



## Book IV Chapter 2 At-Site Flood Frequency Analysis

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## Overview

Evolutionary update of Chapter 10 of ARR(1987)

Major changes:

- Reduced prescription about the choice of flood probability model (GEV, LP3, LH moments to fit right tail)
- Abandonment of at-site product log-moment fitting of the log-Pearson III (LP3) distribution
- Bayesian fitting methods to make better use of available flood information:
  - gauged and censored flow data
  - rating error
  - regional information
- Non-homogeneous probability models to account for long-term climate variability

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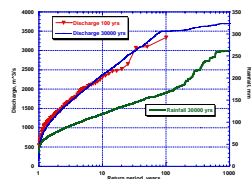
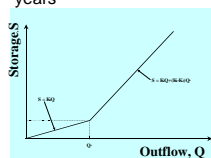
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## Wider Choice of Flood Probability Model

Choice of flood distribution is somewhat arbitrary:

- Both LP3 and Generalized Extreme Value (GEV) distributions fit the bulk of flood data satisfactorily
- GEV has some theoretical justification based on extreme value theory
- Extrapolation well beyond observed flood data not recommended → ARR will continue to recommend rainfall-runoff based methods in preference to flood frequency methods for ARIs much in excess of 100 years



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## New Developments

Research in the last two decades has resulted in:

- More accurate quantile estimates
- Better use of pre-gauged data
- Improved goodness of fit
- Improved expected probability estimates
- Improved quantification of uncertainty
- Better interfacing with regional flood estimates

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## Why Reject Log Pearson III (LP3) Method of Moments

Two major problems with LP3 method-of-moments:

- Relies on log product moments  $E[(\log x)^j]$  which are biased and highly variable for small samples.
- Use of  $\log x$  can overemphasize importance of small  $x$

Monte Carlo simulation illustrates problem with method-of-moments applied to LP3 (Wang):

- For 151 Australian stations assume fitted LP3 is the "true" distribution
- Simulate flood record by sampling from "true" LP3 distribution
- Estimate 50- and 100-year flood by fitting LP3 log-moments and GEV L moments to simulated flood data
- Compute mean-squared-error (MSE) of quantile estimators

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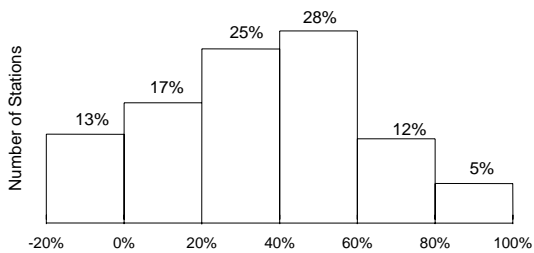
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## Why Reject LP3 Method of Moments



Reduction in MSE of 100-Year event estimate achieved by GEV L moment procedure

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## Bayesian Fitting Methods

Bayesian inference provides the complete solution:

- Works for any probability model
- Can efficiently use gauged flow data, censored historic data and information on rating errors
- Censor outliers to improve fit
- Provides optimal quantiles, accurate expected probability estimates and accurate confidence limits
- Efficient combination of at-site and regional information and transfer of data from nearby gauges

But requires Monte Carlo sampling → need computers!

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## Bayesian Fitting

Select flood probability model:  
LN, LP3, Gumbel, GEV, GP

Prior pdf  $p(\theta)$  derived from

- Non-informative pdf if only at-site data
- Regionalized estimates of  $\theta$

Likelihood function  $p(\text{Data}|\theta)$

- Gauged data
- Censored historic data
- Rating curve error data

Posterior pdf  $p(\theta|\text{Data}) \propto p(\text{Data}|\theta) p(\theta)$

Quantiles, confidence limits, expected probability,...

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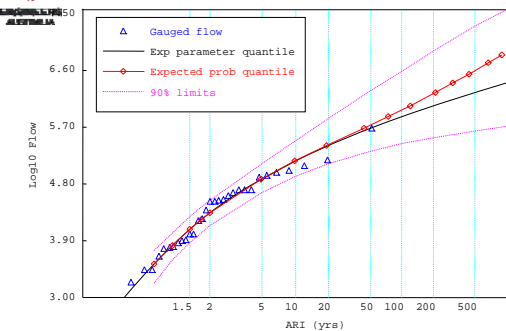
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## Bayesian Fitting: Gauged



Log Pearson 3 fit: Hunter River at Singleton

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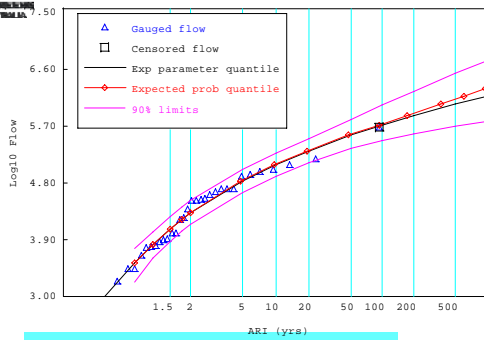
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## Bayesian Fitting: Gauged+Historic



Log Pearson 3 fit: Hunter River at Singleton

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## Bayesian Fitting: Using Regional Prior Information

Prior information on parameters from regional analysis is particularly important for 3-parameter flood models such as LP3 or GEV

Example: Hunter river at Singleton

**Prior info on log skew: mean 0.0, standard deviation 0.35**

LP3 parameter	No prior information		With prior information	
	Mean	Std deviation	Mean	Std deviation
m	6.436	0.236	6.423	0.236
log s	0.350	0.127	0.322	0.127
g	0.146	0.643	0.028	0.305

1 in Y	No prior information				With prior information	
	Quantile $q_y$	Quantile confidence limits		Quantile $q_y$	Quantile confidence limits	
		5% limit	95% limit		5% limit	95% limit
AEP						
10	3888	2222	8287	3619	2184	6933
50	12729	5537	52157	10677	5294	29104
100	19548	7372	108144	15670	7050	50274

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## LH Moments

LH moments are linear combinations of ranked observations

$$L_1(h) = E[X_{(h+1:h+1)}] \dots \text{location}$$

$$L_2(h) = 0.5 E[X_{(h+2:h+2)} - X_{(h+1:h+2)}] \dots \text{scale}$$

$$L_3(h) = 0.333 E[X_{(h+3:h+3)} - 2X_{(h+2:h+3)} + X_{(h+1:h+3)}] \dots \text{shape}$$

where  $X_{(i:n)}$  is the  $i^{\text{th}}$  rank (smallest to largest) in  $n$  samples

As  $h$  is increased LH moments increasingly focus on the right tail of the flood distribution

For  $h=0 \rightarrow$  L moments which are almost unbiased and normally distributed  $\rightarrow$  Particularly useful in regionalisation studies

For at-site estimation more accurate estimators are available (eg for GEV MOM and GMLE are superior)

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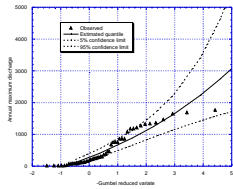
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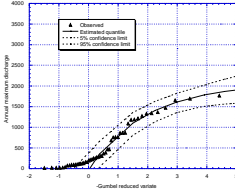
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### Fitting Distributions with Reverse Curvature



GEV L moment fit



GEV LH(4) moment fit

Albert River at Broomfleet

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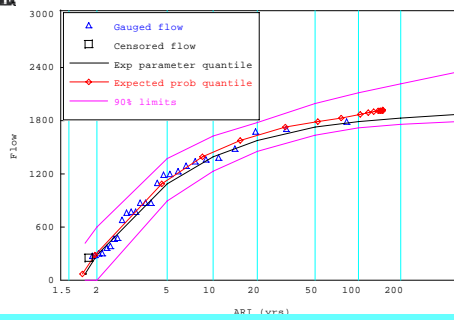
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### Fitting Distributions with Reverse Curvature



GEV fit to gauged flows above 250 m³/s: 23 flows censored

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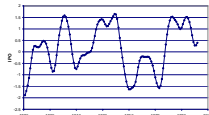
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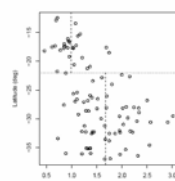
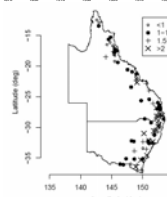
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### Multi-Decadal Climate Variability and Flood Risk



Flood risk appears to vary with Inter Pacific Oscillation (IPO)



Ratio of 10-year IPO- and IPO+ quantiles

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## Multi-Decadal Climate Variability and Flood Risk

Implications:

- Eastern NSW and S-E Queensland flood risk affected by IPO variation
- Standard flood frequency analysis:
  - OK for long records
  - Serious bias in flood risk possible if short records sample from one IPO epoch
- If an IPO epoch is undersampled need to extend record or use regional estimator

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## Conclusions

- Revision of ARR flood frequency procedures is evolutionary and exploits new research developments
- Significant changes:
  - Choice of distribution eg GEV, LP3
  - Improved accuracy in design flood estimates
  - Efficient use of pre-gauged data
  - Improved fitting capabilities in difficult cases
  - Accurate quantification of uncertainty
  - Potential for rational use of at-site and regional data
  - Recognition that flood risk varies on multi-decadal scales in some parts of Australia
  - Dependence on software

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