Modification of SWAT to simulate saturation excess runoff

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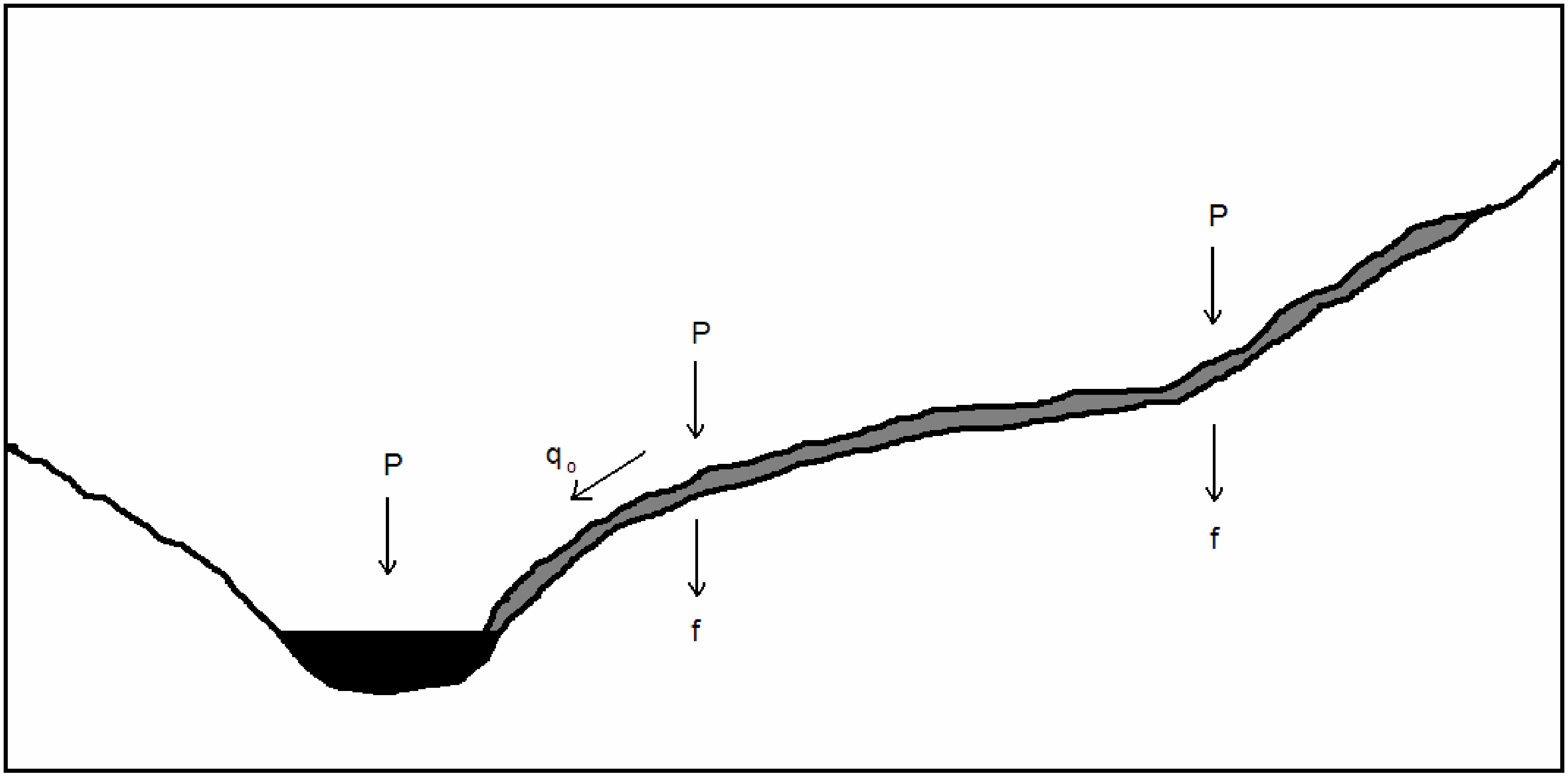
Introduction

- Hillslope hydrology has been studied extensively in the past 50 years
- Storm runoff is an important component of the hydrological cycle
- Research has shown that several storm runoff generation mechanisms exist
- Important to accurately represent storm runoff generation in hydrologic models when making management decisions

Introduction

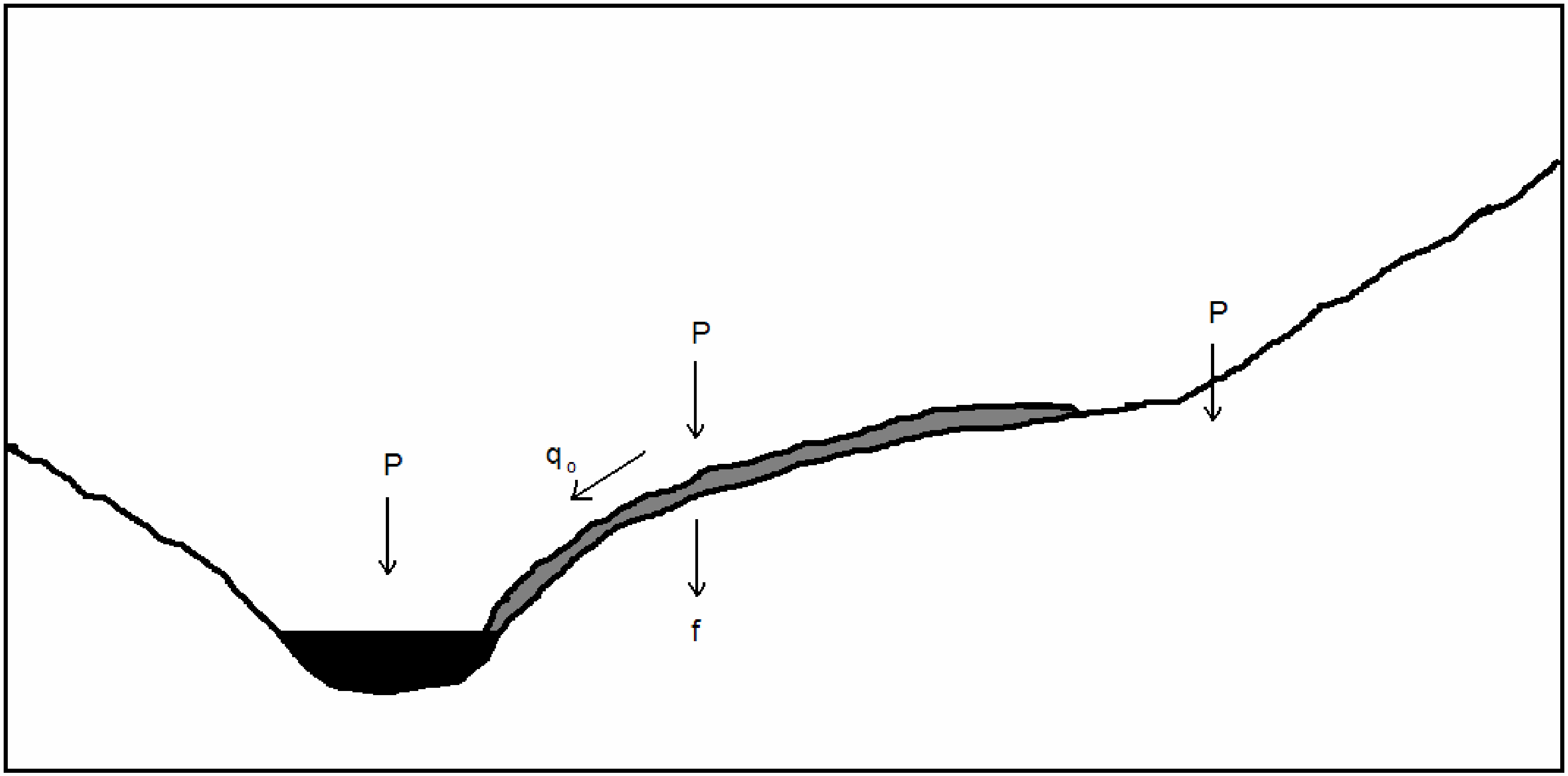
- **Infiltration excess runoff**



Beven (2001)

Introduction

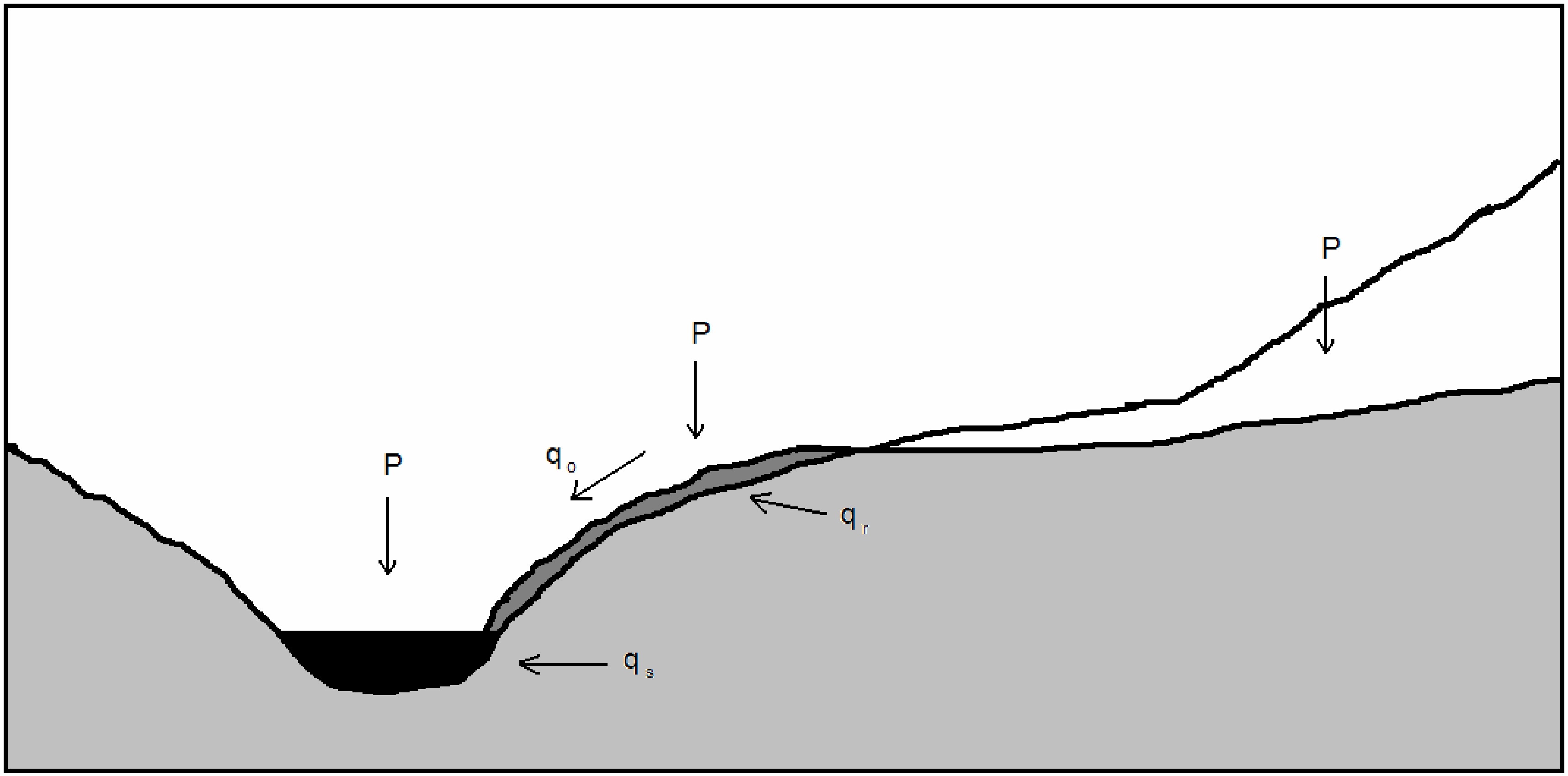
- Partial area infiltration excess runoff



Beven (2001)

Introduction

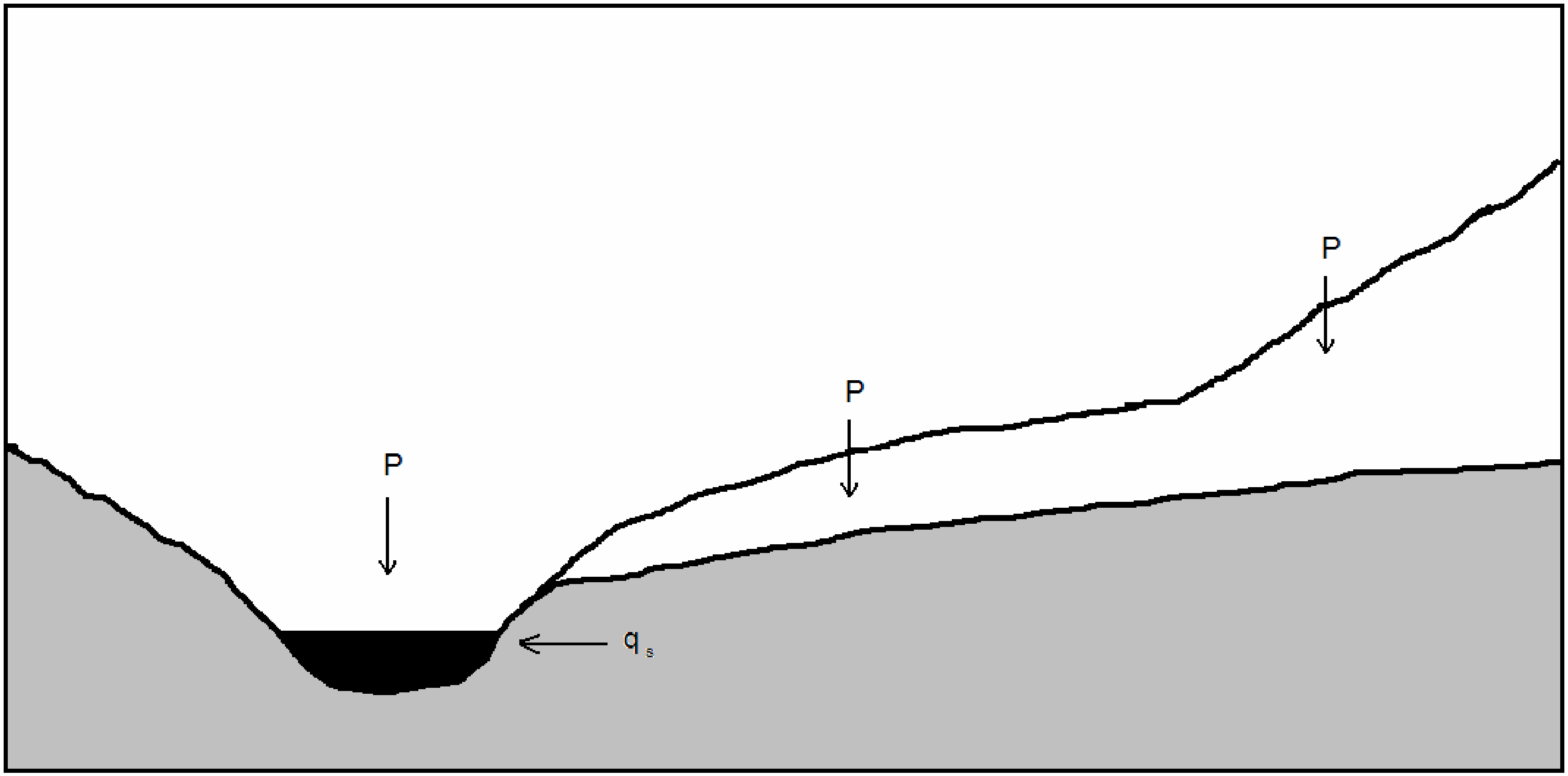
- **Saturation excess runoff**



Beven (2001)

Introduction

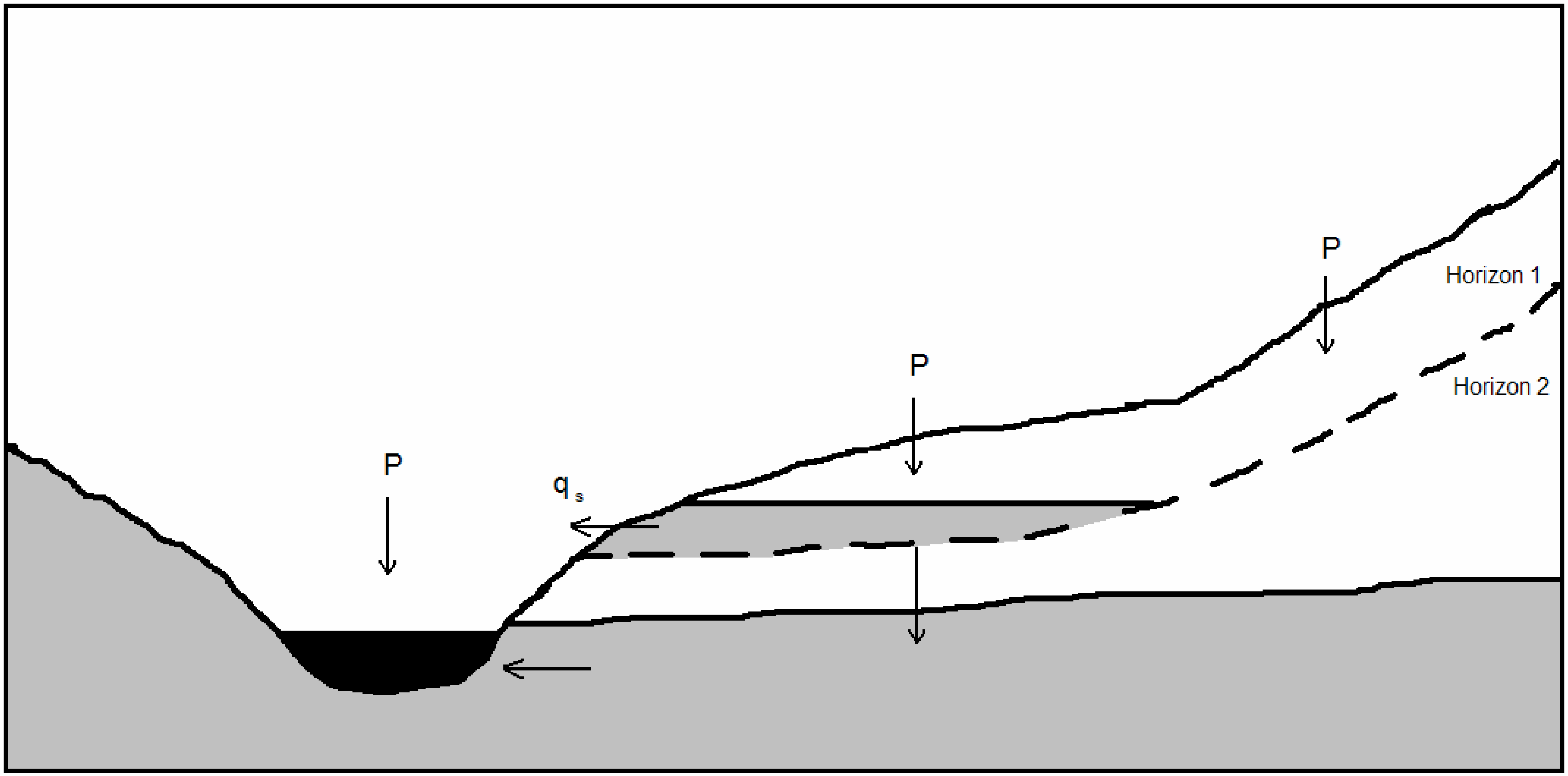
- **Subsurface runoff**



Beven (2001)

Introduction

- Perched subsurface runoff



Beven (2001)

Introduction

- Infiltration excess runoff rarely observed in southeast Australia
- Saturation excess runoff considered to be dominant process
- Catchments dominated by duplex soils
- Thin permeable layer (A horizon) overlying an impermeable layer (B horizon)
- Lack of vertical capacity in B horizon causes pondage and leads to development of an ephemeral, perched water table

Introduction

- Water table intersects ground surface to produce Variable Source Area (VSA)
- Rain that falls onto VSAs is transformed directly into surface runoff

Curve number method

- Empirical formulation developed from data collected in the USA
- Simple method that produces reliable results
- Unable to distinguish between infiltration excess and saturation excess runoff
- Volume of runoff assumed to be generated uniformly over the entire catchment

Curve number method

- Not widely used in Australia
- Method has been criticised due to poor results or inferior results compared to water balance models

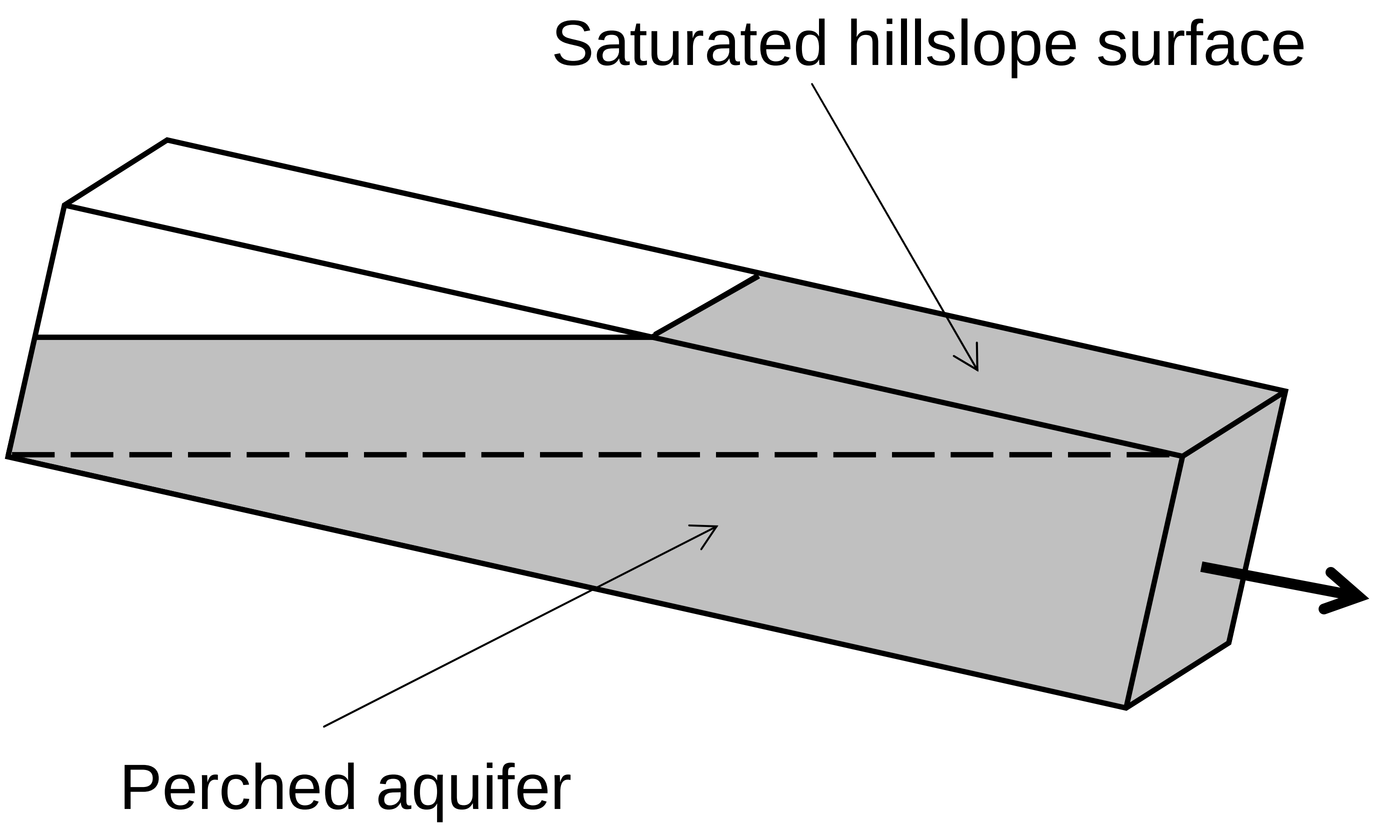
Saturation excess runoff

- Long-standing recognition of the importance of simulating saturation excess runoff in hydrological models
- Models and methods utilised
  - BROOK – empirical formulation
  - TANK – bucket
  - TOPMODEL – topographic index
  - VIC – Xinanjiang distribution
- No allowance made for runoff generated from ephemeral, perched water table

CATPRO

- CATPRO is a daily time-step water balance model developed specifically for Australian conditions
- Simulates occurrence of an ephemeral, perched water table in duplex soils
- CATPRO conceptualisation a generalisation of the kinematic storage model
- Explicitly accounts for relationship perched water tables have with VSAs in a simple and straightforward manner

CATPRO



Kuczera et al. (1993)

Kinematic storage model

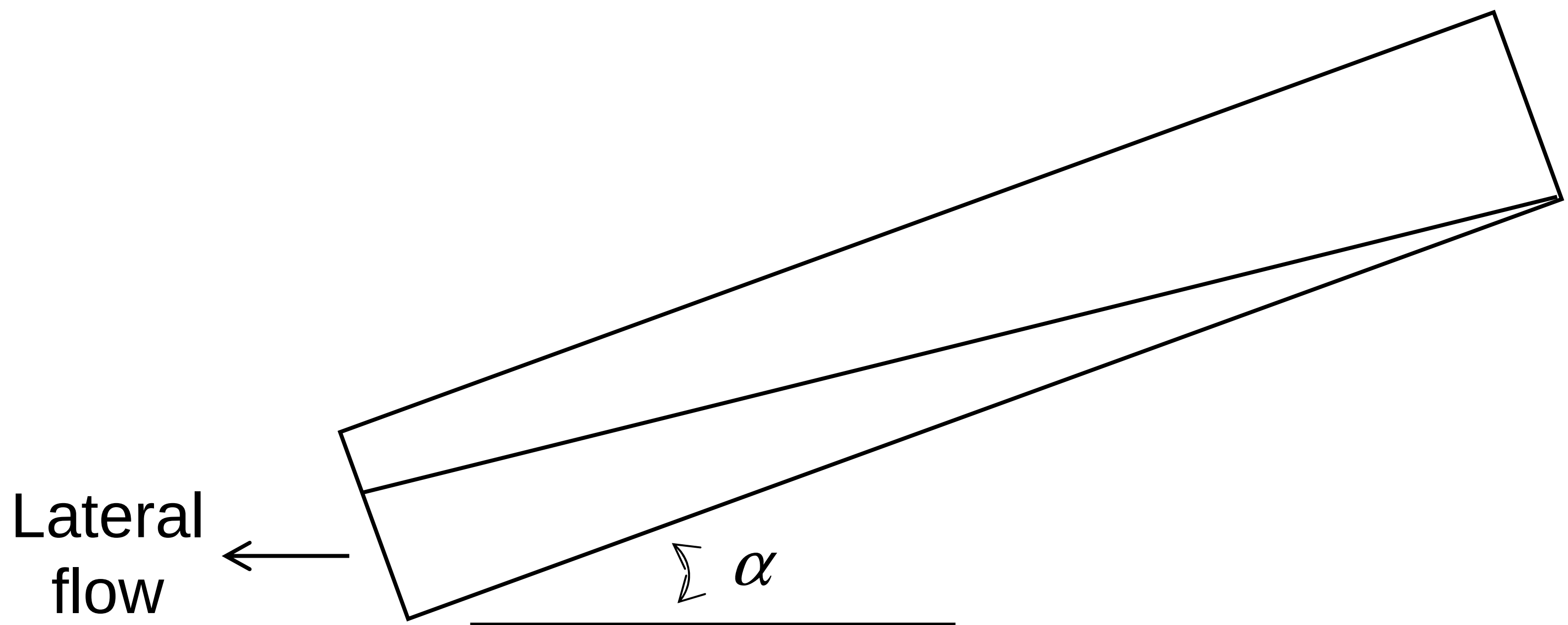
- Kinematic storage model used by several hydrologic models to simulate lateral flow
- Sloan et al. (1983) reported that

  "Surface runoff is easily accounted for in this model"

- Ormsbee and Khan (1989) embedded the kinematic storage model into HEC-1 to simulate surface runoff and lateral flow
- Kinematic storage model extended in SWAT to simulate saturation excess runoff

Kinematic storage model

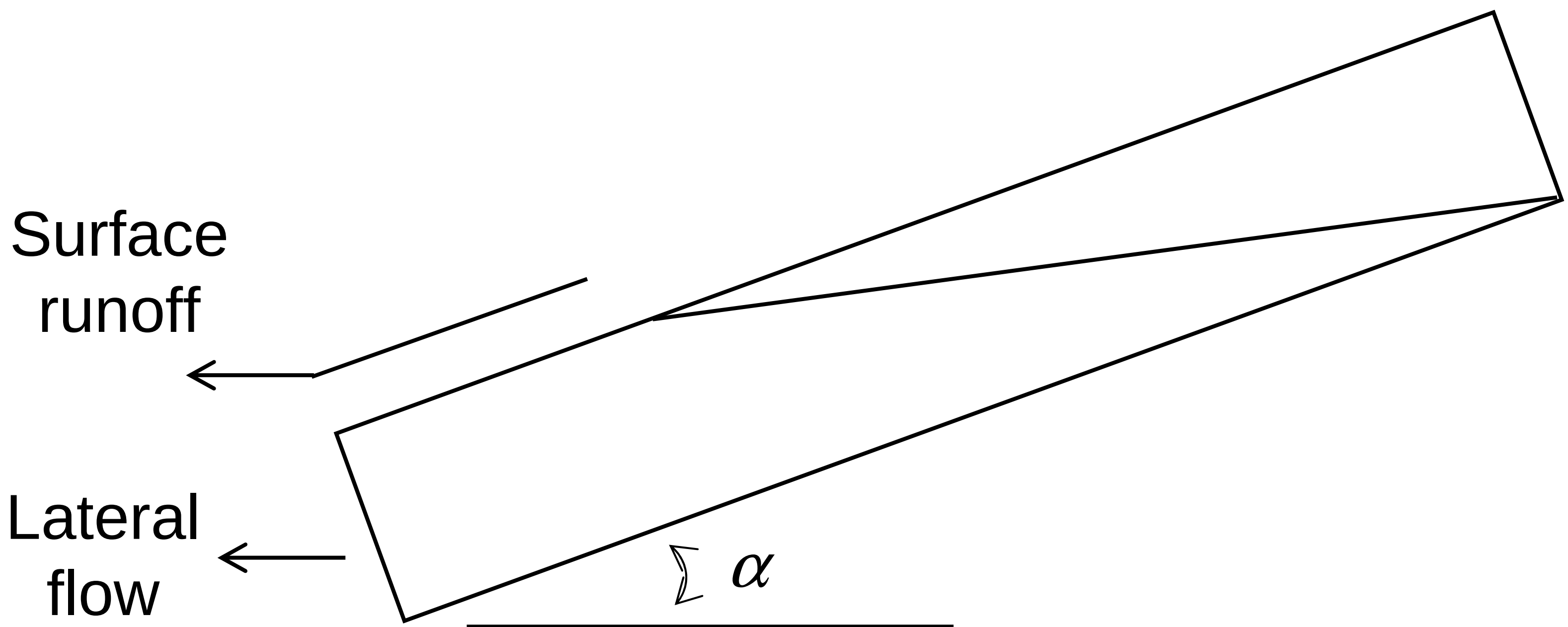
- **Without saturation excess runoff**



Sloan et al. (1983)

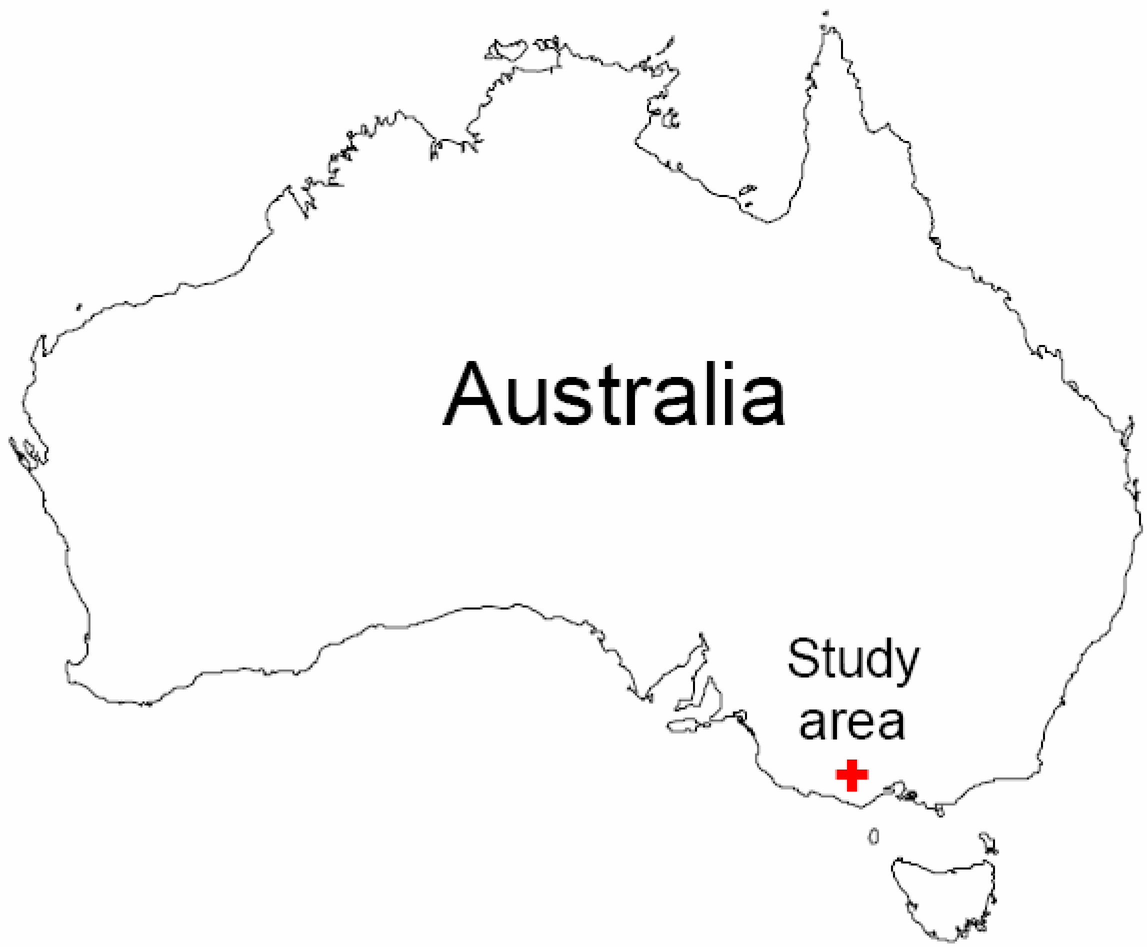
Kinematic storage model

- **With saturation excess runoff**



Ormsbee and Khan (1989)

Study area



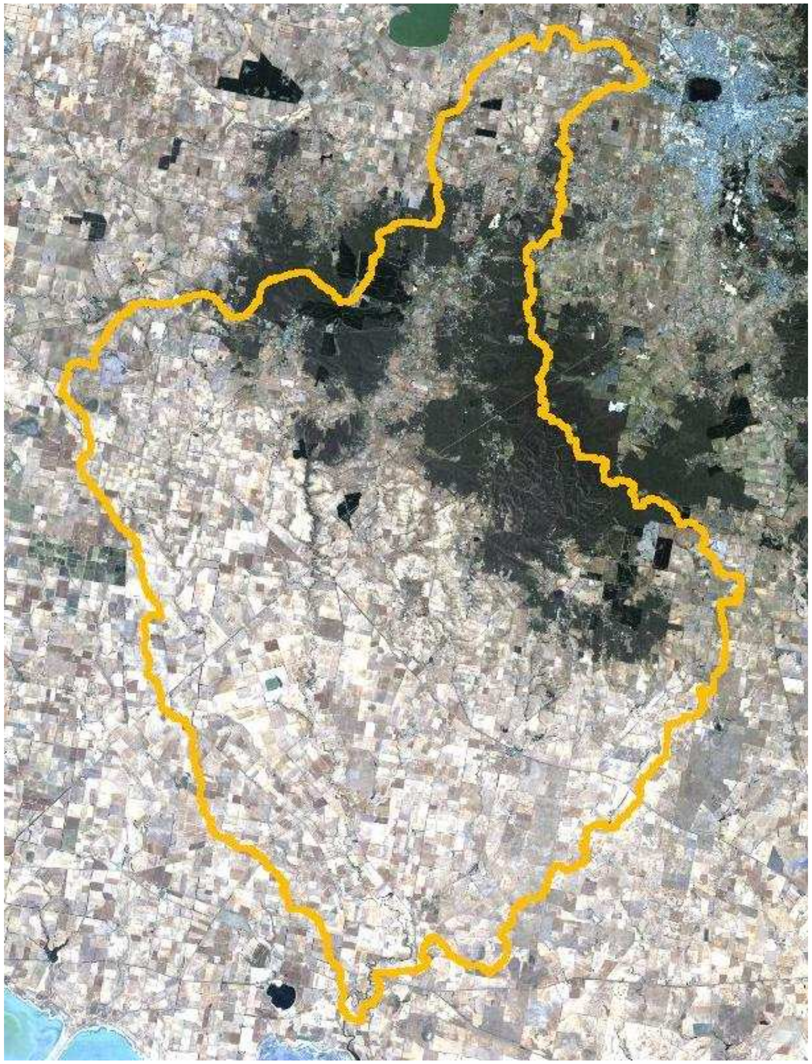
Study area

- Woody Yaloak River catchment
- Major land uses
  - Agriculture (65%)
  - Forest (30%)
- Soils predominantly duplex
- Streamflow gauging stations
  - Pitfield (306 km^2)
  - Cressy (1157 km^2)

Study area

- Low-yielding catchment with ephemeral streams
  - Annual rainfall = 550-700 mm
  - Runoff/rainfall ratio = 0.07

Study area

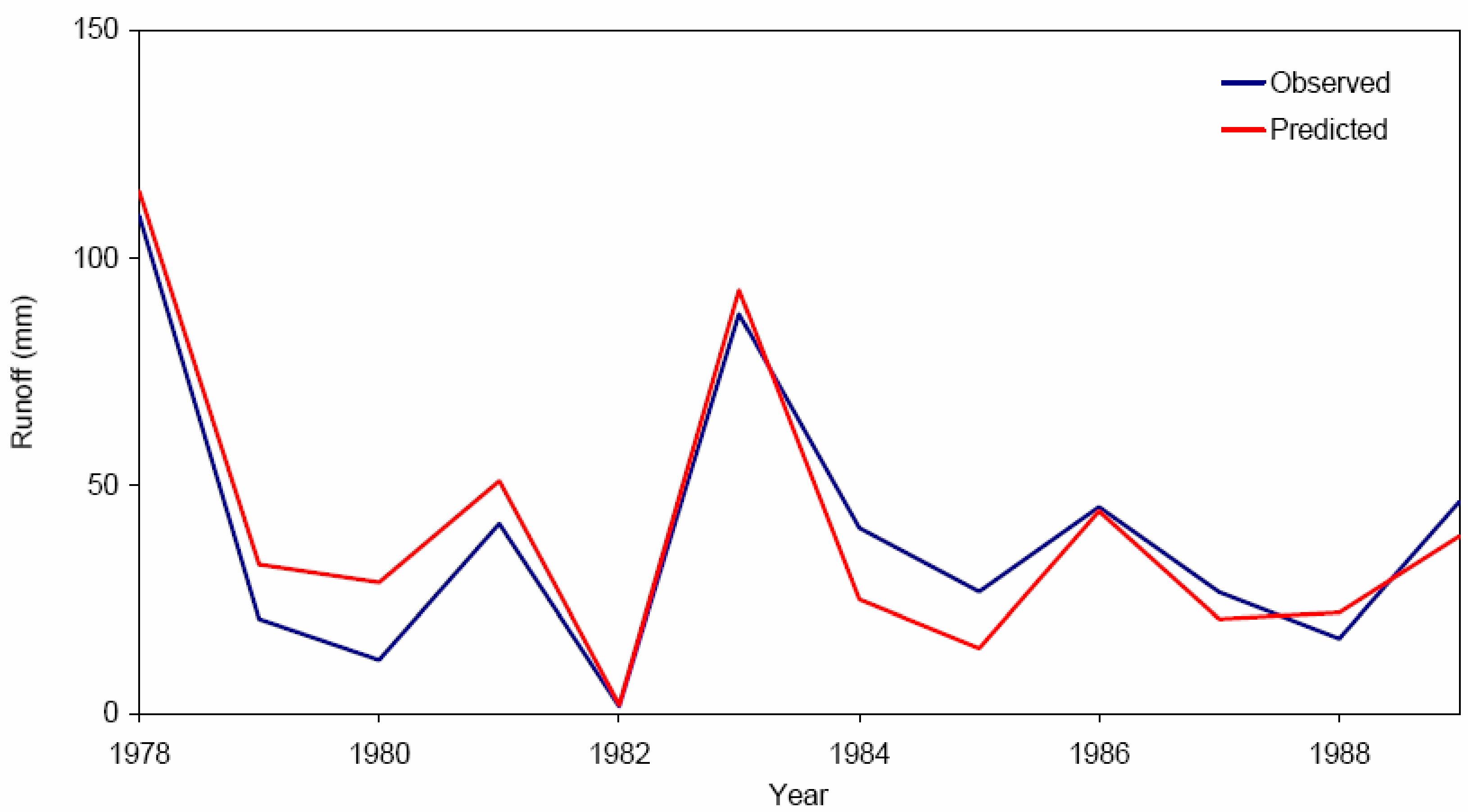


Model calibration and evaluation

- Model automatically calibrated using SCE algorithm
- Calibration performed at Pitfield first then at Cressy
- Split sample test employed
  - Calibration 1978-1989
  - Validation 1990-2001
- Model performance assessed using graphical and statistical techniques

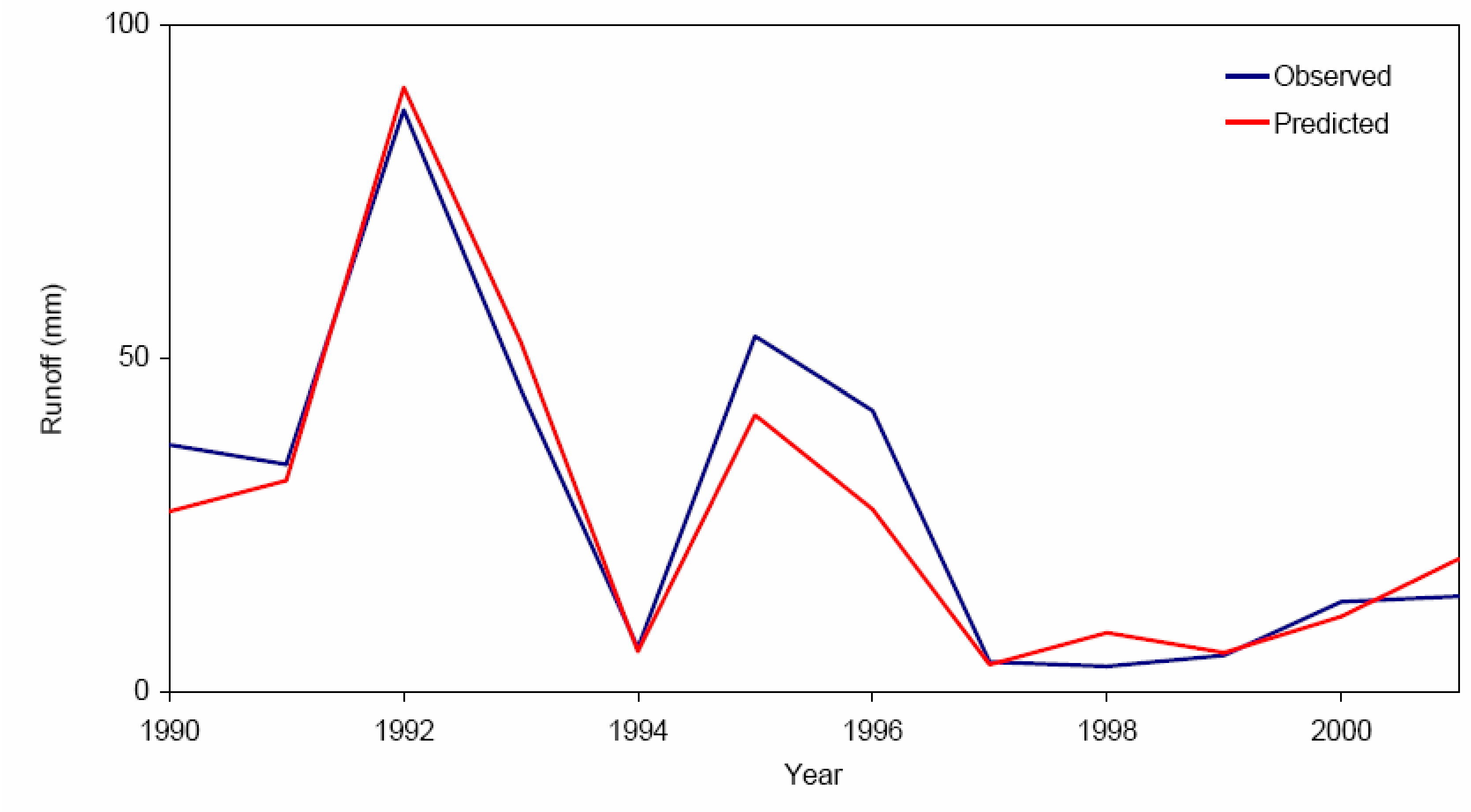
Results

- **Annual runoff – calibration period**



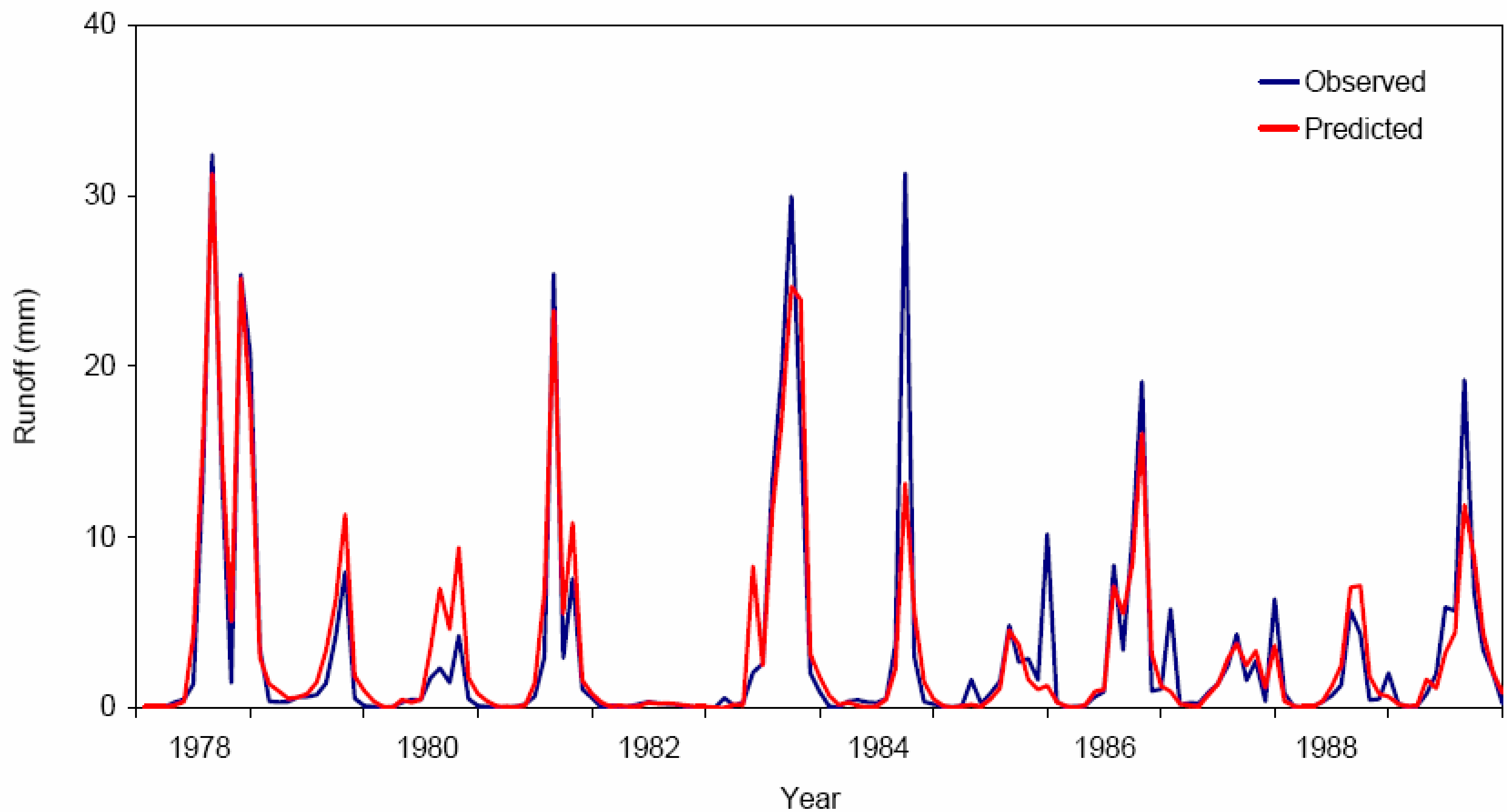
Results

- **Annual runoff – validation period**



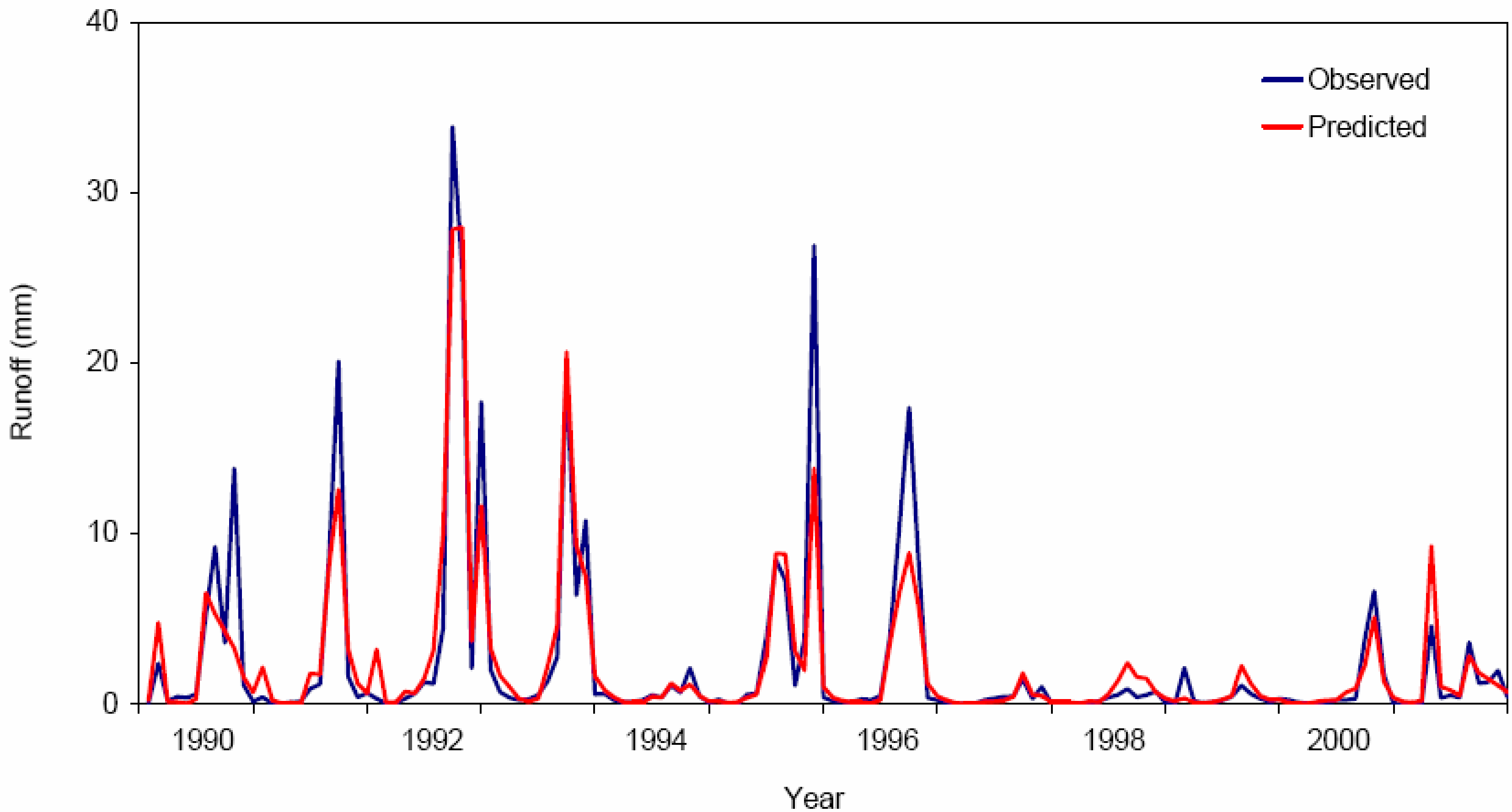
Results

- **Monthly runoff – calibration period**



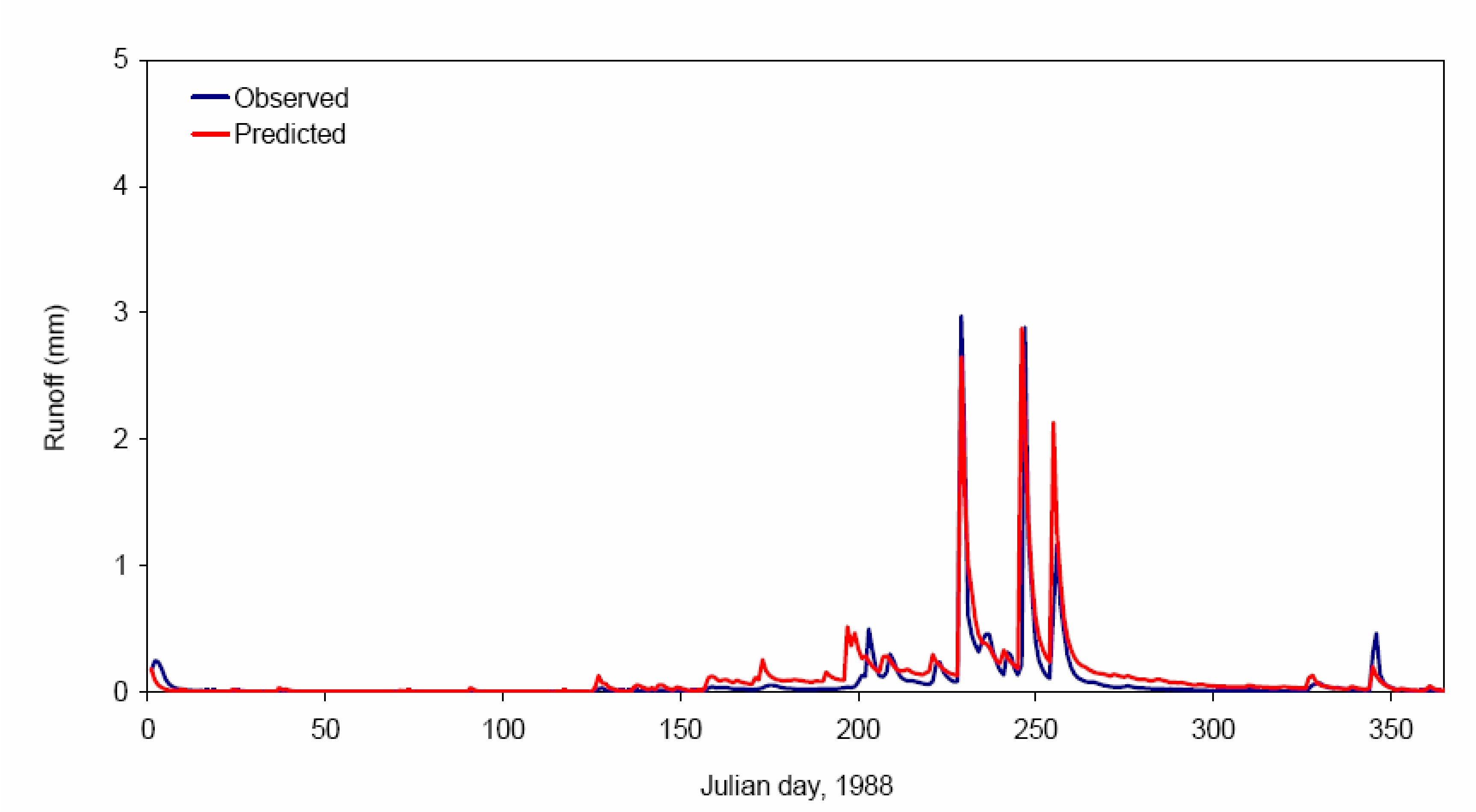
Results

- **Monthly runoff – validation period**



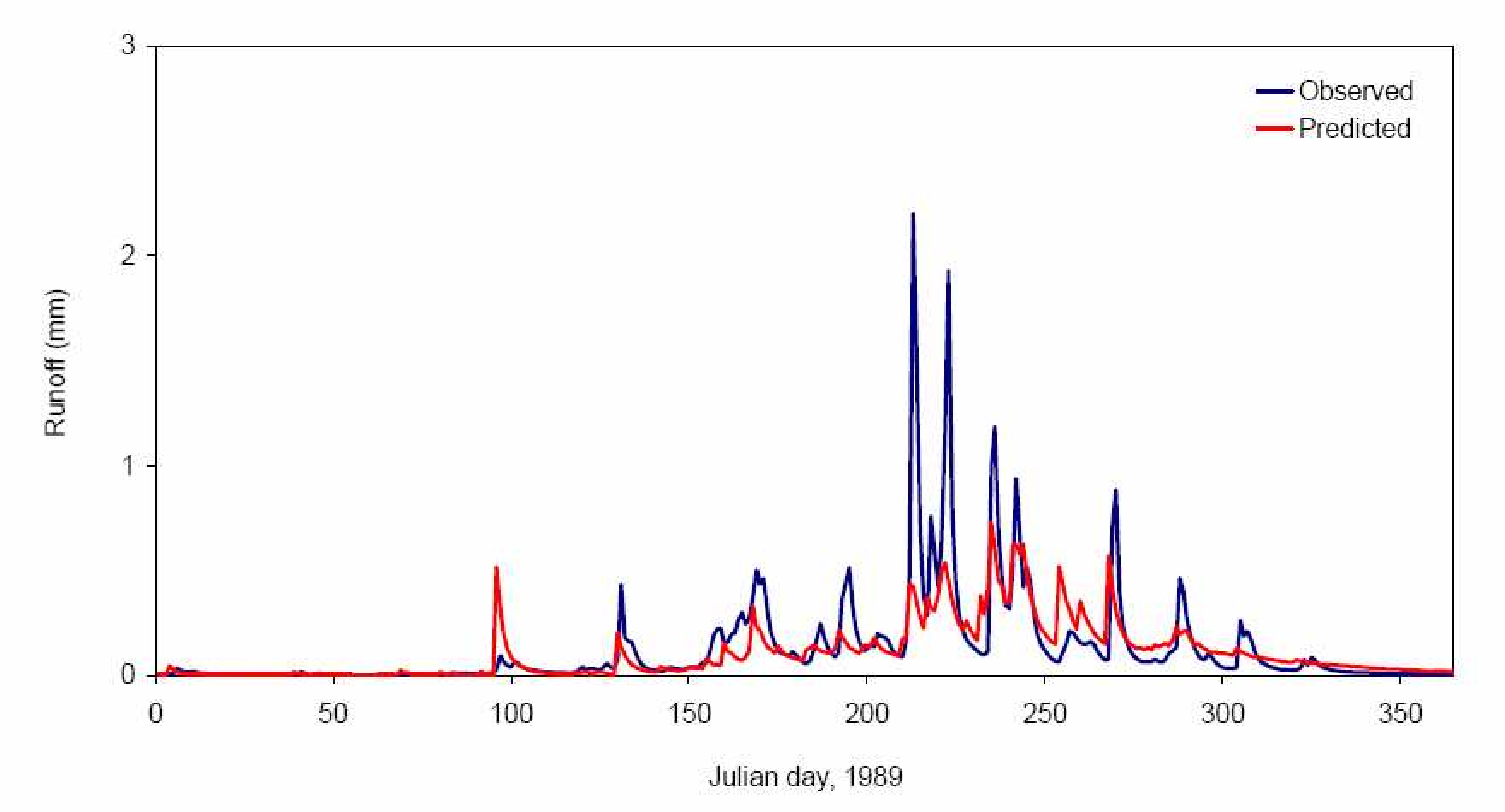
Results

- **Daily runoff - 1988**



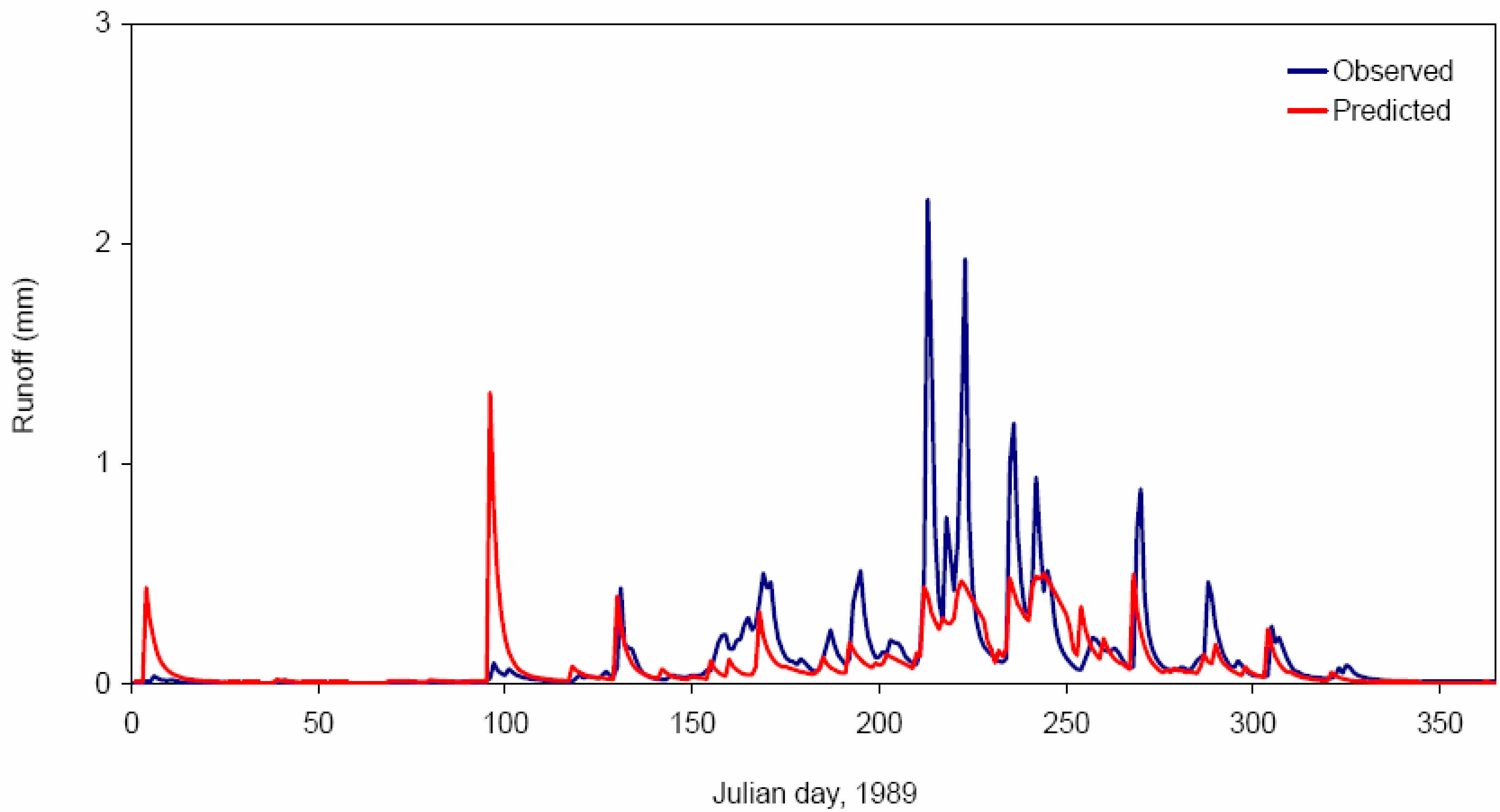
Results

- **Daily runoff – 1989**



Results

- **Daily runoff – 1989 (CN method)**



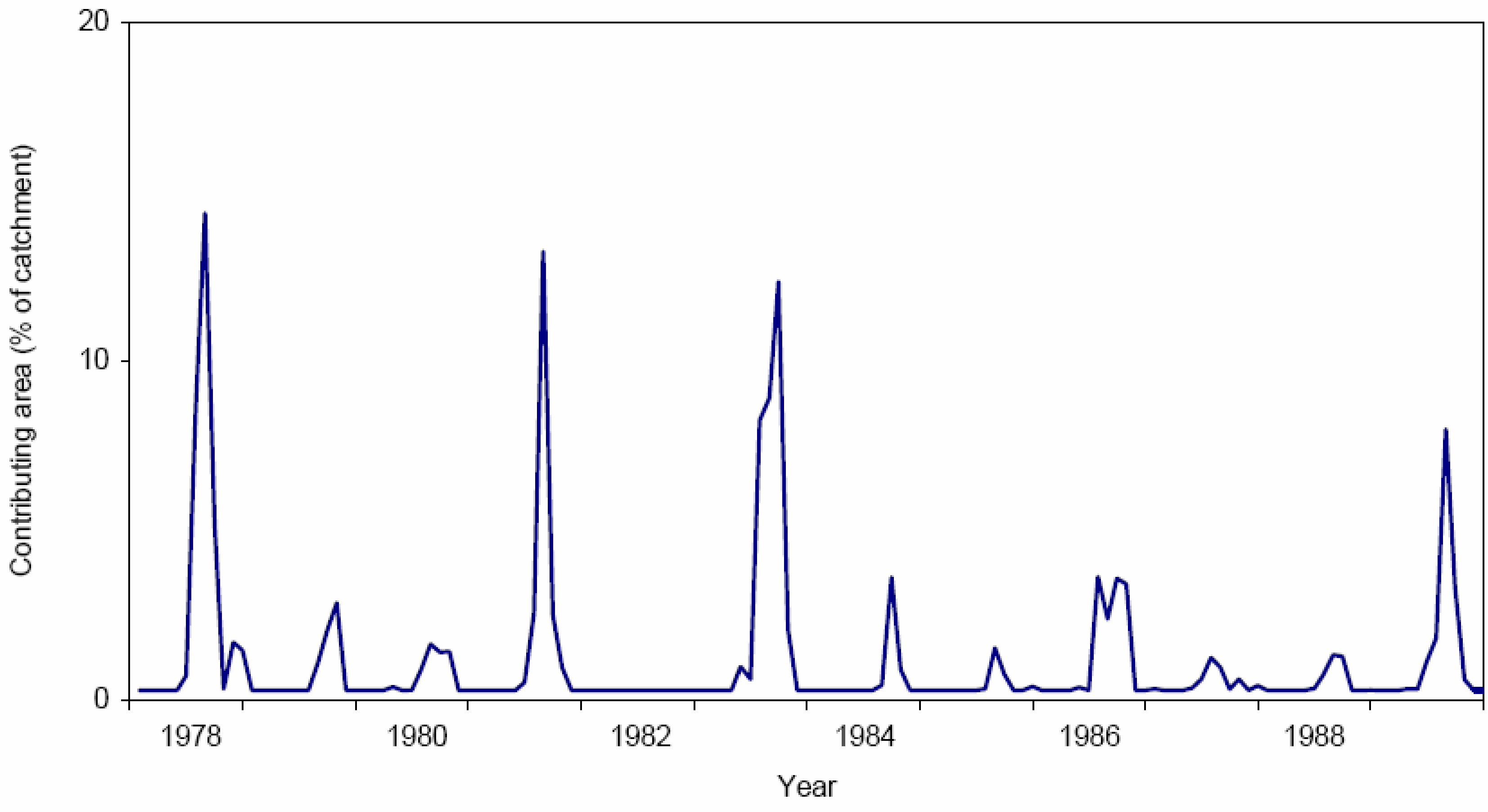
Results

- **Coefficient of efficiency**

	Calibration		Validation	
Time step	**SWAT-KSM**	**SWAT-CN**	**SWAT-KSM**	**SWAT-CN**
Annual	0.90	0.91	0.92	0.93
Monthly	0.85	0.82	0.84	0.82
Daily	0.56	0.55	0.46	0.44

Results

- **Mean monthly contributing area**



Discussion

- Long-term water balance of the study area reproduced relatively well
- SWAT-KSM consistent with the observed dynamics of runoff generation in catchments dominated by duplex soils
- Utilisation of kinematic storage model places SWAT on a more rational, physically correct and less empirical footing
- Possible to use on either daily or sub-daily time step

Discussion

- SWAT-KSM can be applied to other catchments around the world where perched water tables give rise to VSAs
- Application of model to catchments in different regions recommended to stringently test model performance

Conclusion

- Saturation excess runoff dominant runoff generation mechanism in southeast Australia
- Kinematic storage model can be utilised in a manner that is consistent with VSA concept
- Extension of kinematic storage model in SWAT to simulate saturation excess runoff a simple yet effective approach
- Performance of SWAT-KSM for a low-yielding catchment was relatively good
- Further testing of model required

Acknowledgements

- Gordon Putz (University of Saskatchewan)

References

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