Modelling Group
WATER NEW ZEALAND

Modelling Symposium

The National Flood Studies Programme for South Africa: Overview and Development to Date

Presented by

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UMGENI WATER · AMANZI

CWRR

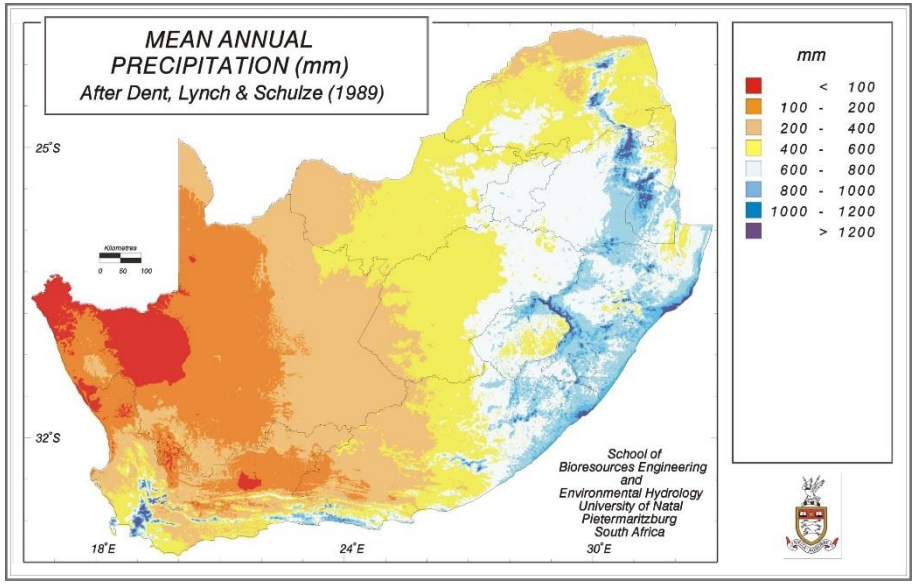
USQ
Centre for Agricultural Engineering

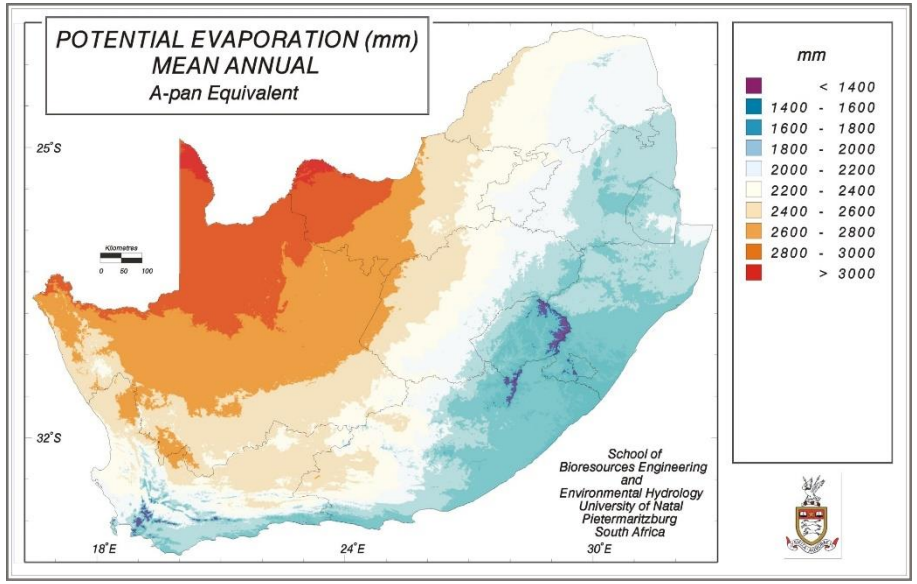
water NEW ZEALAND
The New Zealand Water & Wastes Association Waiora Aotearoa

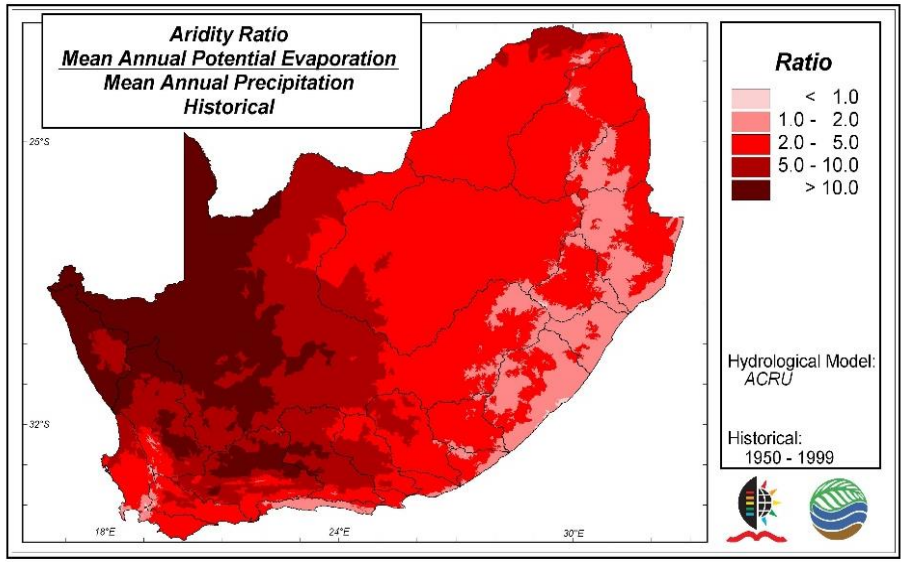
Overview of Presentation

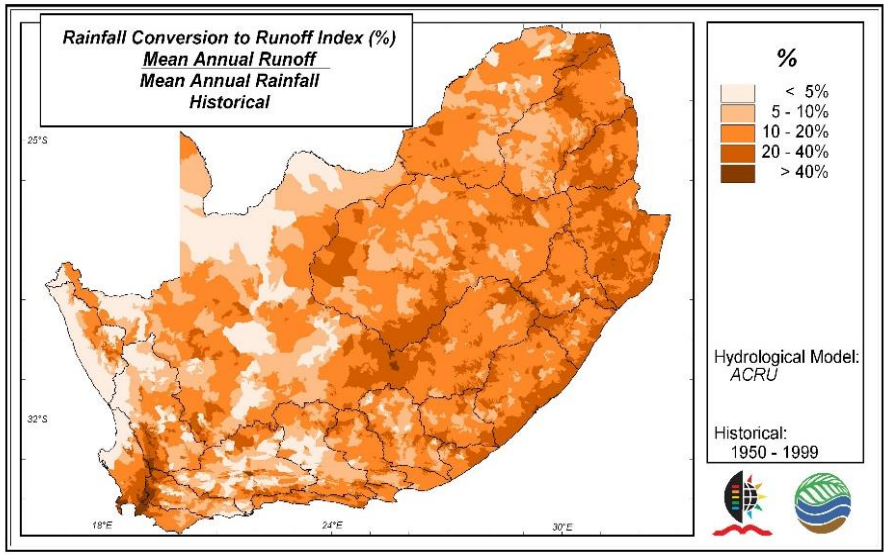
- South African hydrology
- Design flood estimation
- Overview of approaches to design flood estimation in South Africa
- National Flood Studies Programme in South Africa
  - Background and initiation
  - Overview of performance of methods
  - Examples of developments to date
  - Challenges to implementation
- Conclusions

South African Hydrology

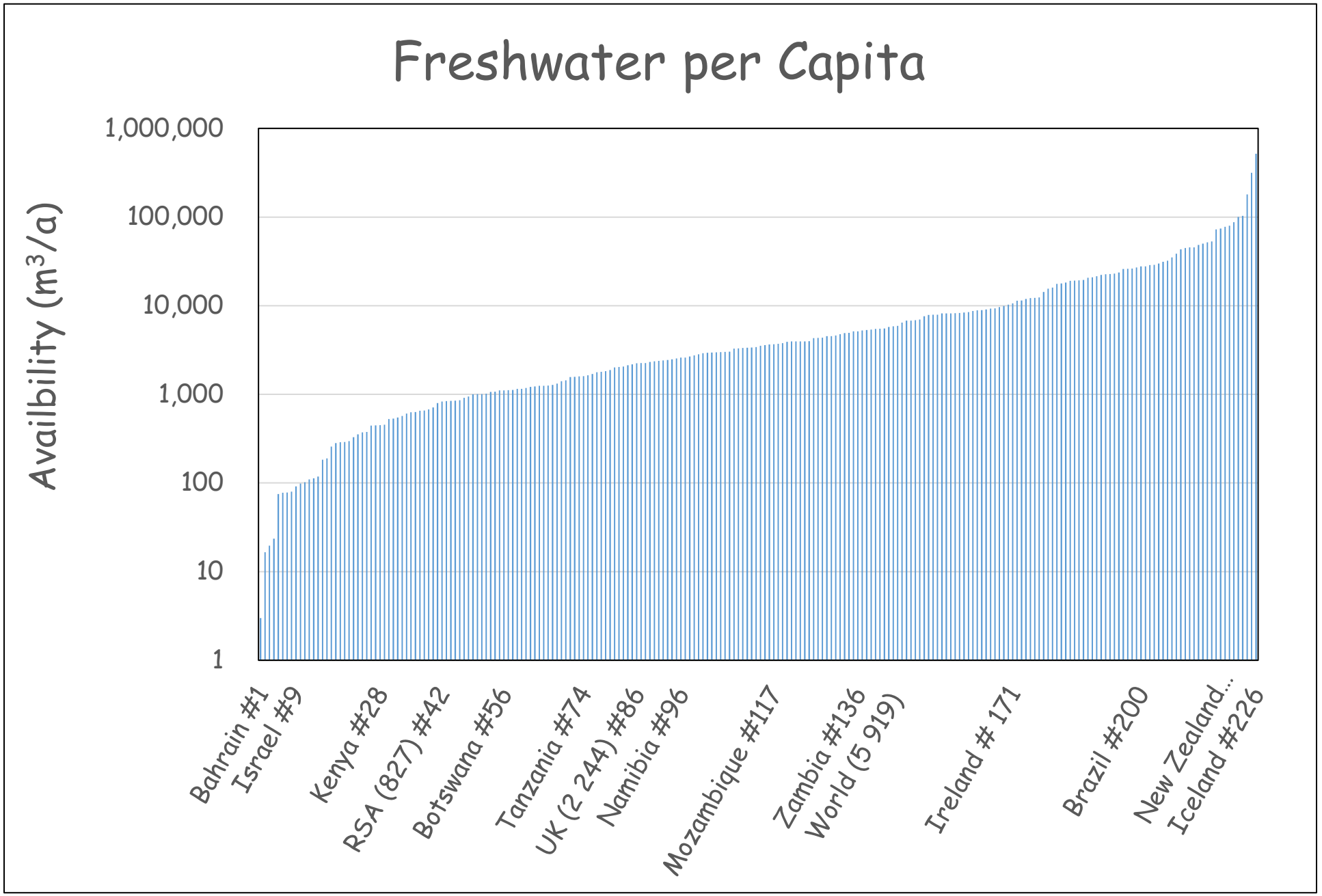






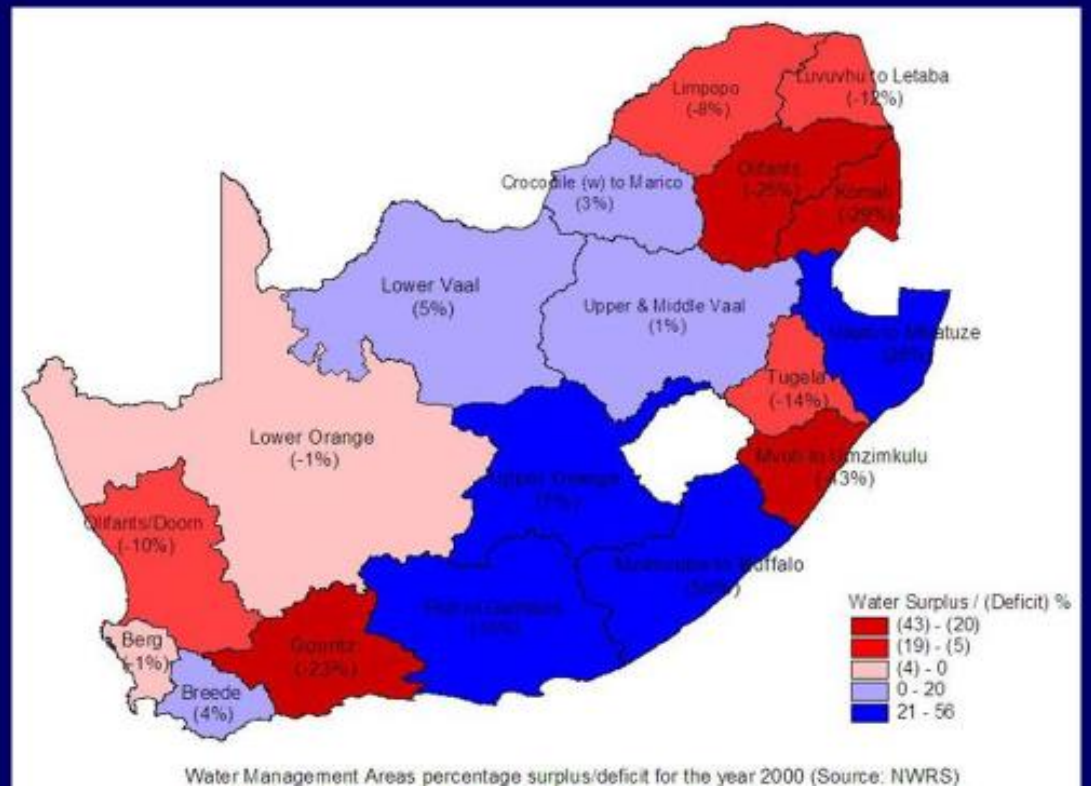


Freshwater per Capita



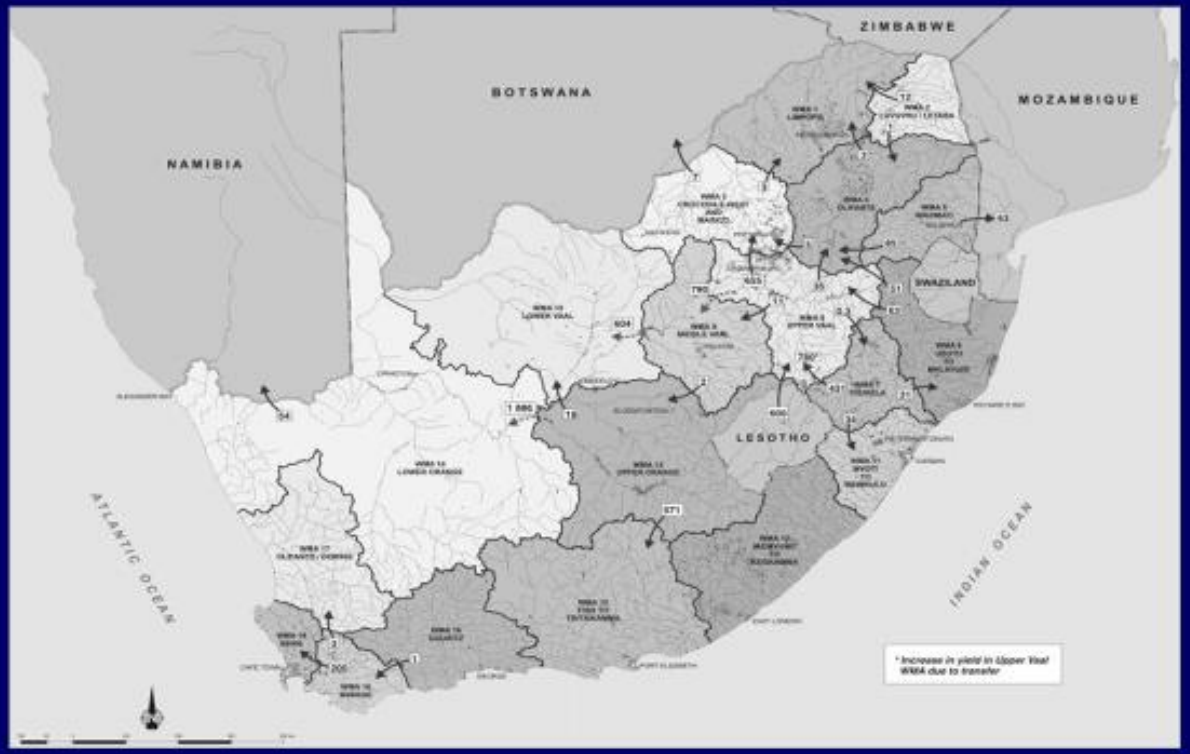
https://data.worldbank.org/indicator/ER.H2O.INTR.PC

Demand and Supply in SA



Water Management Areas percentage surplus/deficit for the year 2000 (Source: NWRS)

Inter-catchment Transfers

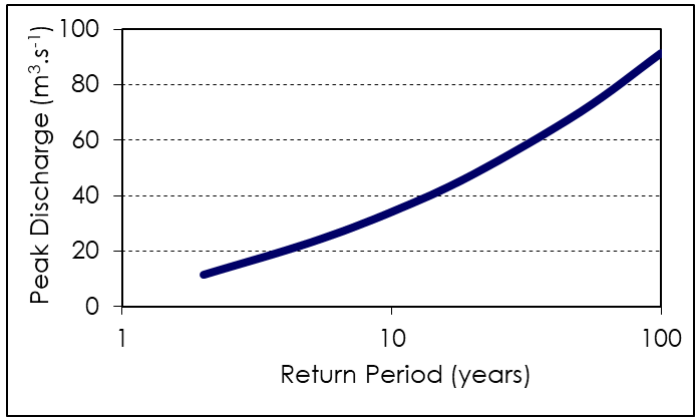


Design Flood Estimation

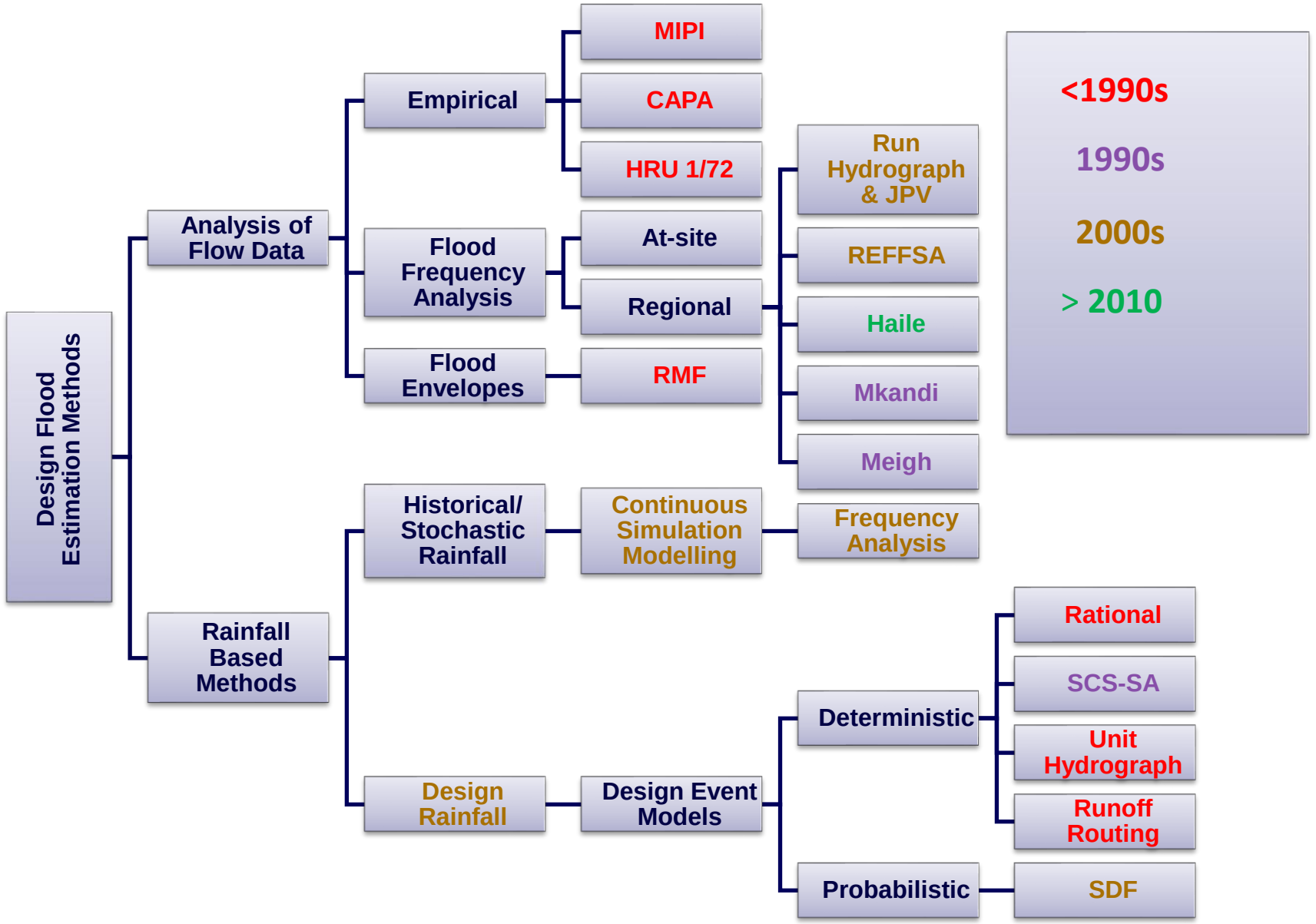
- Limit risk of failure
  - Hydraulic structures
  - Drainage systems

- Return Period: $T = 1/P_e$

- Used for
  - Design and risk assessment of hydraulic structures
  - Flood lines - planning and development
  - Managing developments – flood lines and inundation levels



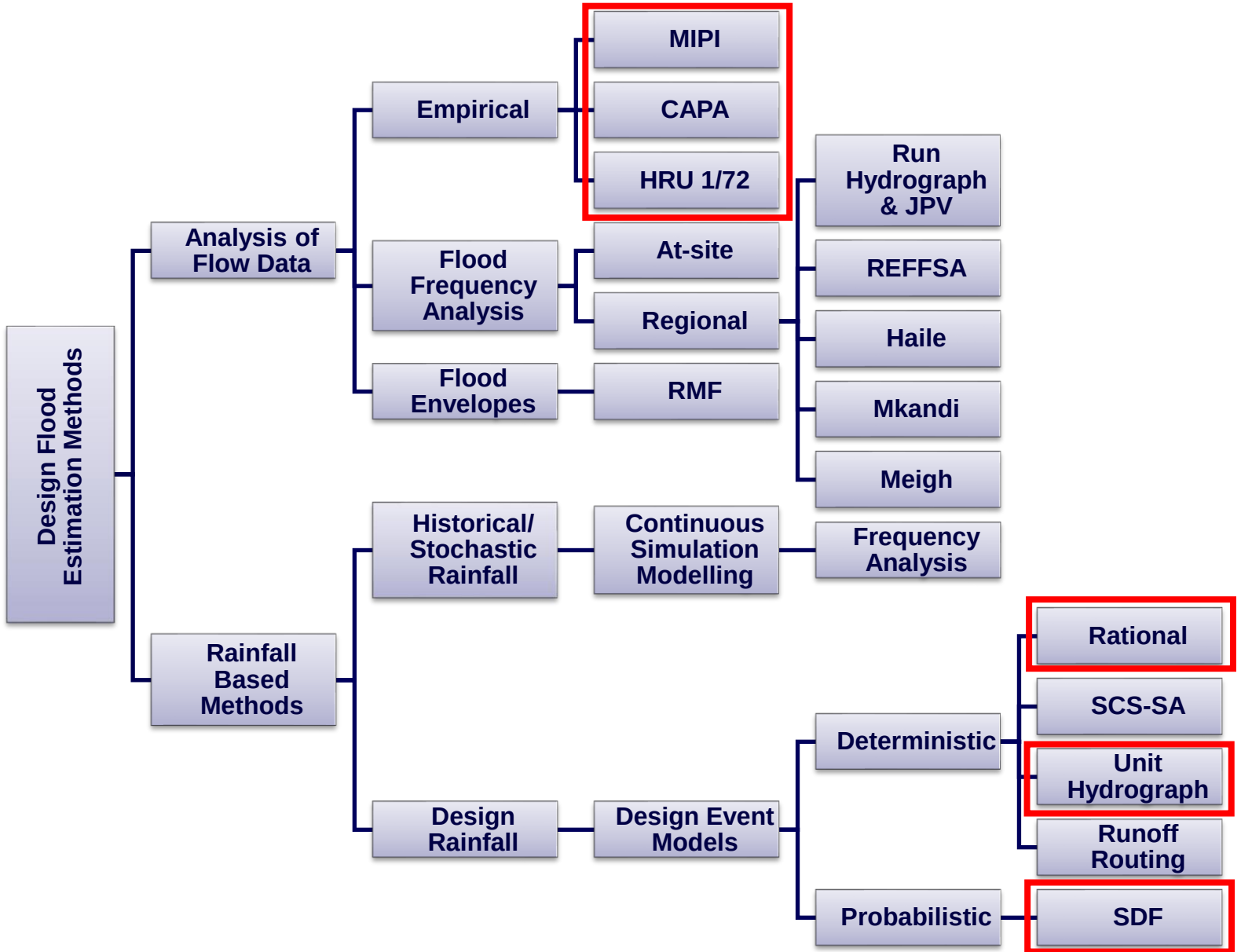
Methods of Design Flood Determination in South Africa



Establishment of the National Flood Studies Programme

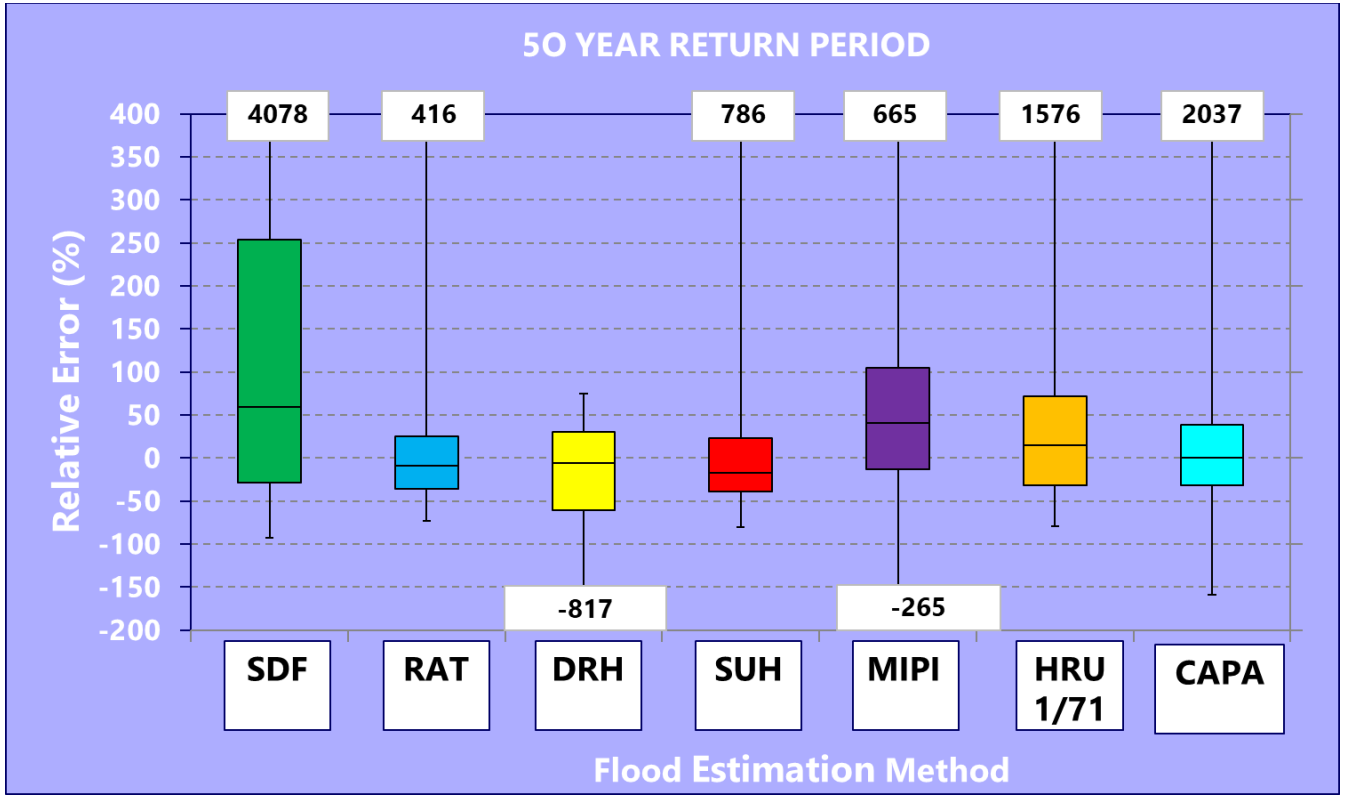
- Initiated by SANCOLD and WRC in 2013
- Four Working Groups (WGs) established in 2014
  - Rainfall analysis, Flood analysis, Hydrological data, Products used for flood estimation
- Draft motivation, plan and budget
  - 19 research projects
  - R 28 million (2014 values)
  - Undertaken over an eight year period
  - Multi-institutional approach and capacity development
- Approval in principle by SANCOLD, WRC, DWS, SANRAL
- Annual Research Review Workshops
  - Additions and some re-prioritisation
  - Currently extended to 23 required projects
- Funding

Performance of Current Methods

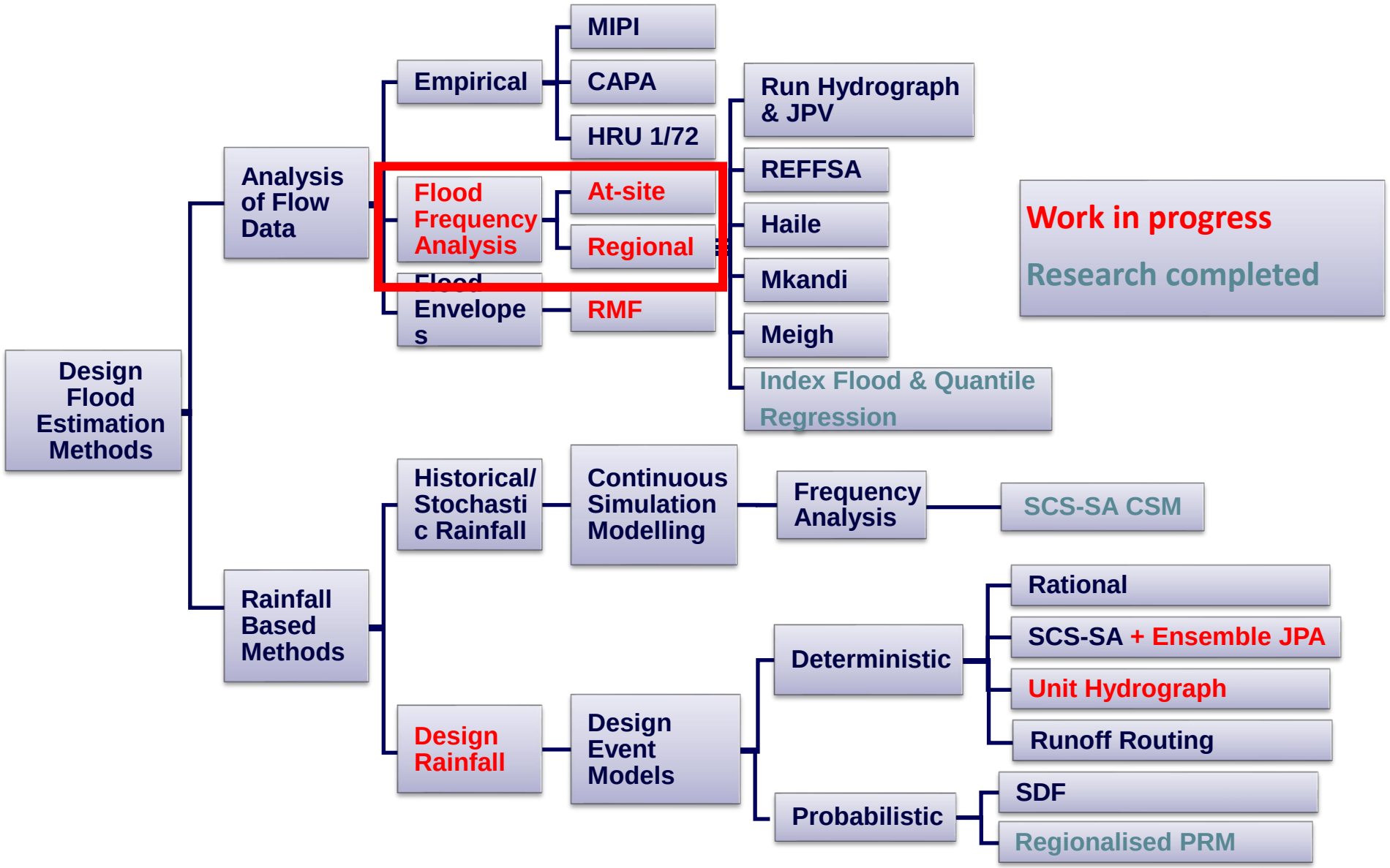


Performance of Selected Empirical and Deterministic Event-Based Methods (Naidoo, 2020)

- 157 DWS dam sites
  - Catchment areas: 10 - 108 360 km^2
- Wide range of performances
- No spatial trends in performance
- Preliminary results - need further confirmation

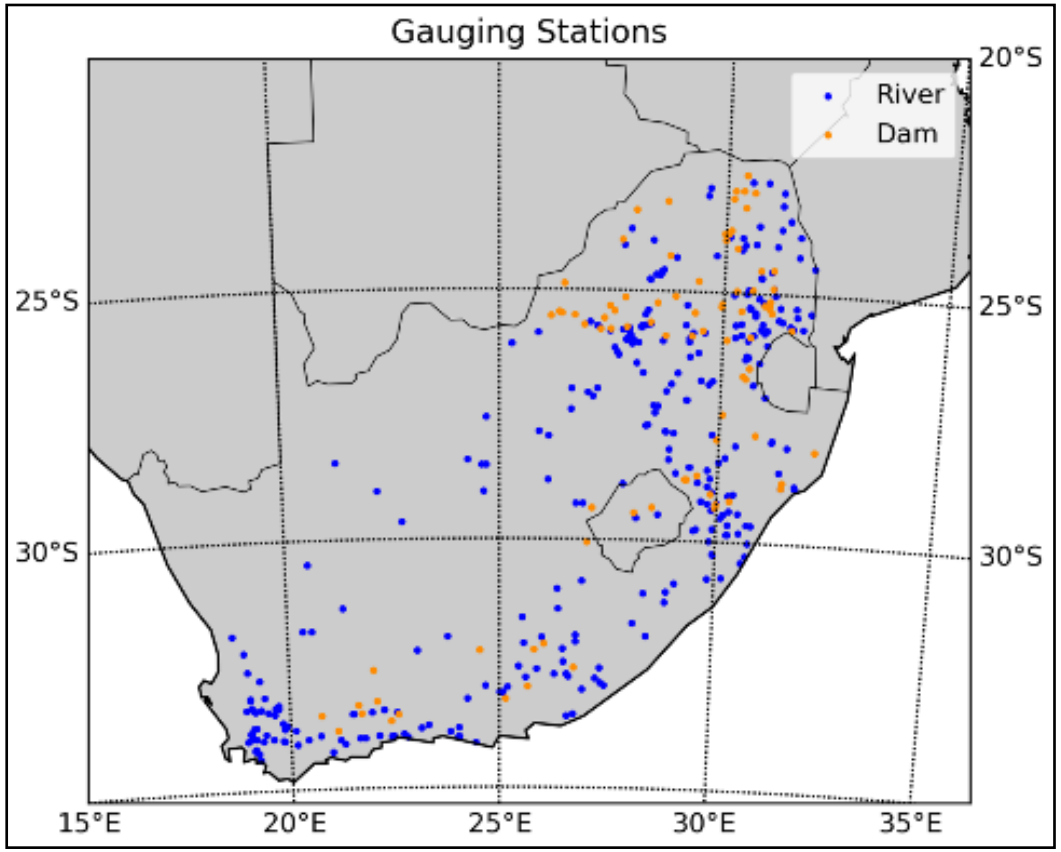


Developments to Date



Selection of Probability Distribution for DFE (Calitz, 2021)

- Data
  - 296 river gauges
  - 87 dam gauges
- Assessment PDs
  - Graphical methods (LMRD)
  - Goodness-of-fit testing
  - Model fit criterion
  - Model uncertainty
- GPA fitted by L-moments recommended for general use for DFE in South Africa



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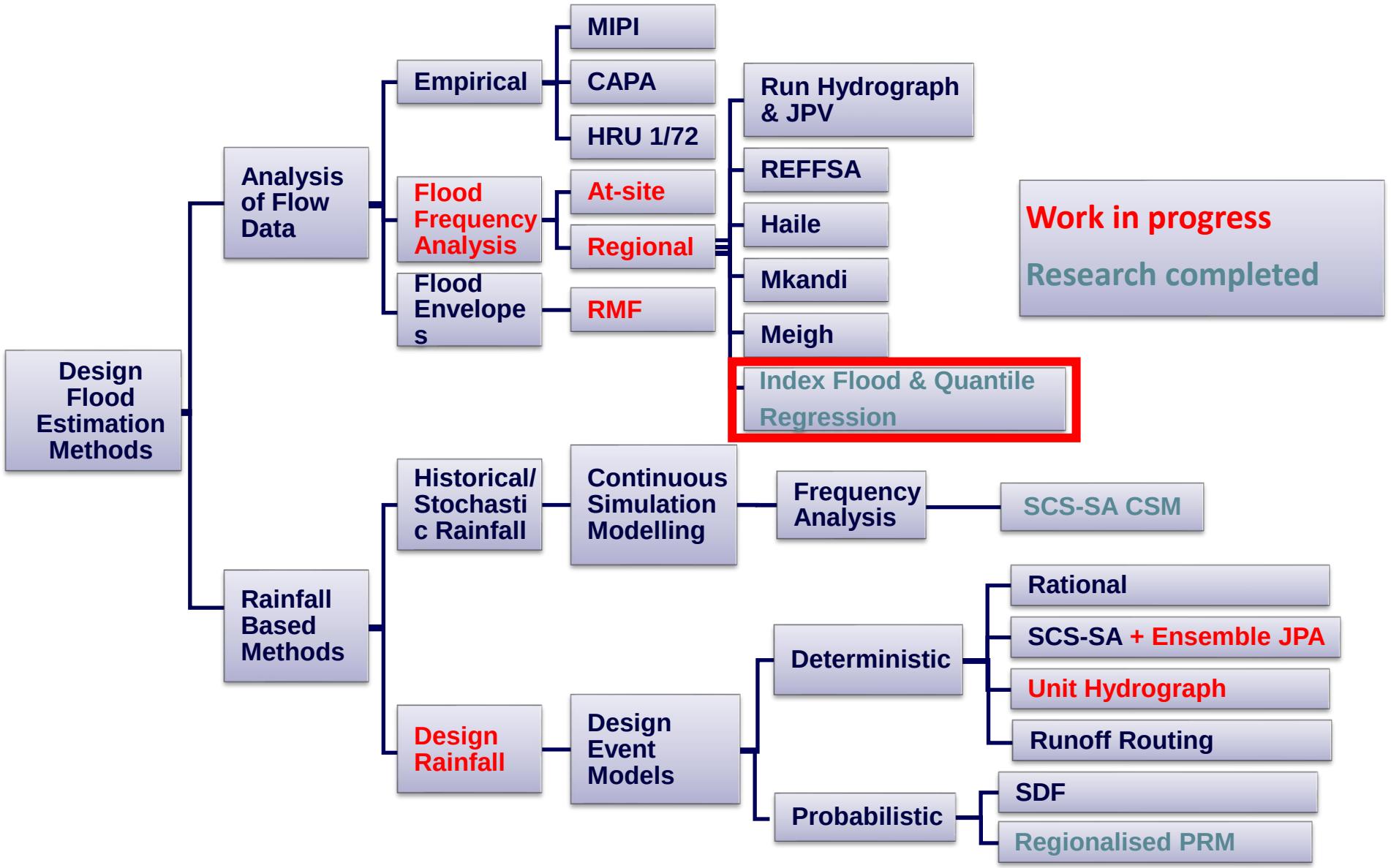
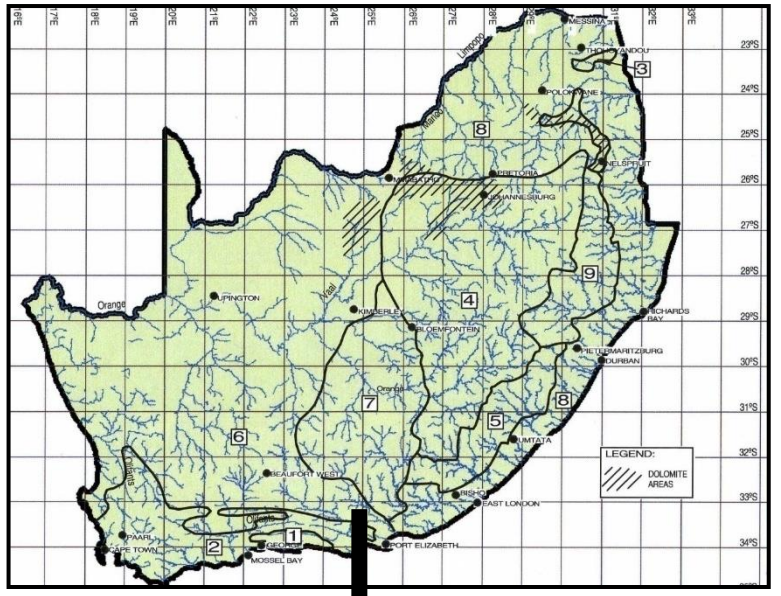
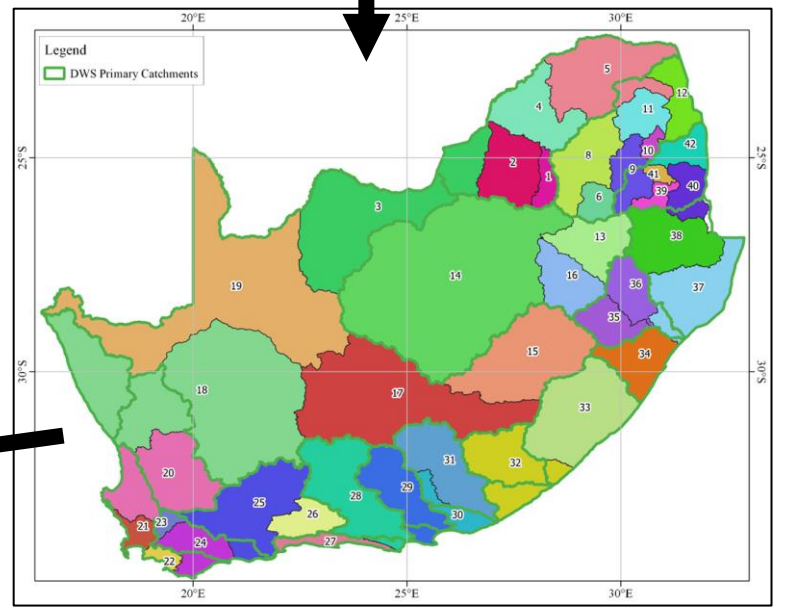
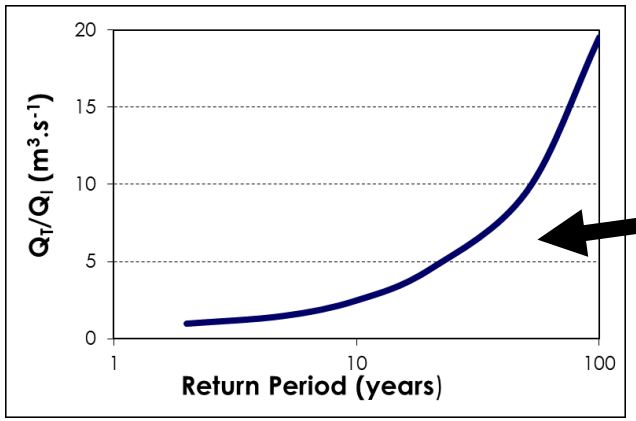


Regional Flood Methods (Calitz, 2021)

- 42 relative homogenous clusters
- Model formulations
  - Quantile Regression (QRT)
  - Regional Index Flood (RIF)
  - Probabilistic Rational (PRM)
- General recommendation
  - QRT - limited to defined RPs
  - RIF method should be applied in SA
  - Index Flood (IF) =f(A, MAP, D2C, $I_{T=10}$)







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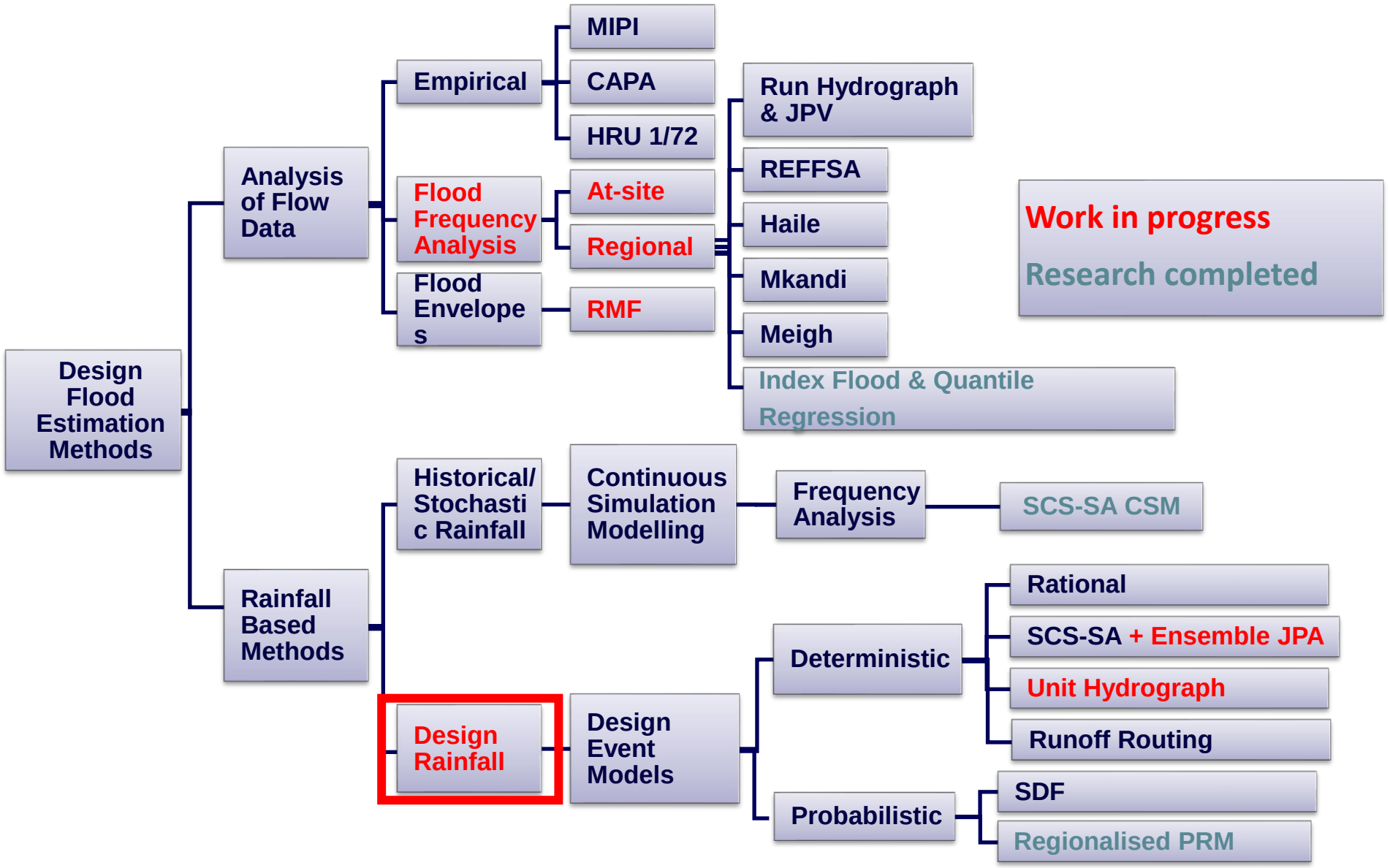
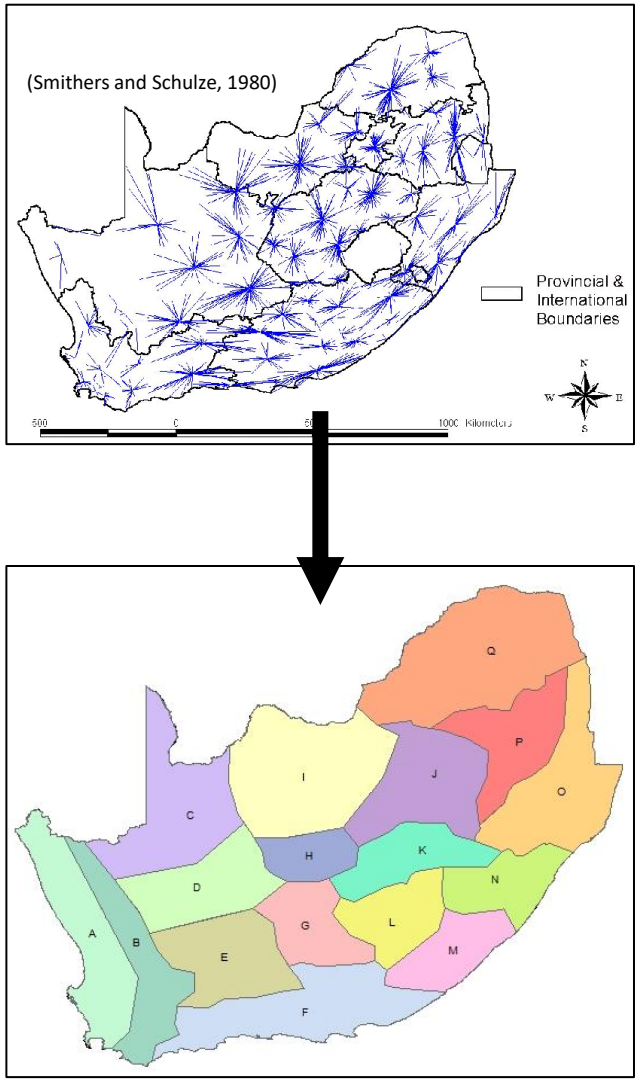


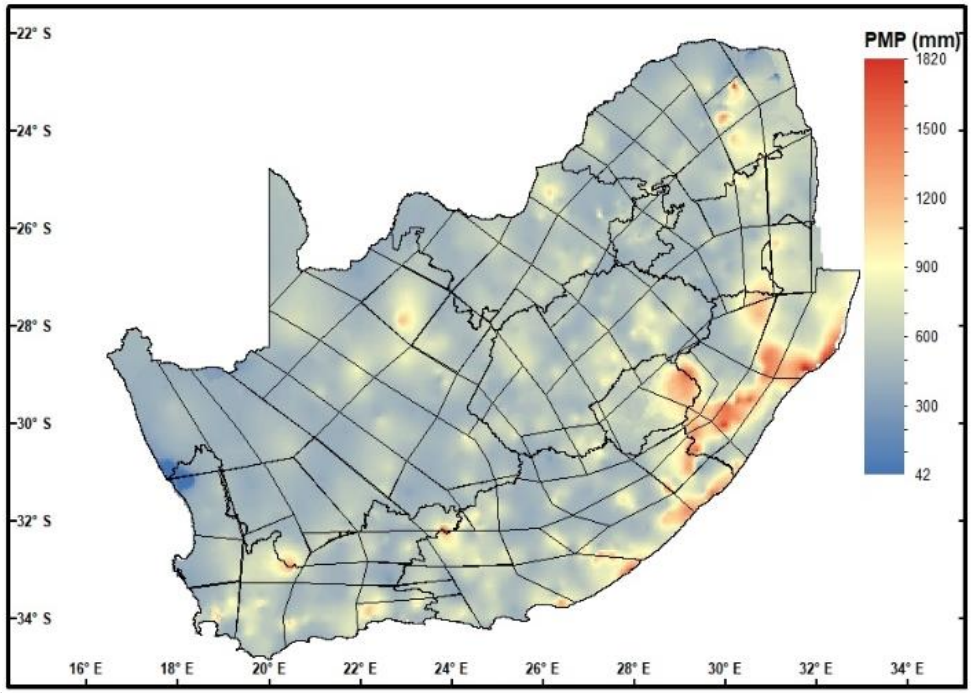
Update - Extreme Design Rainfall (Katelyn Johnson - PhD)

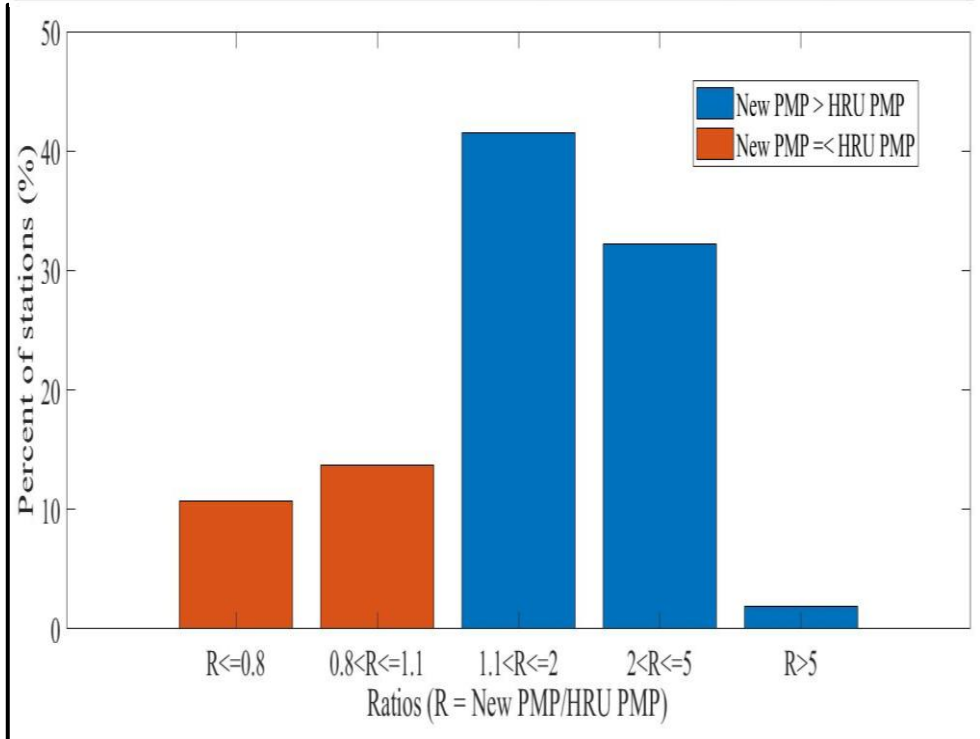
- Current – RLMA&SI (Smithers and Schulze 2003)
  - 1806 stations, 78 homogeneous clusters
- New regionalisation
  - 1 641 daily rain gauges
  - Cluster analysis of site characteristics
  - 17 relatively homogenous regions
- Impacts on design and risk
  - 200-year RP 1-day event
    - 60% of values > RLMA&SI
    - Average difference of 13%



Updated 1-day PMP Estimates
(Johnson and Smithers, 2020)

- Updated WMO approach applied
- 380 representative stations
- 70% of extreme events used in current study after 1960s
- Impacts on design and risk
  - New PMPs > HRU PMPs at 80% of sites





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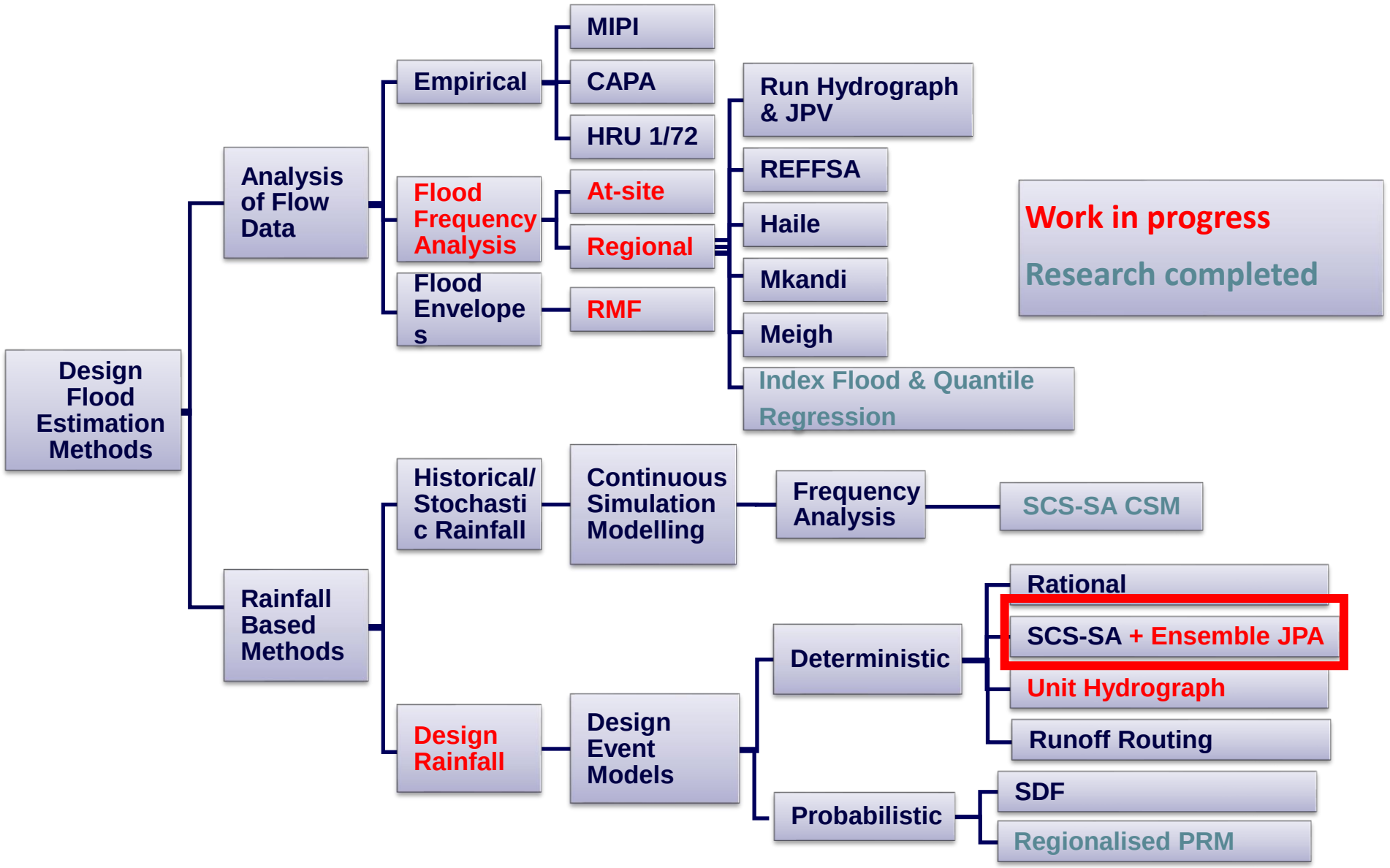
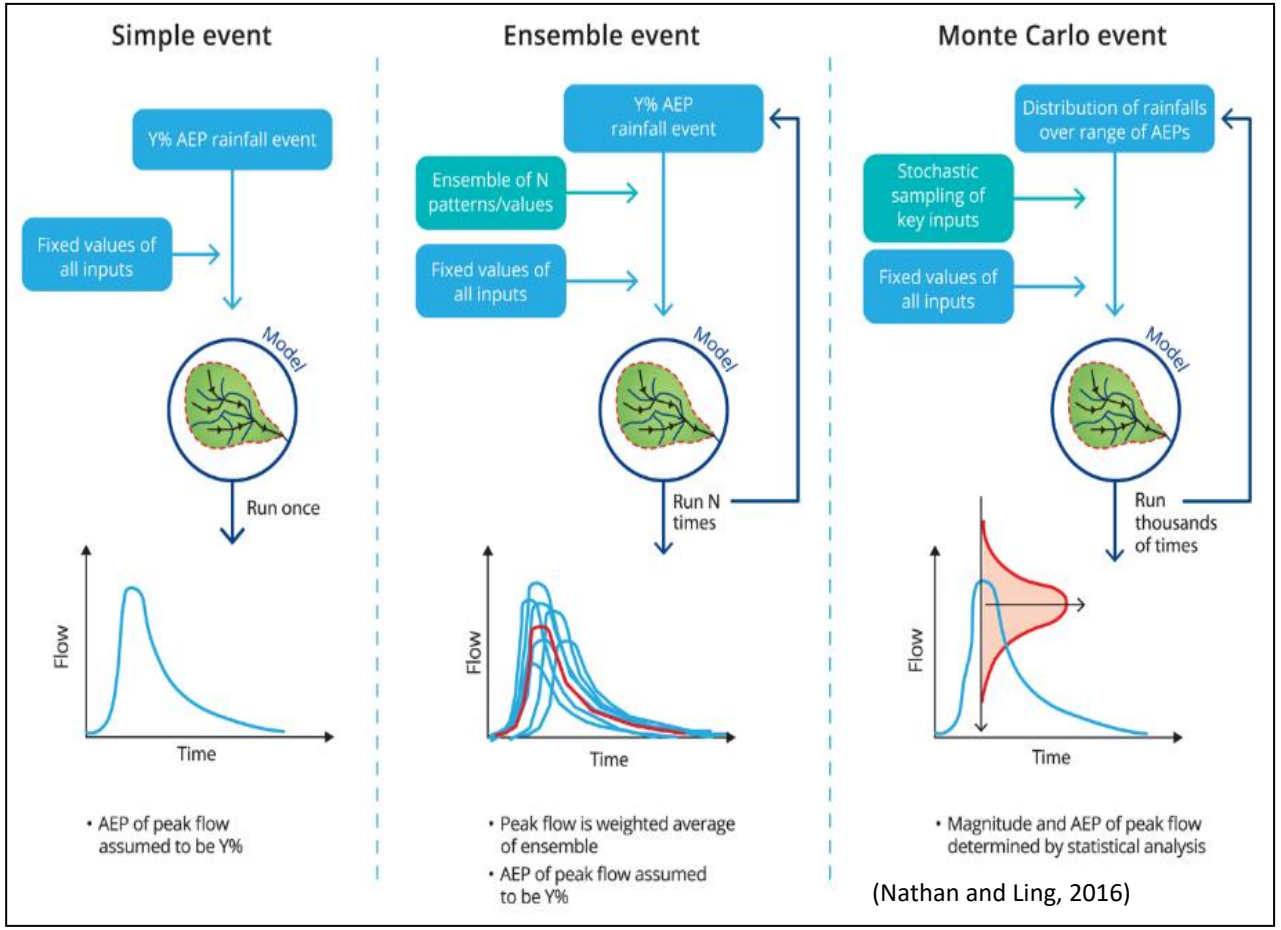


Ensemble Joint Probability

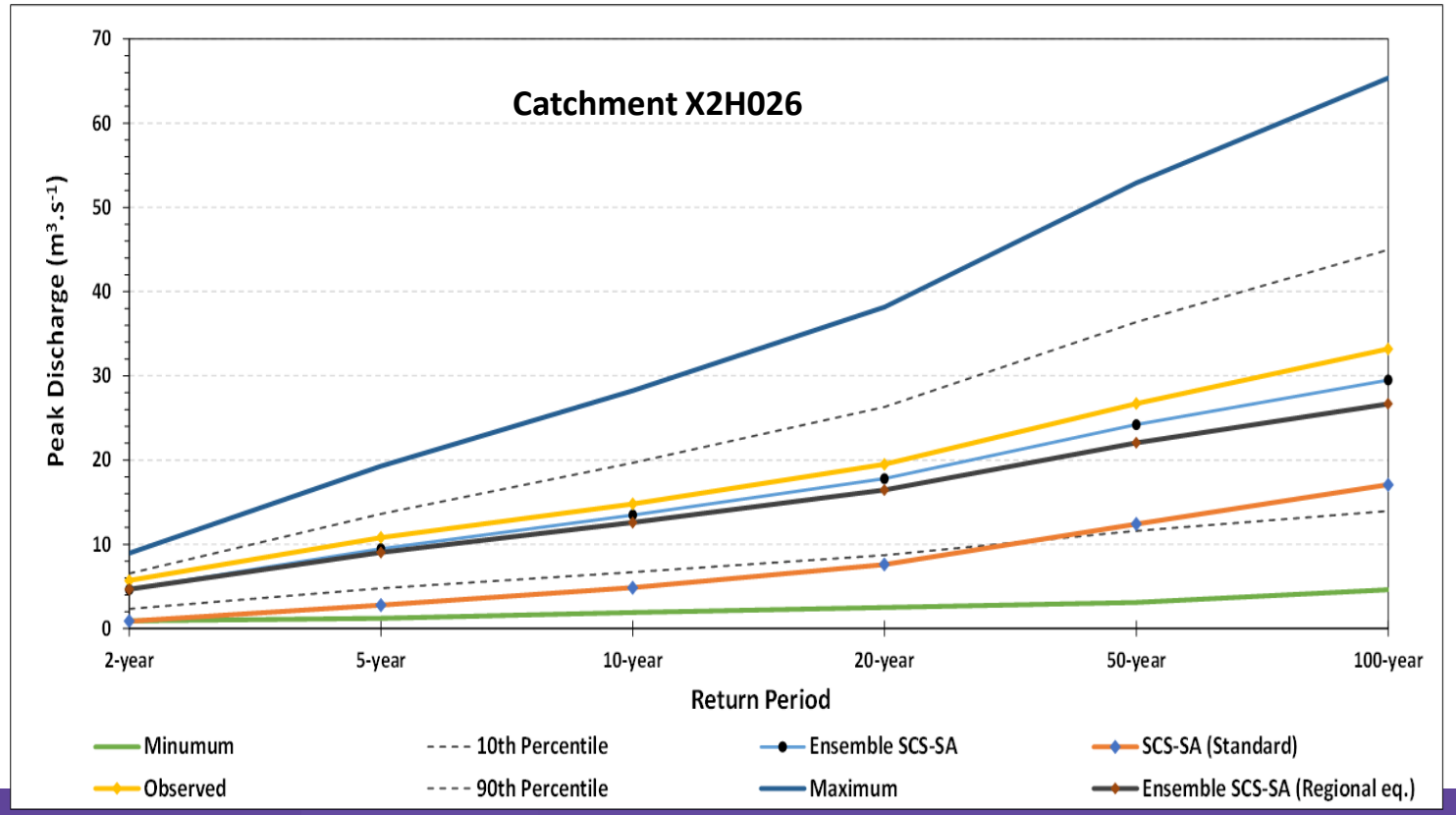
- Limitation of event-based DFE methods
  - Parameter selection
  - Transforming P_T into Q_T



(Nathan and Ling, 2016)

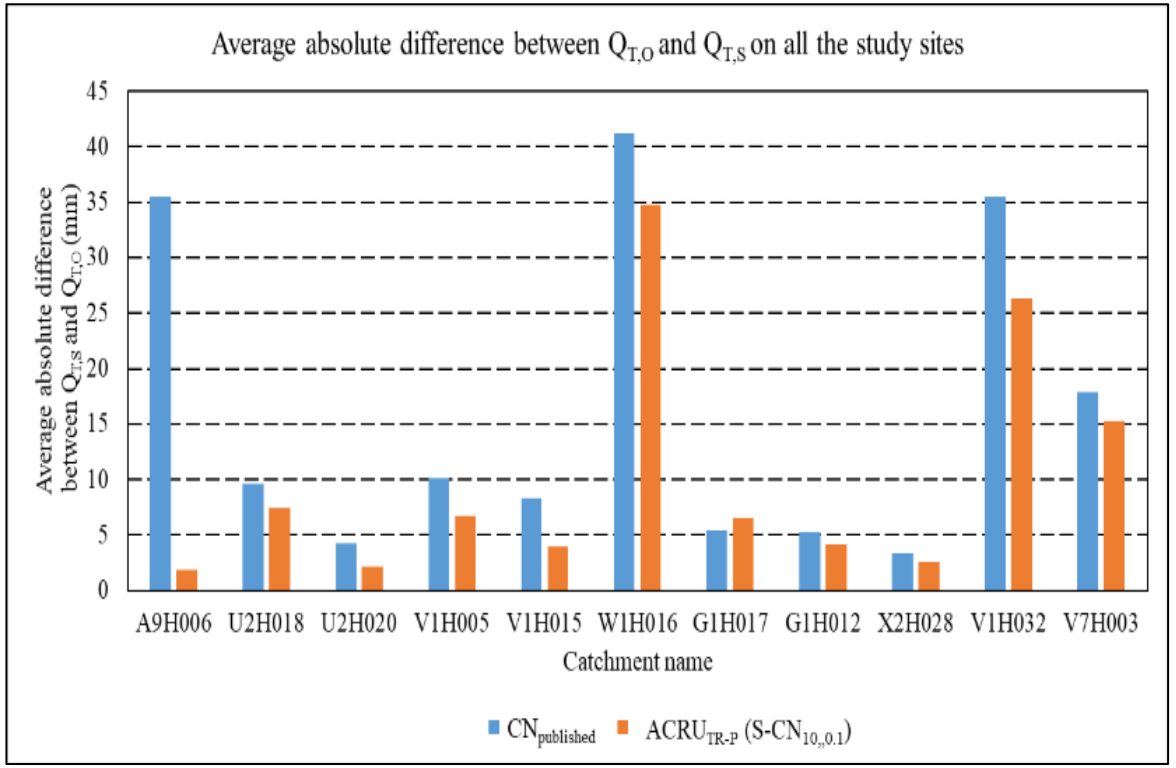
Ensemble Joint Probability SCS-SA (Dlamini, 2020)

- Distributions developed for
  - P, T_p, IRDIST, AMC
- Performance of Ensemble SCS-SA better than Standard SCS-SA



Performance of Published and Derived SCS CNs for Design Flood Estimation (Maharaj, 2021)

- Poor DFE performance using $CN_{published}$
- Best method(s) identified
  - Replicate $CN_{published}$
  - Best DFE – data derived CNs
- Feasible
  - Use simulated data to derive CNs
  - CNs for South African Land Ccover & Soil classifications



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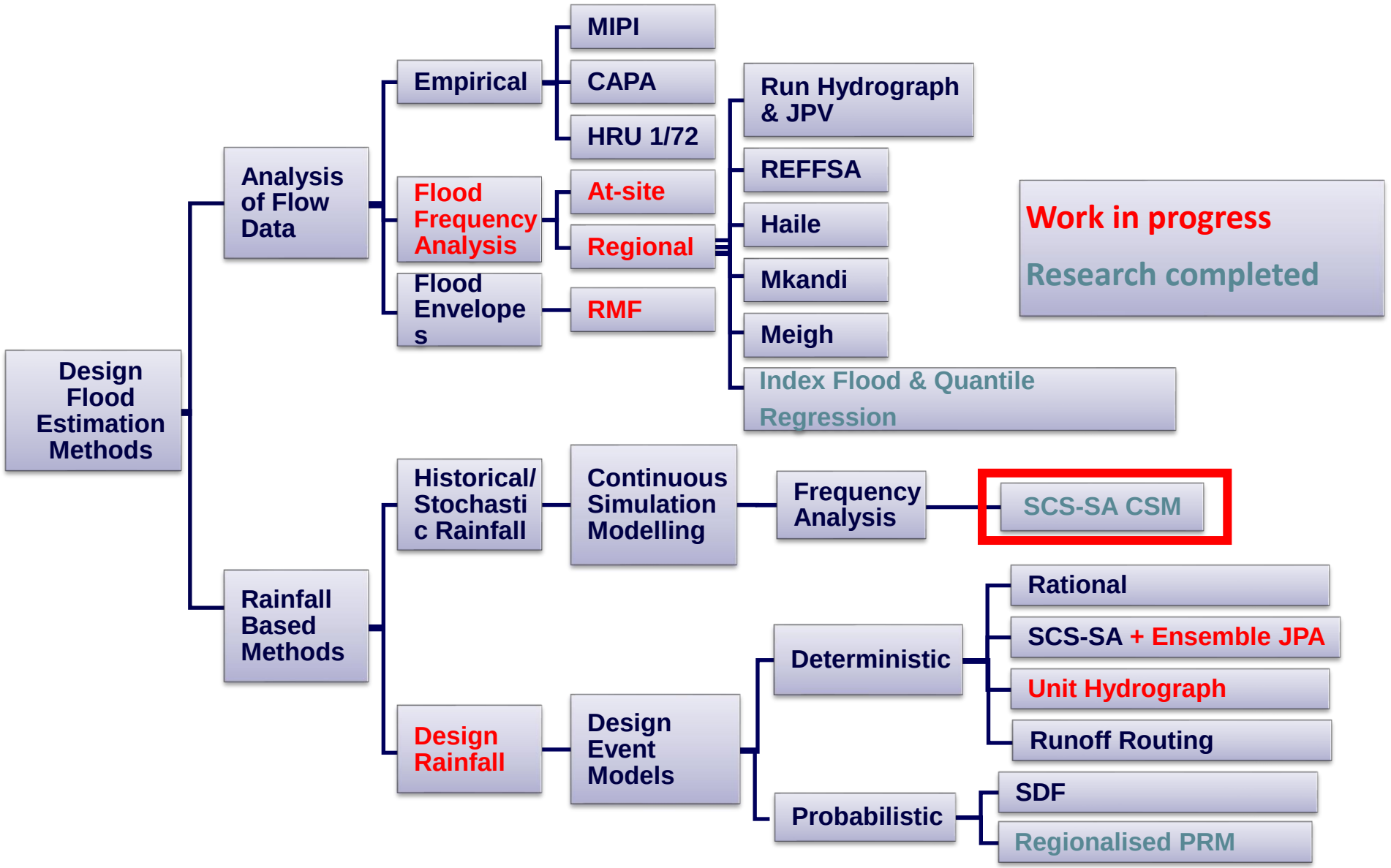
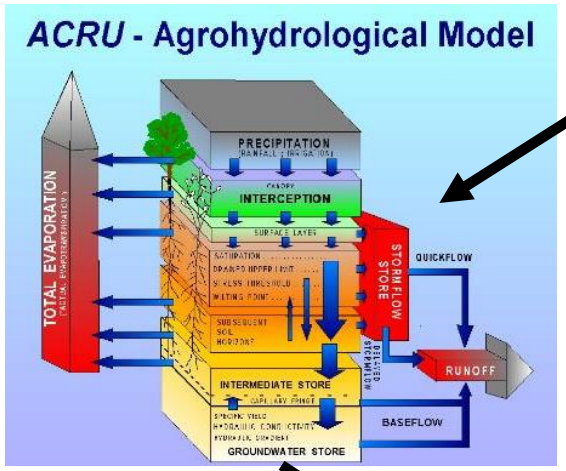
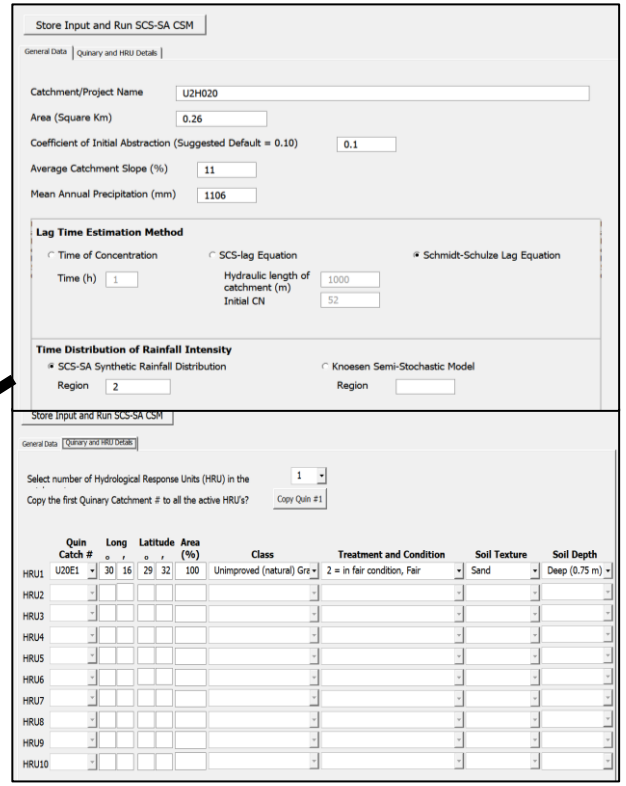
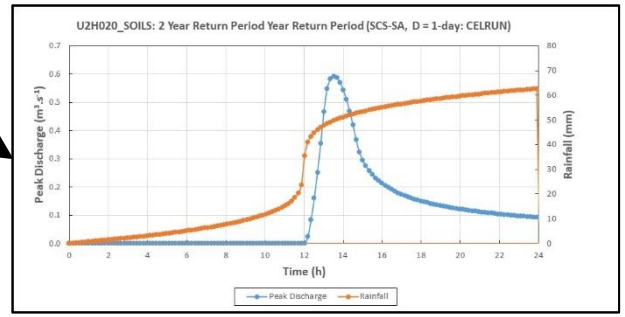


SCS-SA CSM

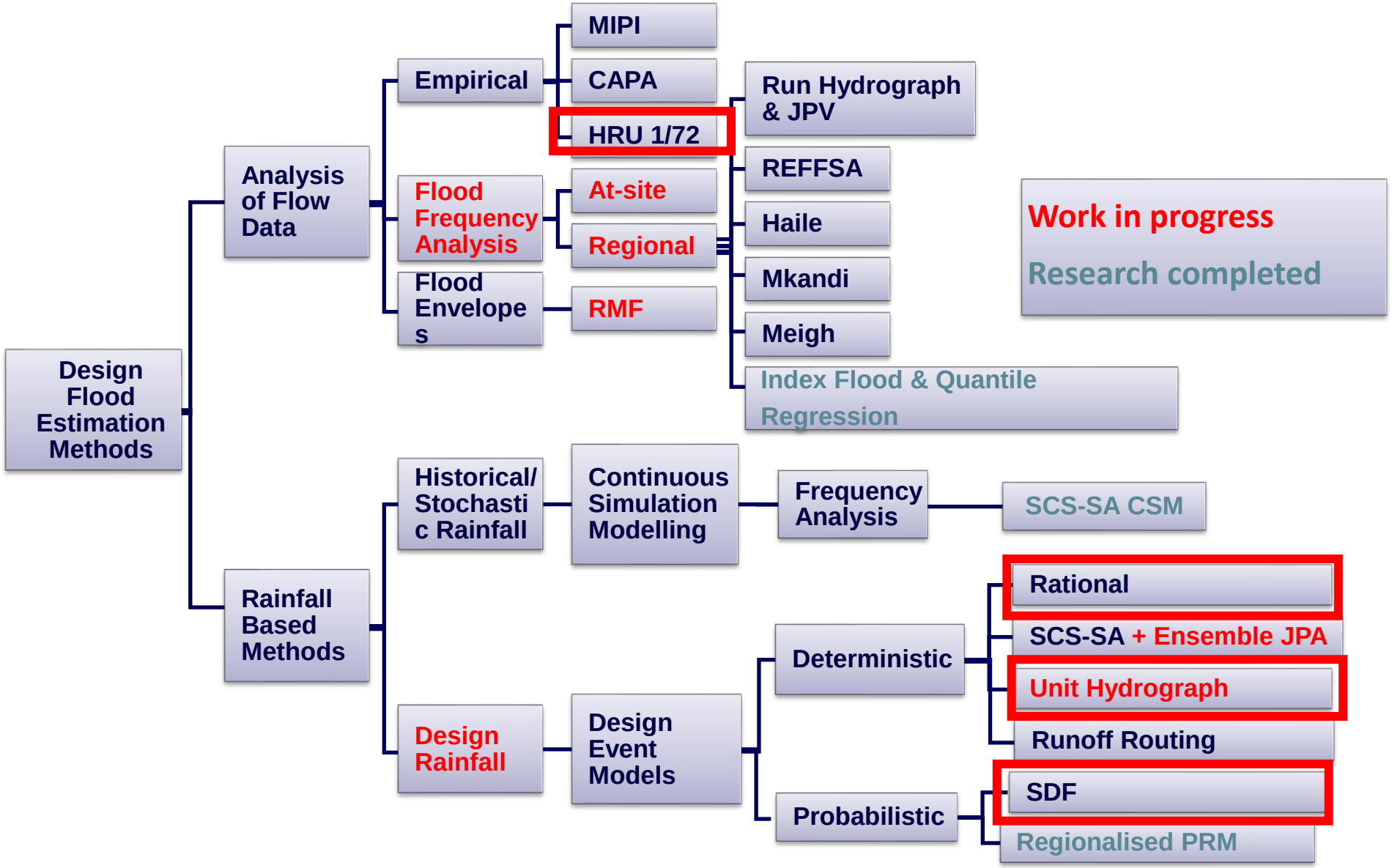
- CSM
  - Daily time step ACRU model
  - Configured for 5 838 Quinary Catchments (QC) in SA
- SCS-SA CSM
  - Land cover and soils
    - QC information
    - User selected
  - QT computed from simulated Q
  - $q_{p,T}$ = f(QT , IRDIST, lag) as per SCS
- SCS-SA CSM Performance
  - Better than SCS-SA
  - QC landcover and soils - reasonable
  - HRUs (catchment specific info) – better than using default QC info





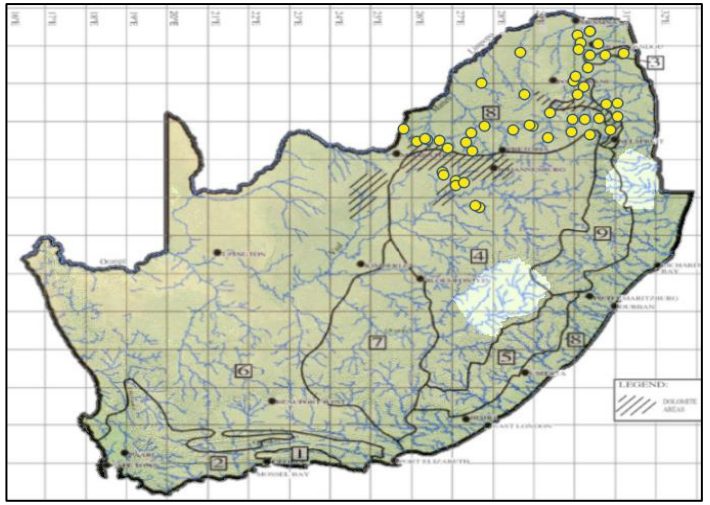


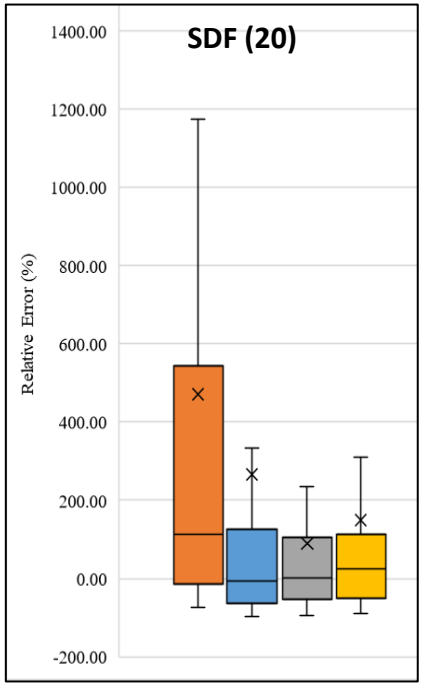
Use of Local Information to Improve DFE

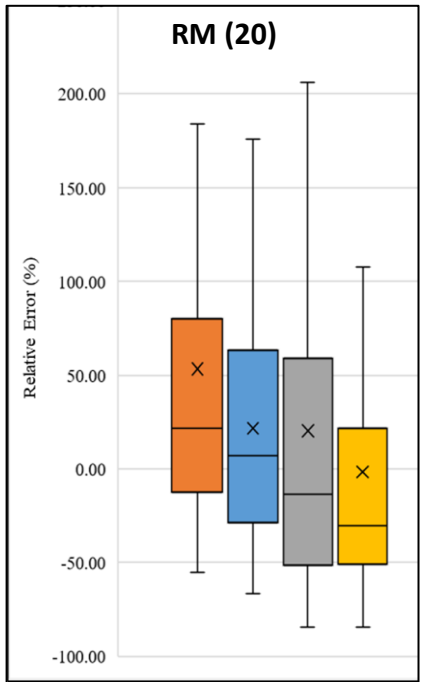


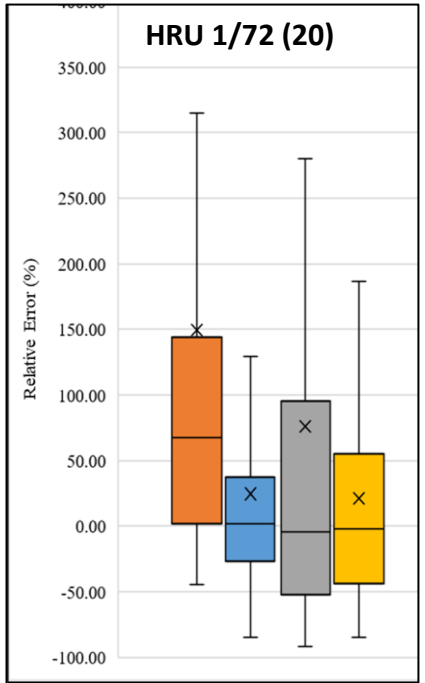
Use of Local Information from Donor Catchments to Improve Selected DFE Methods used in South Africa (Khoosal, 2021)

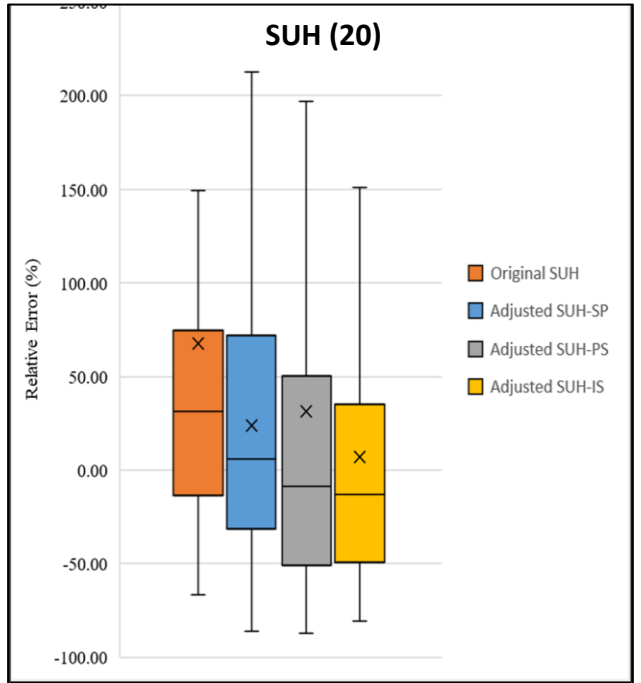
- Pilot study – 48 sites
- Transfer DFE errors at gauged donor site(s) to ungauged site
- Donor catchment selection
  - SP – Spatial Proximity
  - PS – Physical Similarity
  - IS – Integrated Similarity
- One or more donor catchments





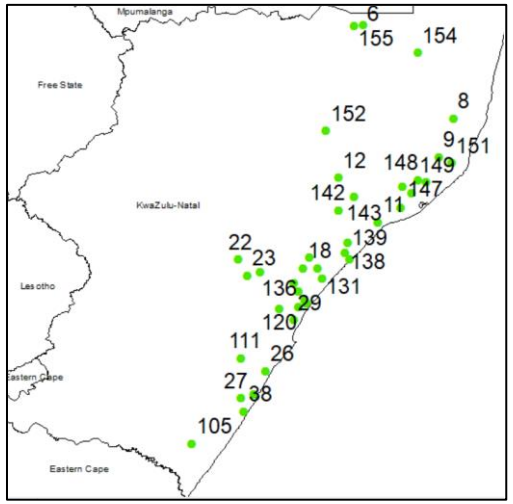


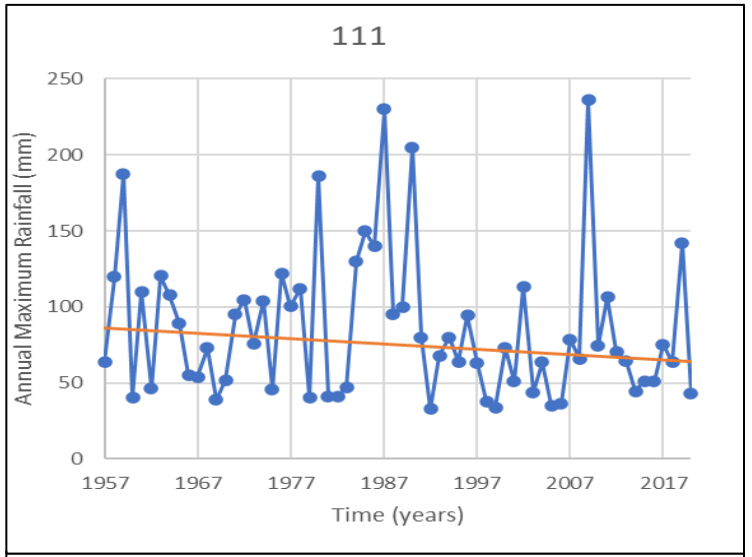


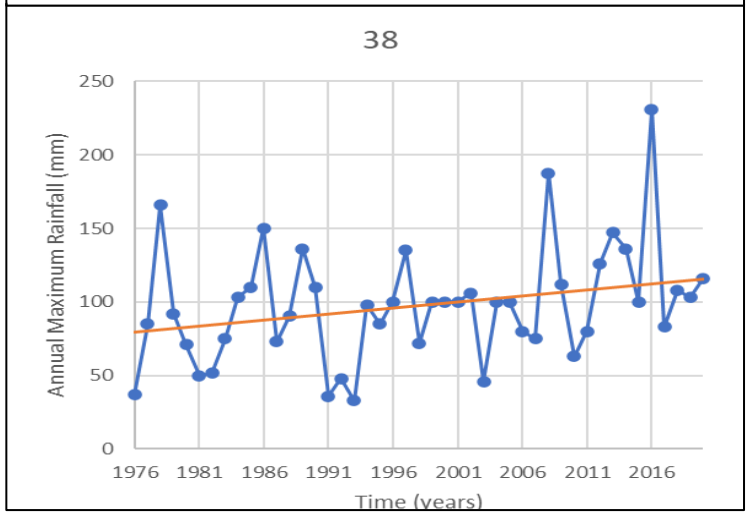


Non-Stationary Extreme Rainfall Analysis: Preliminary Pilot Study Results (Katelyn Johnson - PhD)

- Preliminary analysis
  - KwaZulu-Natal East Coast
  - 39 sites (>40 years, little missing data)
- Mann-Kendall and Sen's tests
  - 24 positive trends (1 significant)
  - 14 negative
  - 1 no trend
- Stationary vs non-stationary model
  - GEV distribution parameters - modelled using time as a covariate
  - 35 stations better modelled through the stationary model (lower AIC, BIC and RMSE)
- Observed trends not consistent with GCM/RCM predictions







Other Current Studies

- Update to Regional Maximum Flood
- National estimation of catchment T_p
- Urban flood hydrology
- Areal Reduction Factors (ARFs)
- Trends in extreme events and DFE
- Temporal distributions for daily rainfall disaggregation

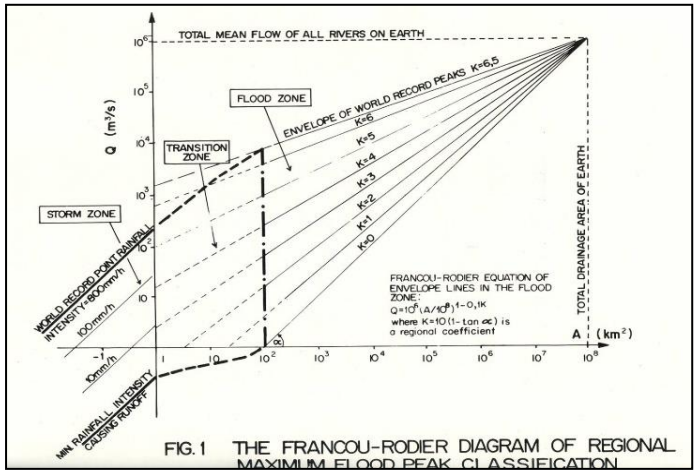
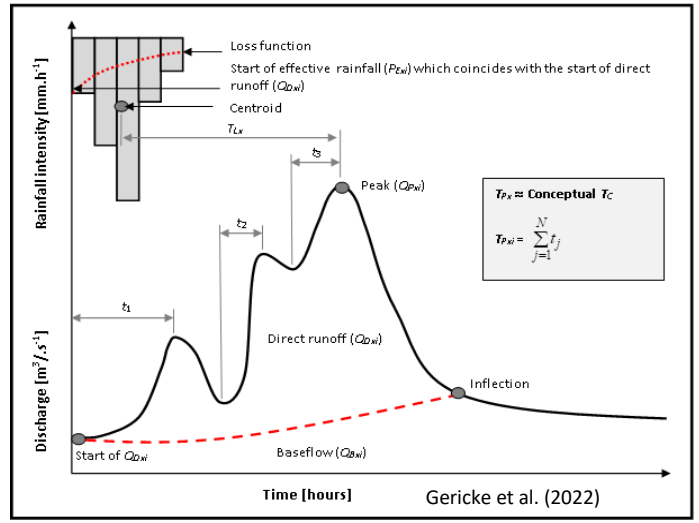
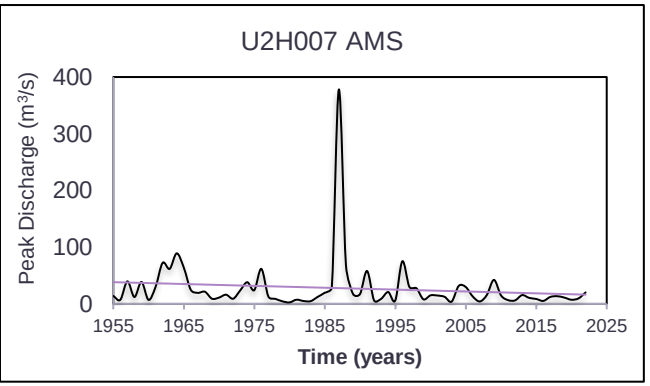
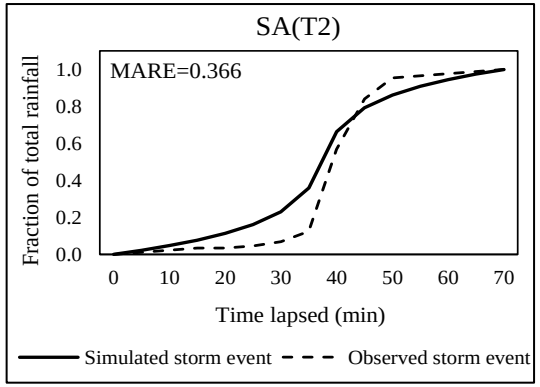


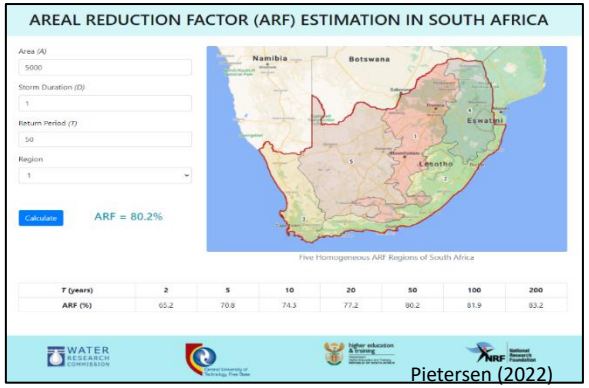
FIG. 1 THE FRANCOU-RODIER DIAGRAM OF REGIONAL MAXIMUM FLOOD PEAK CLASSIFICATION



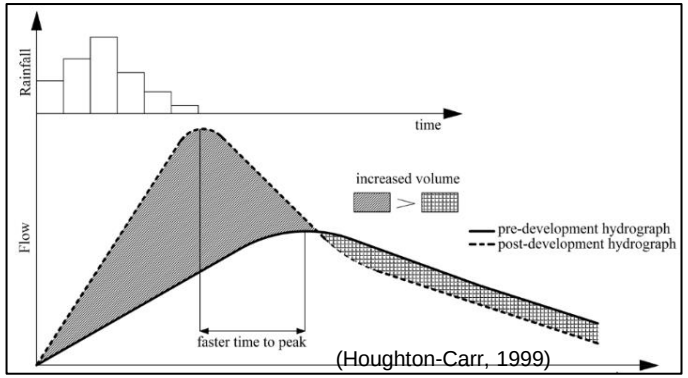
Gericke et al. (2022)







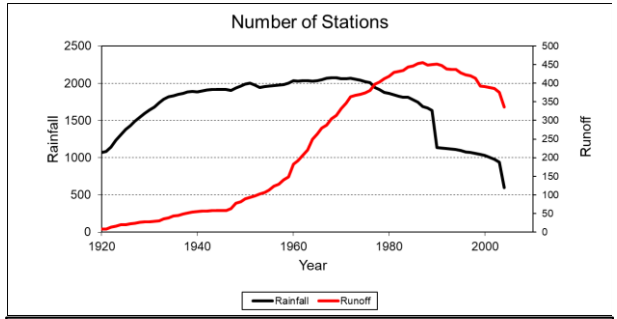
Pietersen (2022)

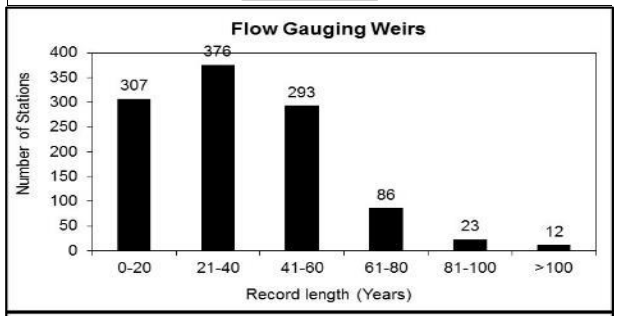


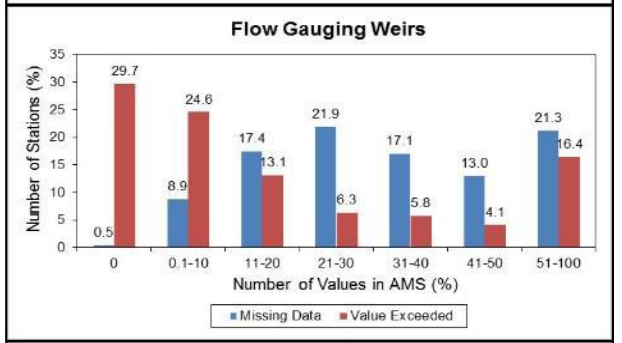
(Houghton-Carr, 1999)

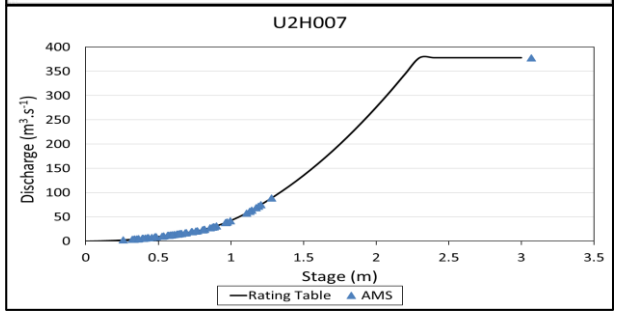
Some Challenges to Implementation

- Declining Hydrological Networks (Pitman, 2011)
- Length of records
- Missing data
- Flow gauging limitations
- Limited research capacity
- Focused and sustained funding for NFSP
- Access to rainfall and climate data from SAWS









Conclusions

- National Flood Studies Programme in South Africa
  - Plan in place
  - Endorsed by WRC, DWS, SANCOLD, SANRAL
  - Multi-institutional team approach adopted
  - International collaboration
  - Capacity development
  - Some progress made to update and modernise methods for design flood estimation in South Africa
  - Convert research products into practice
  - Still a lot to do – collaboration welcomed!

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Thank you

- Comments and questions welcome!