AUSTRALIAN RAINFALL & RUNOFF 2016 – WHAT'S GONE WRONG?

(WITH RURAL FLOOD ESTIMATION)

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Part 1 – development of Australian rainfall & runoff 2016

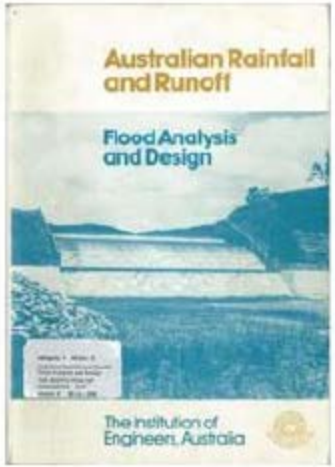
Part 2 – review of Australian rainfall & runoff 2016

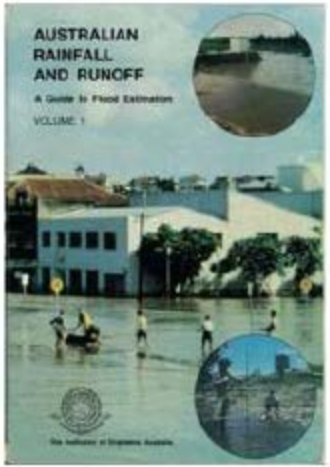
WHAT IS AUSTRALIAN RAINFALL & RUNOFF (ARR)

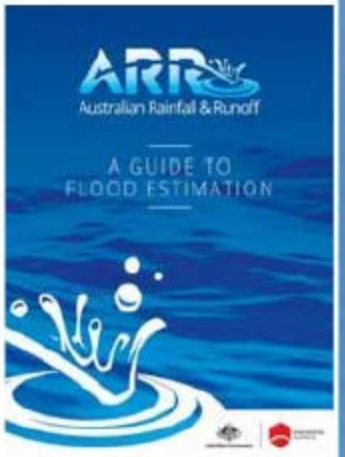
- For the calculation of flows and flood behaviour, both urban & rural
- Guideline not a standard as Australia is too diverse and hydrologic behaviour and the nature of hydrologic problems varies greatly
- ARR is not prescriptive because of this

HISTORY

- 1958 – Version 1
- 1977 – version 2
- 1987 – version 3
- 1999 - Version 3.1 update for extreme floods
- 2016 – version 4







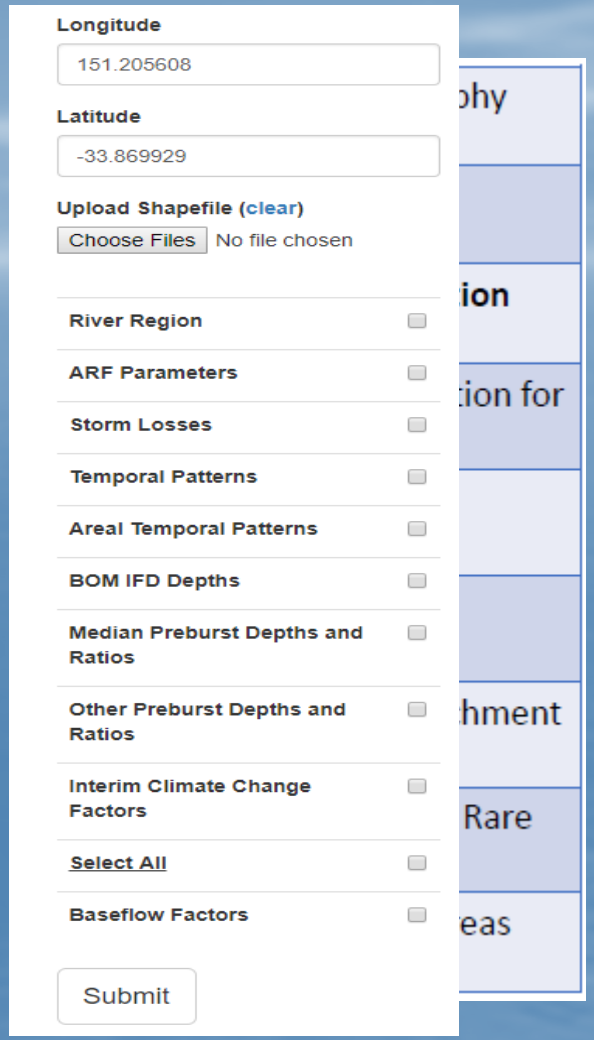
BACKGROUND TO ARR 2016

- ARR2016 was a 8 year project that commenced in 2008 with 9.15million of government funding
- Project has involved:
  - BoM. Geoscience Australia, CSIRO and state agencies
  - Many universities: UTV, UWS, UNSW, UniSA, University of Newcastle, The University of Adelaide and the University of Melbourne
  - Many consulting firms

ARR 2016 PROVIDES…

- **The guideline**
  - Guideline consisting of 9 books: accessed through interactive web page http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

- **Data**
  - Data Hub - http://data.arr-software.org/
  - IFD - http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016



ARR 2016 PROVIDES…

- **Software**
  - RFFE **-** http://rffe.arr-software.org/
  - FLIKE for at-site FFA -https://flike.tuflow.com/purchase-flike/ (not directly via ARR)
  - Interaction of coastal and ocean flooding **-** http://p18.arr-software.org/
- **Supporting documents**
  - Two dimensional modelling in urban and rural floodplains
  - Monte Carlo simulation techniques
  - Project reports - http://www.arr-software.org/project_reports.html
- **Use of information**
  - Document is creative commons

KEY CHANGES

- **Objective and approach**
  - Principal objectives of ARR remain as presented in previous versions
  - ARR 2016 follows the general approach of ARR 1987
- **Updates**
  - Range of updated approaches to accommodate change in technology and engineering business since 1987
  - Computer based and GIS based, minimize human errors
  - Design rainfalls, rainfall spatial and temporal patterns, areal reduction factors
- **Focus** (e.g. flood estimation for small to medium catchments)
  - ARR 1987 - state wide procedure (at varying quality and reliability)
  - ARR 2016 - Australia wide procedure

KEY CHANGES CONT..

- **Use of data**
  - ARR 1987 had limitations in data availability (e.g. 6000 DRG and 750 CR)
  - ARR 2016 use of data in developing new procedures (e.g.15367 DRG and 2722 CR)
  - Encouraged to use local data in projects

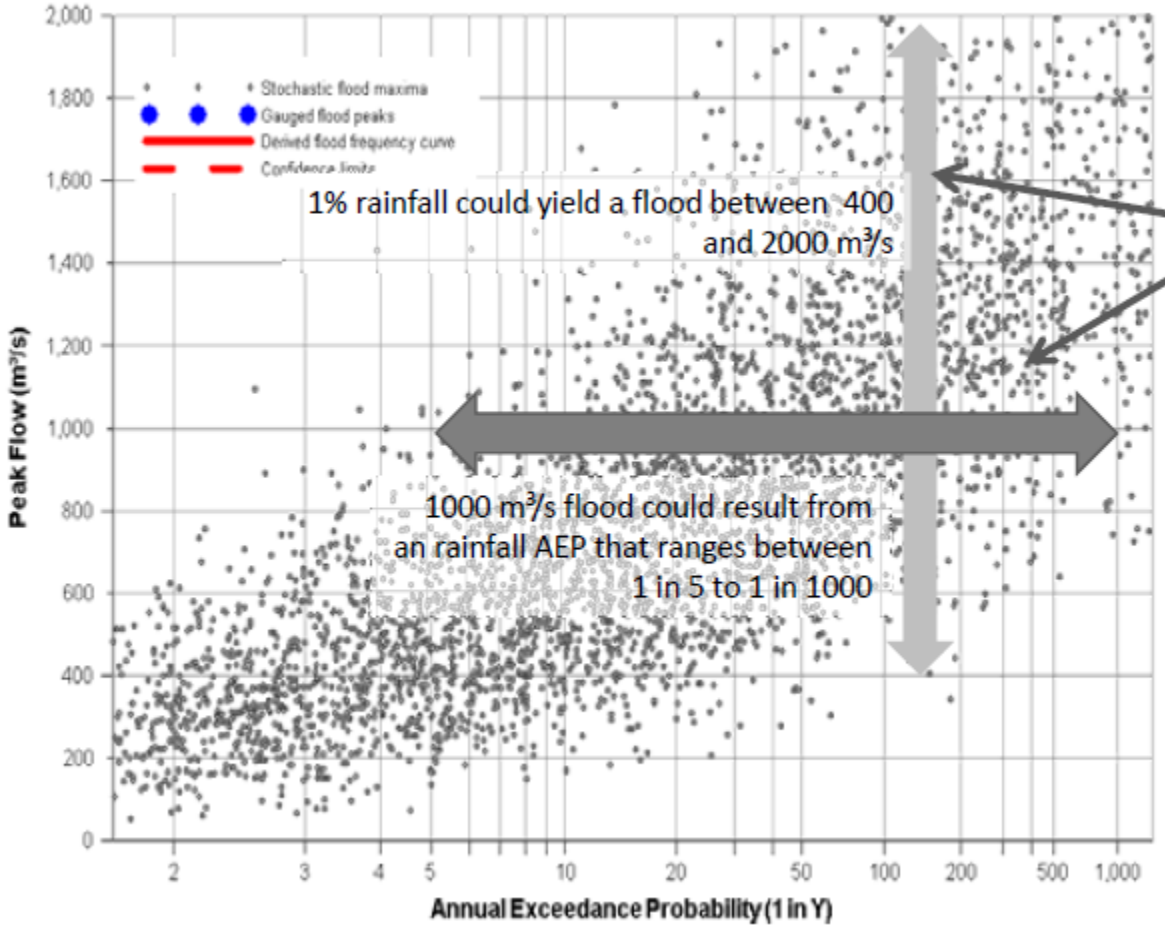
KEY CHANGES CONT..

- Terminology
  - To have a technically correct, practical and understandable terminology
  - Annual Exceedance Probability (AEP) versus Average Recurrence Interval (ARI)
  - For floods larger than 10% AEP, little practical difference between the two

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
Rare	0.11	10	10	9.49
	0.05	5	20	20
	0.02	2	50	50
Very Rare	0.01	1	100	100
	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
Extreme	0.0005	0.05	2000	2000
	0.0002	0.02	5000	5000
			PMP/ PMPDF	

KEY CHANGES CONT..

- **Rainfall based flood estimation: Account of variability (A major change)**
- Move away from design flood for defined probability level
- Developed robust methodology to consider variability in floods
  - Temporal pattern ensembles and
  - Monte Carlo analyses



Possible flood peaks resulting from rainfall of a given AEP

Wide range due to variation in antecedent conditions, losses, temporal patterns, spatial patterns

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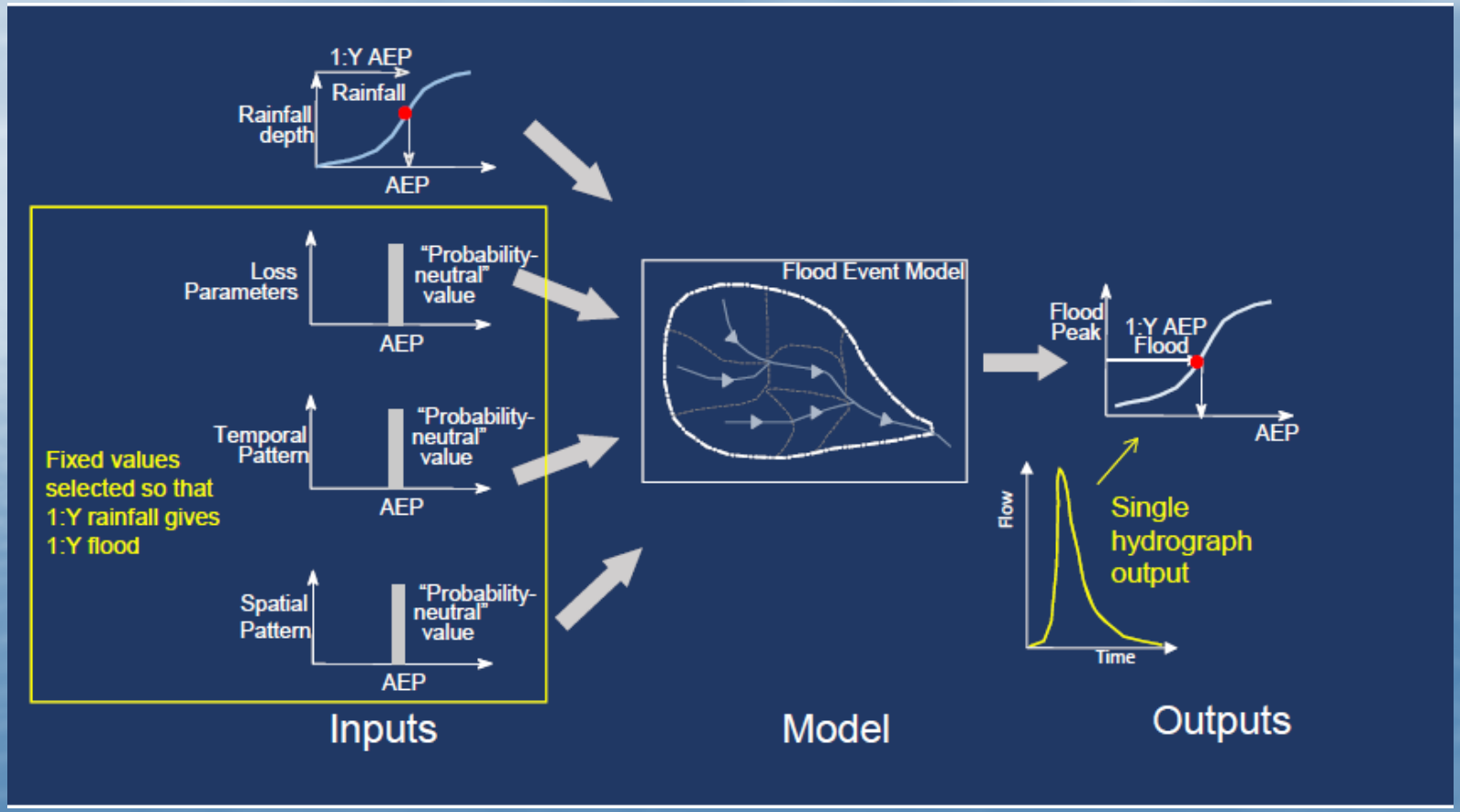
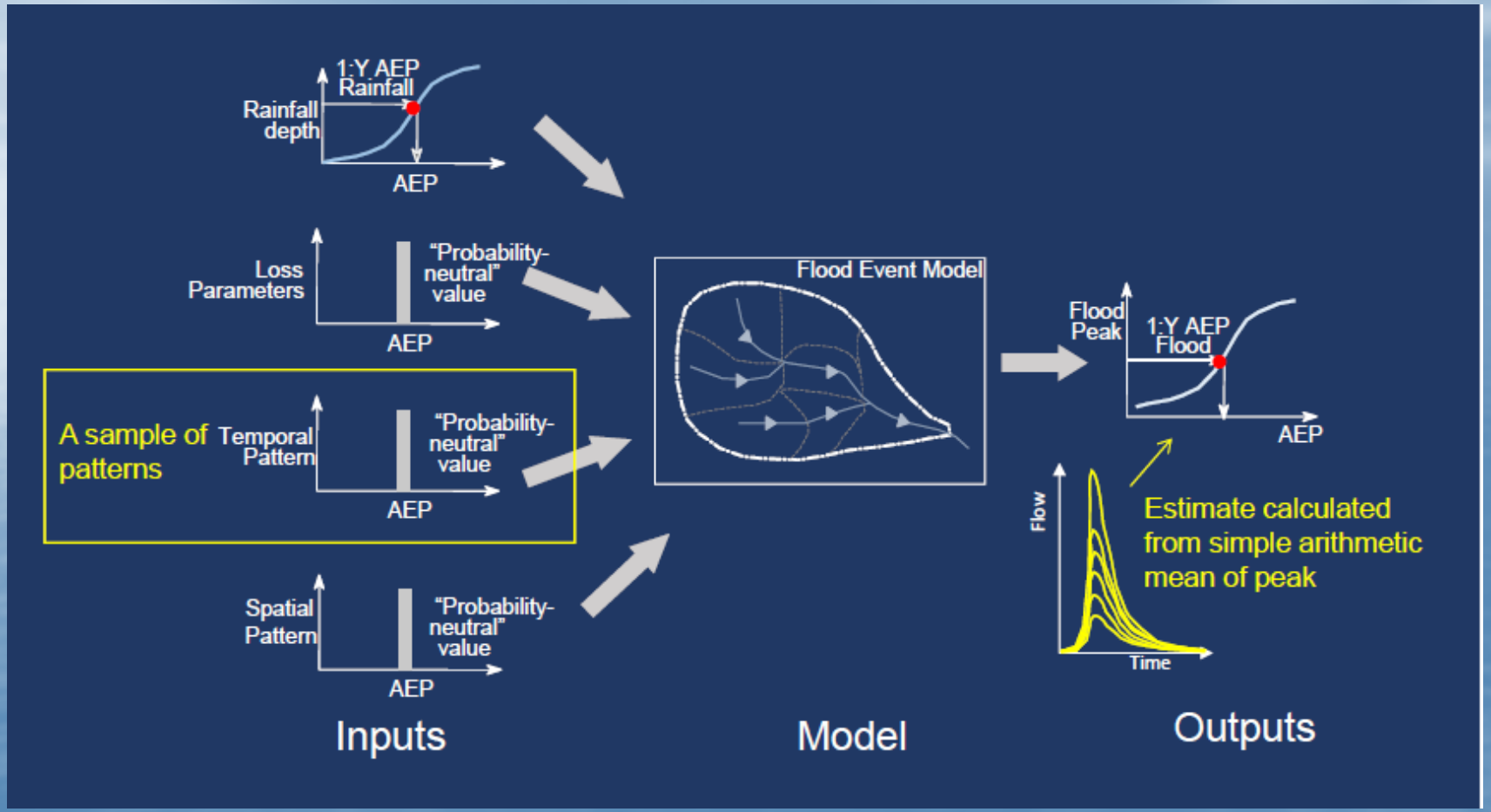
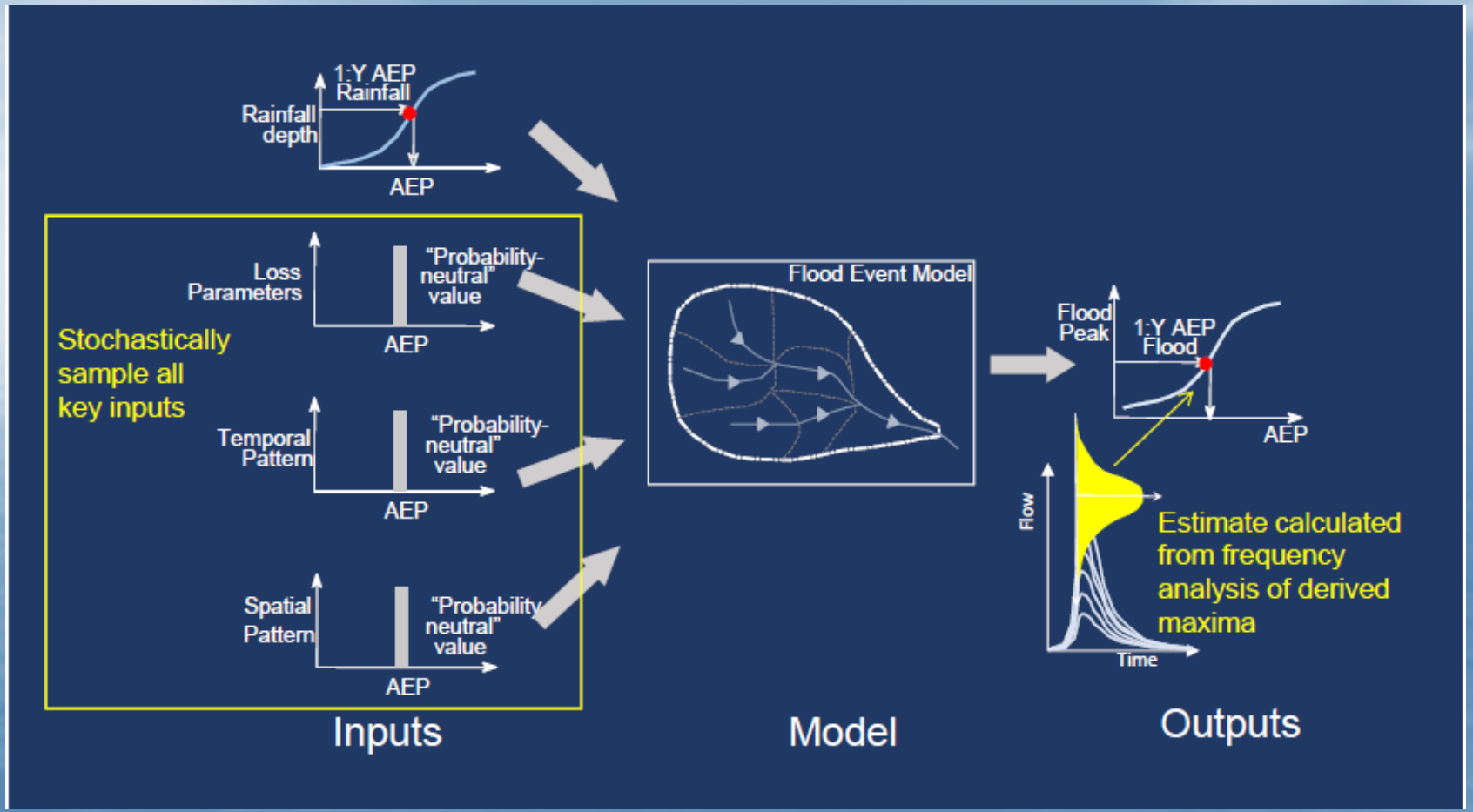
SIMPLE EVENT APPROACH



ENSEMBLE EVENT APPROACH



MONTE CARLO EVENT APPROACH



KEY CHANGES CONT..

- **Runoff based flood estimation**
  - At-site FFA by FLIKE tool (LPIII/MOM, GEV/L distributions)
  - RFFE: ARR2016 has a common approach across Australia.
  - RFFE: through regression analysis of distribution parameters
  - Regions defined by “Region of Influence” approach based on distance between the catchments
  - Estimation for ungauged catchments must therefore be done by software – no regional equations as per ARR1987.

CATCHMENT DATA

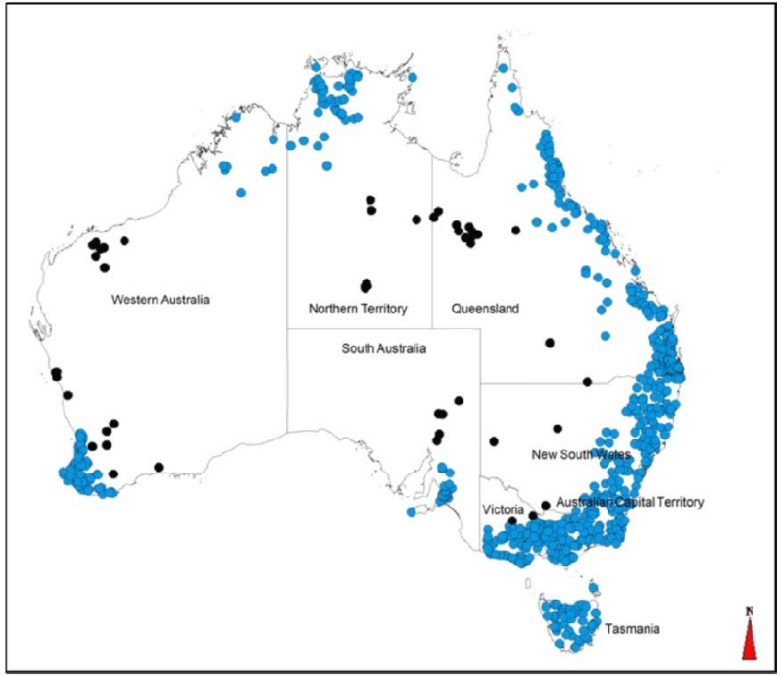


Figure 2.28 Geographical distribution of the selected 853 catchments (data-rich and arid areas)

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RFFE - HTTP://RFFE.ARR-SOFTWARE.ORG/

Regional Flood Frequency Estimation Model

Release Version of the Regional Flood Frequency Estimation Model for the 4th edition of Australian Rainfall and Runoff.

Australian Rainfall & Runoff

Input Data

Basic | Advanced

Catchment Name
Scott Creek

Catchment Outlet Latitude
-35.1

Catchment Outlet Longitude
138.68

Catchment Centroid Latitude
-35.067

Catchment Centroid Longitude
138.696

Catchment Area (km²)
26.8

Submit

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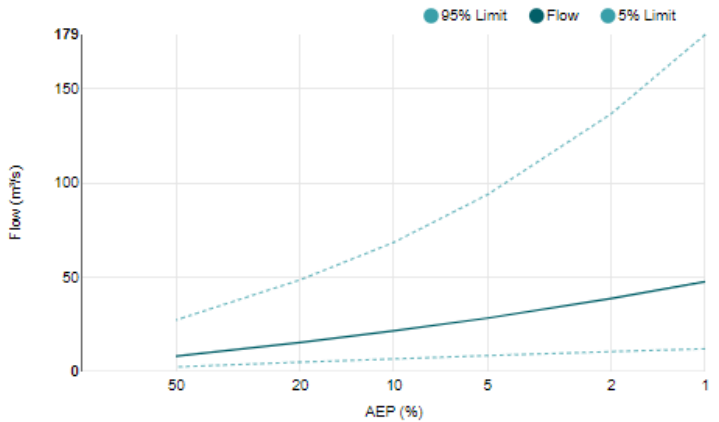
RFFE SUMMARY OUTPUT



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	8.24	2.47	27.4
20	15.5	4.98	48.7
10	21.6	6.73	68.6
5	28.4	8.49	94.0
2	38.8	10.6	137
1	47.7	12.1	179

Variable	Value	Standard Dev
Mean	2.114	0.723
Standard Dev	0.744	0.319
Skew	0.039	0.259

Note: These statistics come from the nearest gauged catchment. Details.

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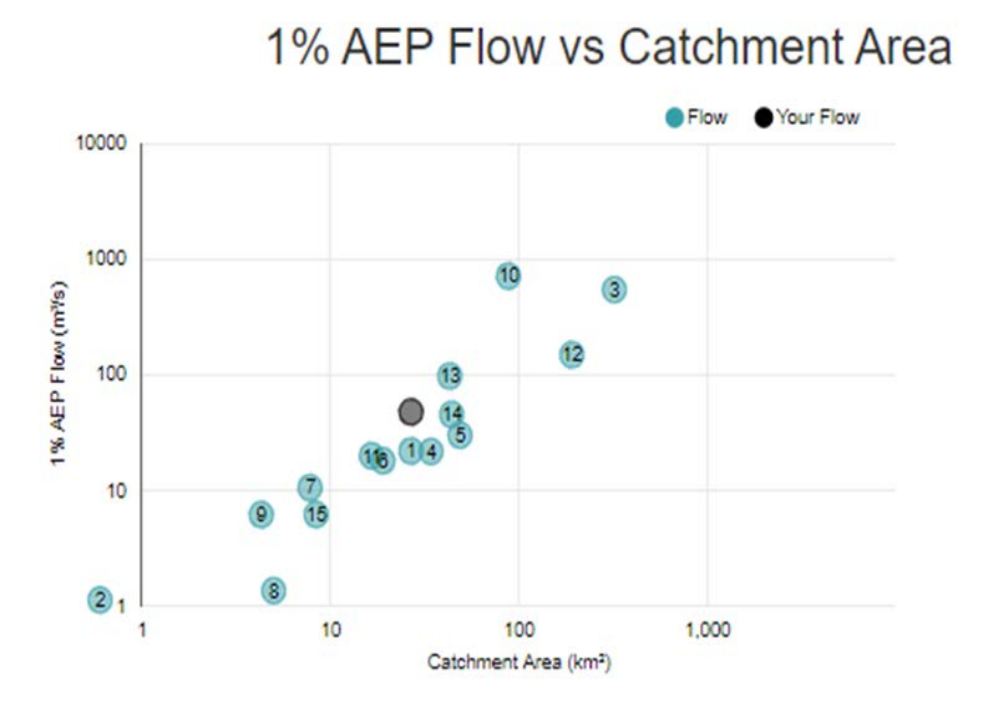
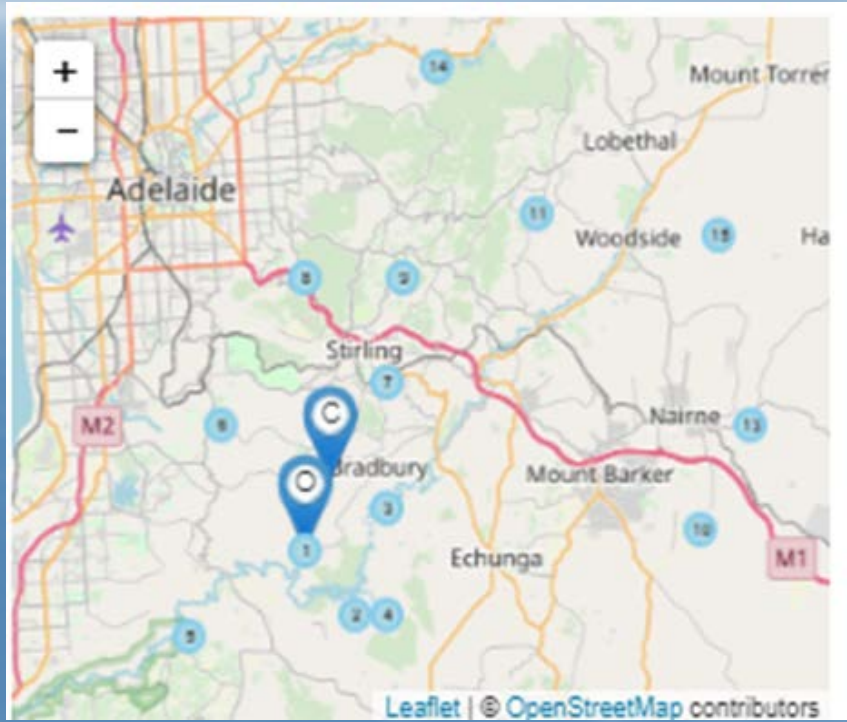
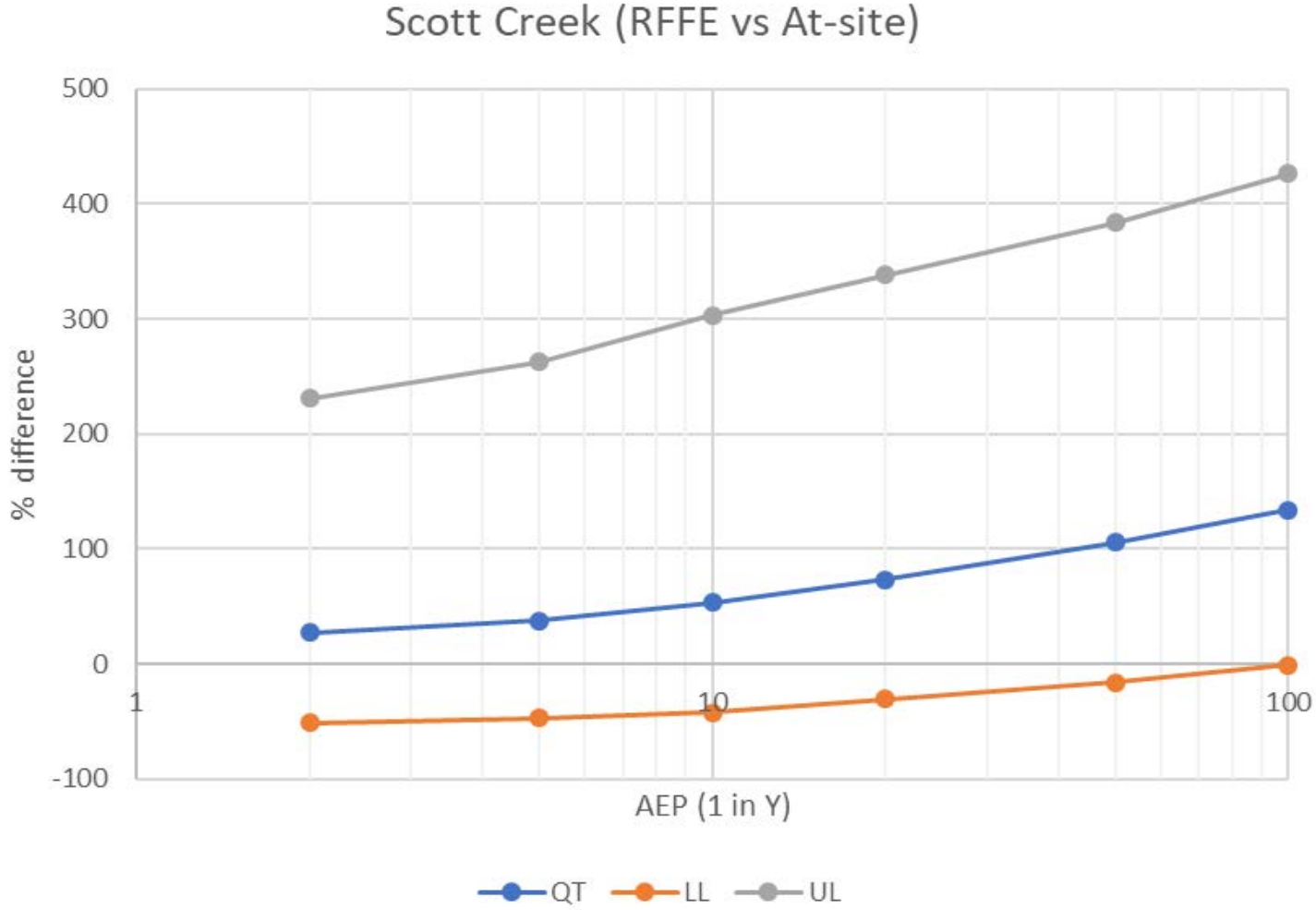
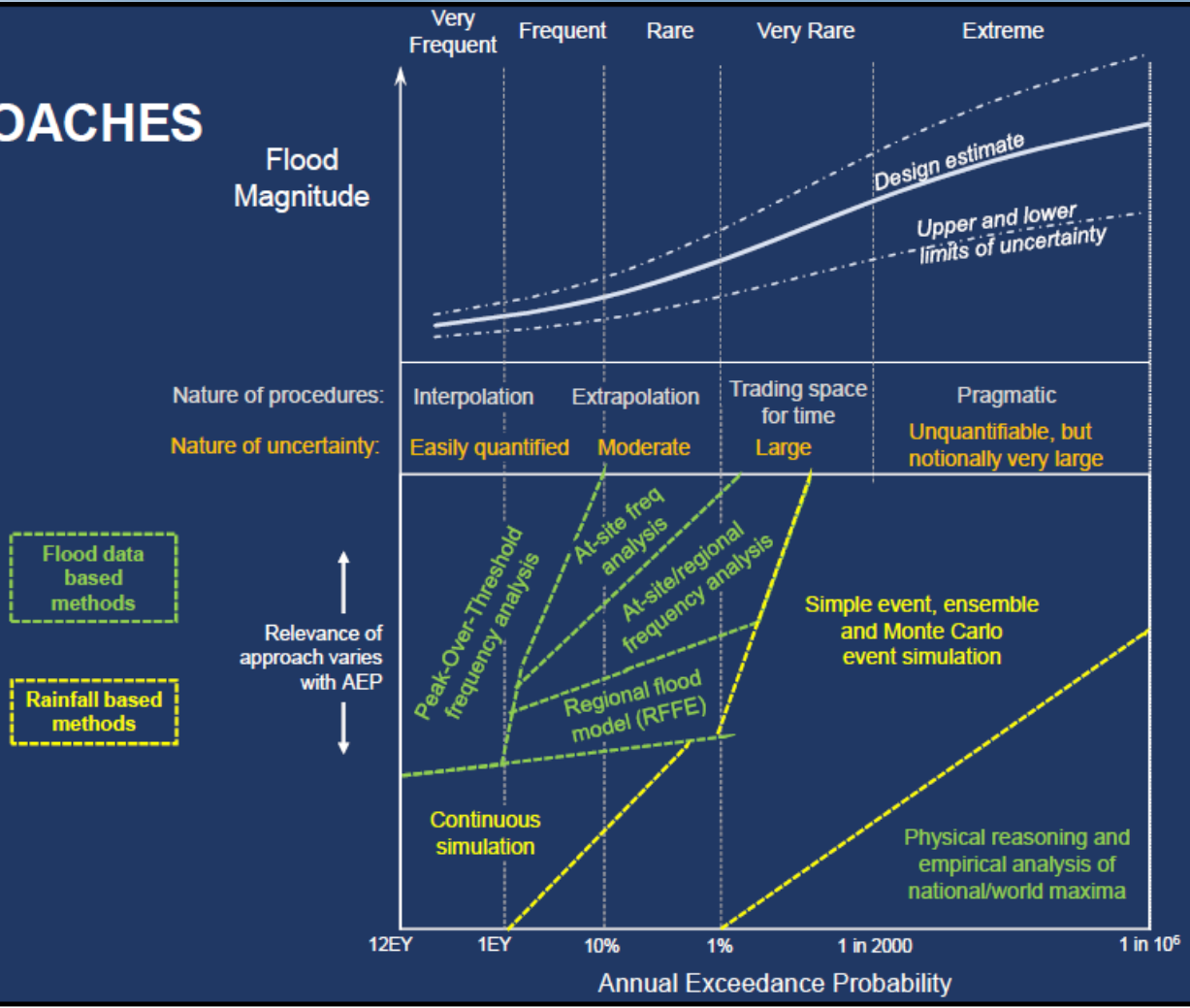
RFFE OUTPUT


1% AEP Flow vs Catchment Area
Flow
Your Flow
10000
1000
100
10
1
1% AEP Flow (m³/s)
1
10
100
1,000
Catchment Area (km²)


Adelaide
Lobethal
Woodside
Stirling
Nairne
Mount Barker
Echunga
M2
M1
Leaflet | © OpenStreetMap contributors


Scott Creek (RFFE vs At-site)
500
400
300
200
100
0
-100
% difference
1
10
100
AEP (1 in Y)
QT
LL
UL

RELEVANCE OF DIFFERENT APPROACHES



OUR INVOLVEMENT AND CONTRIBUTION

- SA Team: Trevor Daniell, David Kemp, Guna Hewa, Sithara Gamage and Subhashini Wella-Hewage
- Involvement in project 5 of ARR2016, to provide a Regional Flood Frequency (RFFE) procedure.
- 1 journal paper, 3 conference papers and 1 report
- Provided a RFFE for South Australia, but was subsequently overtaken by a whole of Australia approach

THERE ARE OTHER UPDATES

- Synthesis of continuous rainfall sequences.
- Impact of climate change.
- Urban hydraulics, particularly the use of 2D models.
- Treatment of the blockage of structures.
- Interaction of coastal and catchment flooding.

- Acknowledgements: Guna Hewa would like to acknowledge that some of the Figures were taken from the ARR-2016 guideline document and ARR-2016 workshop materials

Part 2 – Review of Australian Rainfall & Runoff 2016

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KEY CHALLENGES

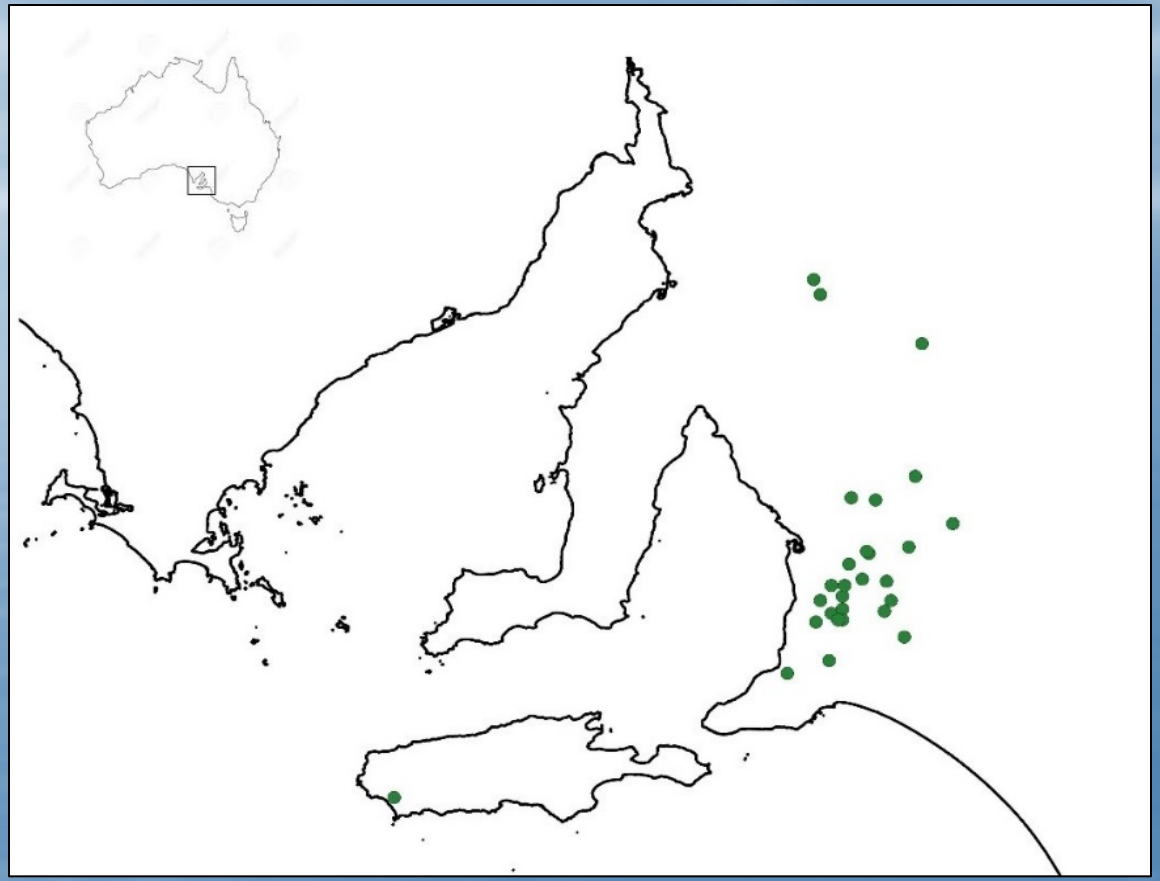
- Losses - No consistent relationship for loss model found for flood flow estimation, based on catchment parameters.
- Monte Carlo simulation *“The conclusions drawn thus far should rightfully shake the confidence of any user of ARR2016. Even though ARR2016 represents the state-of-the-art, the reality is that, despite best efforts, we cannot estimate flood quantiles with much skill.”*

KEY CHALLENGES

- Baseflow separation *“The limitation of the* (recommended) *digital filtering approach is that the derived series do not reflect any underlying physical processes in shape, timing or quantum so it is not possible to make quantitative inferences.”*
- Continuous simulation *“In all the* (tested) *catchments except one, the highest flow peaks were under estimated and the flood frequency curve calculated from simulated annual maximum series provided a very poor fit to the observed flood frequency curve.”*

ASSESSING THE PERFORMANCE OF ARR2016

- Kemp, D.J. and Hewa, G (2018) "*An Investigation into the Efficacy of Australian Rainfall & Runoff 2016 Procedures in the Mount Lofty Ranges, South Australia"* 38th Hydrology & Water Resources Symposium, December 2018
- Compared ARR2016 estimates derived by RFFE and RORB models on 25 Mount Lofty Ranges catchments with at-site flood frequency analysis, using a simplified RORB catchment model



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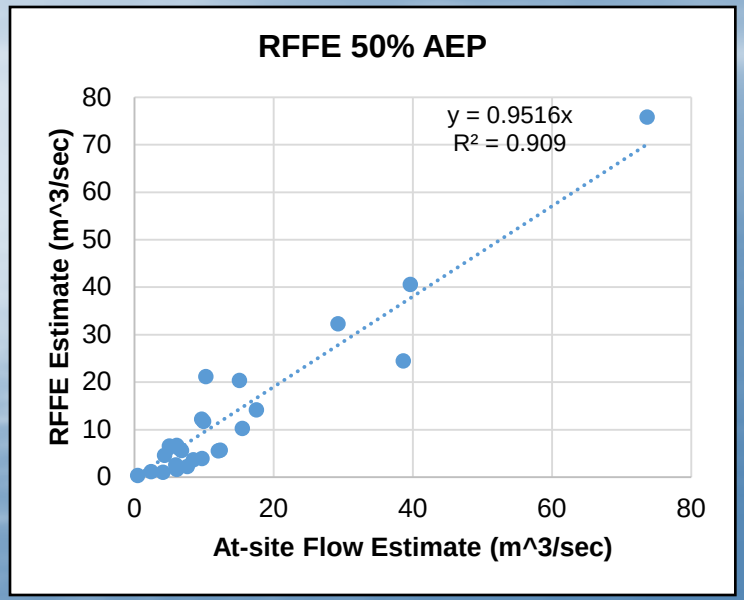
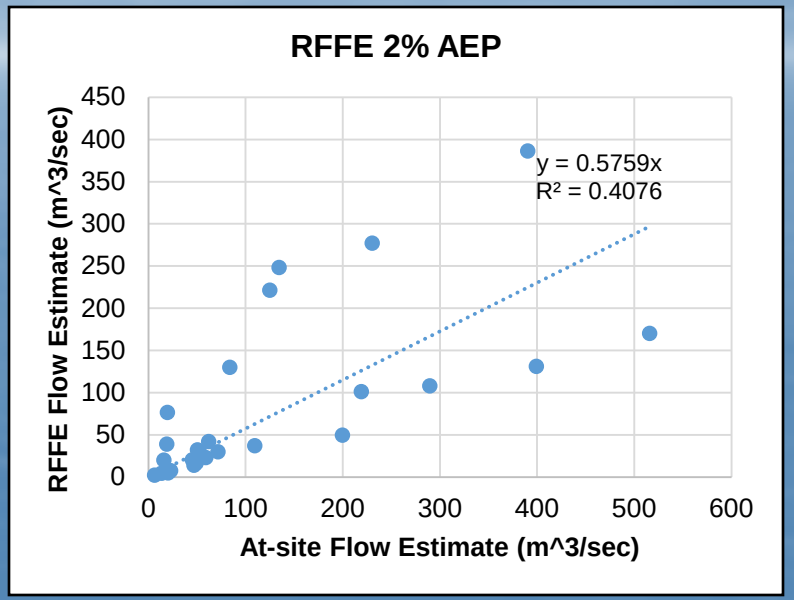
ASSESSING THE PERFORMANCE OF ARR2016

- Found that the RFFE provided reasonable answers for frequent events, worse for rare events
- The RORB results were poor, particularly for frequent events, and were much worse than the ARR1987 estimates

ASSESSING PERFORMANCE – REGIONAL FLOOD FREQUENCY ESTIMATION (RFFE)

- There were errors in the annual maximum flow data used to derive the methodology in the Mount Lofty Ranges
- The methodology used parameter regression (mean, standard deviation, skew) rather than quantile (flood magnitude), so works best for frequent flows
- Problems with the late addition of a bias correction for arid areas led to the exclusion of the region





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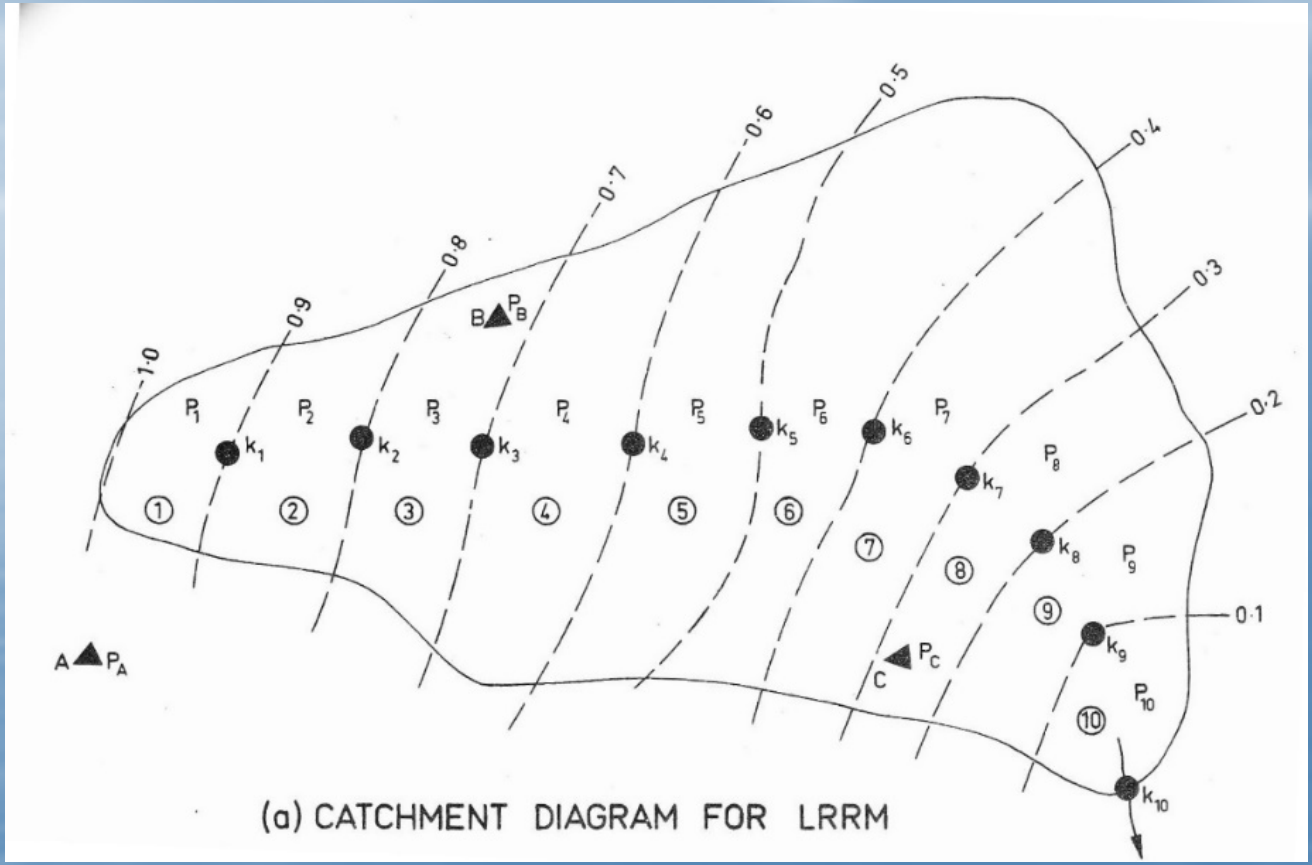
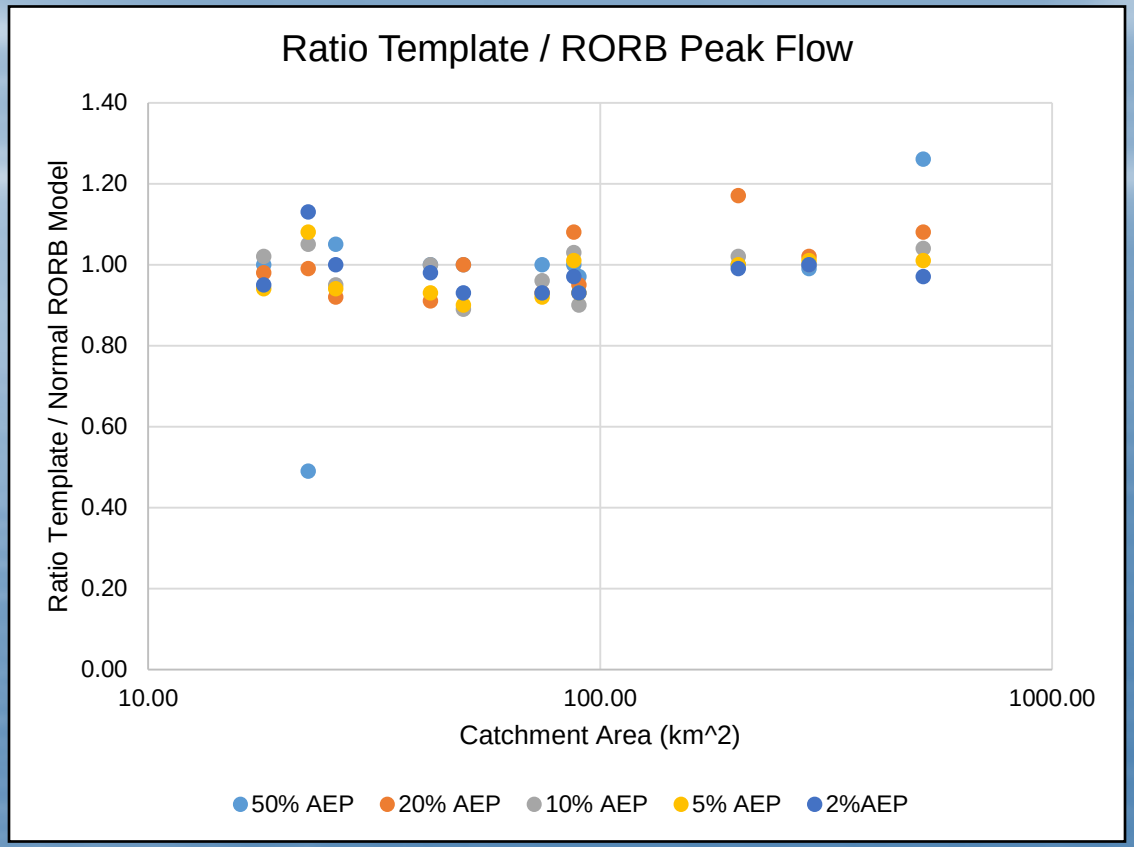
ASSESSING PERFORMANCE – REGIONAL FLOOD FREQUENCY ESTIMATION (RORB)

- Applied a simplified RORB model (LRRM) to estimate flows in the 25 catchments.
- A simple template is used to derive the catchment files.
- With Monte Carlo simulation, ARR temporal patterns, losses and IFD



(a) CATCHMENT DIAGRAM FOR LRRM

Torrens River at Mount Pleasant area = 26km^2
C Only for rural catchments, natural reaches
1, All reaches natural
1,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,1.0,-99
2,0.5,-99
7, print resultant hydrograph
hydrograph at outlet
0
C All areas of equal size. Change for other catchments
2.6,2.6,2.6,2.6,2.6,2.6,2.6,2.6,2.6,2.6,-99
0,-99, No impervious area



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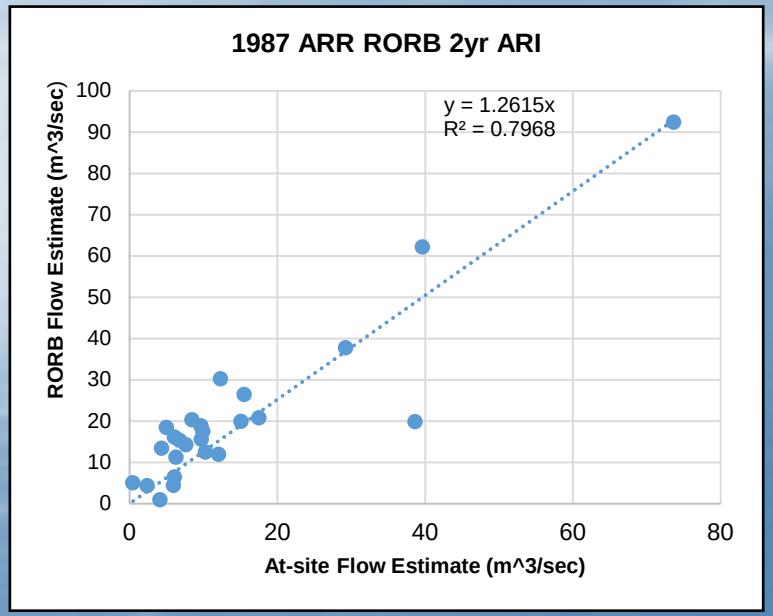

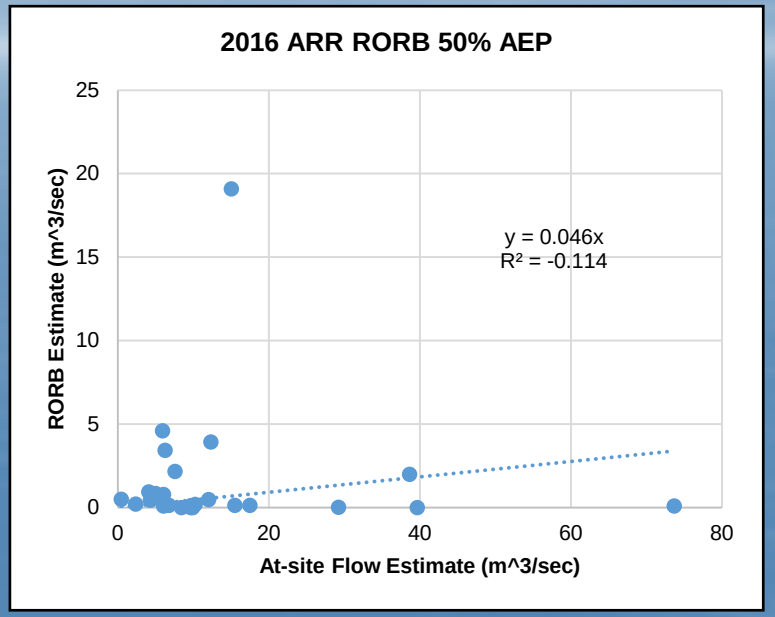

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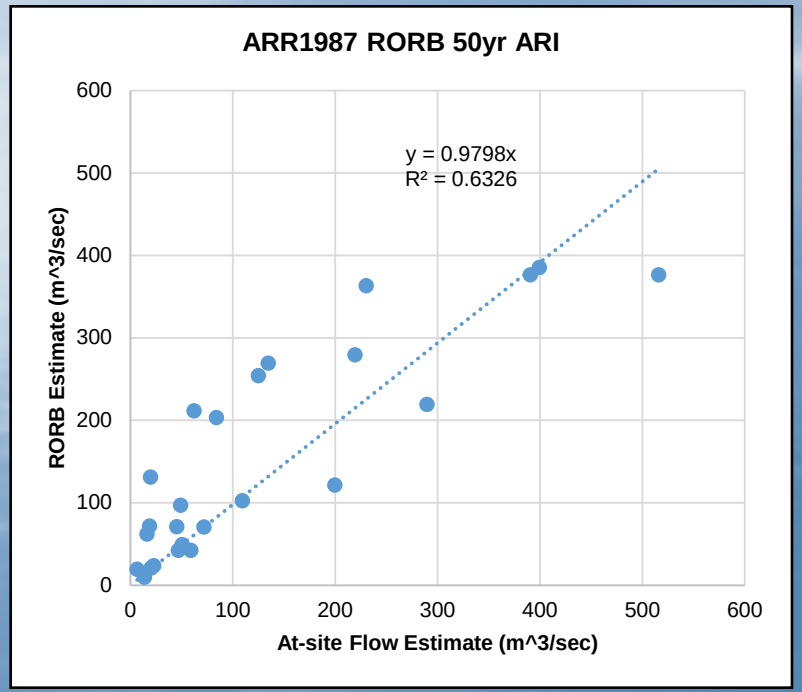

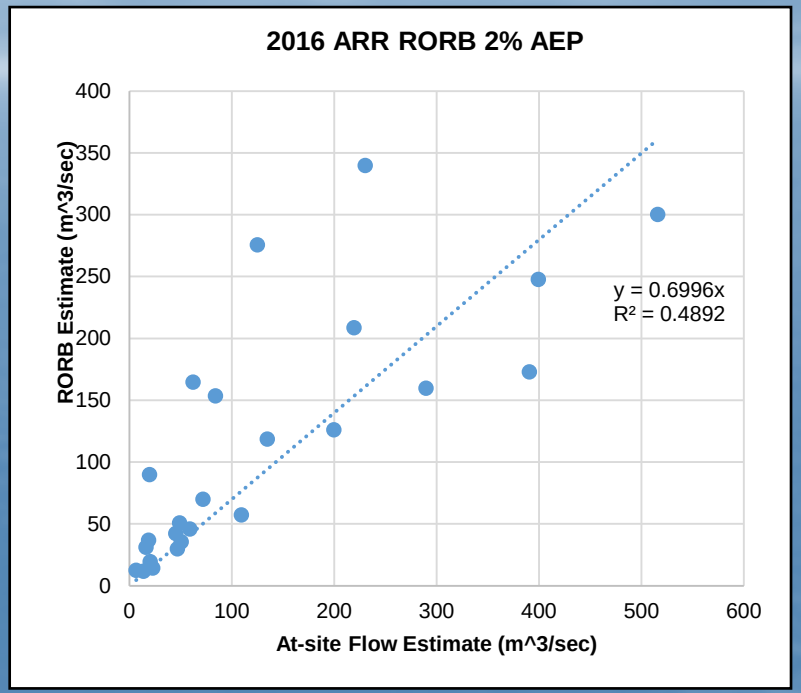

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RESPONSE -RFFE

- RFFE for the Mount Lofty Ranges needs to be redone.
- The RFFE for arid areas looks not too bad, if no bias adjustment made. However not published. Probably only applicable to the Flinders Ranges
- Use index flood method, where $Q_{10} = 0.0692A^{0.758}I_{6,50}^{1.08}$

AEP (%)	50	20	10	5	2	1
Growth Factor	0.28	0.68	1.00	1.47	1.92	2.54

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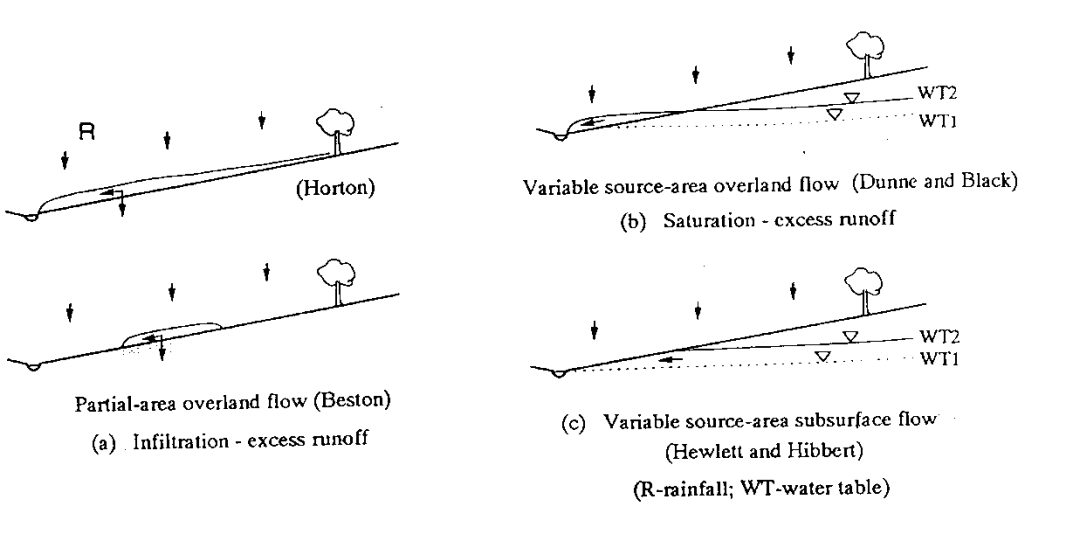
RESPONSE - RORB

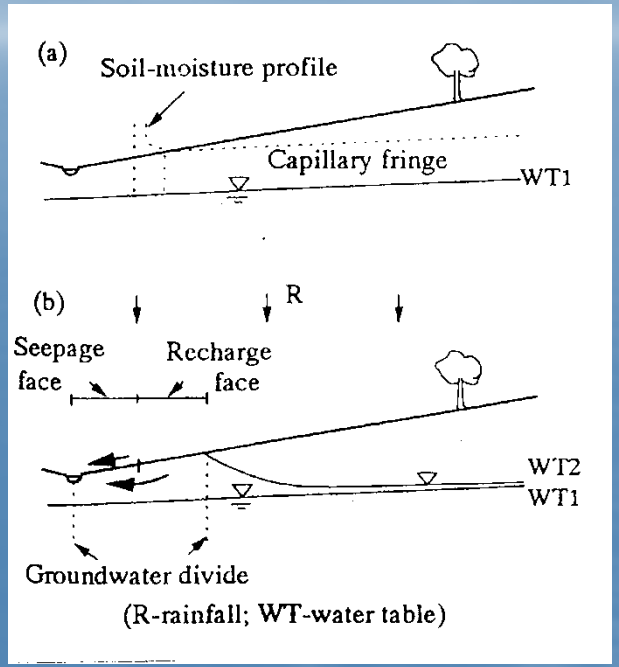
- KEMP, D.J and DANIELL, T.M. (2016) *"Stuck in the 1960s – the Need for Fundamental Change in Flood Hydrology in Australia"* I.E.Aust / NZ Hydrological Society Infrastructure and the Environment Conference, Queenstown, New Zealand December 2016.
- ARR2016 runoff routing modelling is evolutionary rather than revolutionary.

RESPONSE - RORB

- ARR2016 still recommends the use of a single process runoff routing model, even though it is well known that many processes can occur in any catchment, depending on climate, soils and antecedent condition.
- Multi – process runoff routing models such as the RRR model can do much better.

RUNOFF PROCESSES





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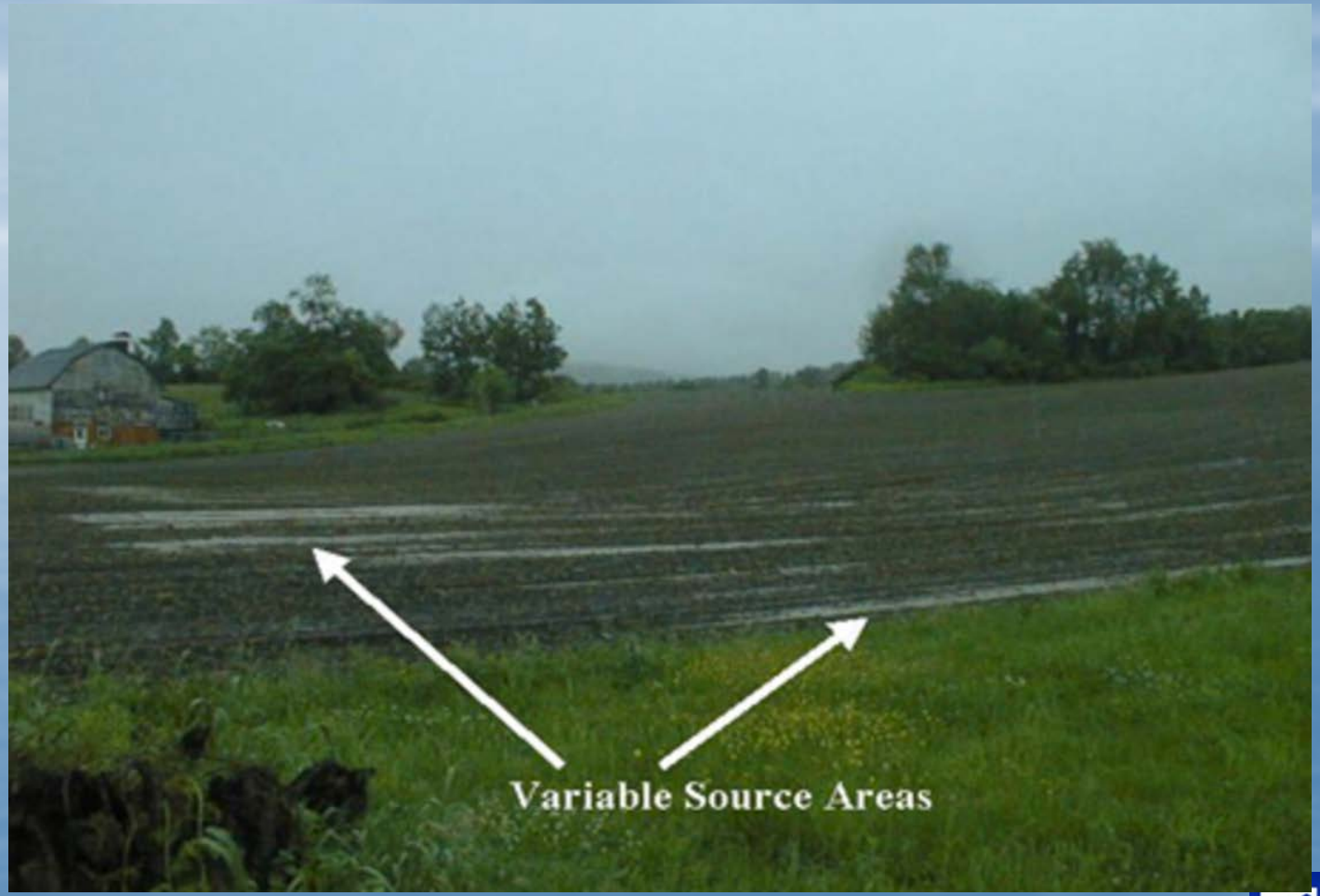
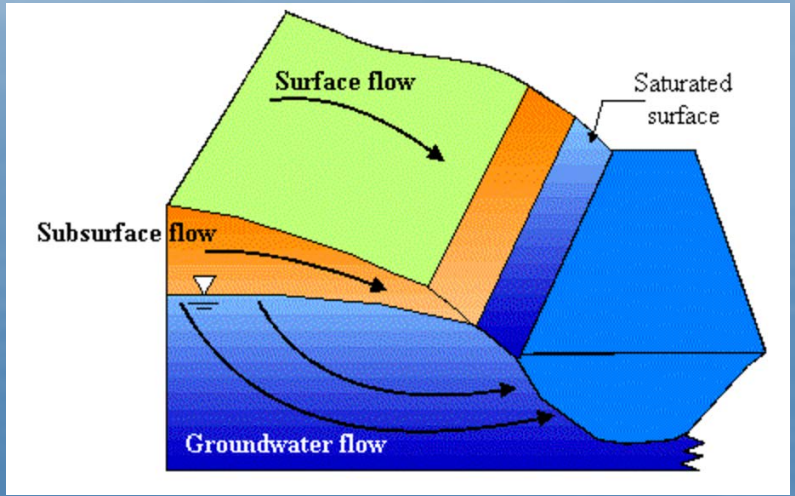
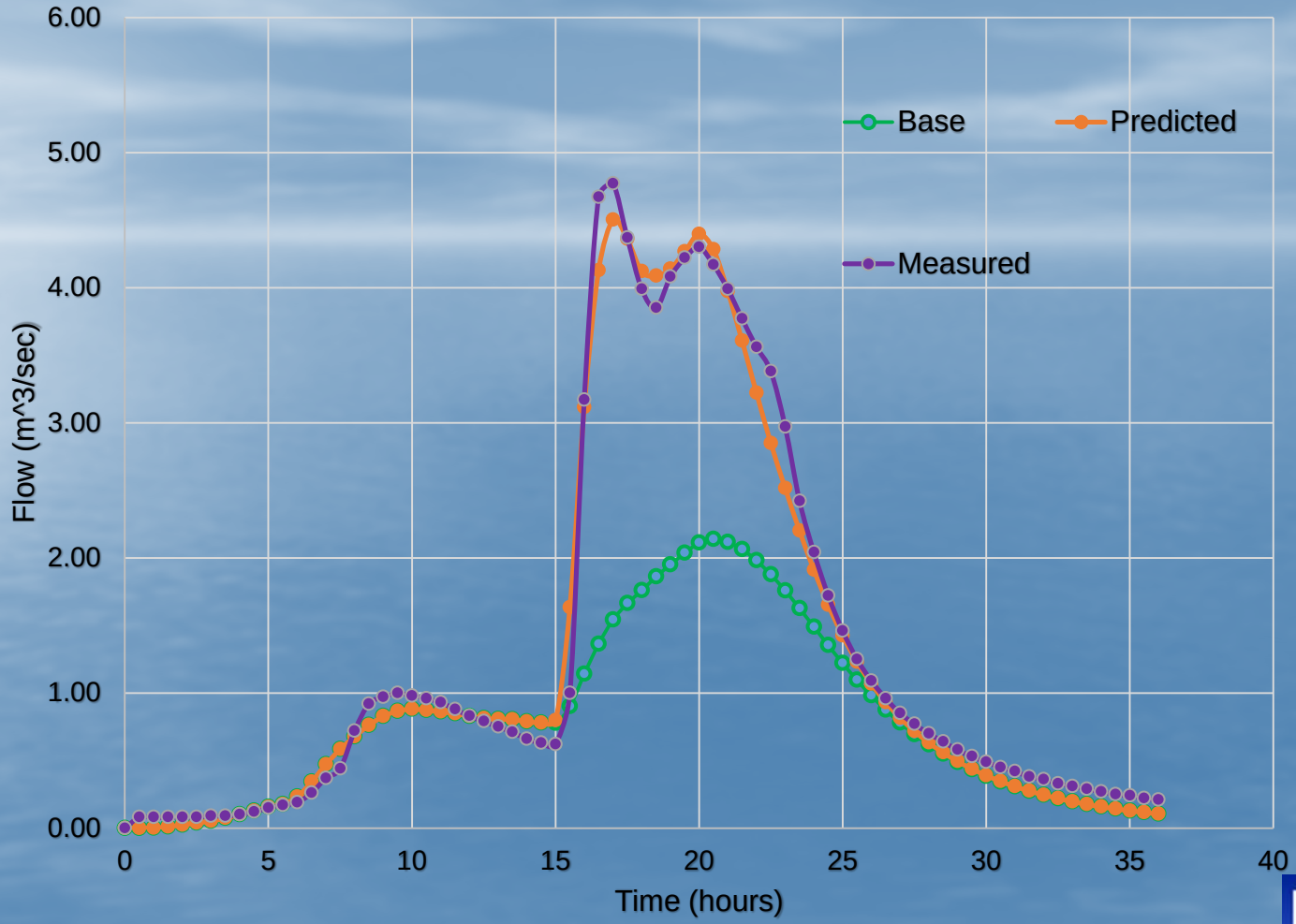


RUNOFF PROCESSES

- Can be summarised into three categories
- Runoff routing models such as RORB only deal with one runoff process – or simplistically with two
- Baseflow must be extracted





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RESPONSE - RORB

- An investigation in New South Wales found that flow prediction by RORB was unsatisfactory – similar to Mount Lofty Ranges.
- Has led to an update of pre-burst rainfall, from the use of median to probability pre-burst rainfall.
- Median pre-burst rainfall used the average of pre-burst rainfalls, but:
- Probability neutral pre-bust rainfall selects a rainfall that results in a predicted flow of the same AEP as the rainfall.

RESPONSE - RORB

- This update has been included in the ARR data hub for NSW
- UniSA has completed an investigation using probability neutral pre-burst rainfalls on Mount Lofty ranges catchments, and made recommendations
- But still there is a need to update the ARR data hub for South Australia

OPPORTUNITIES

- More data are becoming available all the time.
- Rainfall on catchments is better understood, but;
- Given the challenges, there is a need for basic research on how catchments behave, and how they differ one from another.
- And leading from this how to predict flood flows, but will use a multi-process model.
- Must be done with an open mind.
- But who is going to fund this, given the huge investment (monitory and in kind) to ARR2016?

SUMMARY

- The update of flood estimation procedures in ARR2016 was a large undertaking, with input from UniSA and Adelaide University
- Main changes were:
    - to Annual Exceedence Probability (AEP) rather than Average Recurrence Interval (ARI)
    - the prediction of peak flows (RFFE) and;
    - moving from event based estimates to joint probability analysis using Monte Carlo simulation.
- Modelling evolutionary rather than revolutionary
- Has some significant shortcomings to be addressed.