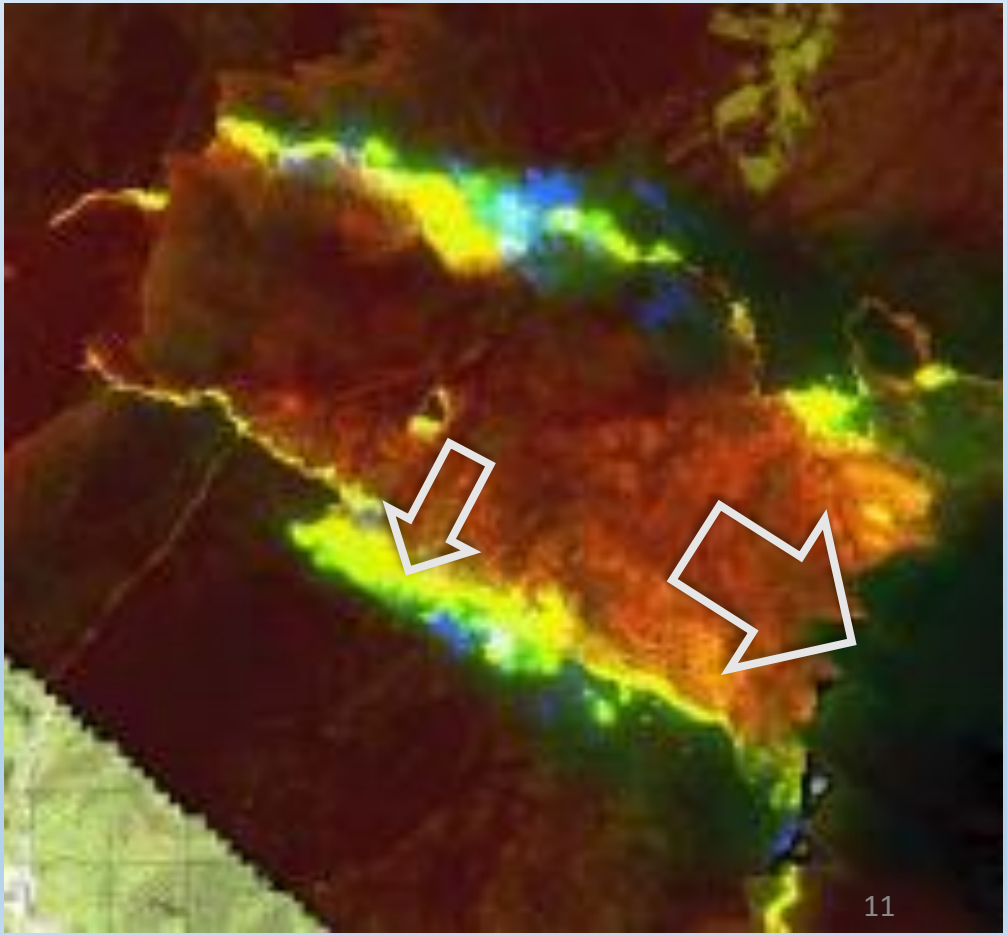
September 11 2012 at Curtin Springs, Northern Territory

Lateral vortices

- Spread of the fire perpendicular to the wind direction

(Simpson et al. 2013; Sharples et al. 2011; Sharples et al. 2012)

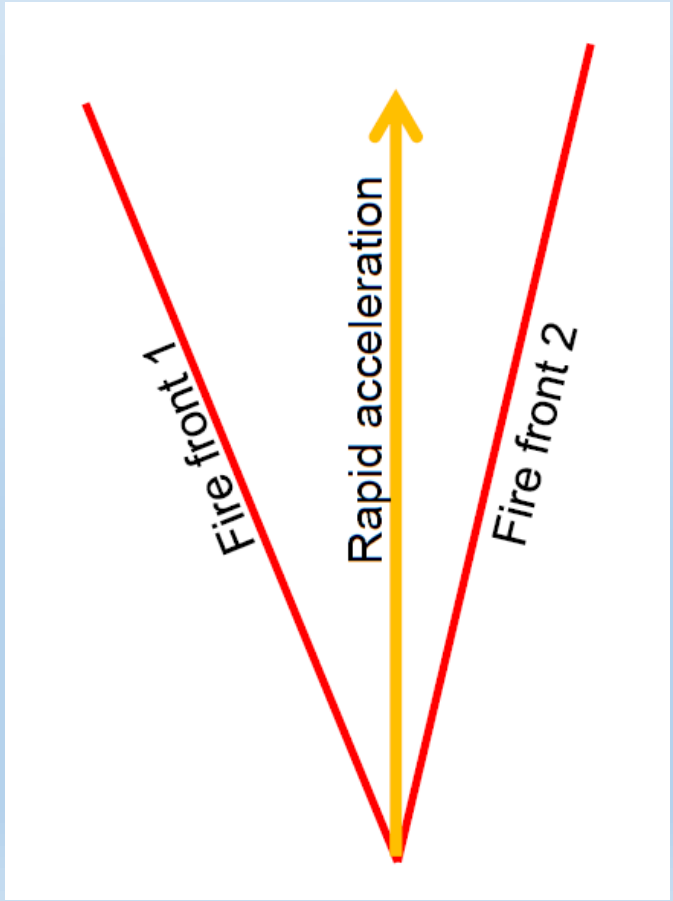
Australian examples:
McIntyre's Hut 2003,
Aberfeldy 2013,
Wambelong 2013

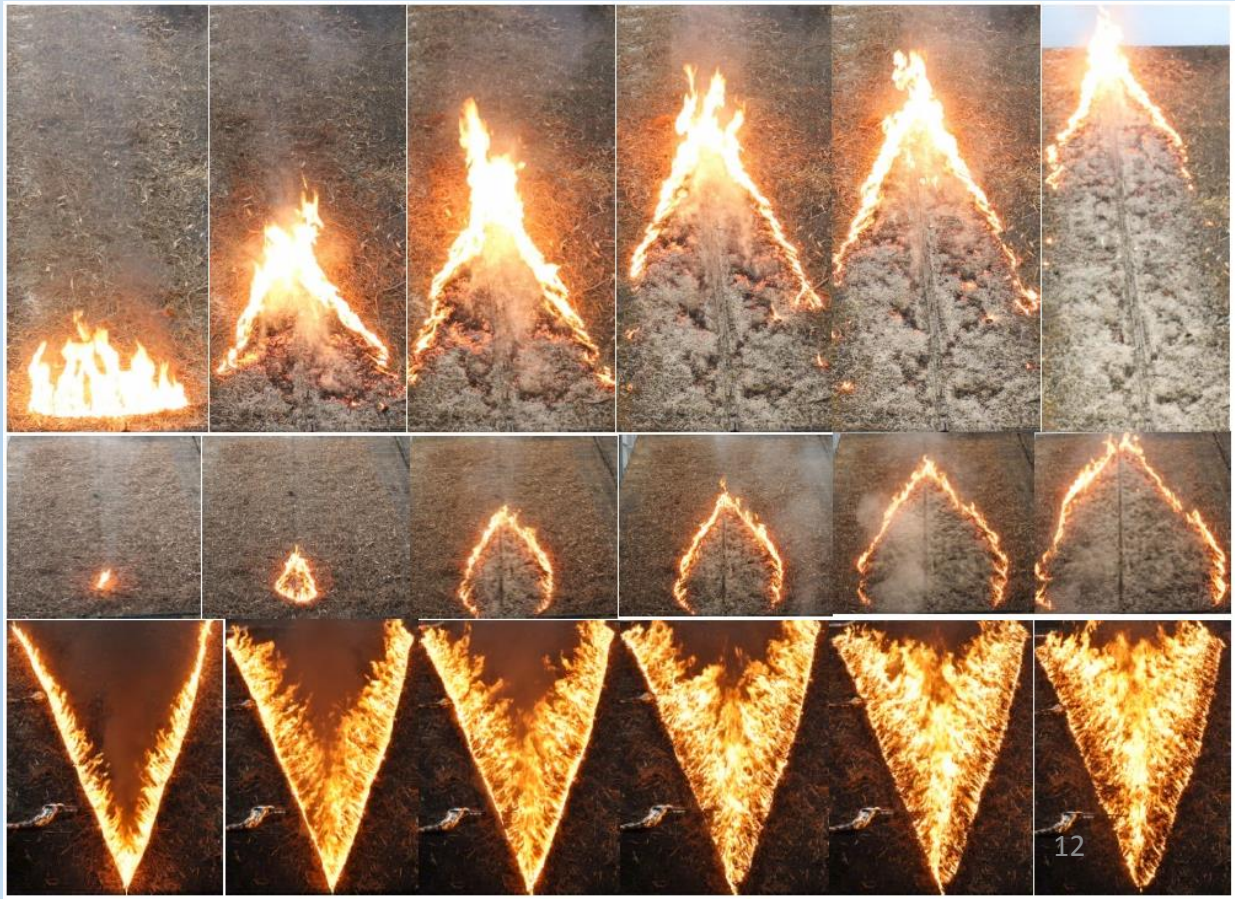


Junction zones (Jump fires)

- A jump fire denotes the phenomenon that two fire fronts spread and meet each other, making up of a V-shape fire topology, and then merge to produce very high rates of spread because of high concentration of energy.

e.g. Canberra 2003, ThirtyMile fire USA 2001





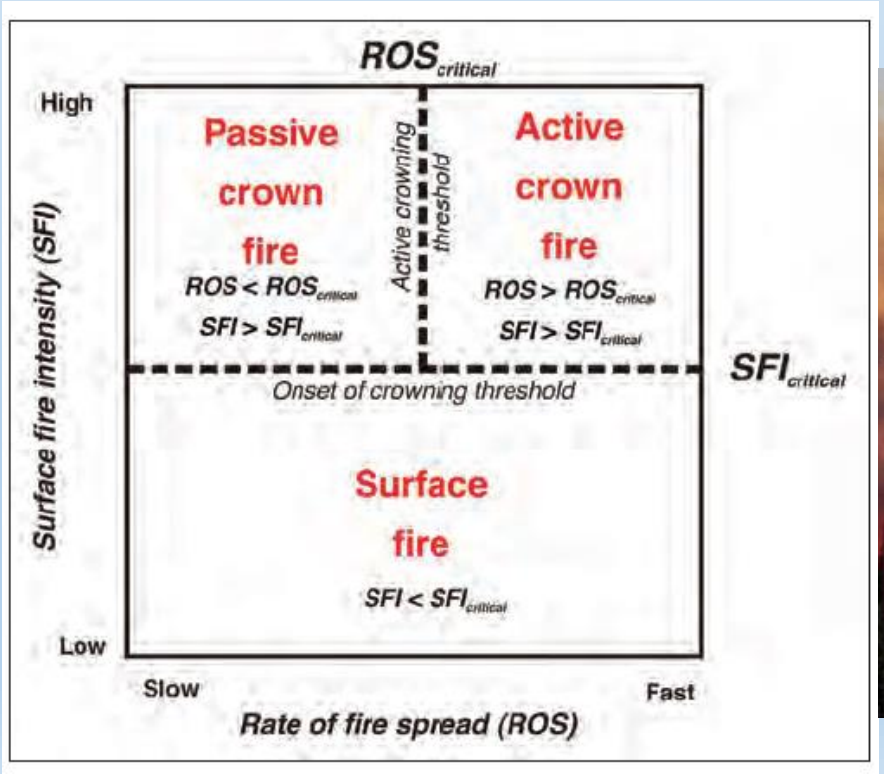
Eruptive fires

- Eruptive fire behaviour characterized by a sudden change of spread rate and energy-release rate.

Dold, JW, Zinoviev, A (2009)

Crown fires

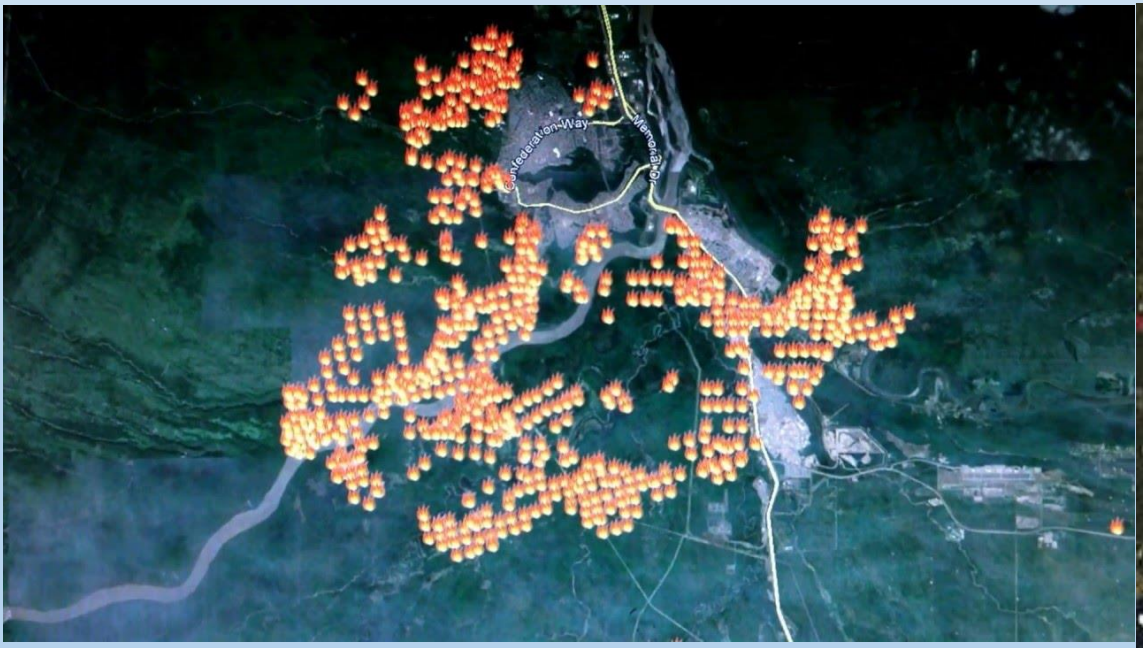
- Van Wagner recognized three types of crown fires: passive, active, and independent. An independent crown fire no longer depends in any way on the surface phase, spreading ahead of the surface phase in the crown fuel layer entirely on its own.



Conflagrations

- A conflagration is a large and destructive fire. Usually they are weather driven fires and upper end of the statistical distribution.

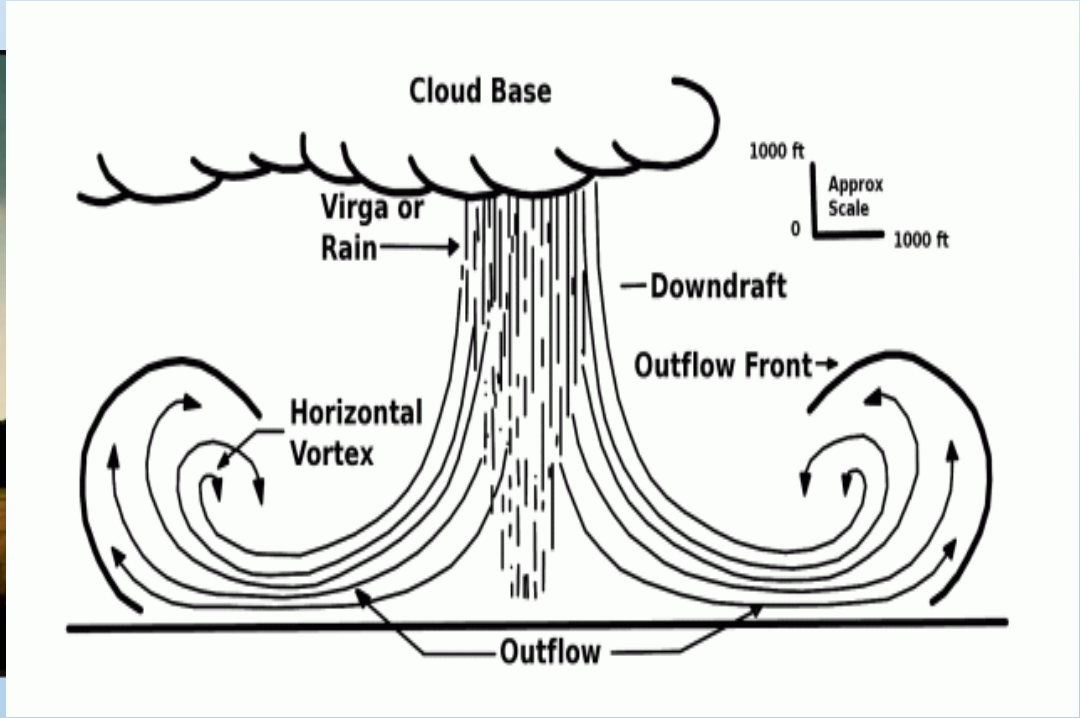
A number of examples in the last ten years: Portugal 2003, Wambelong 2013, State Mine Lithgow 2013, Black Saturday Complex 2009, Tasmania 2013, Canada 2016



Fort McMurray fire 48hr timelapse map with EDMONTON. May 3-5, 2016

Downbursts

- Plume dominated fires can produce a cumulonimbus cloud, which can generate powerful downbursts (or downdrafts). This fires can abruptly change direction and rate of spread.



Database compiling

Data

Data required:

- Fire progression/development data, mapped perimeters
- Fuel data – type (canopy, heavy fuels, surface, elevated, bark), load etc
- Weather data (observations and simulations including, upper atmospheric conditions, DFMC, KBDI, DF etc.)
- Topography
- Weather RADAR data
- Airborne LIDAR data
- Satellite data
- On-ground fire observations / Interviews (Video and photographs)
- Fuel reduction history
- Line scans and imagery
- Information about suppression activity
- House loss data
- Fuel moisture content (field observations)

Potential case studies

Date	Region	Event	Terrain	Fuel
2013	NSW	Wambelong	Hills	Forest
2013	NSW	State Mine	Hills	Forest
2013	NSW	Winmalee	Mountains	Forest
2013	NSW	Deans Gap	Hilly coastal	Forest
2013	NSW	Howes Swamp	Hills	Forest
2001/02	NSW	Mt Hall	Mountains	Forest
2015	NSW	Gold Mine Rd Fire	Mountains	Forest

7 fires/fire complexes

Date	Region	Event	Terrain	Fuel
2003, 2006, 2007	VIC	Alpine fires	Mountains	Forest
2009	VIC	Black Saturday	Hills	Forest
2013	VIC	Harrietville North	Mountains/Hills	Forest
2013	VIC	Aberfeldy	Mountains	Forest
2014	VIC	Lake Albacutya	Flat	Forest / Grassland
2014	VIC	Bronzewing Fire	Flat	Grassland
2014	VIC	Malle Grass Fire	Flat	Grassland
2014	VIC	Red Bluff	Hills	Grassland / Shrub
2014	VIC	Grampians	Mountains/Hills	Forest
2015	VIC	Scotsburn	Hills	Forest / Grassland
2015	VIC	Wye River	Hilly coastal	Forest
2015	VIC	Denaleys Road Fire	Hills	Forest / Grassland

14 fires/fire complexes

Date	Region	Event	Terrain	Fuel
2005	SA	Wangary	Flat	Grassland
2007	SA	Kangaroo Island	Mostly flat	Heath / Woodlands
2014	SA	Ngarkat	Flat	Grassland / Heath
2014	SA	Billiat Conservation Reserve	Flat	Grassland
2014	SA	Eden Valley	Flat	Grassland
2015	SA	Pinary	Mostly flat	Crop / Grassland
2015	SA	Sampson Flat	Hills	Forest

7 fires/fire complexes

Date	Region	Event	Terrain	Fuel
2015	WA	Esperance	Mostly flat	Woodland
2016	WA	Yarloop-Waroona	Undulating	Forest and grassland
2015	WA	Lower Hotham	Undulating	Forest
2015	WA	O'Sullivan	Undulating	Forest, heathland
2006	WA	Leeuwin Ridge (Contos)	Undulating	Heathland
2005	WA	Pickering Brook	Undulating	Forest
2003	WA	Mt Cooke	Undulating	Forest
2003	WA	Lake Tay	Flat	Mallee and heath
1994	WA	Forrestania	Flat	Woodland, mallee and heath
1961	WA	Dwellingup	Undulating	Forest
1980	WA	Boyicup	Undulating	Forest

11 fires/fire complexes

Date	Region	Event	Terrain	Fuel
2003	ACT	Canberra	Hills	Forest
2015	ACT	Cotter River	Hills	Forest
2016	ACT	Brandy Flat	Hills	Forest

3 fires/fire complexes

QLD – in progress

Tas – in progress

NT – in progress


Timor Sea
NORTHERN TERRITORY
Coral Sea
QUEENSLAND
Australia
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
ACT
Great Australian Bight
TASMANIA

Collected data

Date	Region	Event	Data
2009	VIC	Black Saturday	▪ Fire progression/development data, mapped perimeters ▪ Aerial imagery ▪ Video and photographs ▪ Suppression activity ▪ Reports
2013	VIC	Aberfeldy	▪ Fire progression/development data, mapped perimeters ▪ Photographs ▪ Line scans ▪ Observations
2014	VIC	Lake Albacutya	▪ Fire progression ▪ Line scans ▪ Photos
2014	VIC	Bronzewing Fire	▪ Mapped perimeter ▪ Photos ▪ Line scans
2014	VIC	Malle Grass Fire	▪ FLIR footage ▪ Line scans

2014	VIC	Red Bluff	▪ Fire area ▪ Reconstruction
2014	VIC	Grampians	▪ Mapped perimeter ▪ Photographs ▪ Line scans
2015	VIC	Scotsburn	▪ Video and photographs ▪ Suppression activity ▪ Line scans and aerial imagery
2015	VIC	Wye River	▪ Fire progression/development data, mapped perimeters ▪ FLIR footage ▪ Line scans and imagery ▪ Video and photographs ▪ Suppression activity ▪ Gridded weather, drought factor
2015	VIC	Denaleys Road Fire	▪ Line scans
2016	VIC	Mt Bolton	▪ Fire progression/development data, mapped perimeters ▪ Photographs and video ▪ Line scans

Date	Region	Event	Data
2015	WA	Esperance	▪ Reconstruction and report
2016	WA	Yarloop-Waroona	▪ Fire progression ▪ Reports
2015	WA	Lower Hotham	▪ Meteorological data ▪ Reconstruction
2015	WA	O'Sullivan	▪ Fire progression ▪ Reports
2006	WA	Leeuwin Ridge (Contos)	▪ Reconstruction
2005	WA	Pickering Brook	▪ Severity map ▪ Reconstruction
2003	WA	Lake Tay	▪ Report
1994	WA	Forrestania	▪ Paper and presentation
1961	WA	Dwellingup	▪ Reconstructions and report
1980	WA	Boyicup	▪ Report

Date	Region	Event	Data
2005	SA	Wangary	▪ Operational plans and maps ▪ Line scan ▪ Fire progression/development data, mapped perimeters ▪ Imagery ▪ Suppression activity
2007	SA	Kangaroo Island	▪ Situation maps ▪ Operational plans and maps ▪ Photos and video ▪ Line scan ▪ Imagery ▪ Severity maps
2014	SA	Ngarkat Complex	▪ Progression reports ▪ Photos ▪ Imagery
2014	SA	Billiat Conservation Reserve	▪ Progression reports ▪ Photos ▪ Imagery
2014	SA	Eden Valley	▪ Imagery ▪ Situation maps

2015	SA	Pinary	▪ Imagery ▪ Situation maps
2015	SA	Sampson Flat	▪ Severity maps ▪ Fire progression/development data, mapped perimeters ▪ Imagery ▪ Line scans

Date	Region	Event	Data
2003	ACT	Canberra	▪ Report ▪ Line scans
2015	ACT	Cotter River	▪ Burning plans and suppression activity ▪ Fire progression/development data, mapped perimeters
2016	ACT	Brandy Flat	▪ Photos ▪ Burning plans and suppression activity ▪ Gridded weather ▪ Fire progression/development data, mapped perimeters

Radar data

2014-2016

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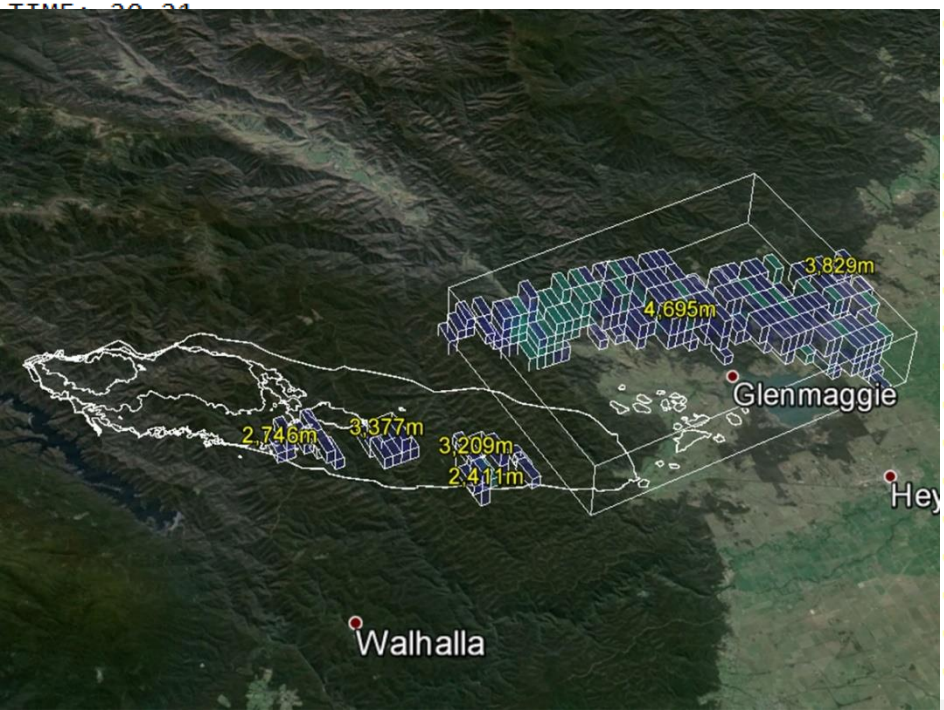

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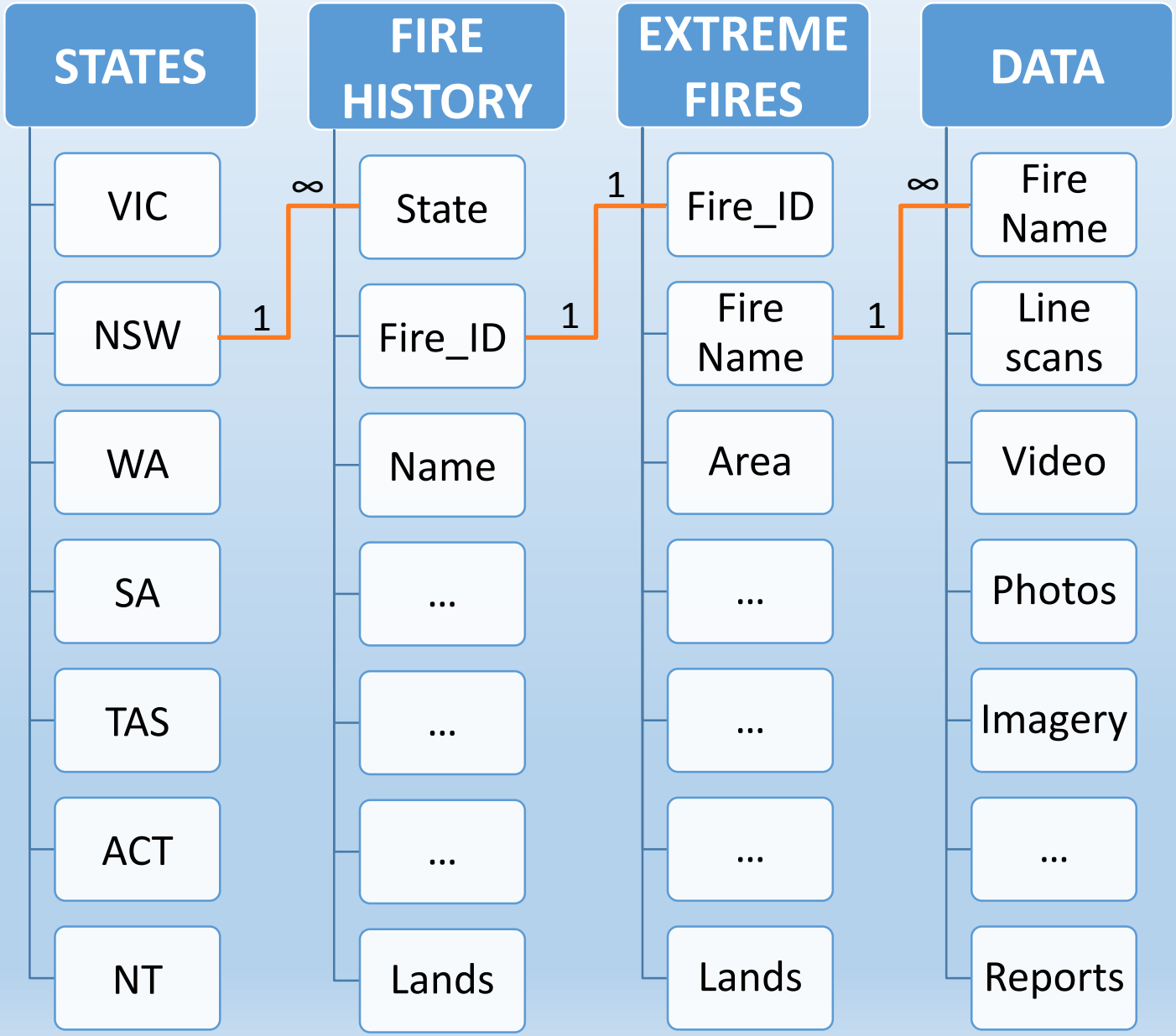
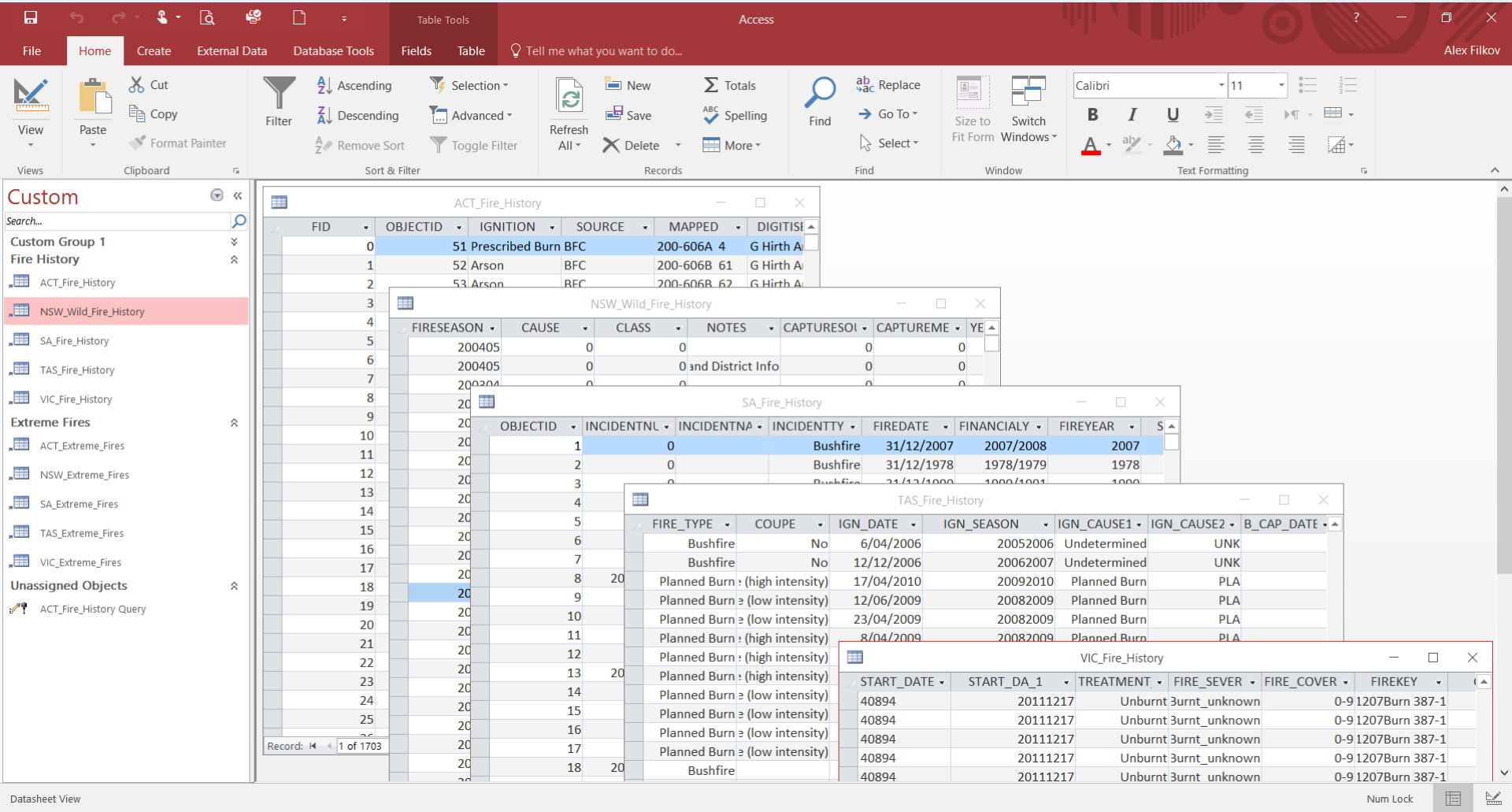
Access database development

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Alex Filkov
View
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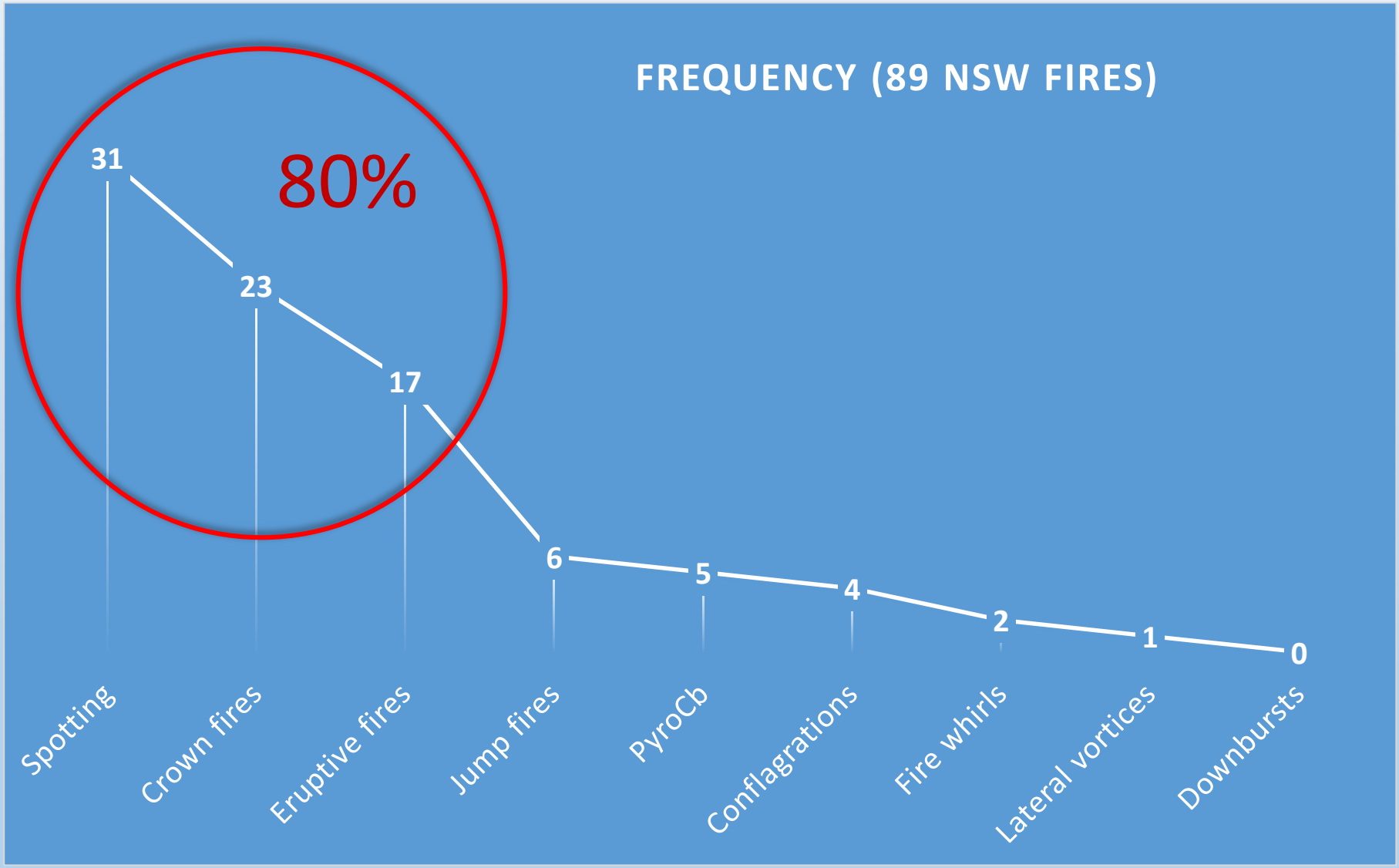
Datasheet View
Num Lock

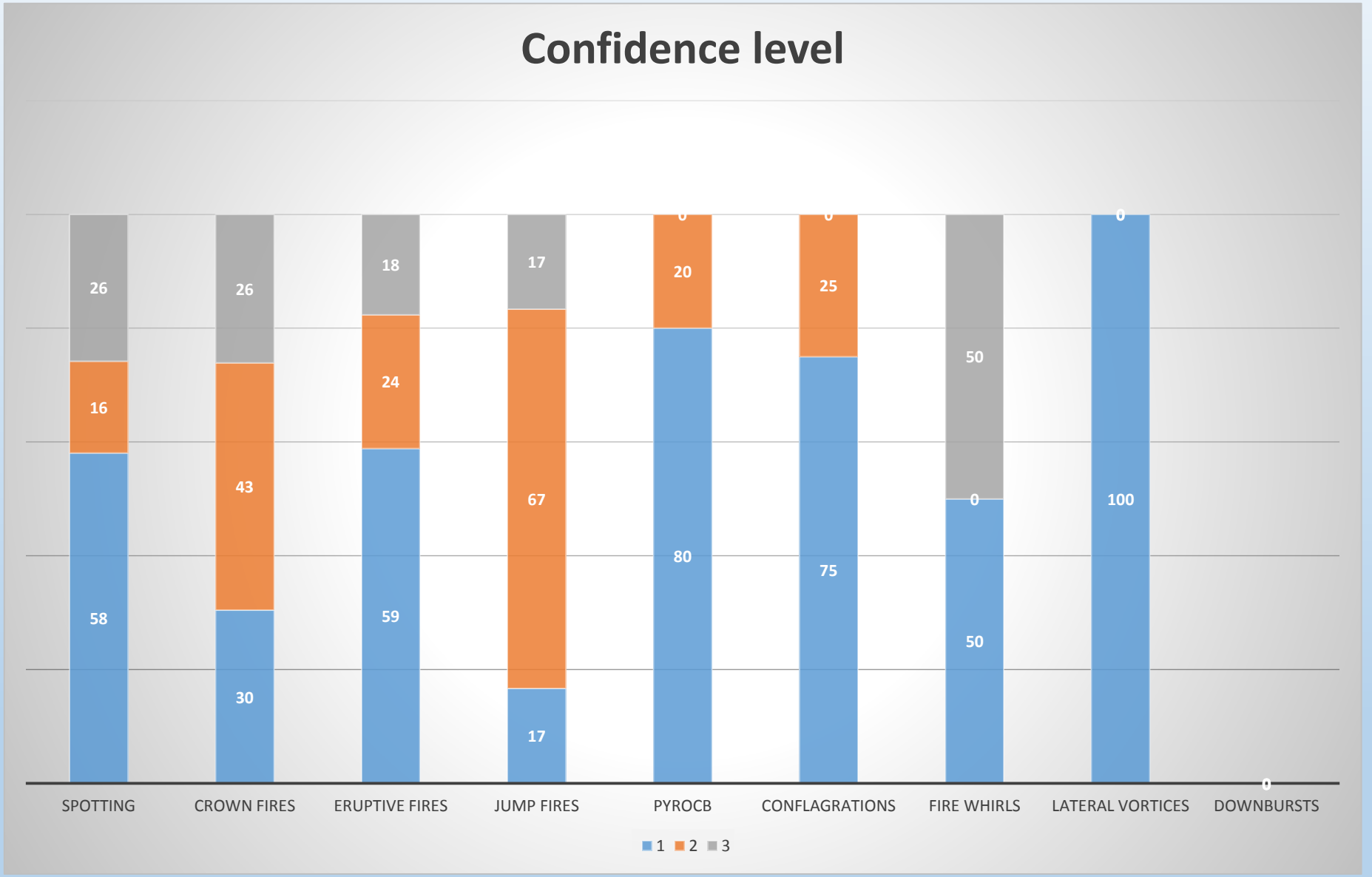
Preliminary analysis of extreme fire behaviours

- List of fires > 1000 ha for each RFS zone during last 10 years
- Survey to investigate more often extreme fire events

Extreme fire behaviour	1 - Direct data	2 - Indirect data	3 - Anecdotal data
Spotting/Fire storm			
Fire tornado/wirls			
Lateral vortices			
Junction zones (Jump fires)			
Eruptive fires			
Crown fires			
Conflagrations			
Downbursts			
Pyro-convective events			

Conclusions and Results





1 - direct data, 2 - indirect data, 3 - anecdotal

- Initial findings indicate that ‘extreme’ processes are associated with the most damaging fires Australia wide.
- Preliminary results show that frequency of extreme fire behaviours depends on their type.
- As a number of fire impact models use radiant heat as an input, an investigation of dynamic radiant heat on fire front propagation and structures ignition will allow us to better understand the processes that occurring and prioritise the modification of operational fire spread models.
- The ability to better predict the behaviour of extreme fires can help fire managers plan firefighting efforts more effectively, reducing impacts and the potential for the loss of lives.

Objectives for future research

- To analyse the frequency and importance of extreme fire behaviours in the context of landscape scale fire behaviour and impact prediction.
- To determine the contribution dynamic radiant heat to fire front propagation and structure ignition.

1. Analysis of occurrence and importance of extreme fire behaviours

Objectives: To understand the likelihood of occurrence of extreme fire behaviour phenomena and identify those that are most important to fire behaviour or impacts

Methods

- continue to develop the historic fire dataset
- undertake an analysis to determine the frequency of specific fire phenomena
- investigate by comparing what actually occurred to what was predicted to occur using a fire behaviour simulator (or simulators)
- determine the magnitude of effect of each phenomenon on fire behaviour and impacts
- prioritise which phenomena are focused on for future modelling

2. Understanding ignition process of natural fuels under dynamic conditions

Objectives: To study the ignition of fuels under dynamic radiant heat flux to develop impact equations aligned with existing approaches.

Methods

- create an experimental program to evaluate the effect of dynamic heating
- emulate the dynamic flames to expose to common Australian wood and surface fuels
- determine the ignition time of various natural fuels under variable heat flux
- compare findings to data where a static heat flux is used
- provide insight into fire front propagation for improvements of fire behaviour operational models and better modelling of impacts to structures

Potential outcomes

- Data sources for use for validation/verification of existing processes/physical models
- Creation of a fire behaviour archive
- Development of quick-reference materials for operational guidance
- Recommendations for future simulators development
- Improvement of the organisation capability to predict fire behaviour and risks to people and property under dynamic conditions
- List of most likelihood extreme fire behaviours identified and described Australia wide

- Analysis of influence of extreme fire behaviours on fire propagation
- Determination of the ignition characteristics of various natural fuels under dynamic heat flux
- Development of guidelines for identifying environmental conditions causing the extreme fire behaviour phenomena during operational fire behaviour analysis
- Development of statistical relationships between the environment and extreme fire behaviours
- Improvement of the efficiency and safety of fire suppression activities, better targeting of public information and warnings
- Improvement of understanding of the potential effectiveness strategies for managing landscape fire risk

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Laurence McCoy (NSW)

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and many more….

Thank you!