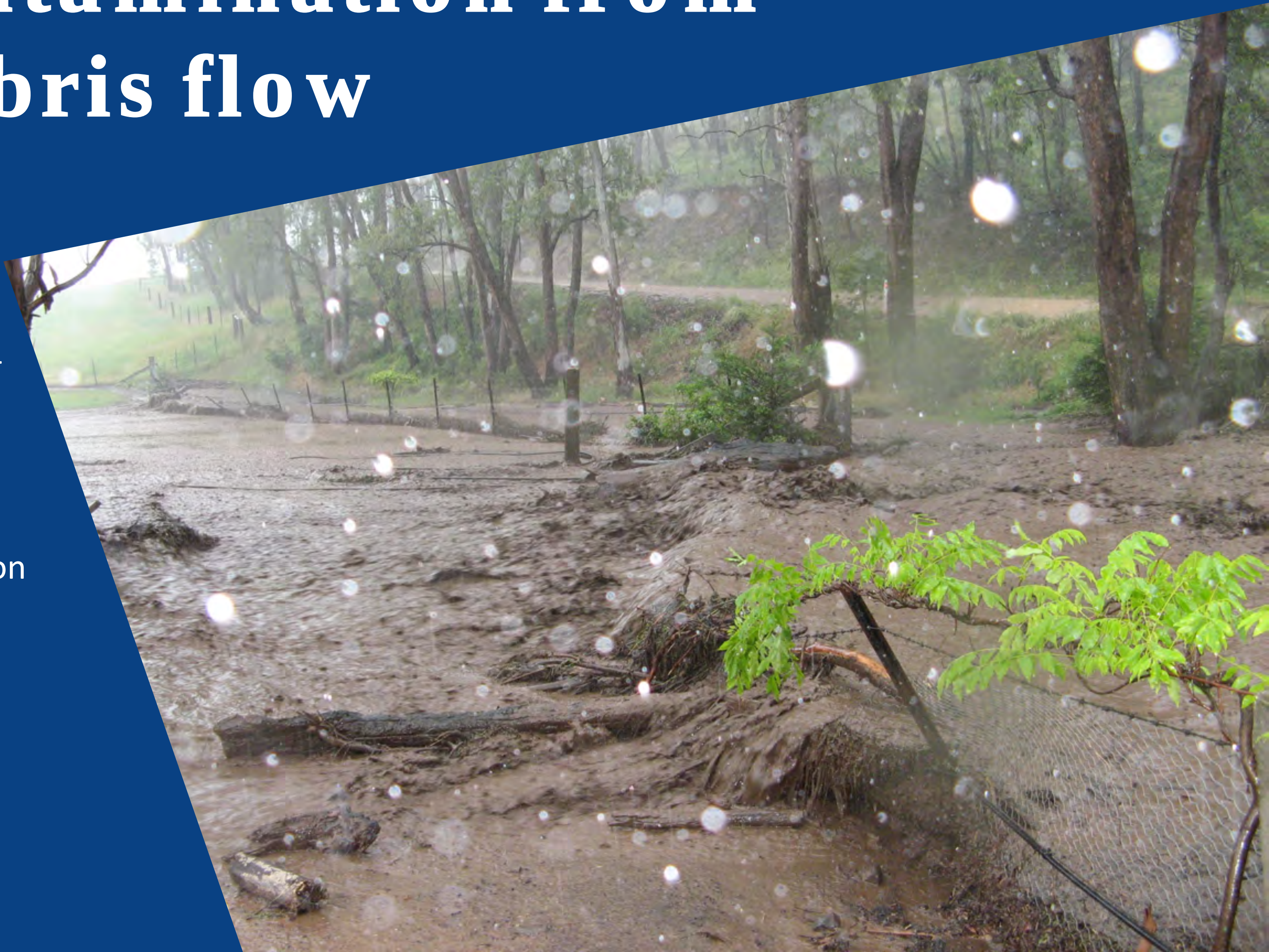
Probability and consequence of water contamination from post-fire debris flow

Petter Nyman[1], Peter Yeates[2], Philip Noske[1], Gary Sheridan[1]
Patrick Lane and Shane Haydon[3]

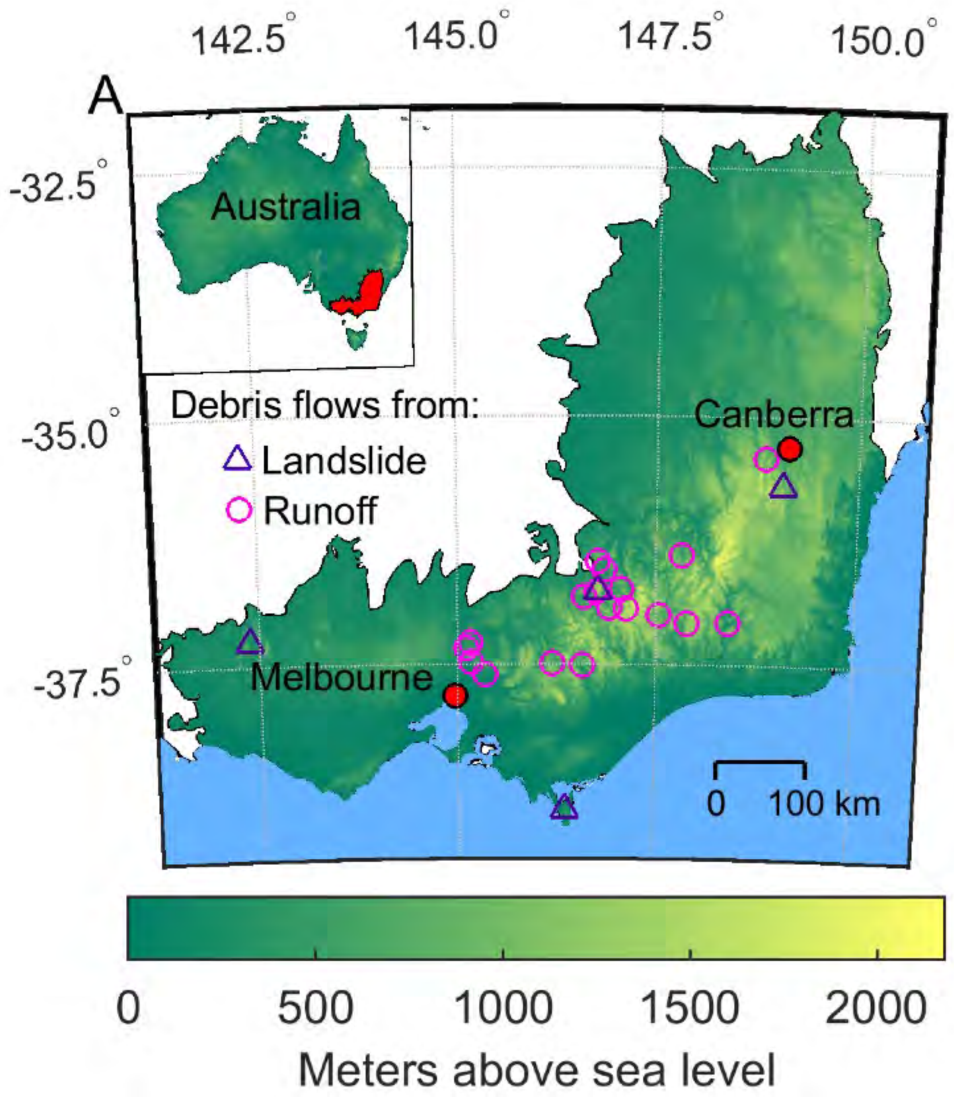
[1]School of Ecosystem and Forest Science, The University of Melbourne, [2]Hydronumerics, [3]Melbourne Water Corporation

August 2019



Debris flows in SE Australia - regional context

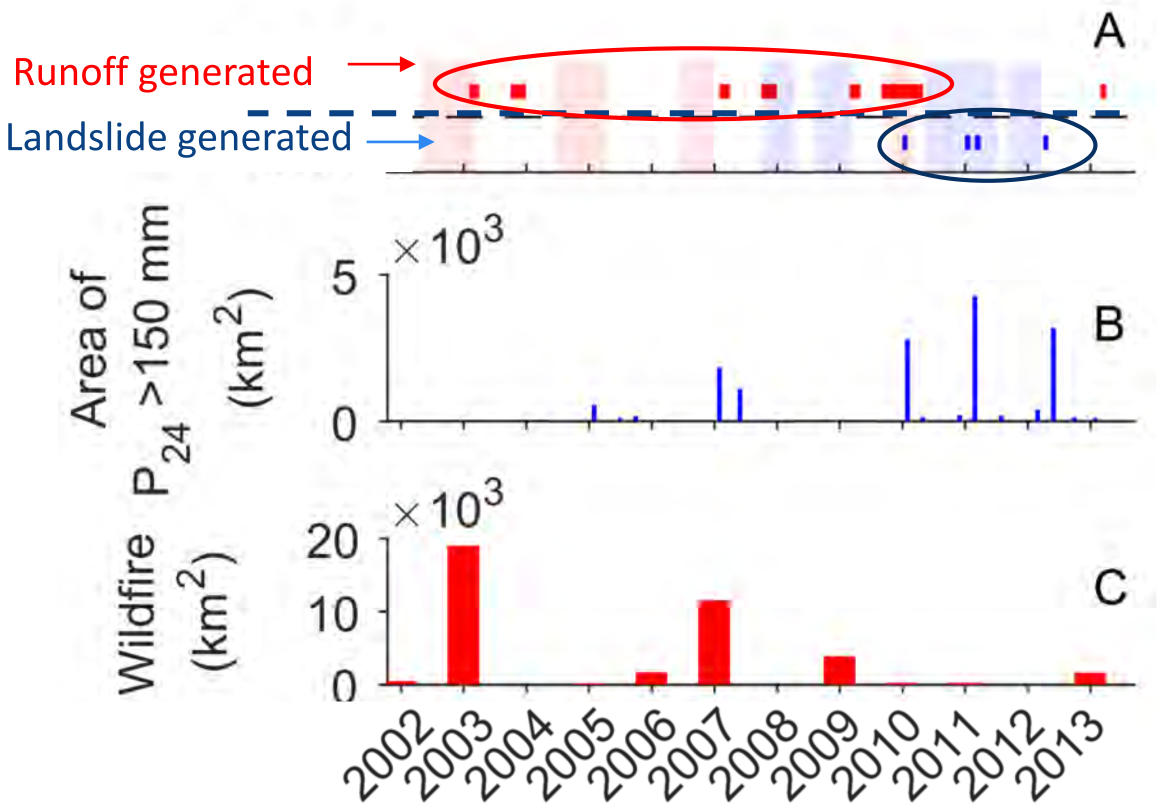
- SE Australia was subject extraordinary hydroclimatic conditions (drought and flooding) between 2000 and 2015
- Drought (2000-2009) and La Nina floods (2010-2012)
  - Both unprecedented in historical records in terms of extent and severity
- Several periods of widespread debris flow activity in forest catchments



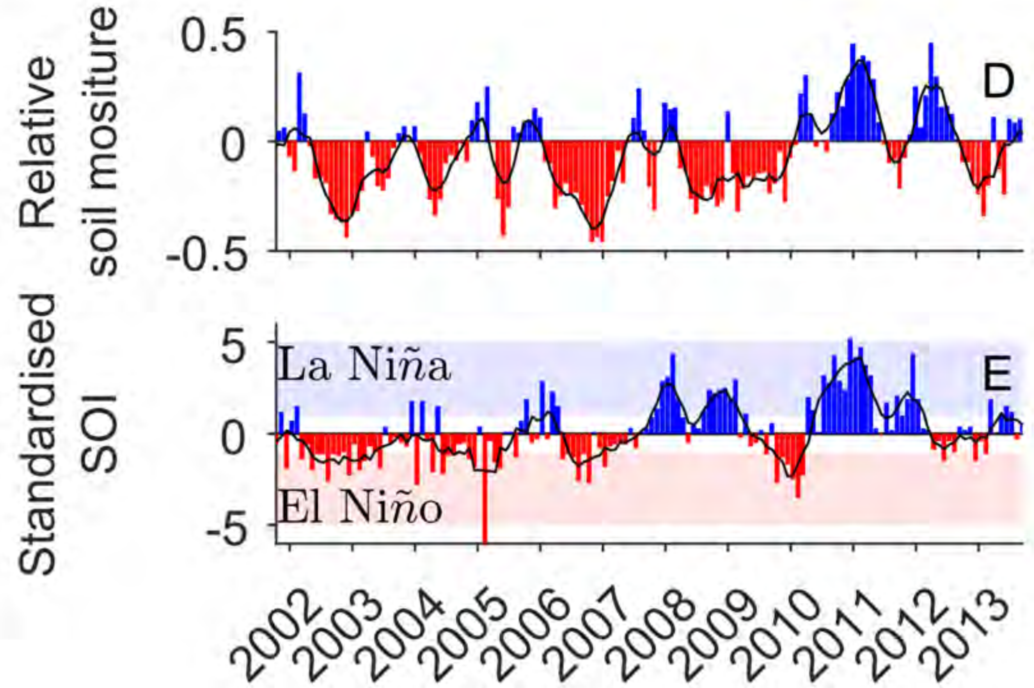
Debris flows in SE Australia - regional context

- Periods of debris flow activity linked to regional hydroclimate (Nyman et al, 2019)

Debris flow linked to wildfire and large rainfall events:



Regional hydroclimatic controls evident in ENSO cycles and soil moisture:



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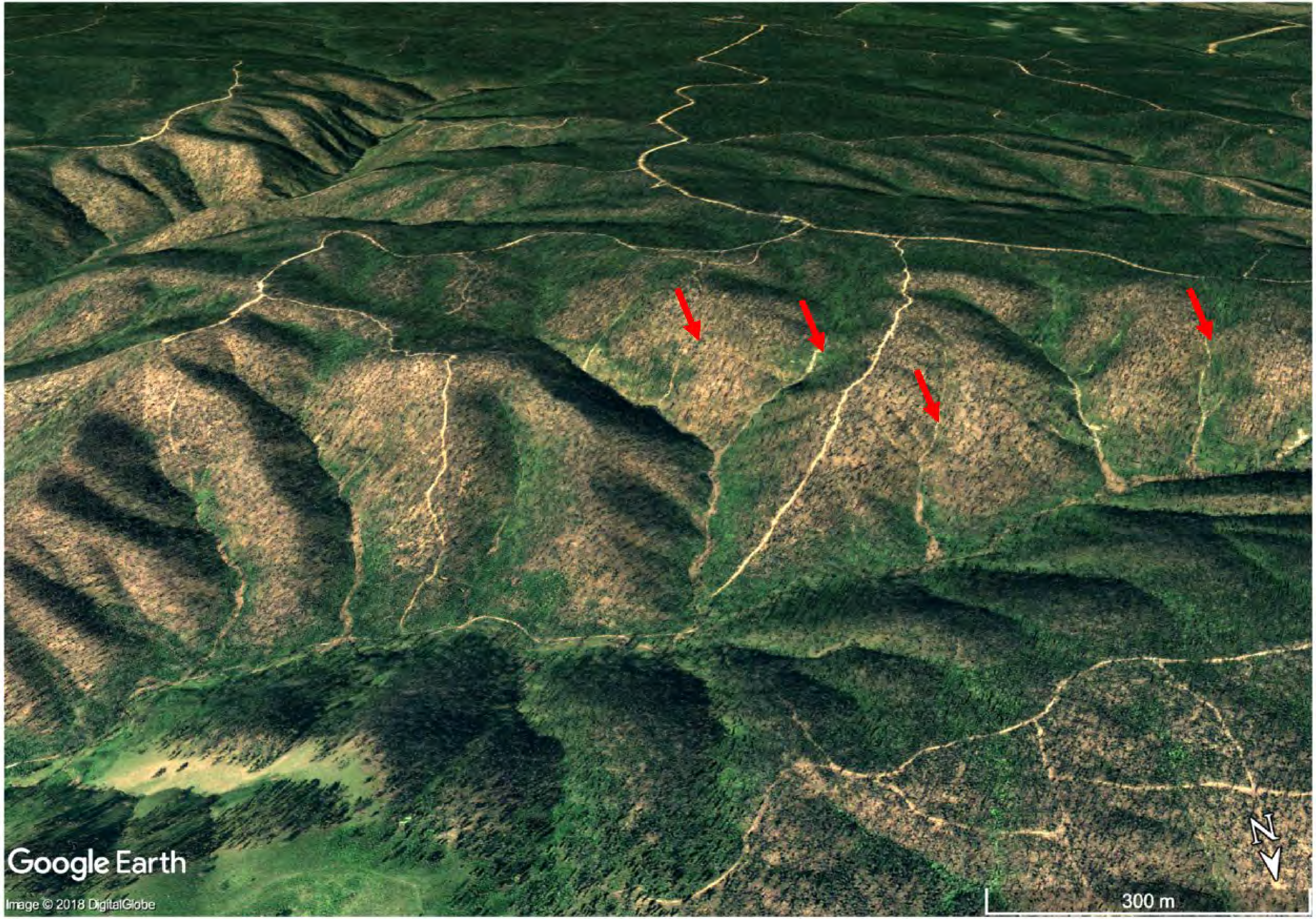
Google Earth
Image © 2018 DigitalGlobe
300 m
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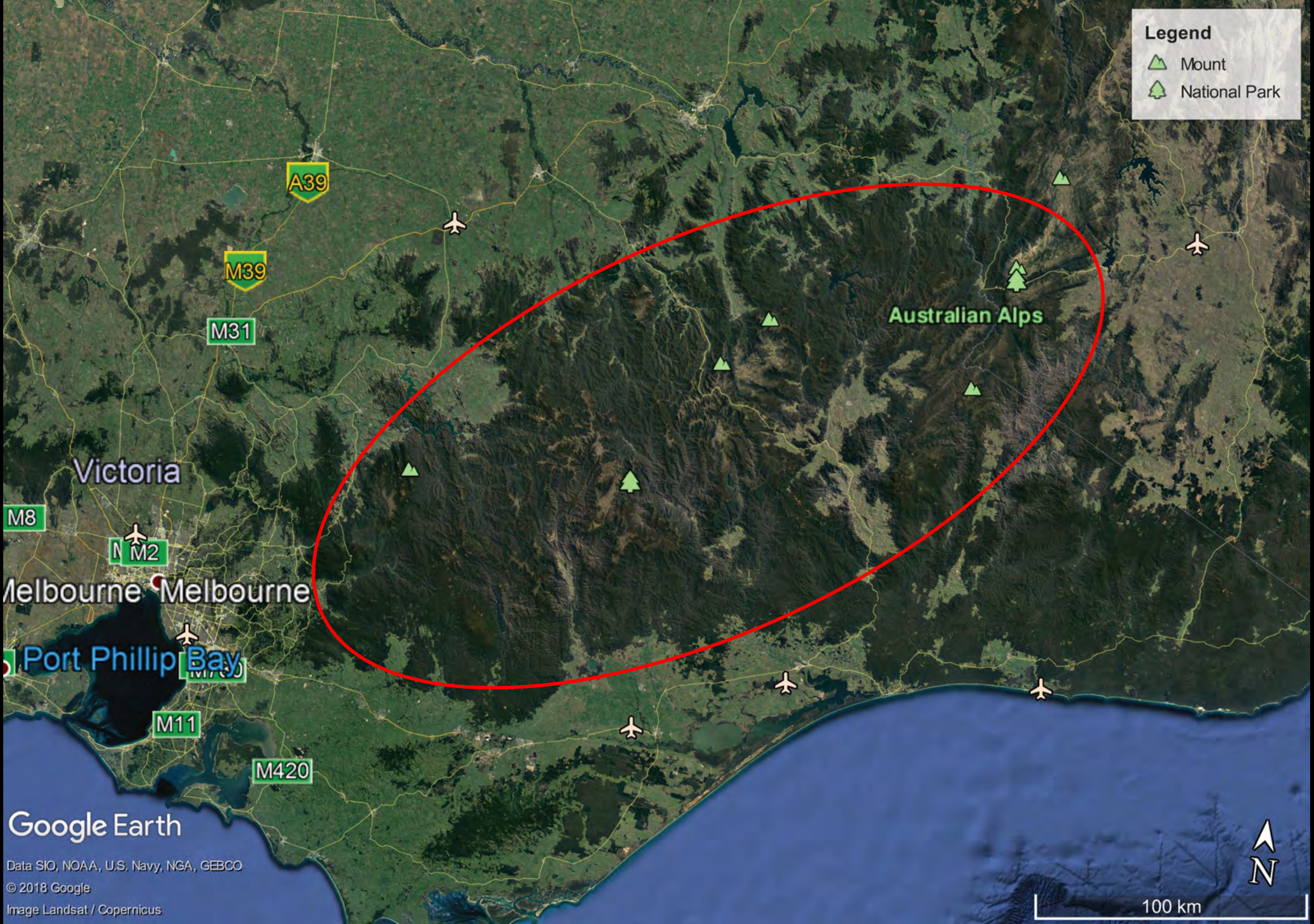
Legend
Mount
National Park
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M39
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Melbourne
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Port Phillip Bay
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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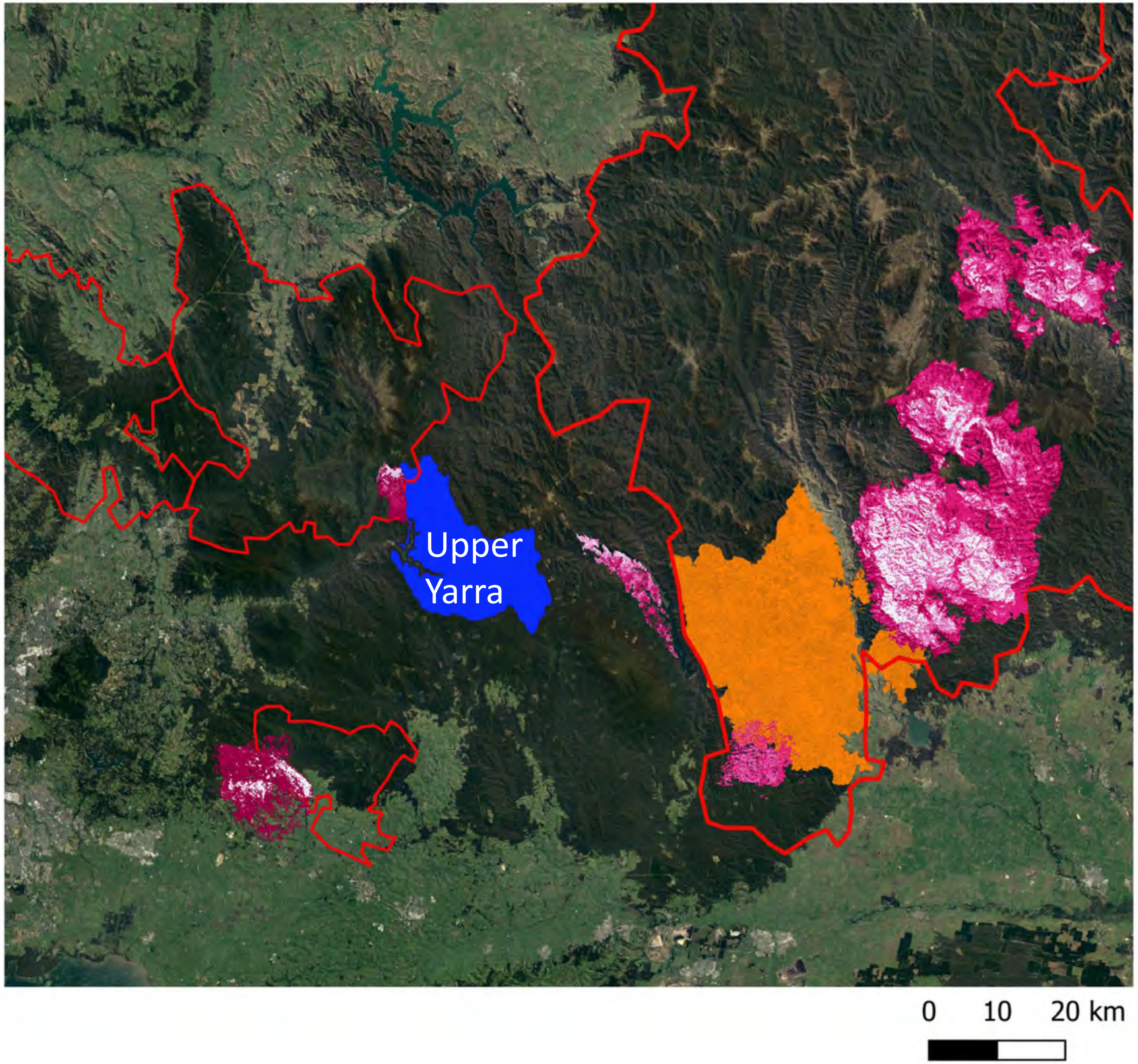
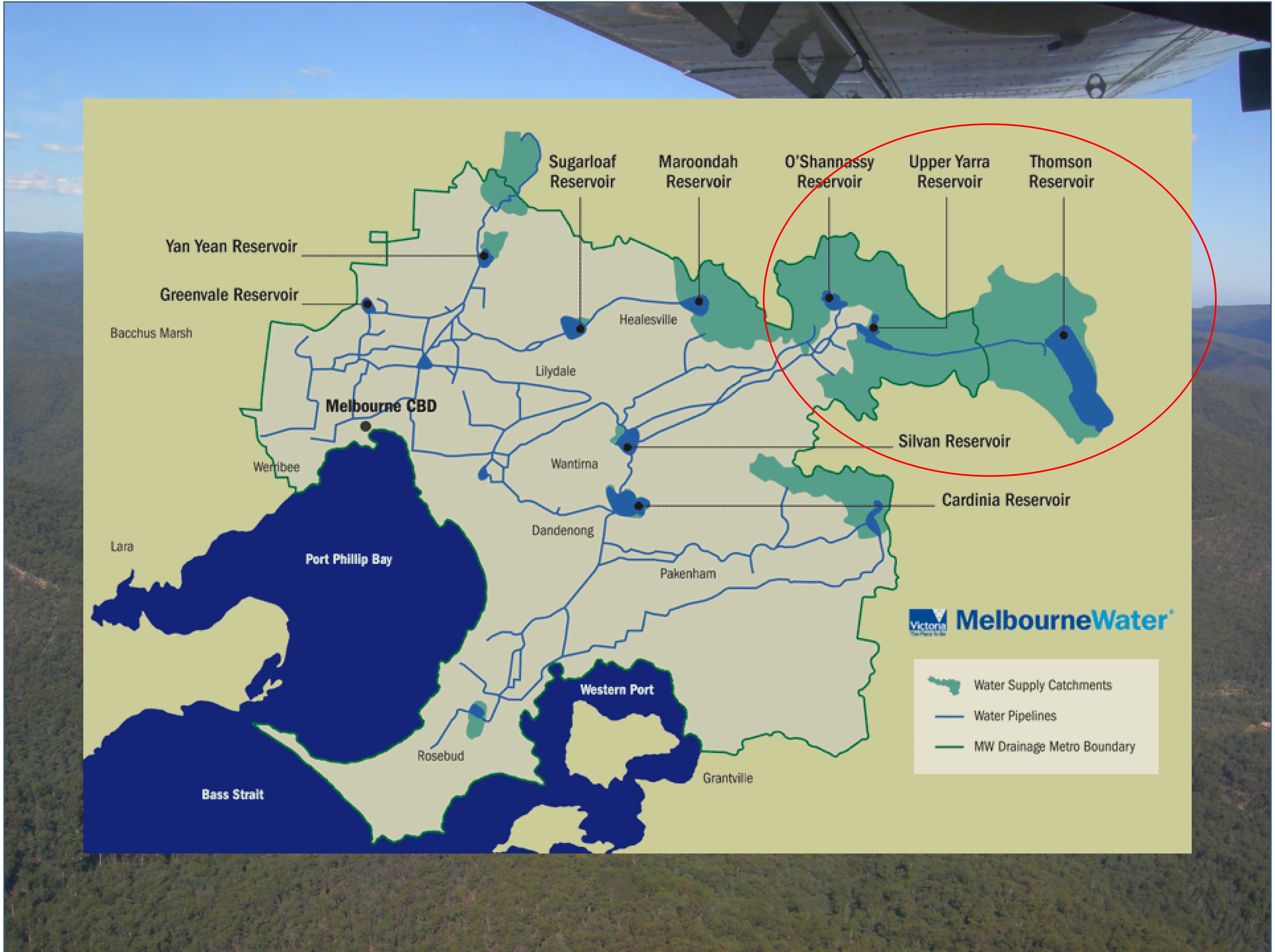
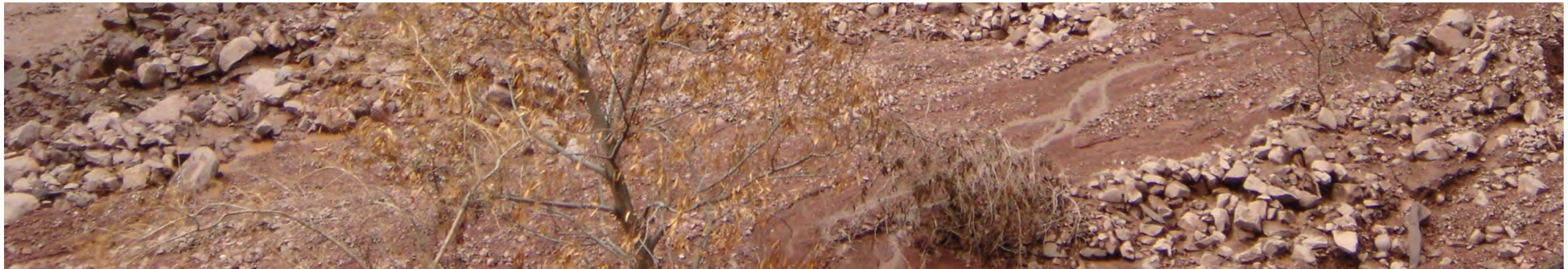

Upper Yarra
0 10 20 km


Sugarloaf Reservoir
Maroondah Reservoir
O'Shannassy Reservoir
Upper Yarra Reservoir
Thomson Reservoir
Yan Yean Reservoir
Greenvale Reservoir
Bacchus Marsh
Healesville
Lilydale
Melbourne CBD
Silvan Reservoir
Werribee
Wantirna
Cardinia Reservoir
Dandenong
Lara
Port Phillip Bay
Pakenham
MelbourneWater
Western Port
Water Supply Catchments
Water Pipelines
MW Drainage Metro Boundary
Rosebud
Grantville
Bass Strait

Motivating questions:

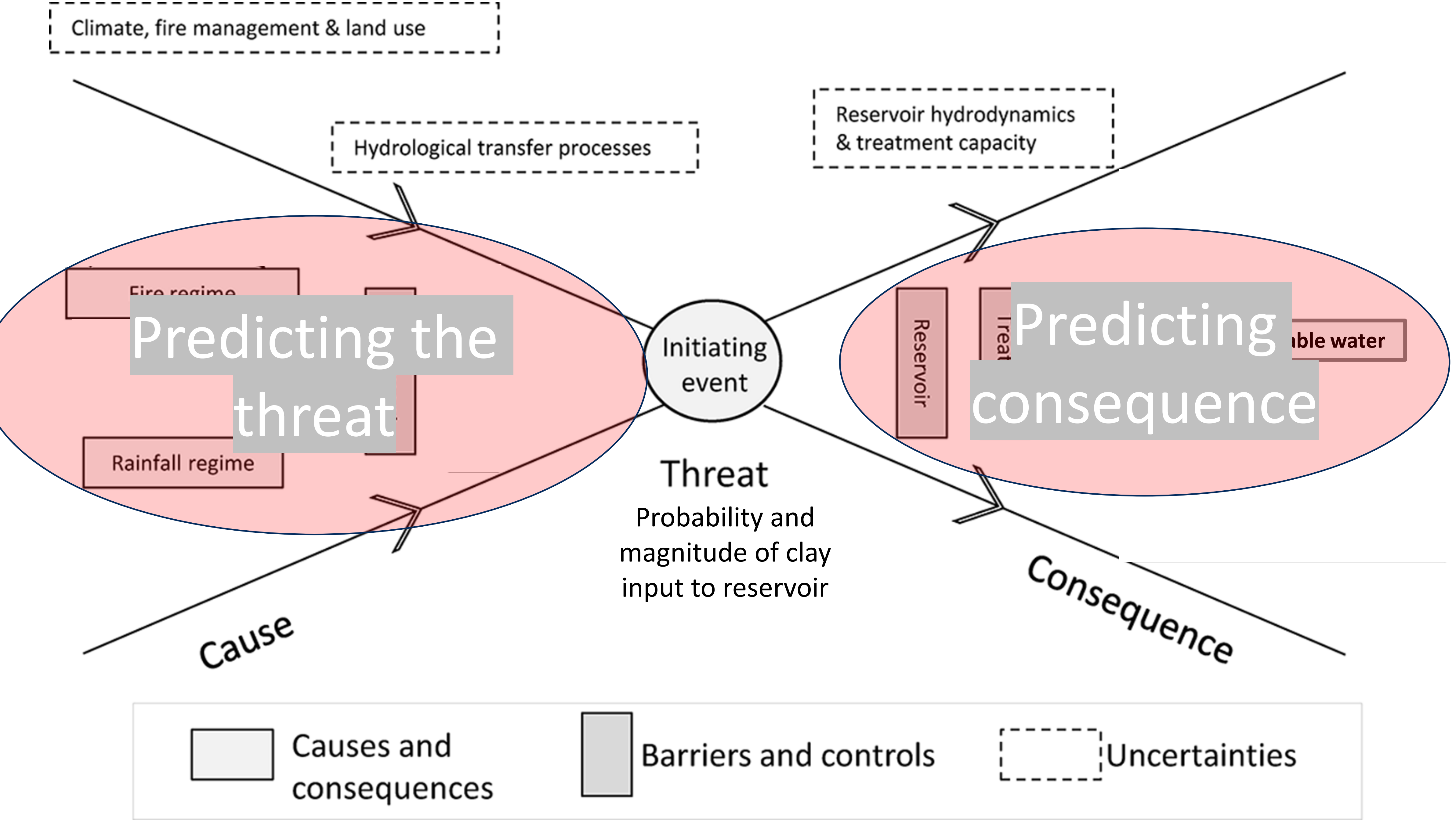
- What are the likely consequences for water supply?
- How do these vary with fire severity?
- How is risk distributed spatially in water supply catchments?
- What are the costs-and benefits of mitigation?



Debris flows begin on the hillslope

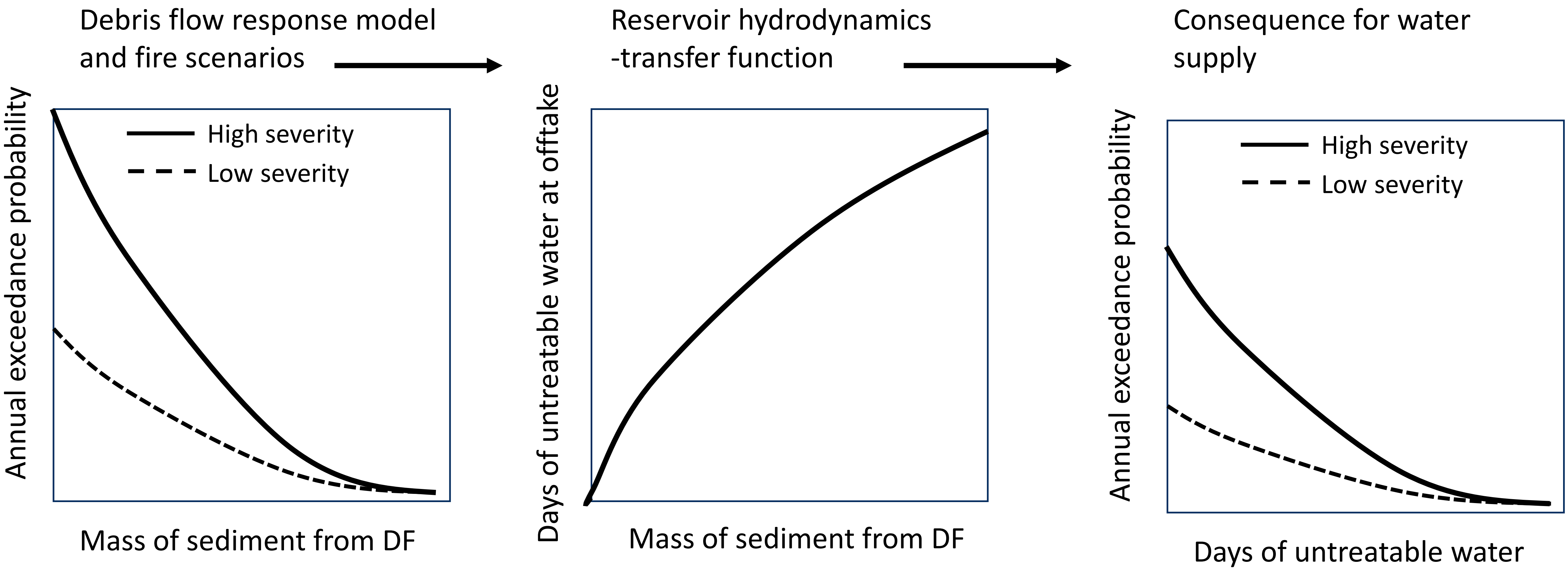
Objectives

1. ***Develop and evaluate** a model of debris flow rainfall thresholds.*
2. ***Apply the model** to Upper Yarra Catchment with two contrasting fire scenarios.*
3. ***Calculate the consequence to treatability of water** using model of reservoir hydrodynamics.*

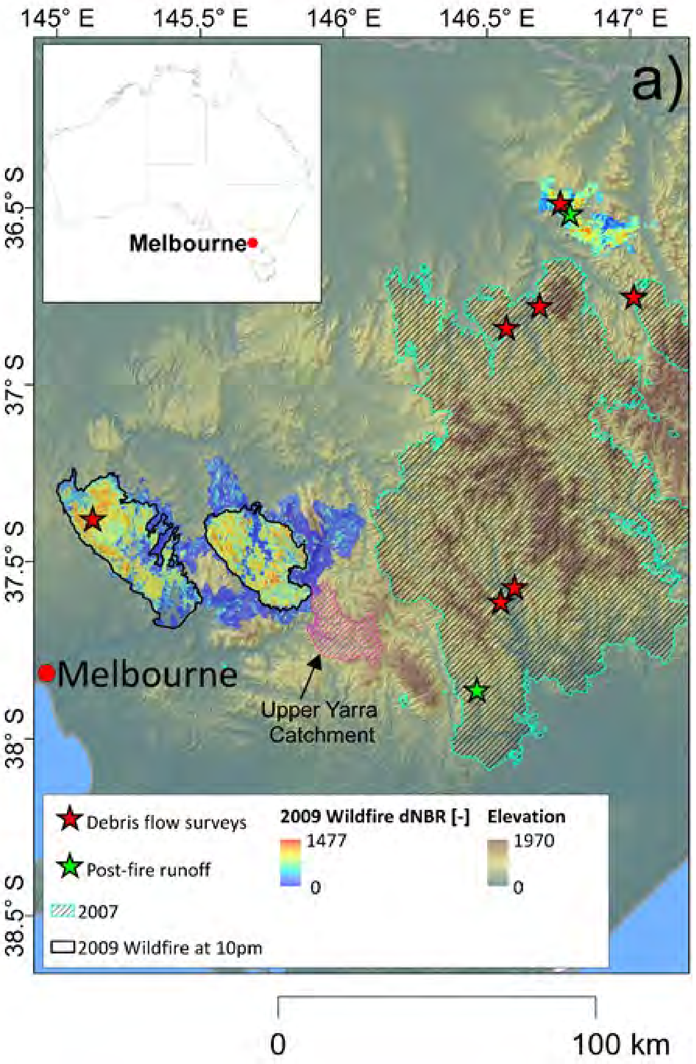


Climate, fire management & land use
Hydrological transfer processes
Reservoir hydrodynamics
& treatment capacity
Fire regime
Predicting the threat
Rainfall regime
Initiating event
Reservoir
Predicting consequence
Threat
Probability and magnitude of clay input to reservoir
Cause
Consequence
Causes and consequences
Barriers and controls
Uncertainties

Modelling approach



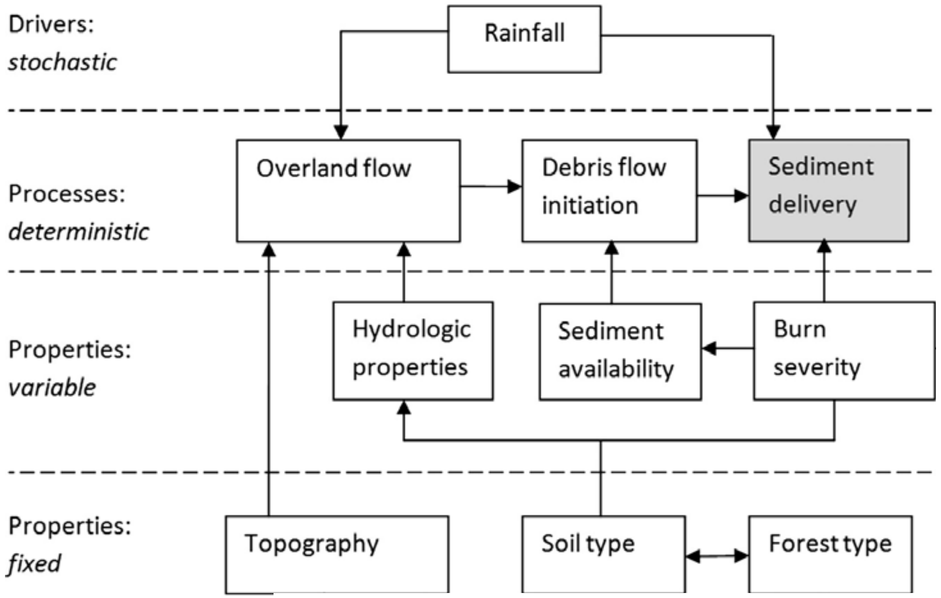
Debris flow thresholds – model description



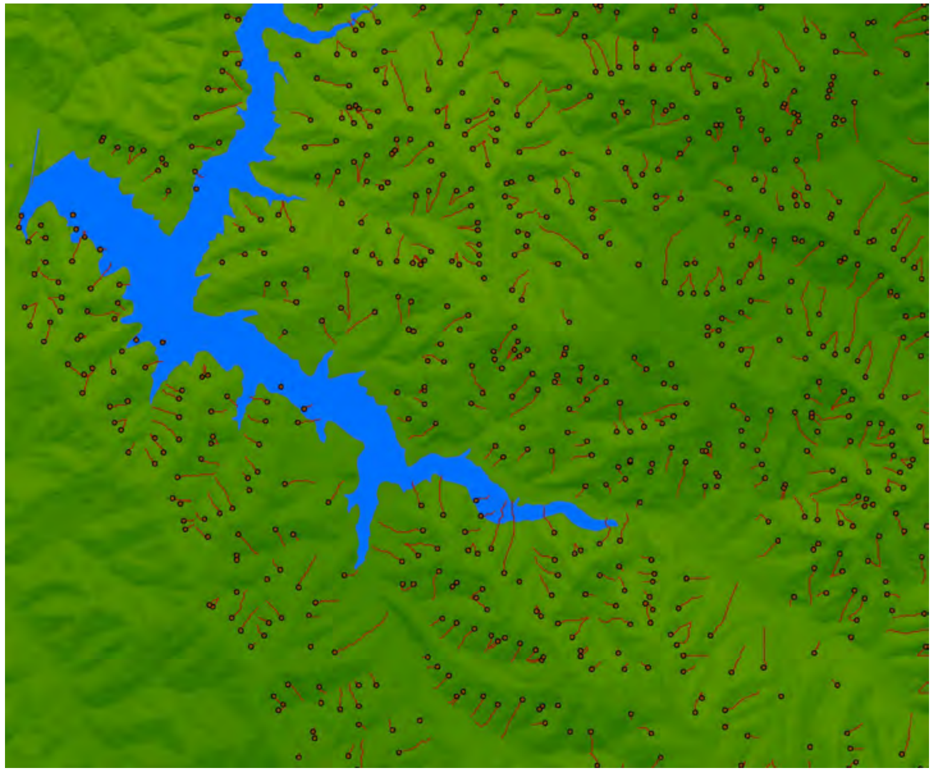
Debris flow model description

Debris flow model (Langhans et al, 2016):

- Predict probability and magnitude of debris flows
- Capture variability in thresholds caused by recovery and spatial variation in soil hydraulic properties
- Attribute sediment loads to sources with different grain size distributions



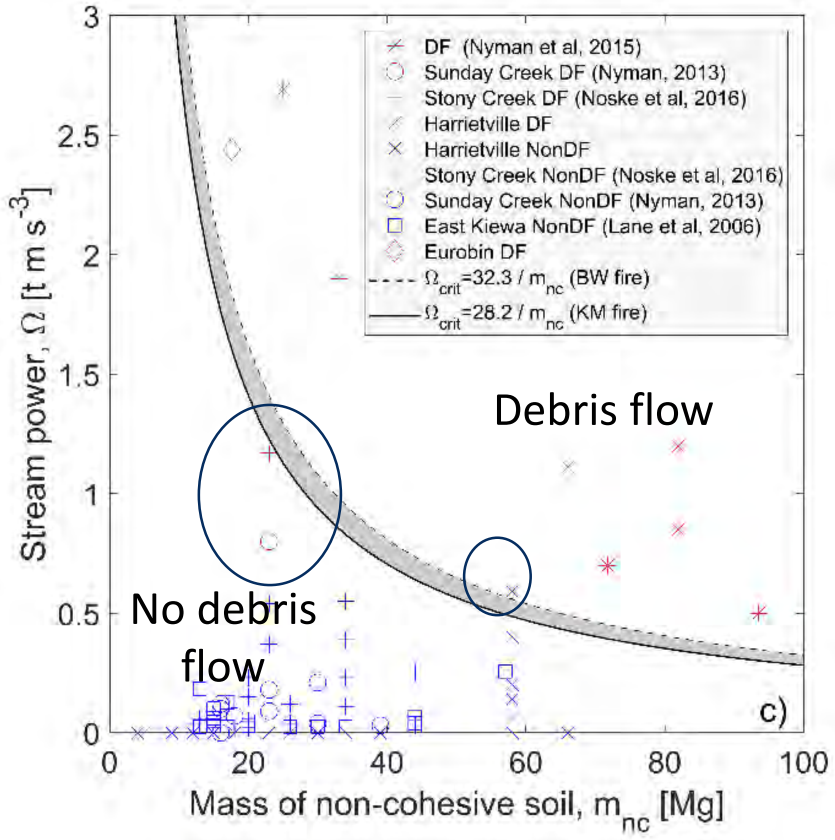
- Debris flow thresholds determined in zero-order headwaters
- Debris flow load determined at the outlet of first-order drainages (Nyman et al 2015)



Model evaluation – debris flow occurrence

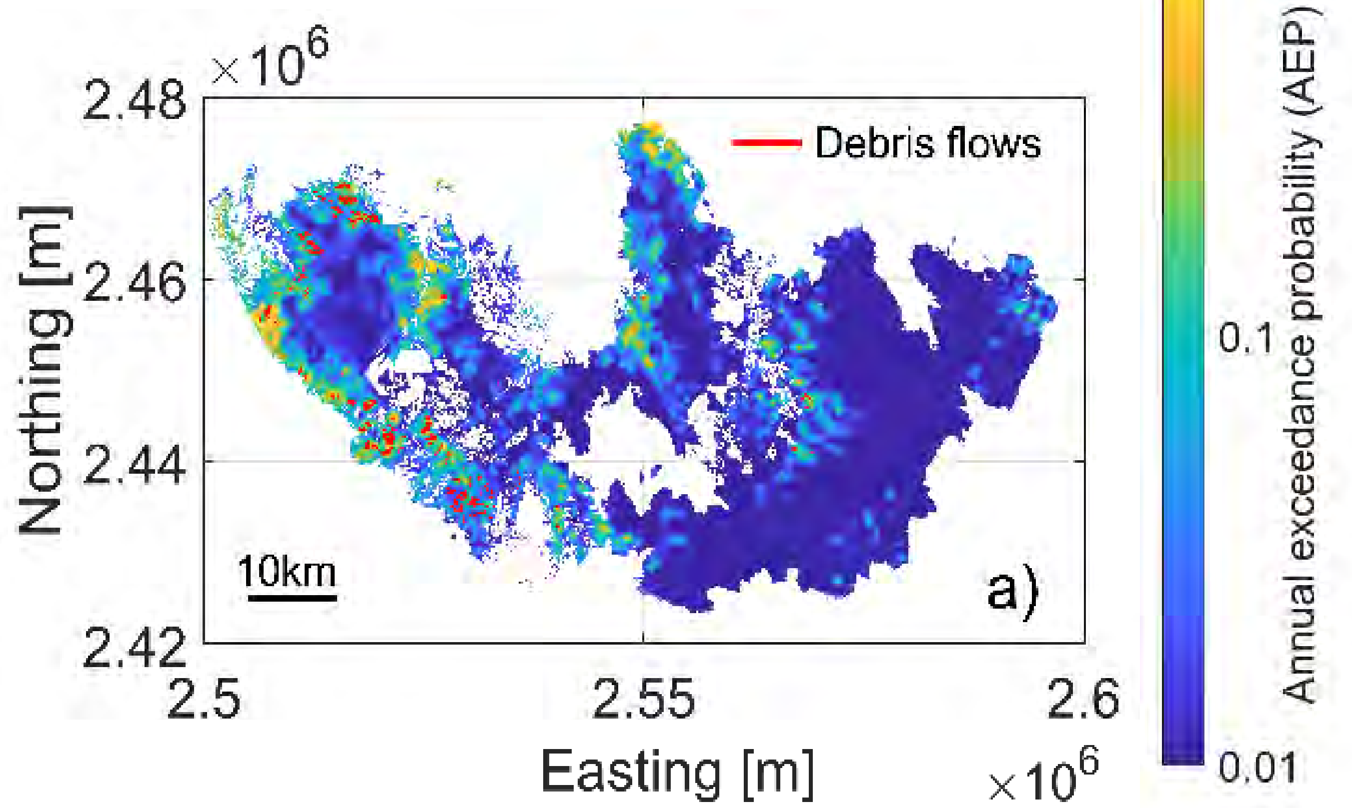
Debris flow thresholds – model evaluation

- Model does pretty good job of predicting debris flows
- 2 false negatives (20%), 1 false positive (~1%)



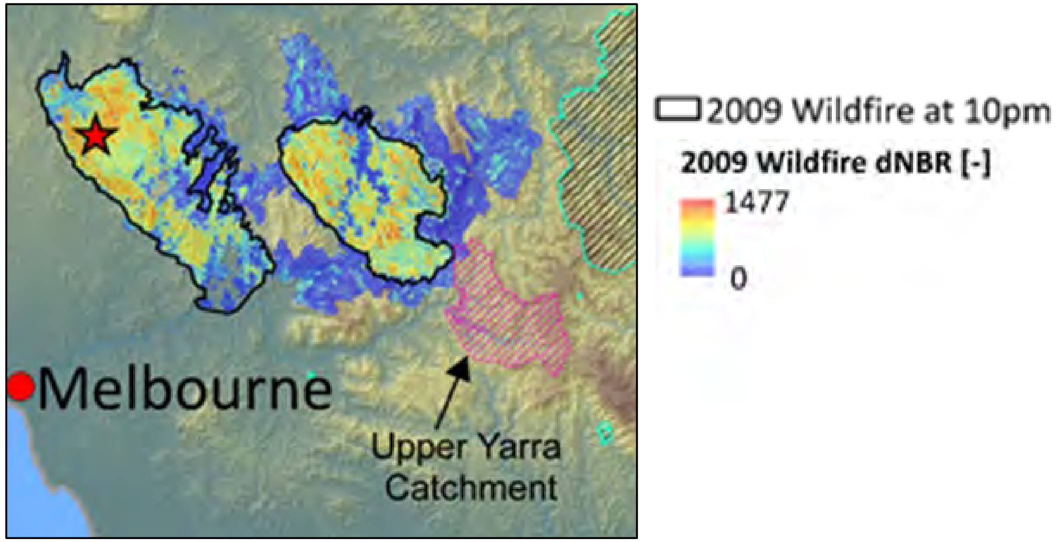
Kilmore-Murrundindi fire (2600 km^2: 440 debris flows)

- Debris flow observed in 7% of first-order headwater
- Expected debris flow response from model = 4%

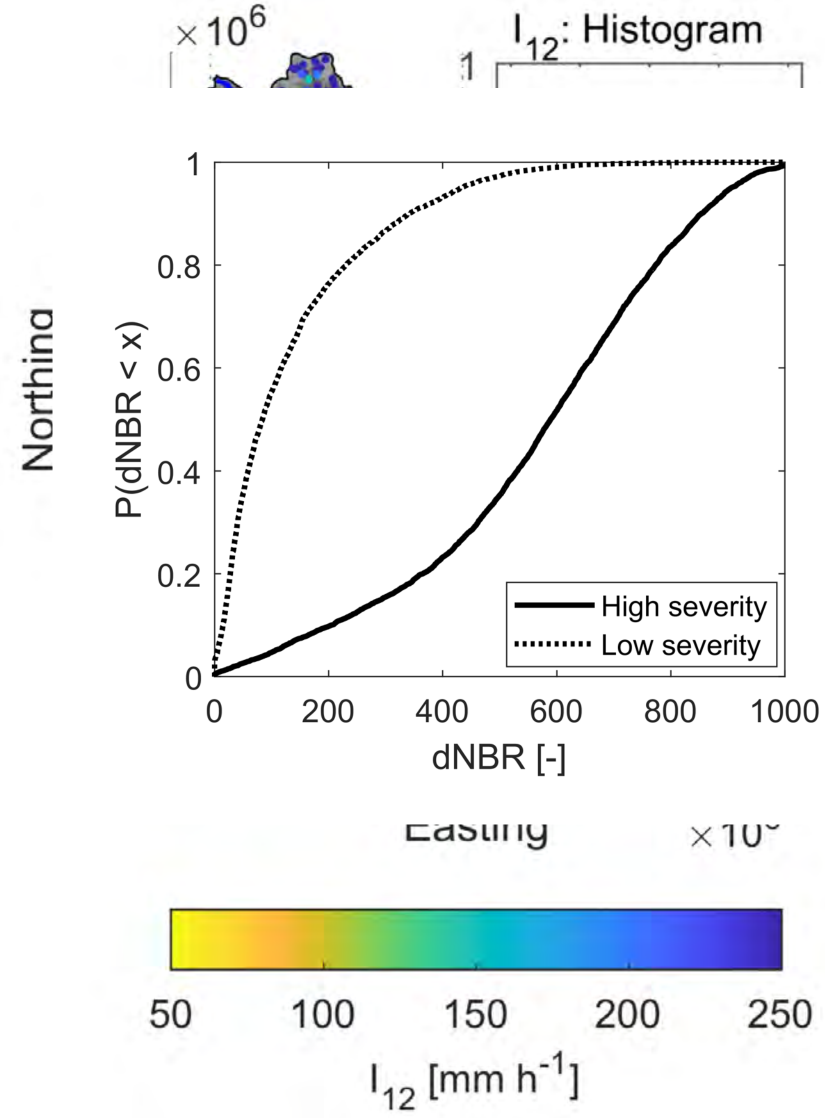


Upper Yarra case study – debris flow thresholds

- Two fire severity scenarios based on 2009 Black Saturday Wildfires
  - High severity during peak fire activity (before 10pm)
  - Low severity for subsequent days (after 10pm)
- Distribution applied randomly to zero-order headwaters in the catchment



Rainfall thresholds



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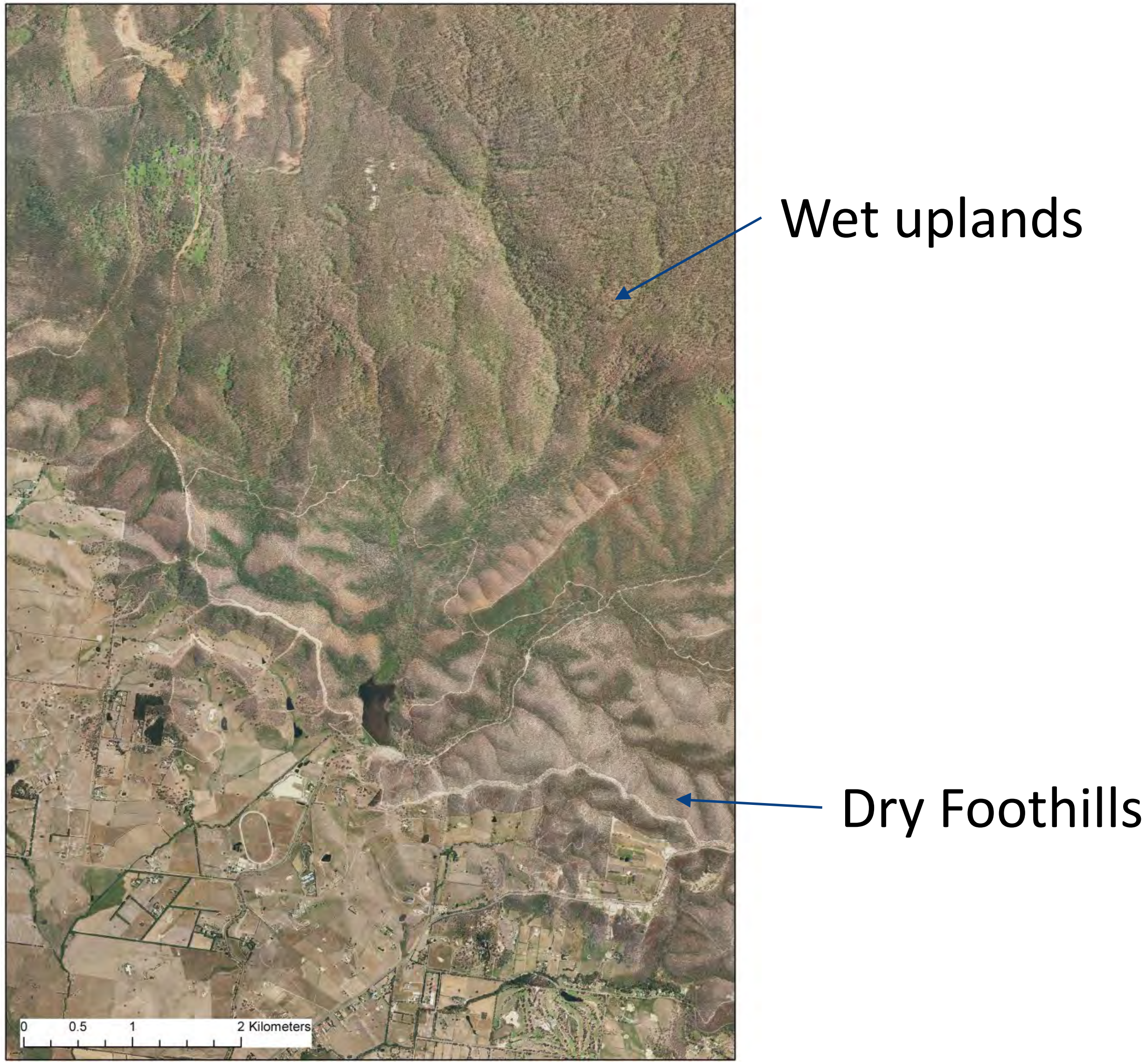
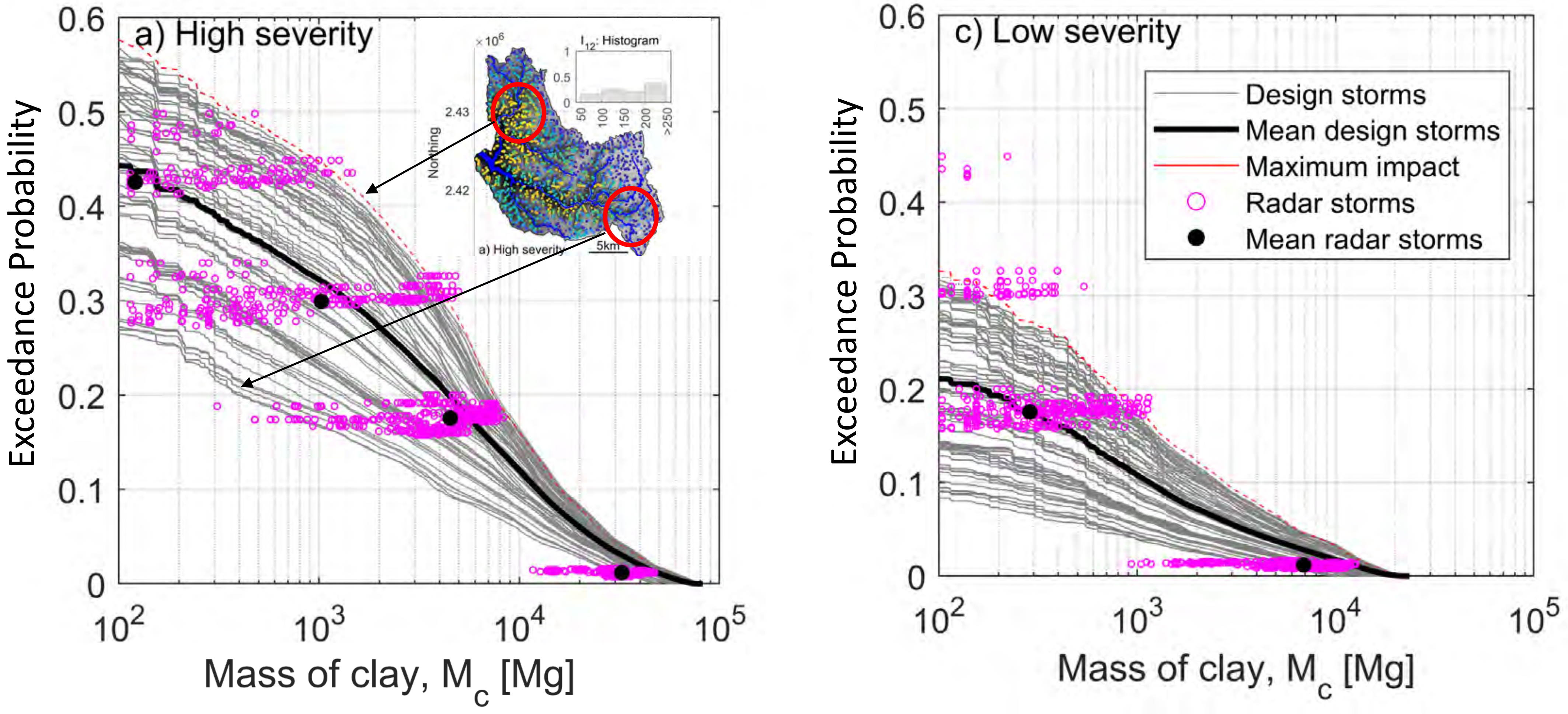


Upper Yarra case study – the threat

Exceedance probability of clay inputs to the reservoir after a wildfire

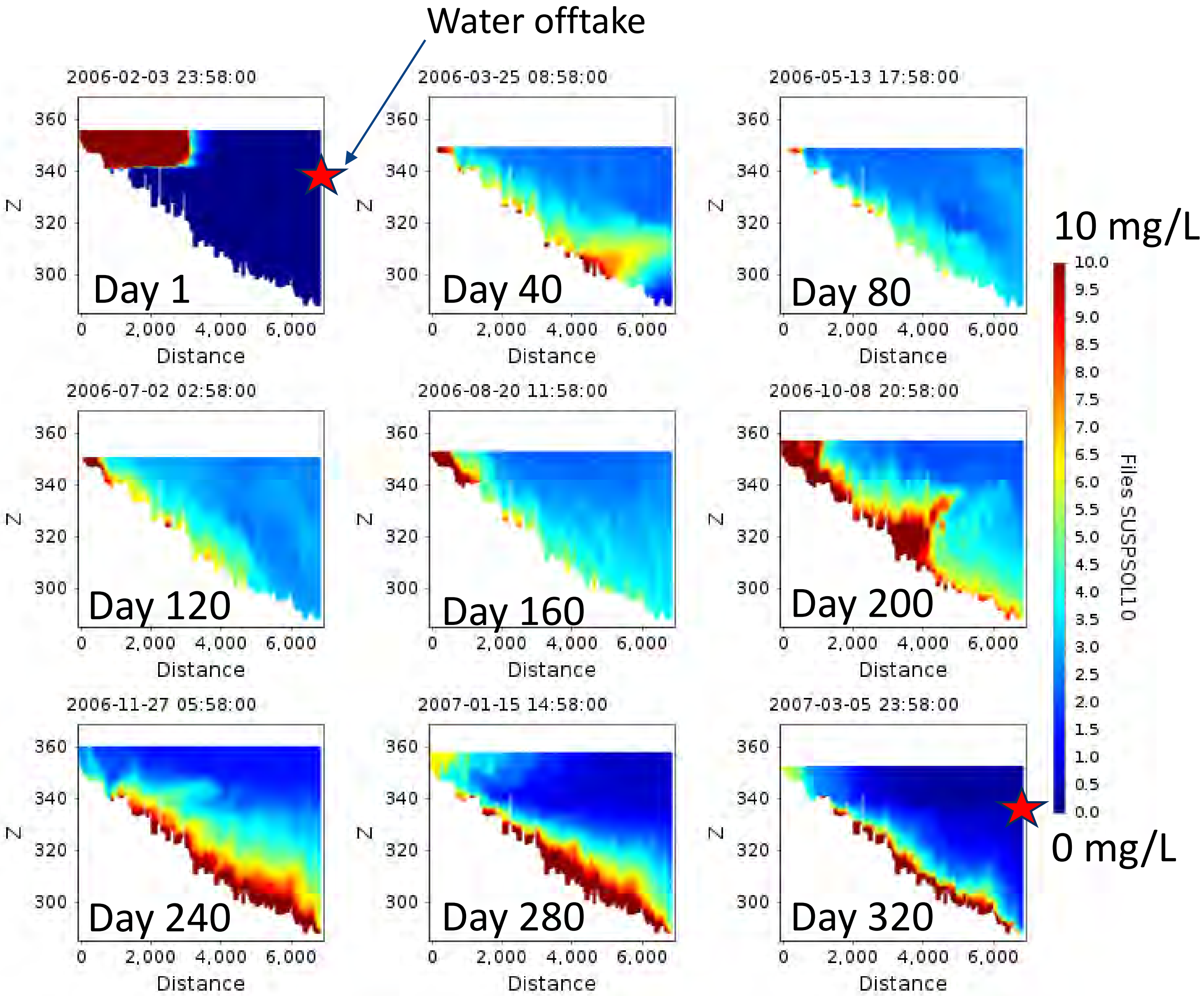


Upper Yarra case study- the consequence

Hydronumerics Pty Ltd

Propagation of sediment (30,000 m^3) plume in reservoir:

- Three-dimensional Aquatic Ecosystem Model (AEM3D): Navier-Stokes equations for incompressible flow.
- Sediment in suspension (**4µm size-class, 0.004mm**)
- Sediment concentration > treatment threshold (~5mg/L) at offtake for 0 days



Upper Yarra case study- the consequence

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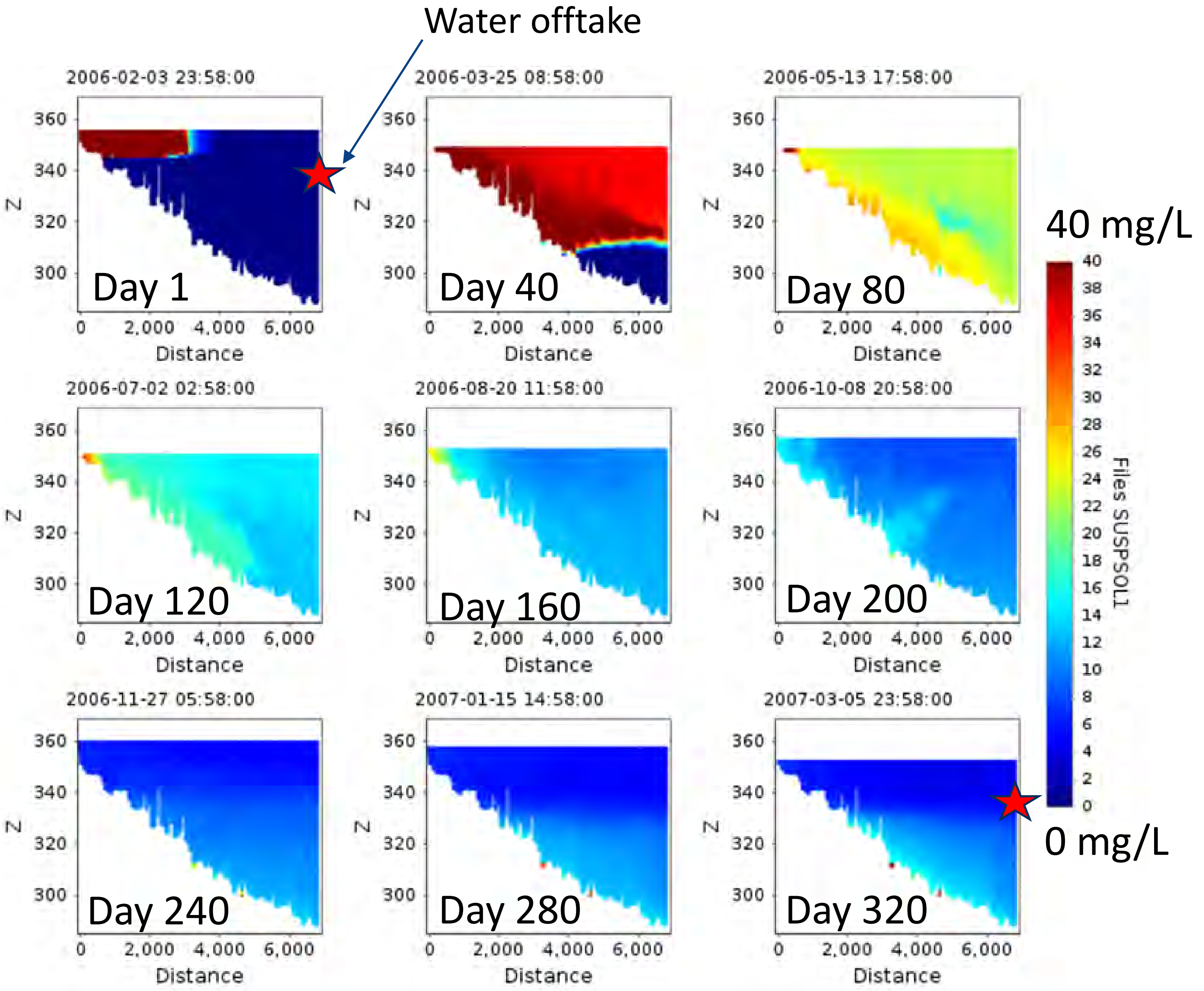
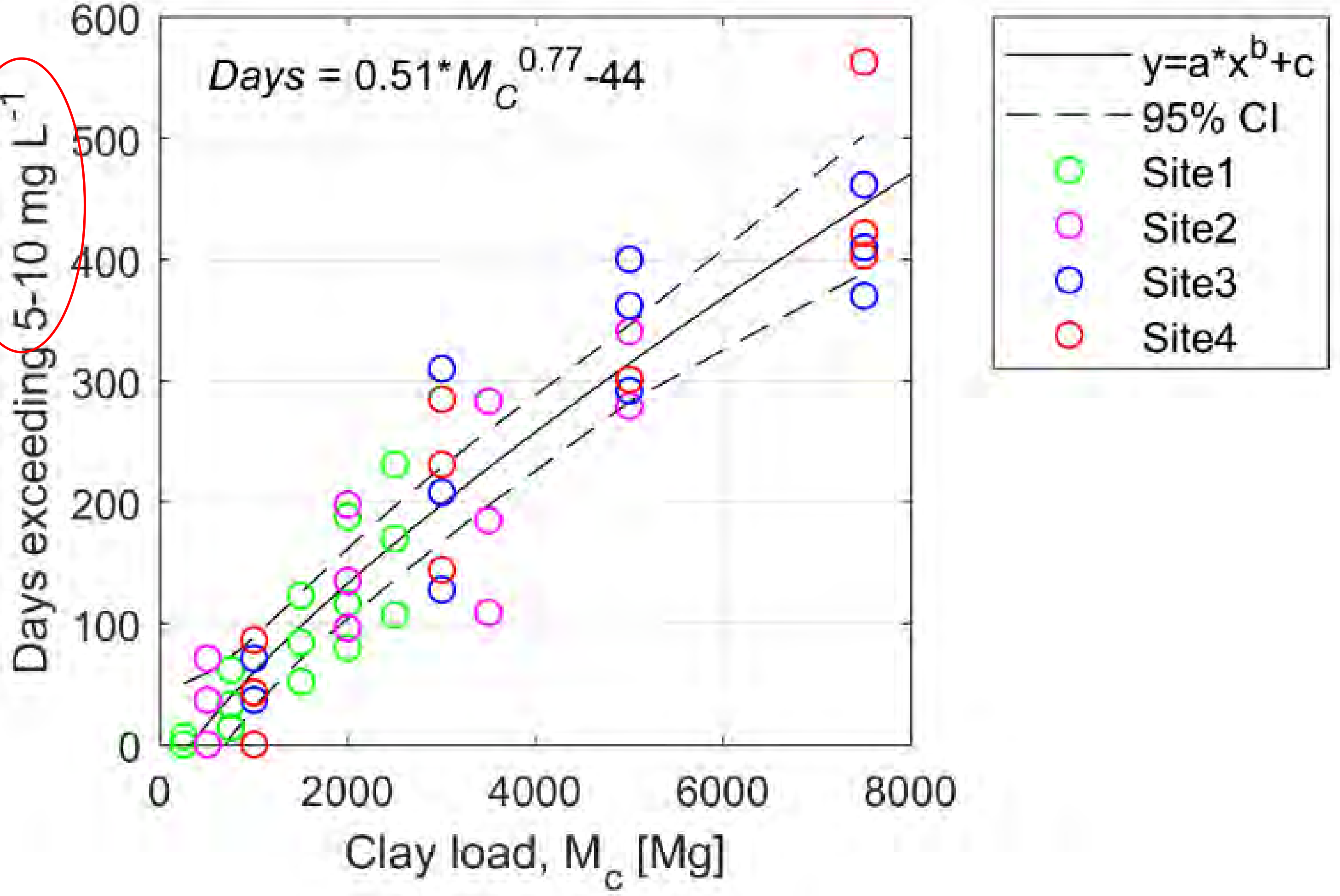
Propagation of sediment (30,000 m^3) plume in reservoir:

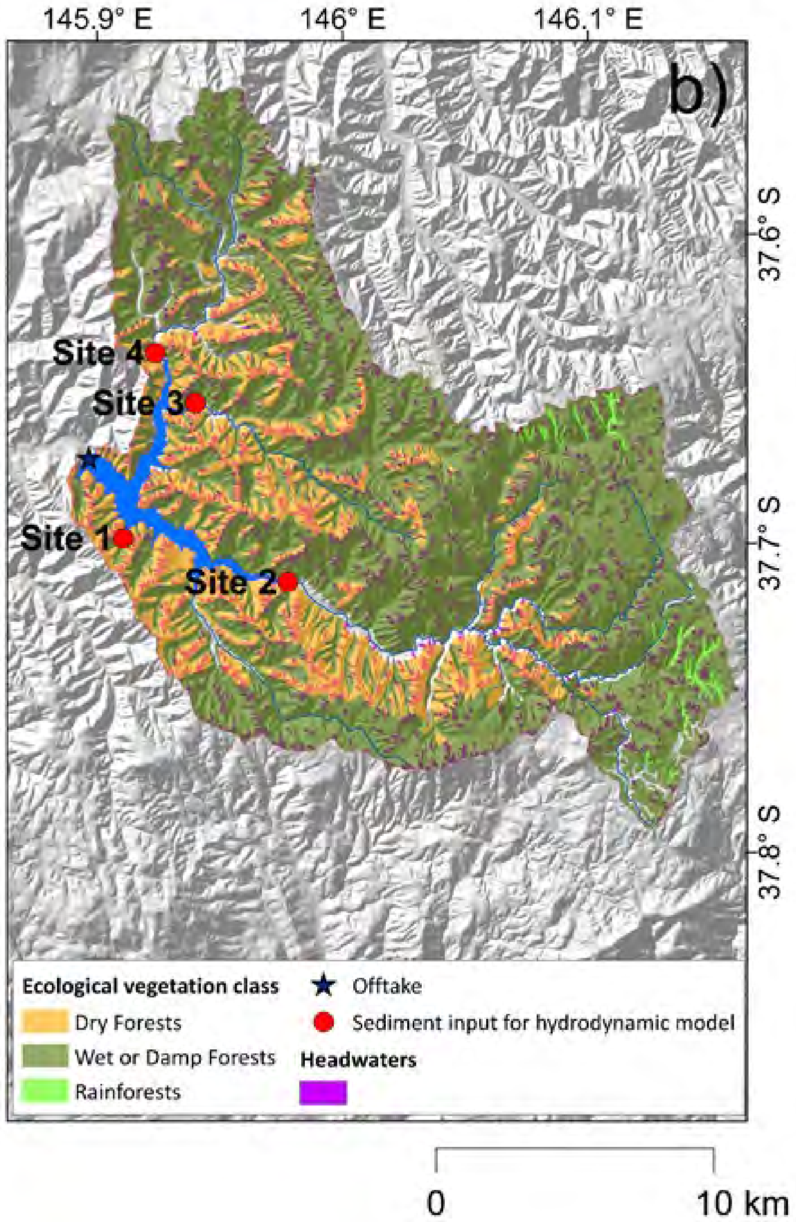
- Sediment in suspension (**1µm size-class, 0.001mm**)
- Sediment concentration above treatment threshold (~ 5mg/L) at offtake for > 300 days



Upper Yarra case study – the consequence

~UY treatment threshold

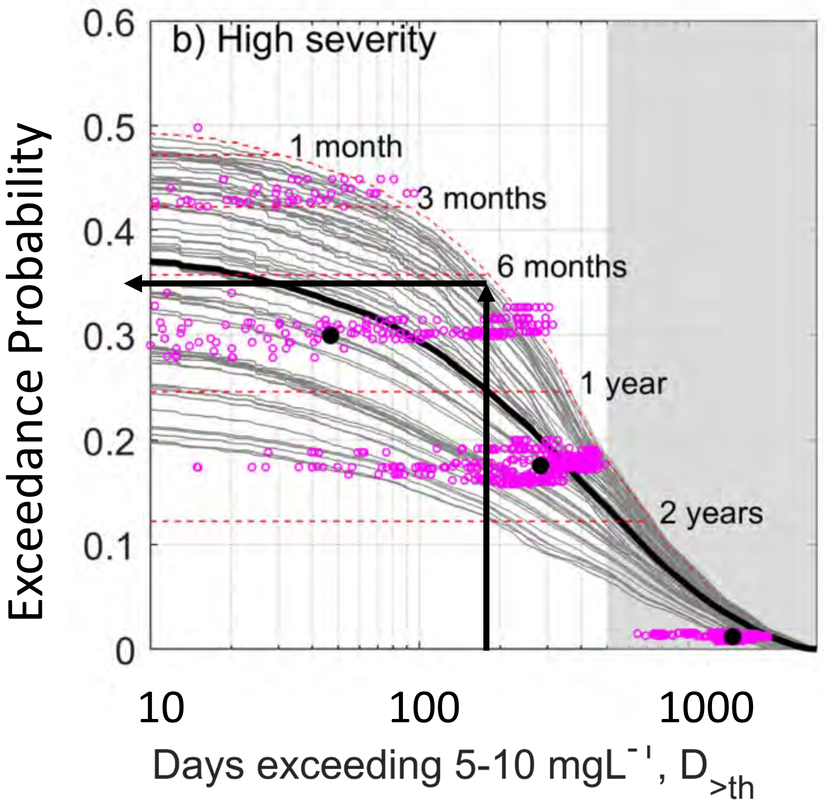


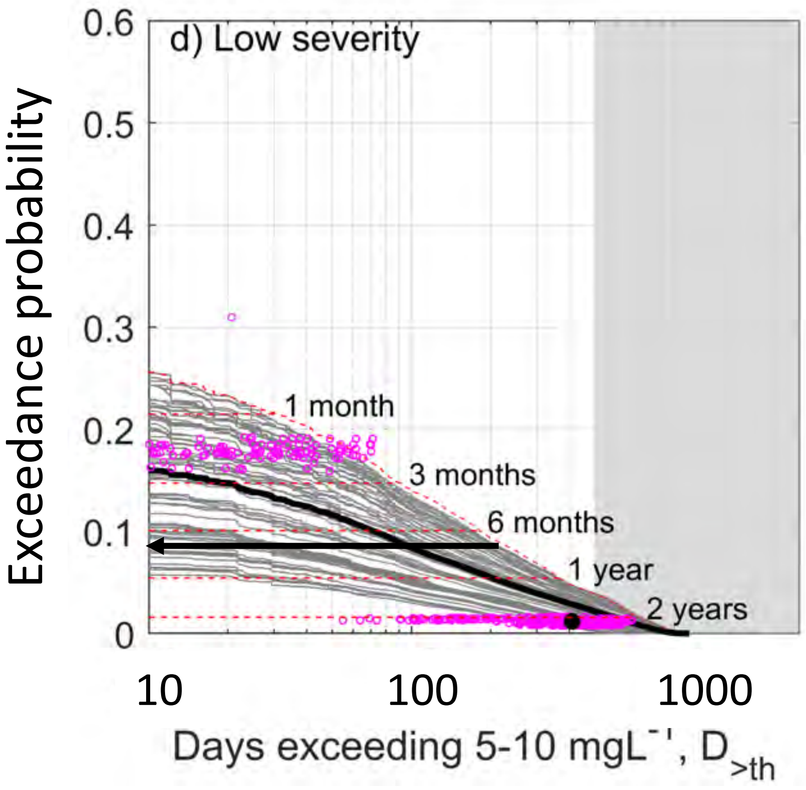


Upper Yarra case study – the consequence

We can predict the number of days that sediment concentration at Upper Yarra water offtake exceed treatment thresholds

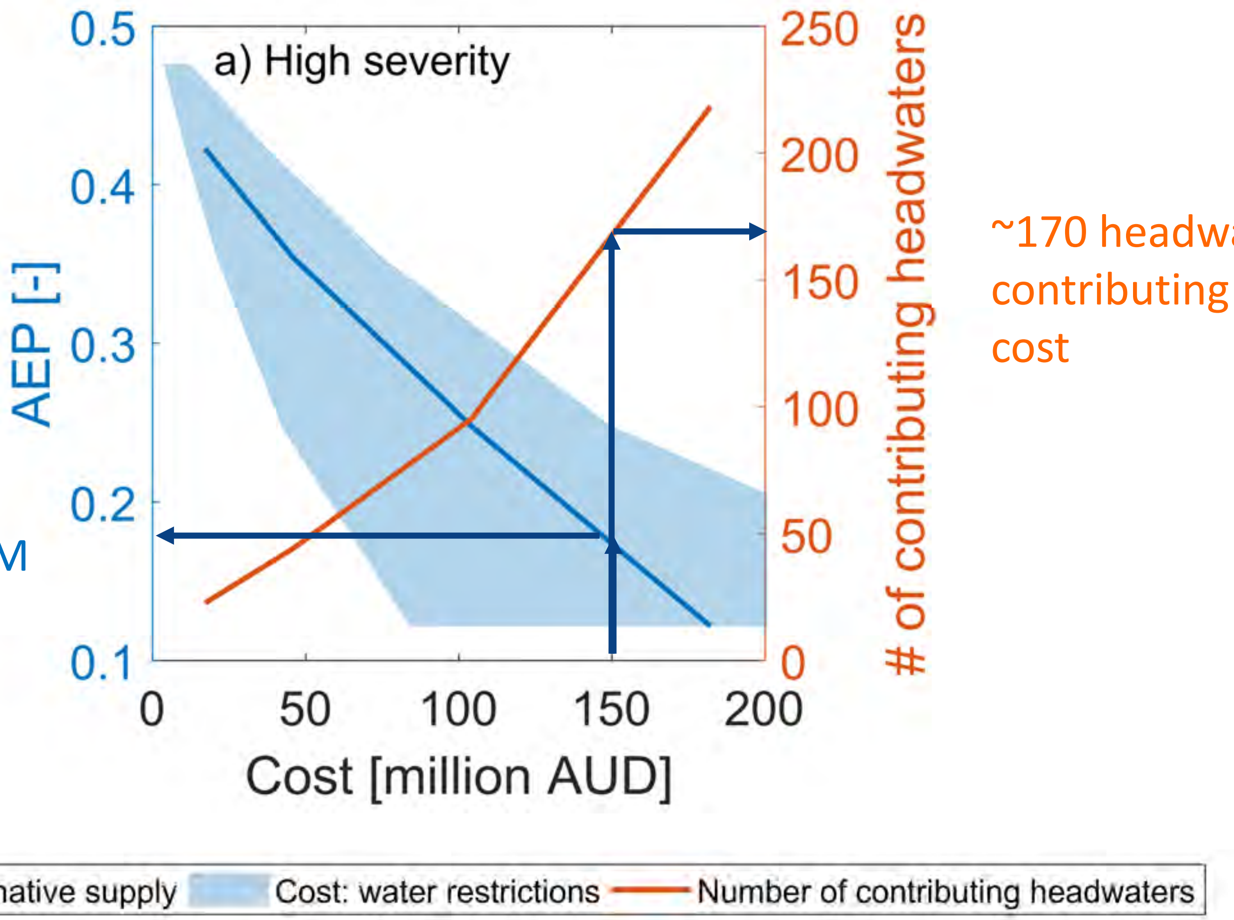
~35% chance that turbidity exceed treatment capacity for at least 180 days





Upper Yarra case study – the consequence

What does this mean in terms of cost?



~20% chance of the cost being greater than $150M

~170 headwaters contributing to that cost

Summary

- Modelling approach provides a means for **translating threat (geomorphic response) to potential cost.**
- After high severity wildfire there is a **25-50% chance** of water supply **interruption lasting several months to a year**.
- The threat from post-fire erosion and debris flow is increasing.
  - **Stronger and more frequent La Nina** and **increase frequency of extreme fire weather** means more fire.
  - **15% increase in hourly rainfall intensities** per every degree of warming.

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Thank you

Risk mitigation

- **Reduce exposure to high severity wildfire. How?**
  - Strategic fire breaks (a large part of MW fire management strategy)
  - First attack response - many successful first-attacks in summer 2019
  - Fuel management to promote low severity and patchy fires
    - *Not much leverage to reduce the extent of wildfire with fuel reduction. But what about fire severity?*

Risk mitigation

- **Increase preparedness for a post-fire response**
  - Understand the threat (magnitude, spatial distribution, etc in different fire scenarios)
  - Facilitate rapid response following a fire
    - Map out the relevant legislation, logistics and processes for inter-agency response.
  - Understand constrains and opportunities for erosion/sediment control.
    - Can existing infrastructure provide opportunities?
    - Effectiveness of hillslope and channel structure in reducing erosion and trapping clay?

Existing infrastructure – Swingler Weir

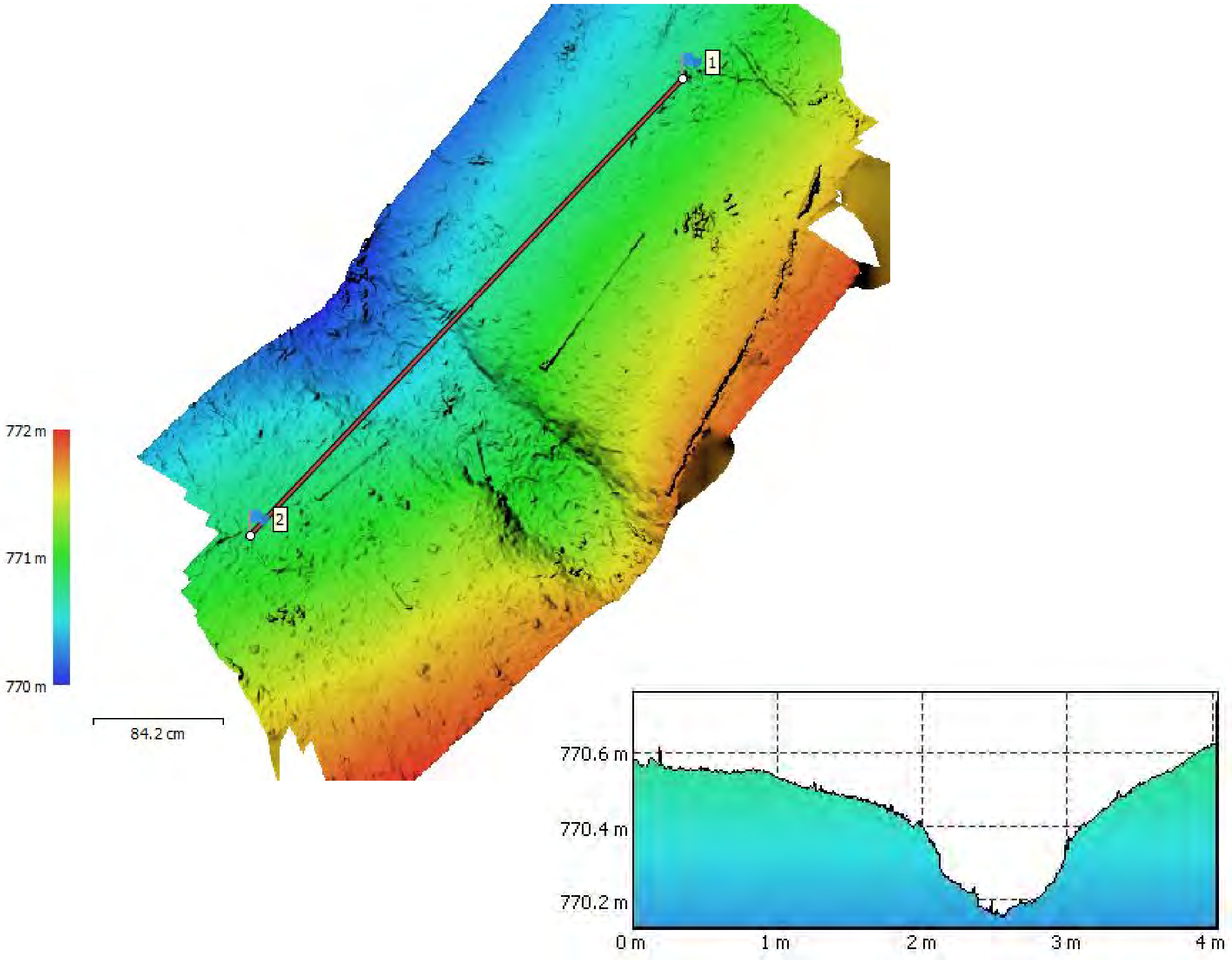
Mitigation – opportunities?

Mitigation – opportunities?

Mitigation - the Thomson Fire case study

~1.5 km of debris barriers on hillslopes
(15 crew over 2-3 weeks)

Risk mitigation – evaluating effectiveness of erosion control



Mitigation - the Thomson Fire case study