

Natural variability versus anthropogenic change: modelling climate and discharge characteristics of the Meuse basin during Holocene and recent periods

9th January 2007

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Structure of Presentation

- Aims and Rationale
- Approach and Methods
- Calibration and Validation
- Preliminary Results and Discussion
- Conclusions

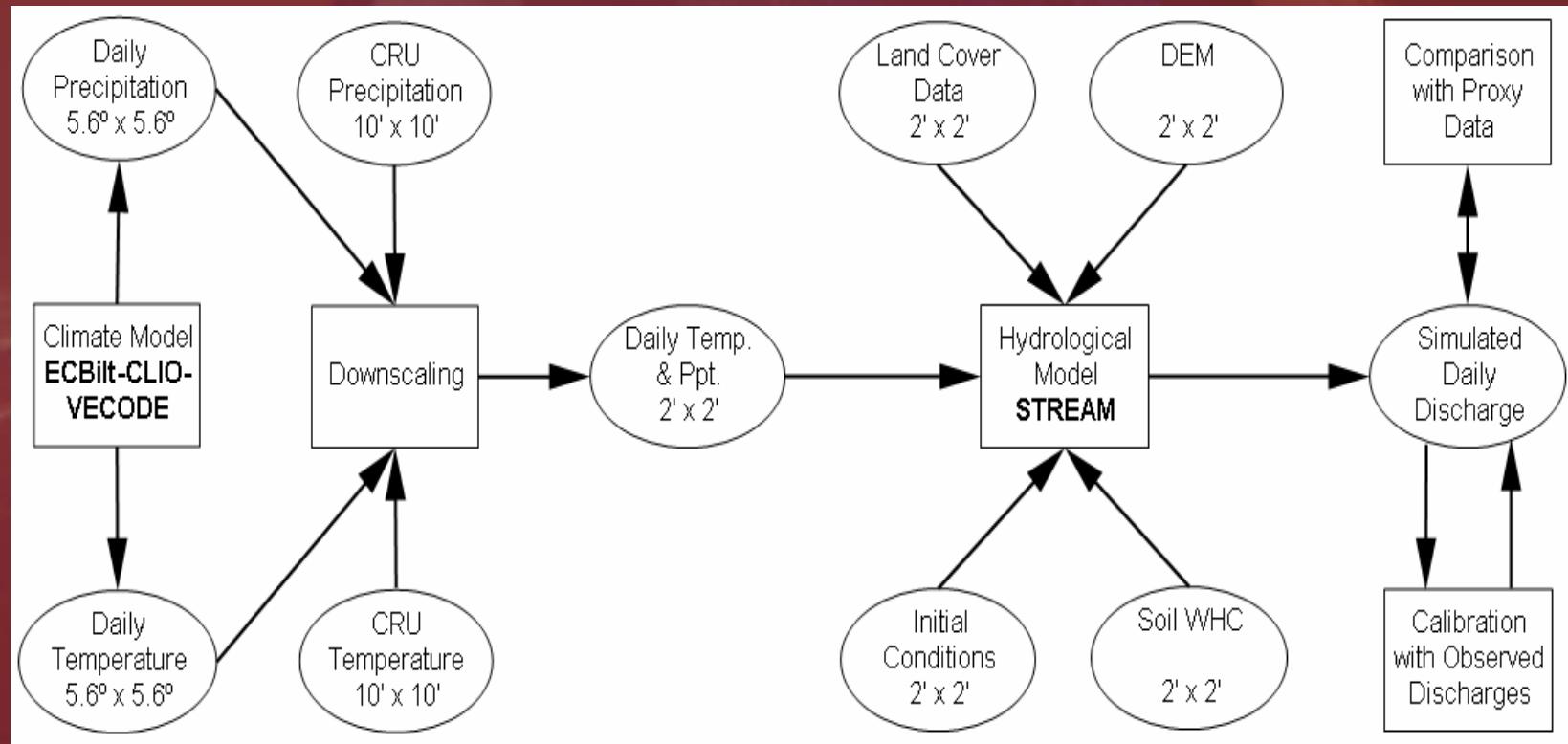
Rationale



Aims

- Set up and validate a coupled climate-hydrological model to analyse the link between flood frequency, precipitation events and weather regimes in The Netherlands
- Analyse Meuse discharge characteristics in 4000-3000 BP (reference period) and 1000-0 BP
- Examine effects of anthropogenic changes
- Develop floodplain sedimentation module
- Examine future climate change scenarios

Research Approach

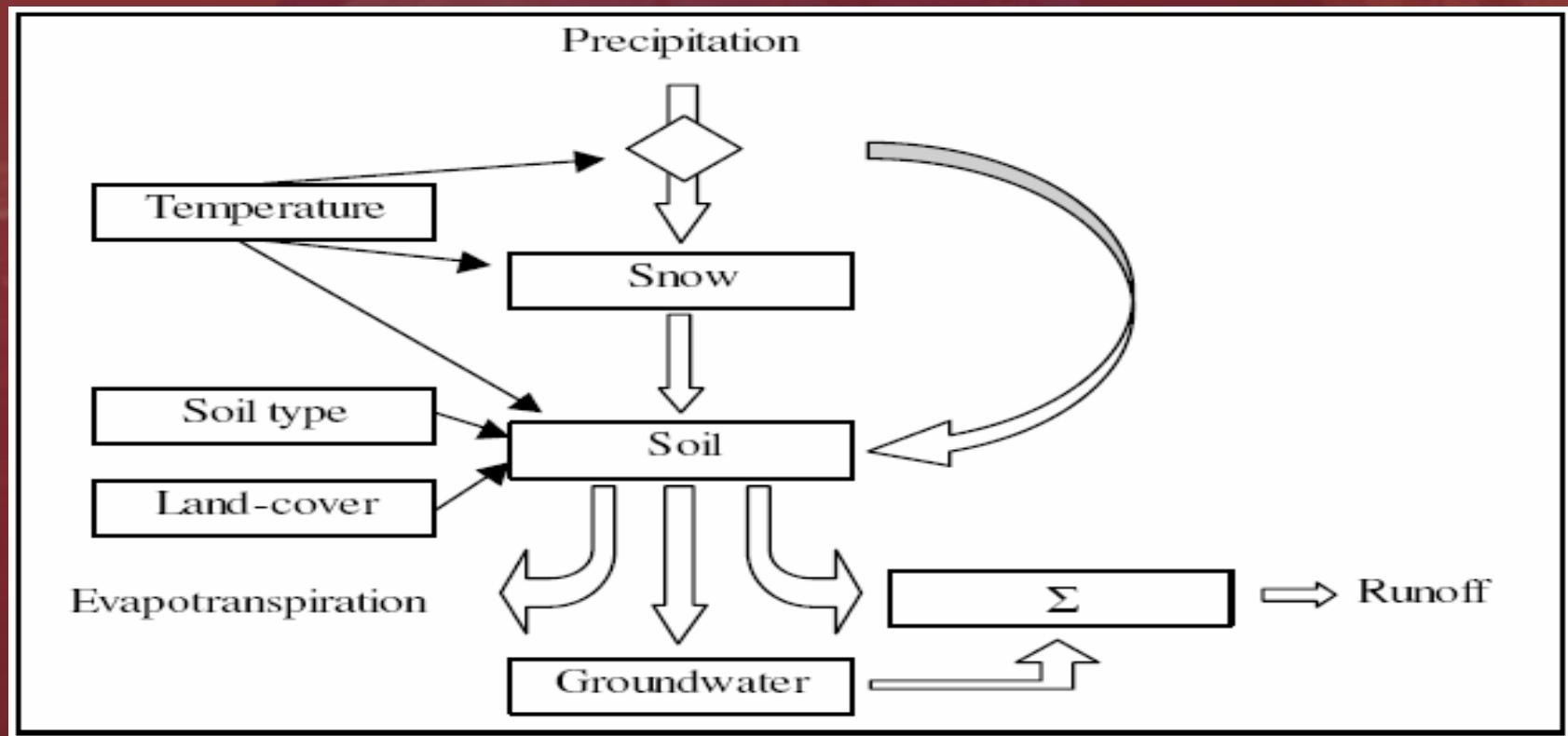


Climate Model – ECBilt-CLIO-VECODE

- **Resolution:** 5.6° - 5.6° (~ 550 x 550 km²)
daily
- **Forcing parameters:** orbital parameters
greenhouse gases
volcanic aerosols
solar irradiance
- **Output:** daily temperature
daily precipitation

Hydrological Model - STREAM

- Raster based hydrological model ($2' \times 2'$)
- Calculates water balance per grid-cell



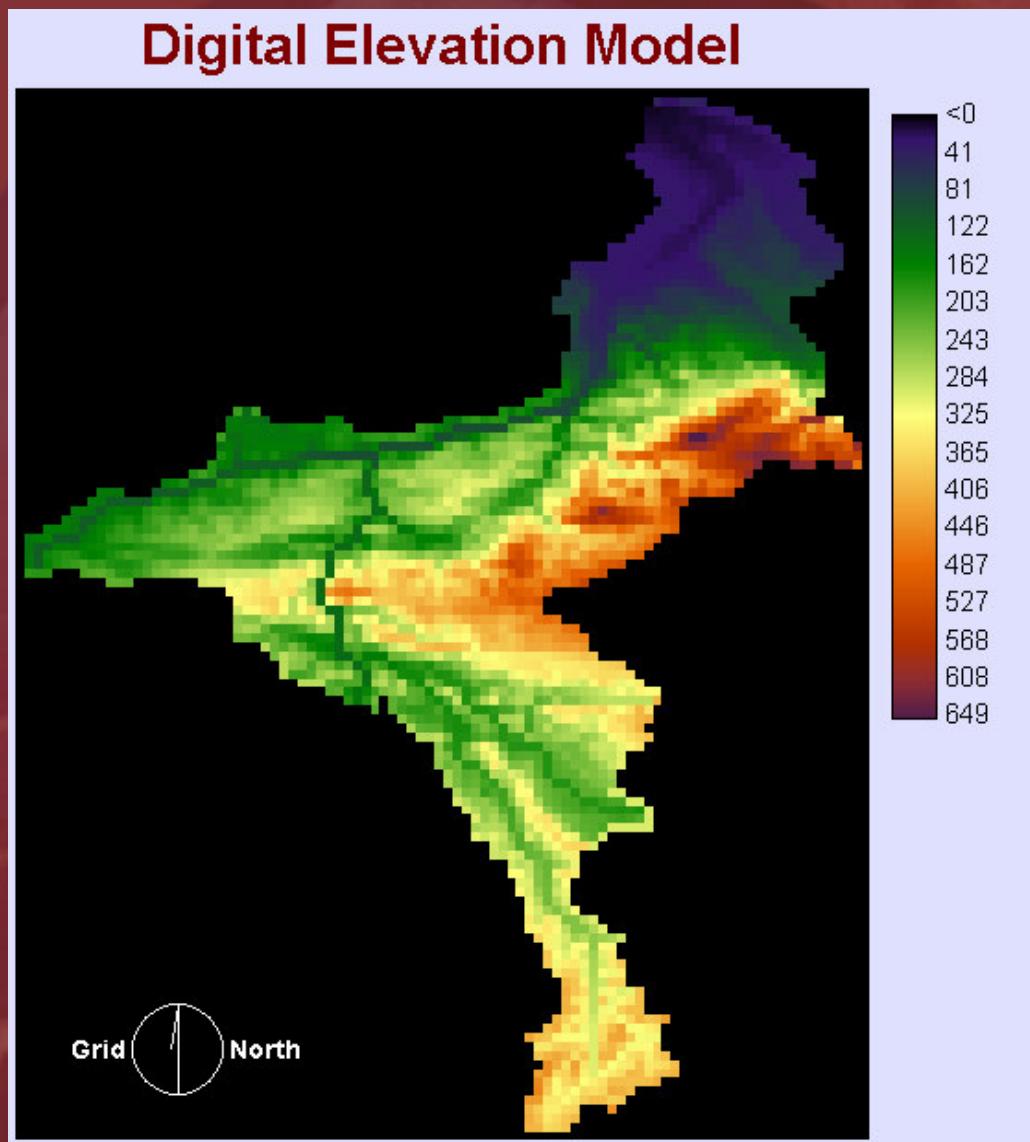
Aerts et al. (1999)

STREAM Meuse – Input Data

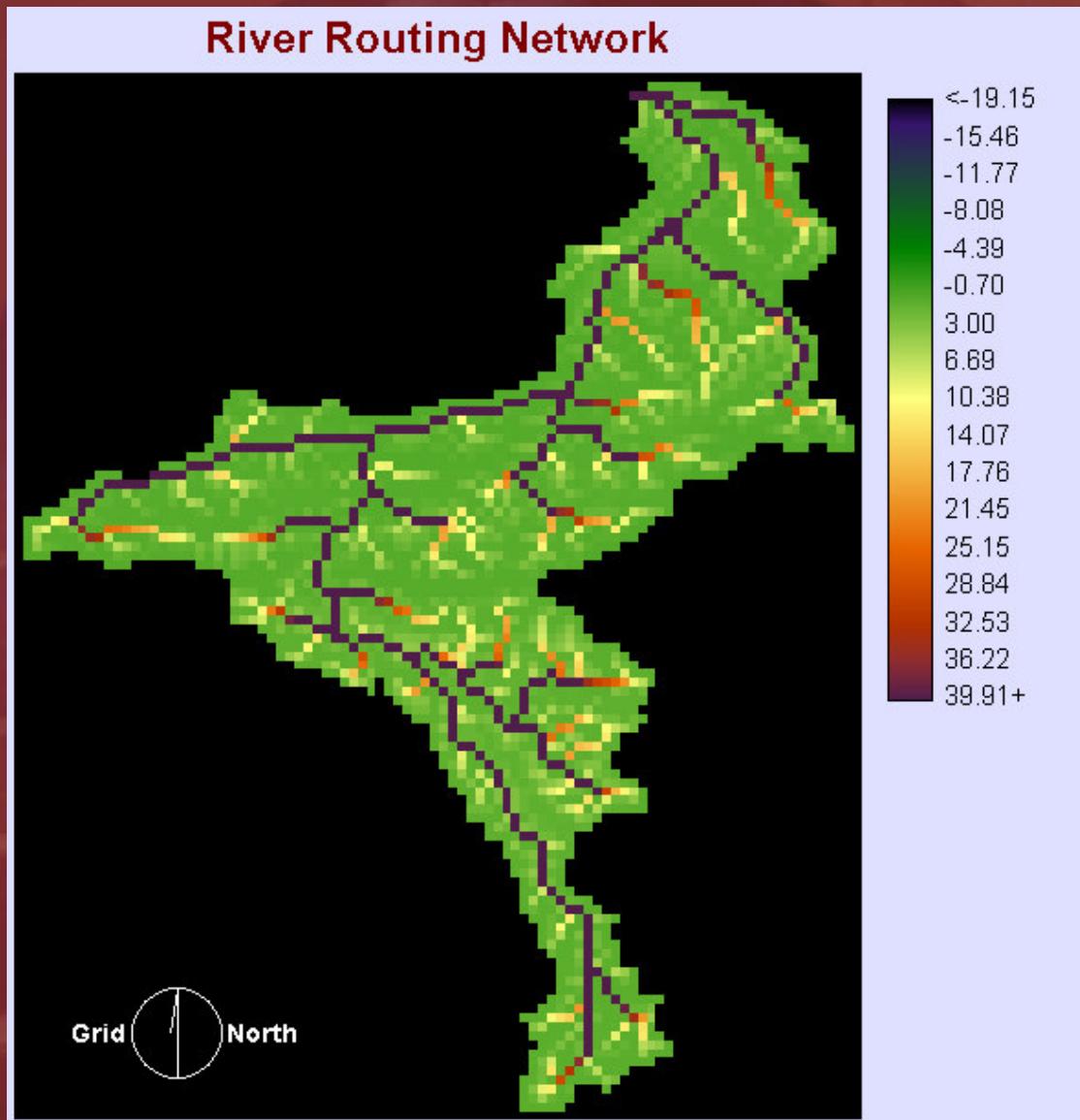
GIS raster database: 2' x 2'

- Daily climate data (temperature and precipitation)
- DEM / River Routing Network
- Land Cover
- Soil Water Holding Capacity

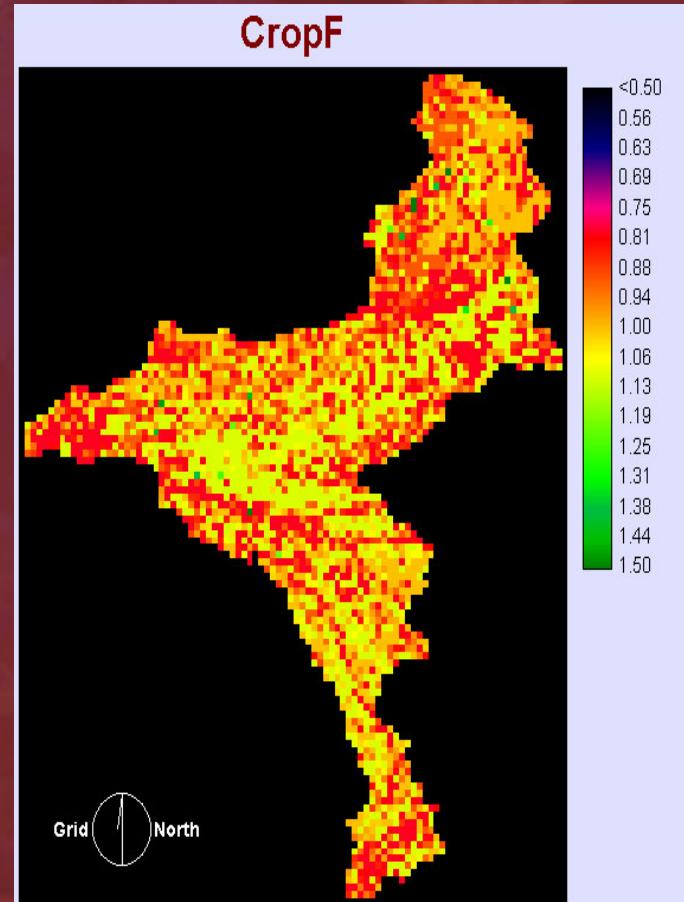
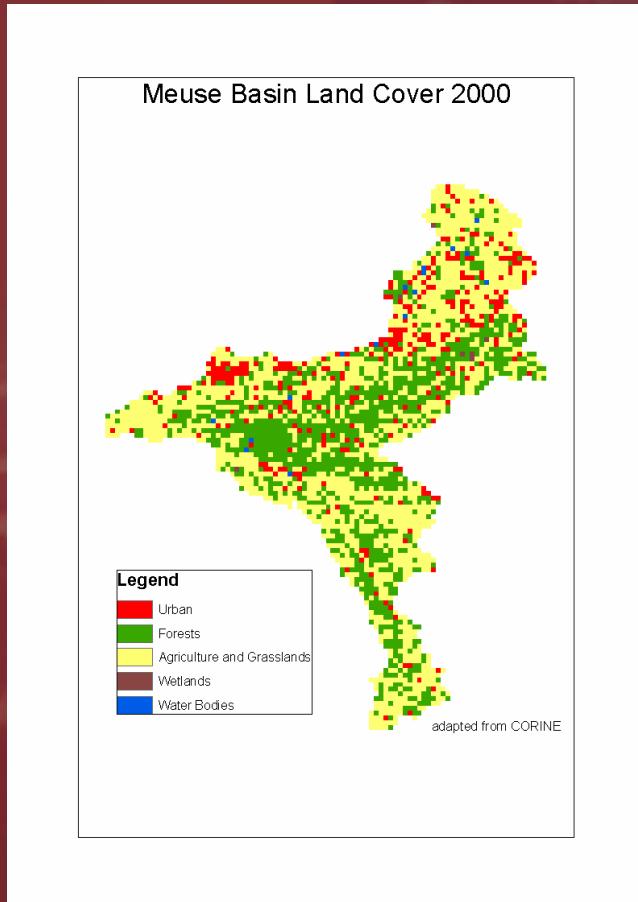
DEM – GTOPO30 (USGS)



River Routing Network

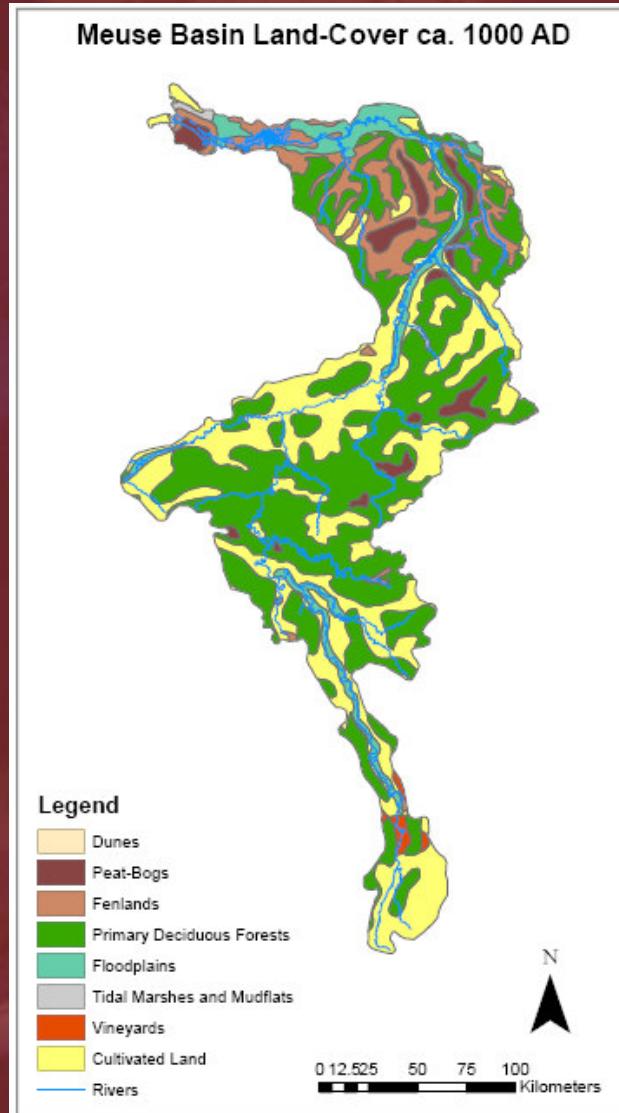


CropF (recent) - based on CORINE Land Cover



Land-Cover Maps

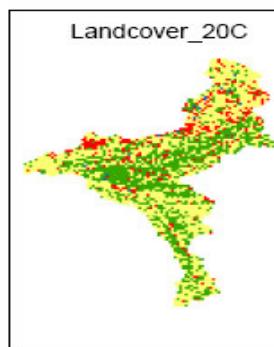
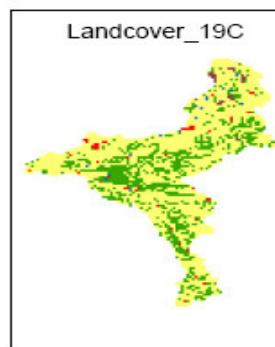
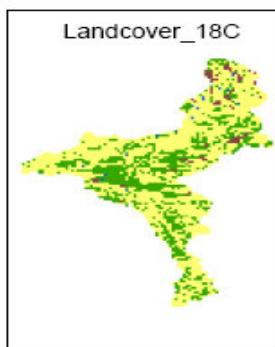
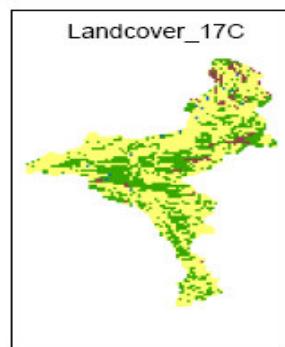
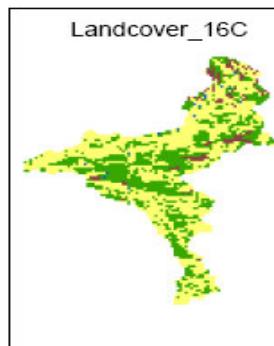
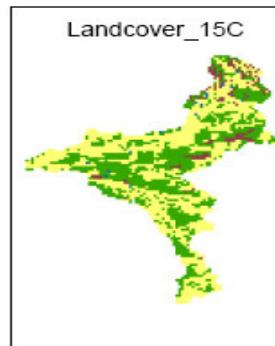
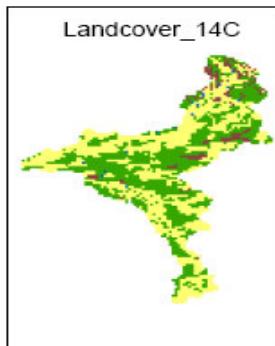
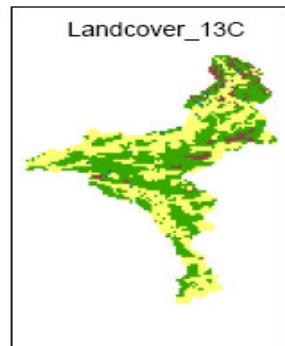
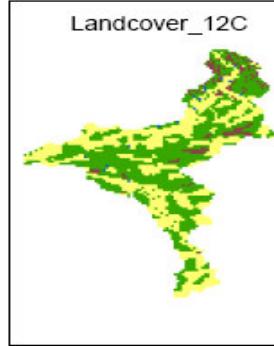
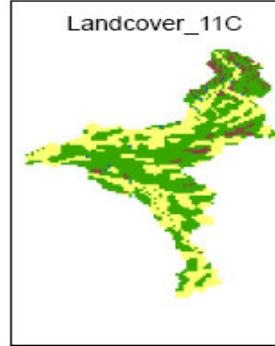
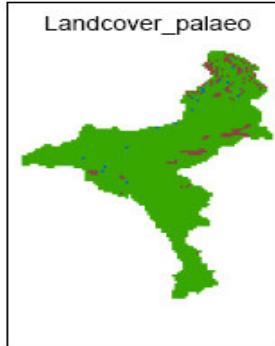
- Present: CORINE 250 m
- 1000AD: RWS Limburg/IWACO, 2000
- 1000-2000 AD:
 - Historical Maps
 - Historical Records
 - Pollen Analysis



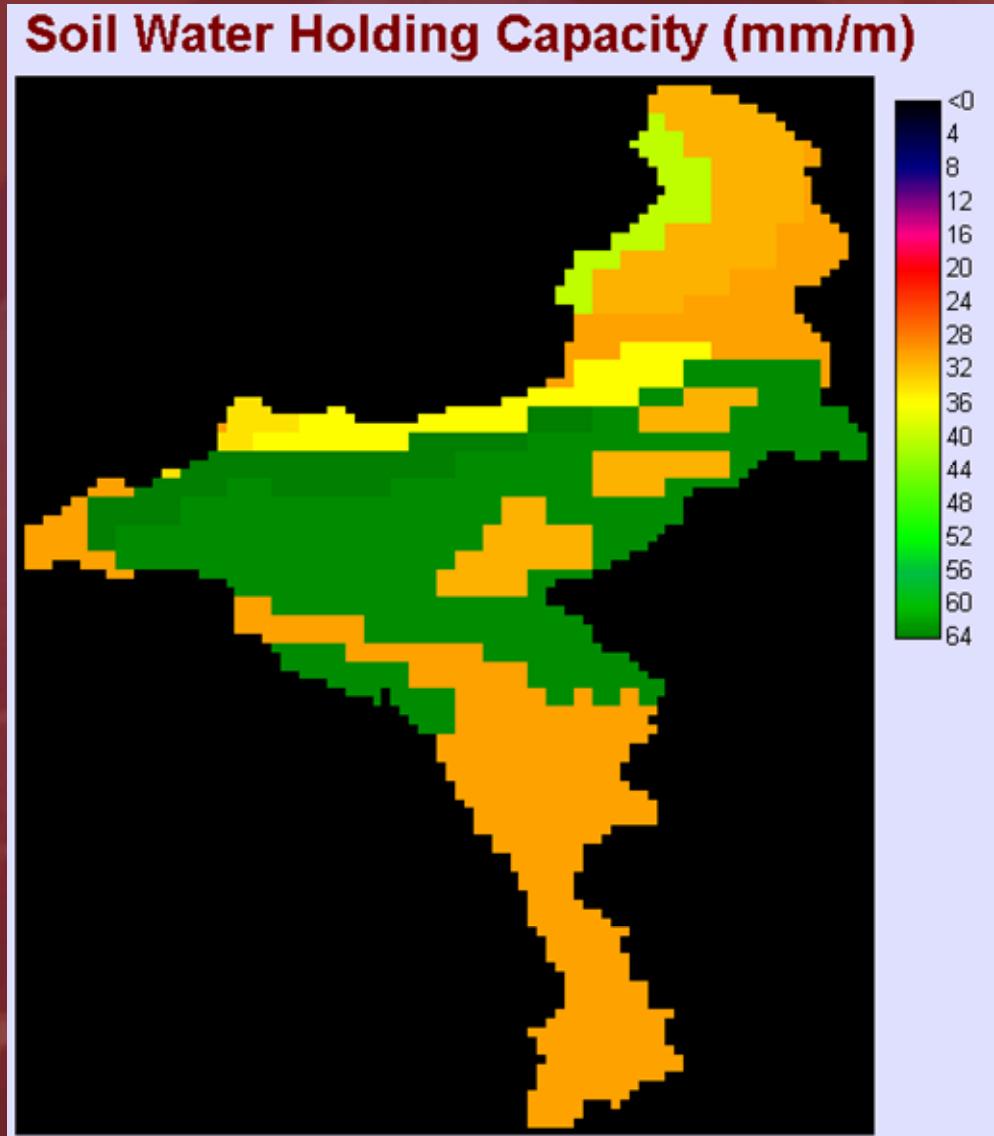
Land-Cover Maps

Land-Cover

- Urban
- Forests
- Agriculture and Grasslands
- Wetlands
- Water Bodies



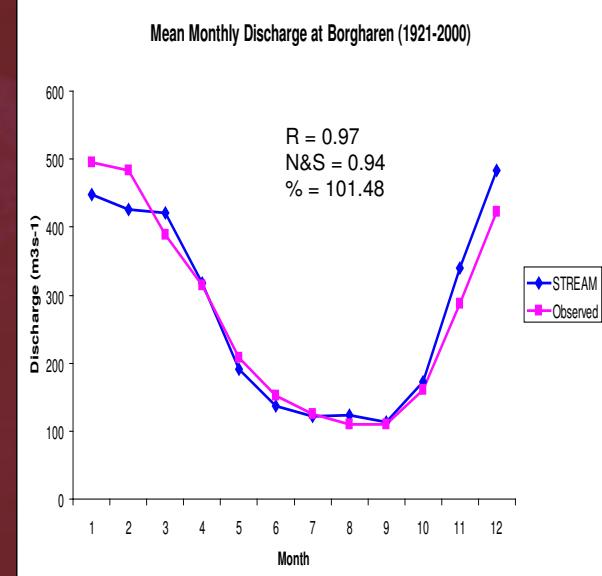
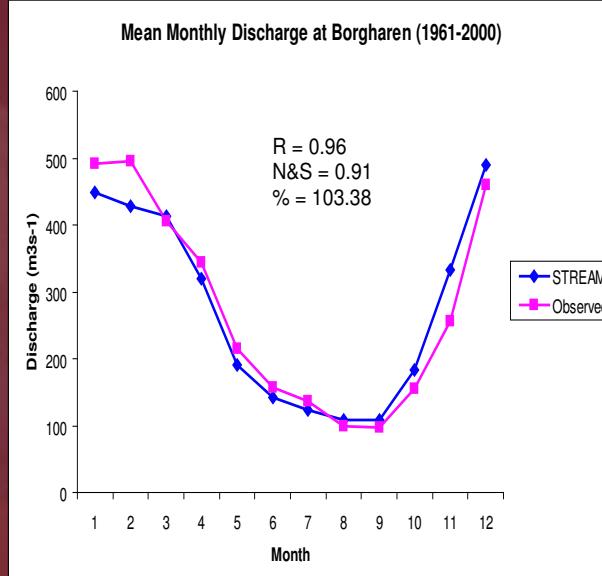
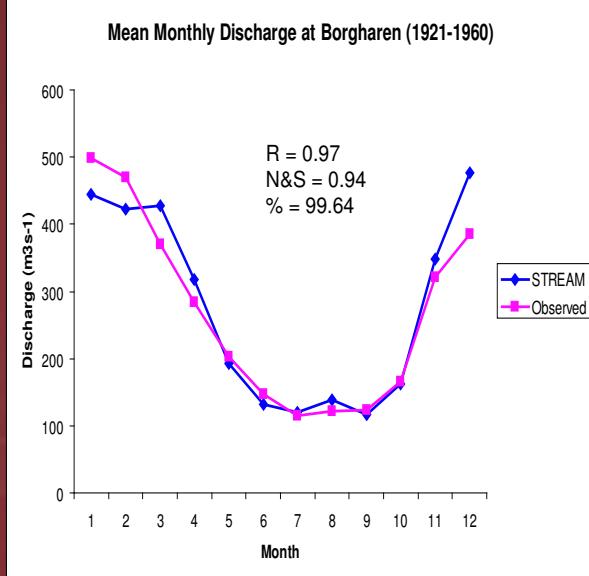
Soil WHC – based on FAO Soil Map of the World



STREAM Meuse: Calibration & Validation

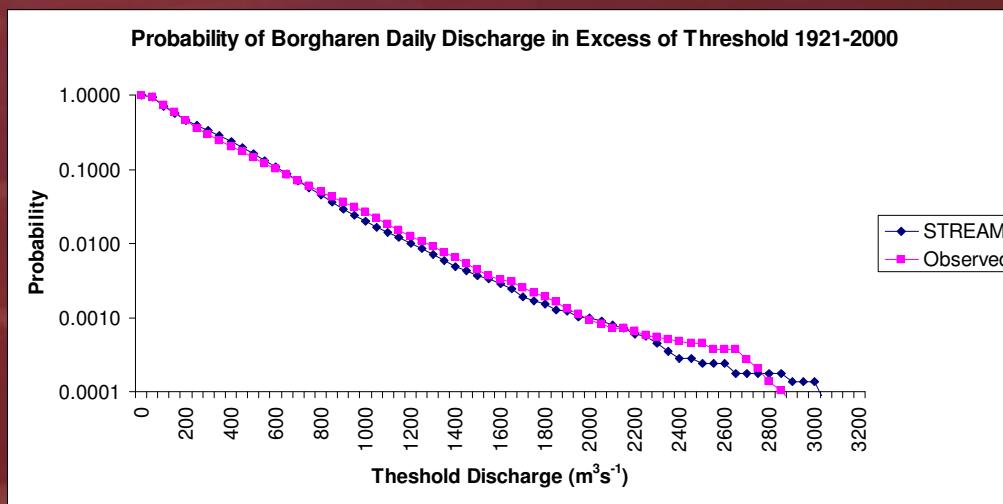
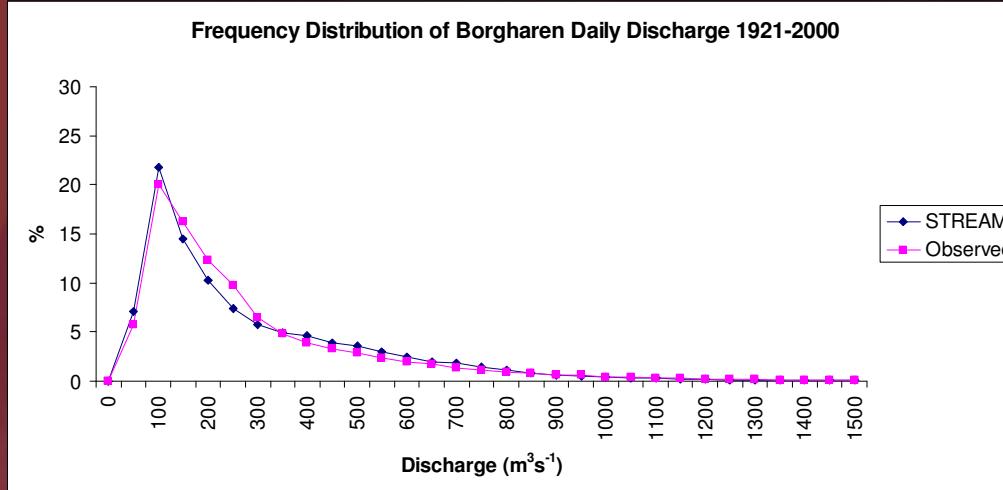
- Parameter Estimation using modelled / observed data:
 - Discharge Borgharen
 - Discharge major tributaries
 - Basin average monthly evapotranspiration
 - Daily snow-cover at Maastricht
- Calibration: 1961-2000
- Validation: 1921-1960 & 1921-2000

STREAM Meuse: Calibration & Validation



Station	River	Total Accuracy (%)	r	N&S
Stenay	Meuse	96.6	0.92	0.84
Chauvency-le-Château / Membre	Chiers / Semois	94.3	0.96	0.92
Gendron	Lesse	76.2	0.98	0.69
Martinrive	Amblève	89.0	0.91	0.68
Meerssen	Geul	129.3	0.92	-1.64

STREAM Meuse: Calibration & Validation

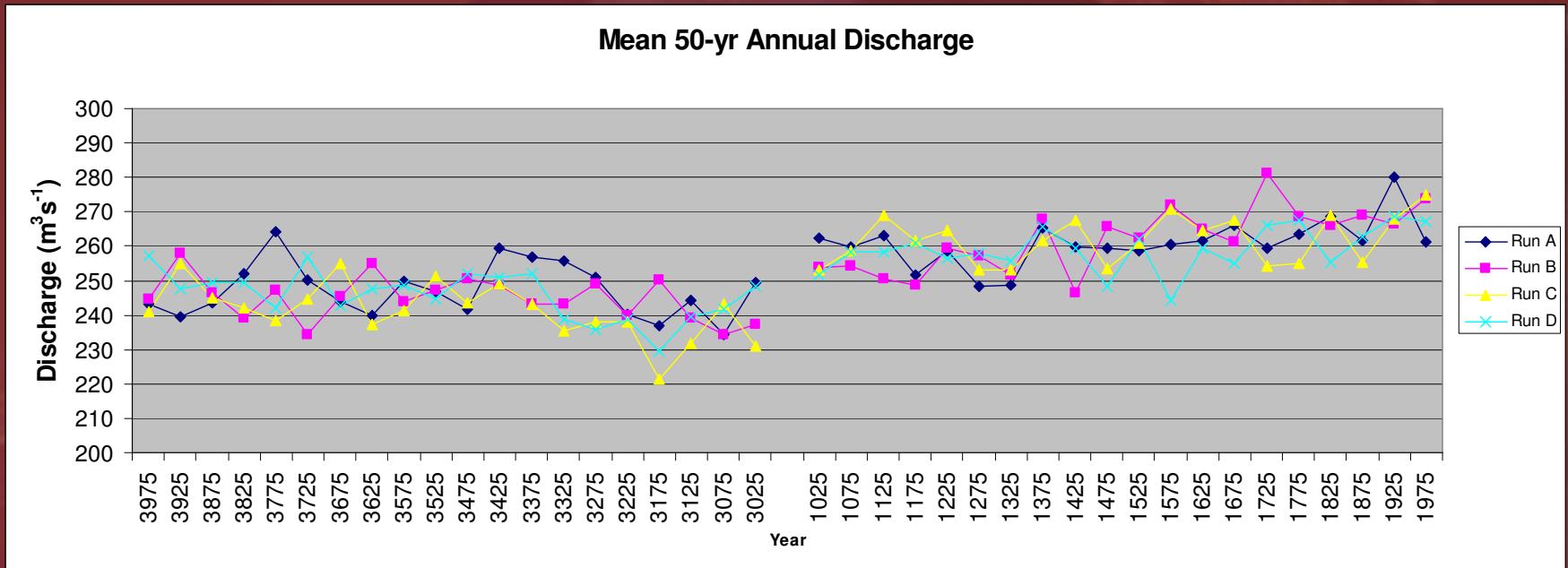


STREAM Meuse: Calibration & Validation

Calibration Conclusions

- Generally good agreement between modelled / observed values for annual, monthly and daily discharge characteristics
- The frequency of high and low flow events appears to be well simulated by the model
- Simulation of small tributaries (Geul) poor

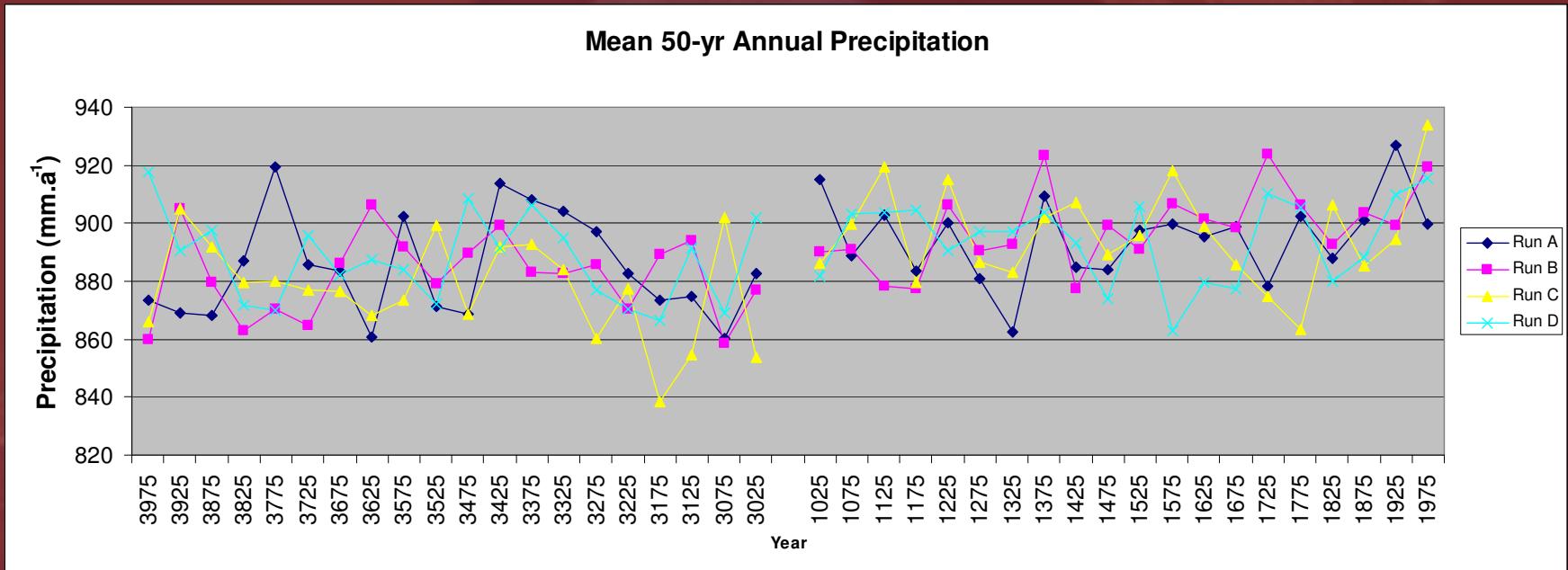
Preliminary Results



Recent mean Q > Holocene mean Q in all cases (*t-test*: $p < 0.001$)

Recent: increasing discharge (*Mann-Kendall*: $p < 0.001$)

Preliminary Results

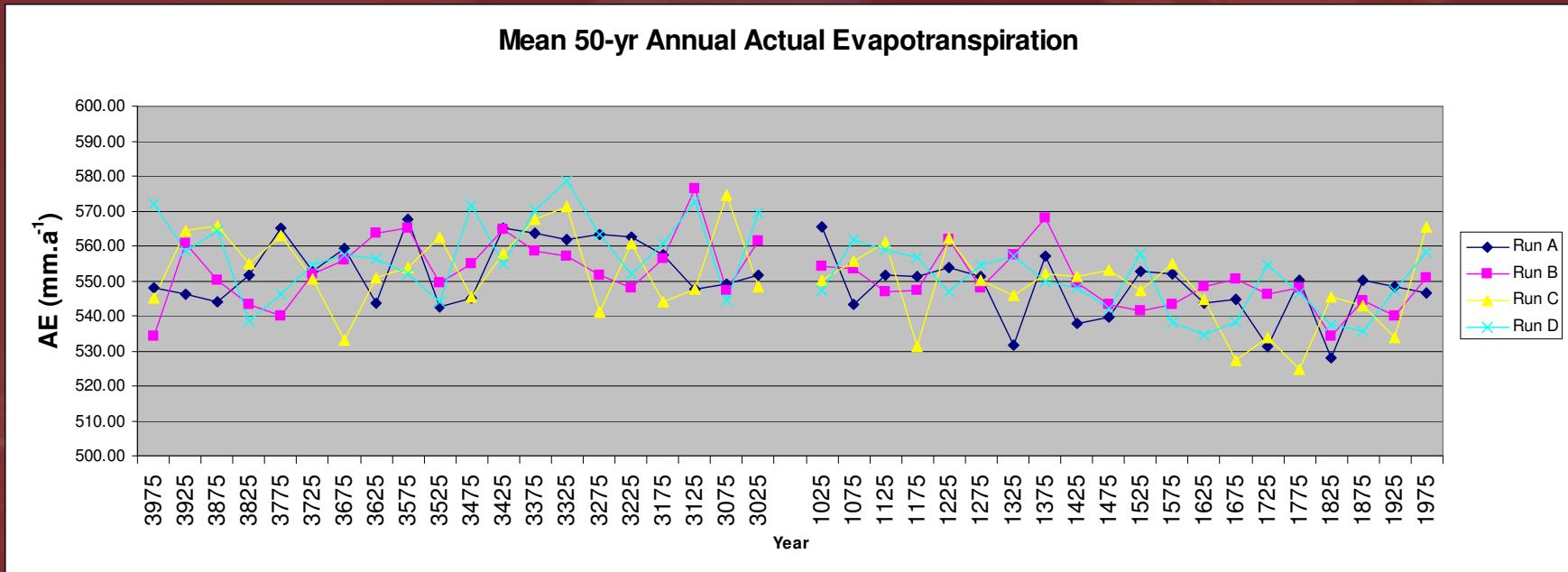


Recent mean pre > Holocene mean pre in 3 cases
(*t*-test: $p = (A) 0.043; (B) 0.001; (C) 0.001; (D) 0.144$)

Recent: no trend (*Mann-Kendall*: $p = 0.218$)



Preliminary Results

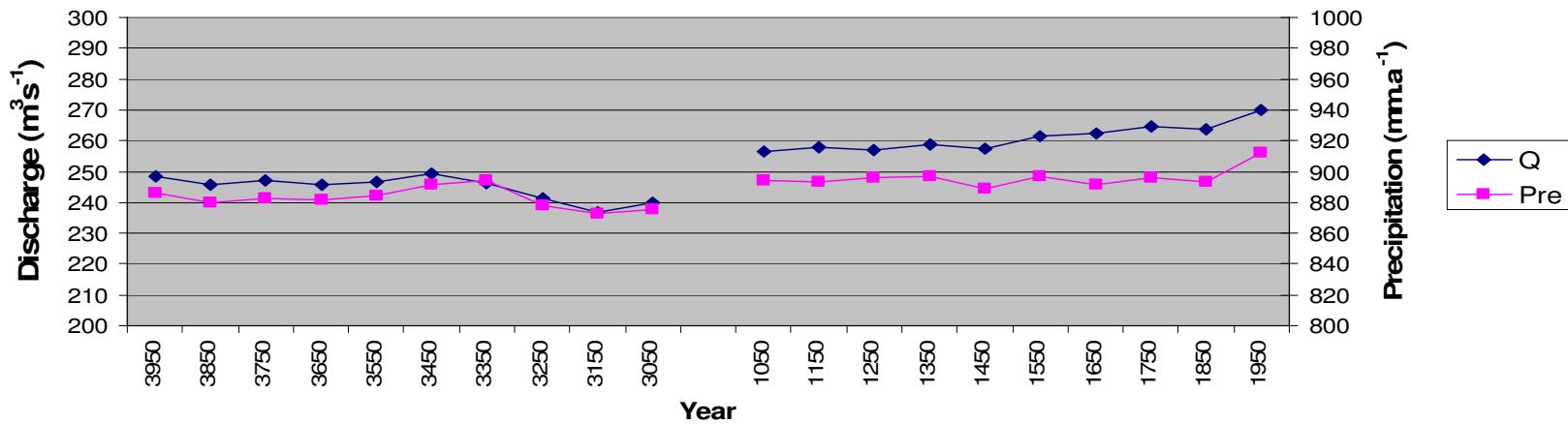


Recent mean AE < Holocene mean Q in all cases
(*t-test*: $p = (A) 0.008; (B) 0.047; (C) 0.022; (D) 0.002$)

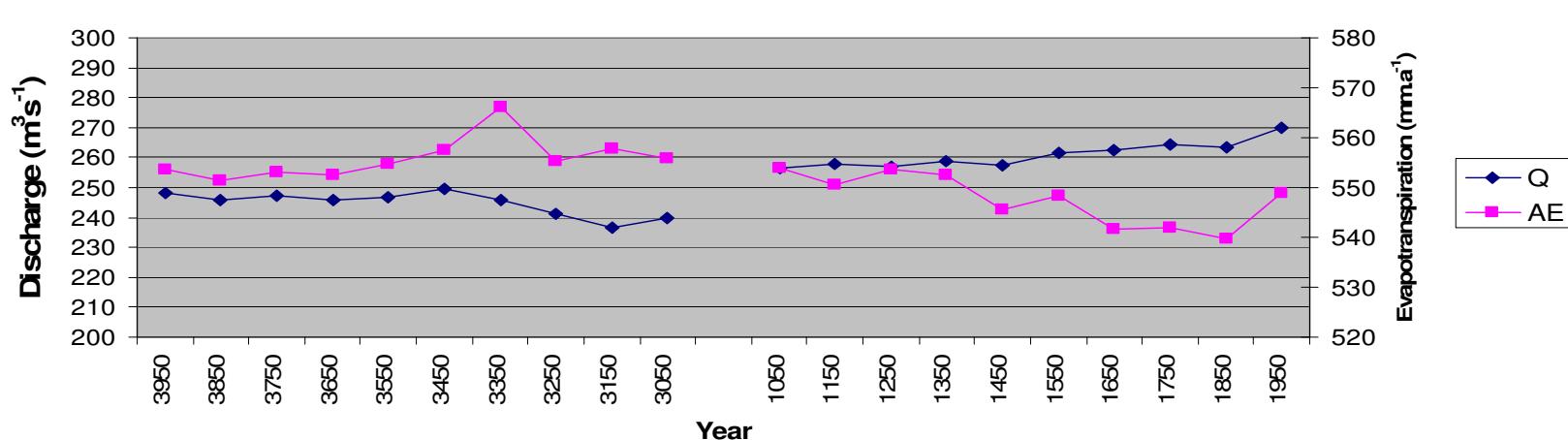
Recent: decreasing AE (*Mann-Kendall*: $p < 0.001$)

Preliminary Results

Mean 100-yr Meuse Discharge and Precipitation



Mean 100-yr Meuse Discharge and Actual Evapotranspiration

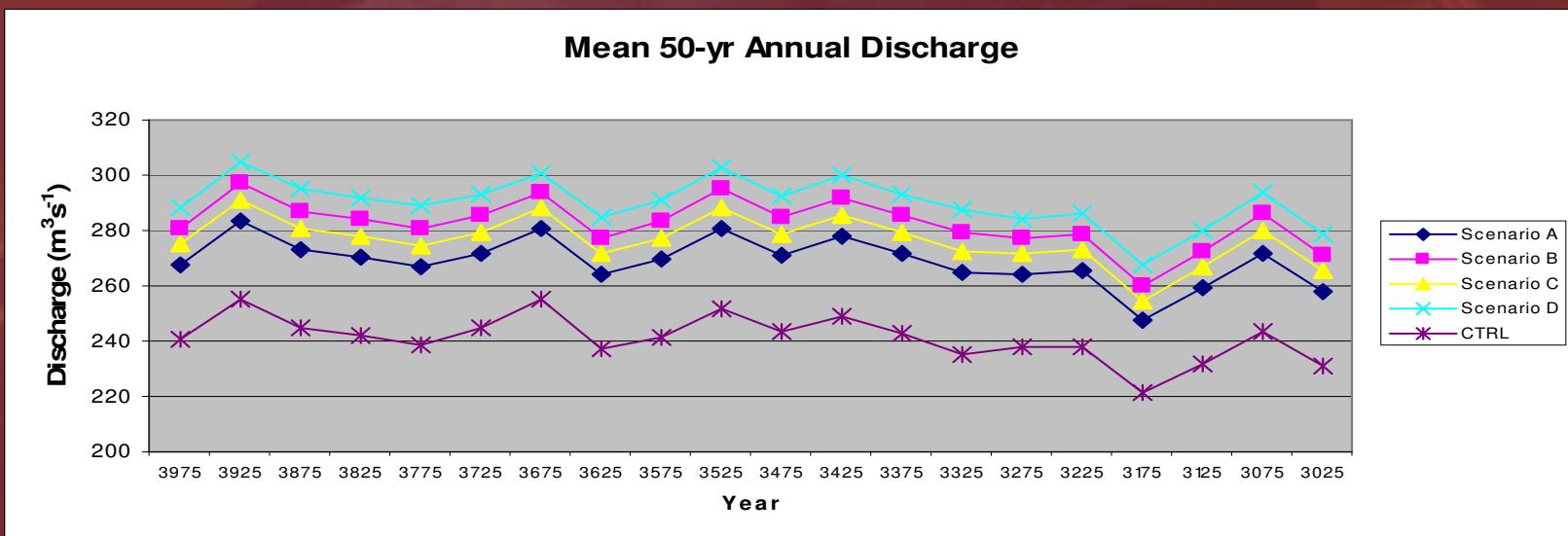


Deforestation scenario

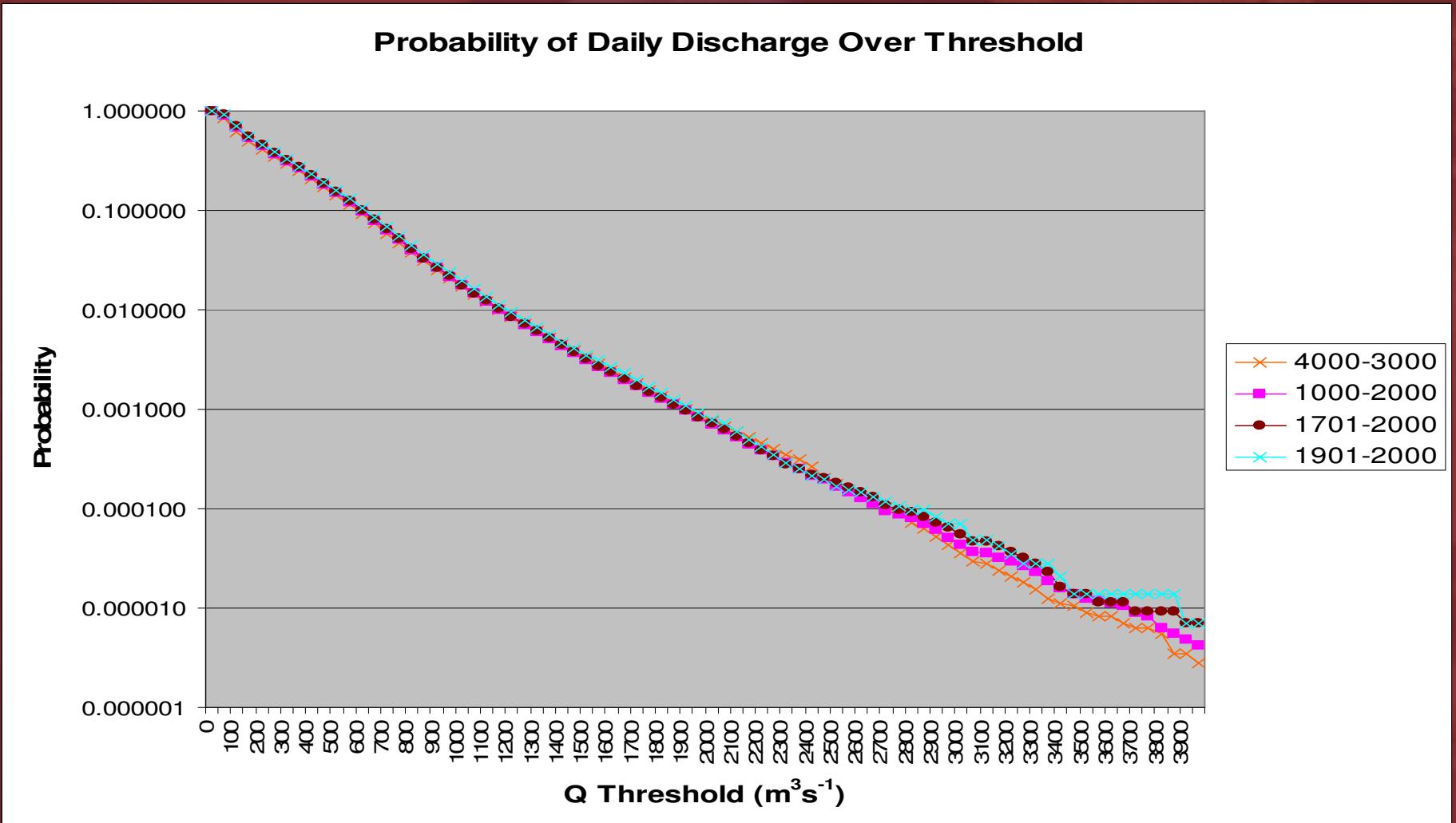
Land cover change scenarios superimposed on Holocene climatic data:

- Scenario 1: 2000 AD land-use
- Scenario 2: Zero forest
- Scenario 3: 2000 AD land-use & annual mean temp reduced by 0.5 °C
- Scenario 4: Zero forest & annual mean temp reduced by 0.5 °C

Deforestation scenario



Preliminary Results



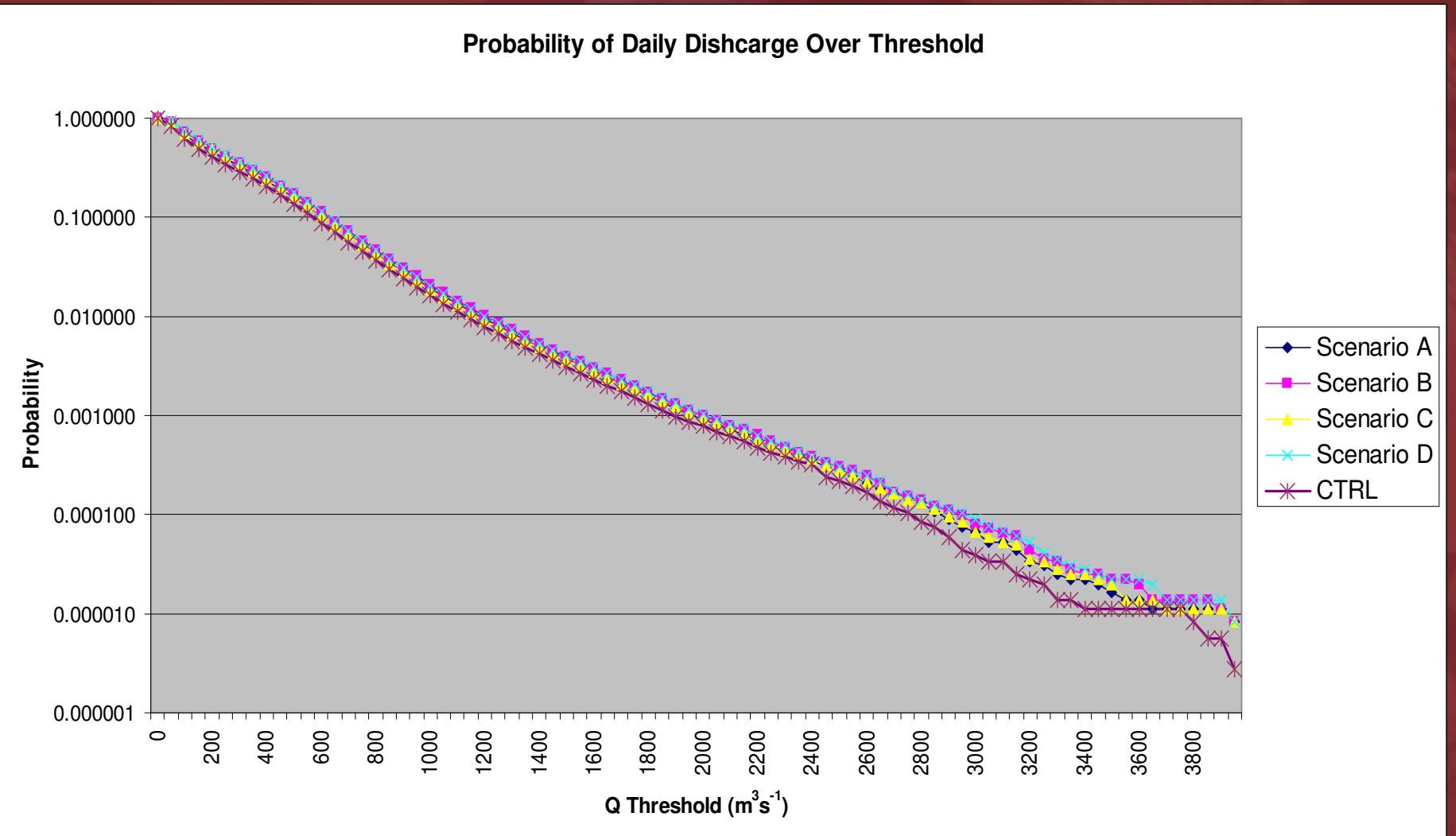
Preliminary Results

Calculated recurrence times of daily discharges over given thresholds

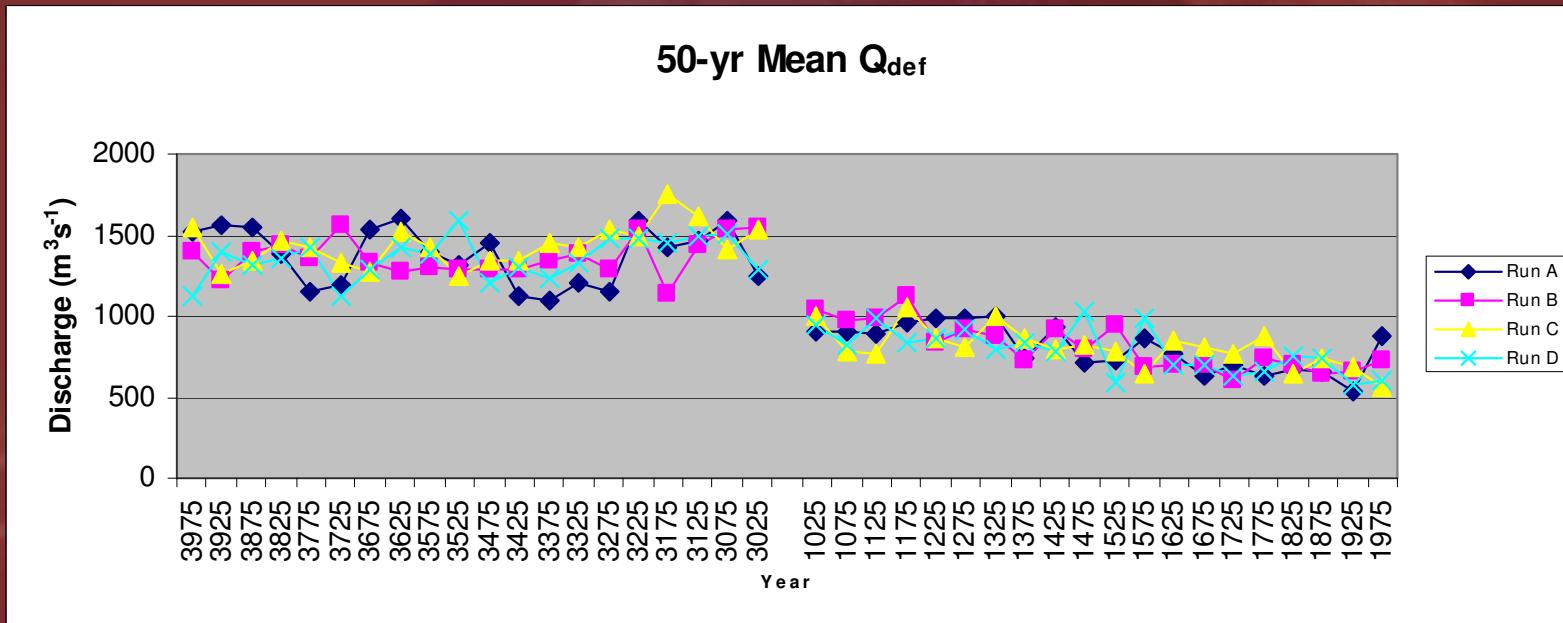
Discharge:	Recurrence Period (yrs)	
	> 3000 (m^3s^{-1})	> 4000 (m^3s^{-1})
3999 – 3000 BP	77	992
1001 – 2000 AD	65	665
1701 – 2000 AD	50	400
1901 – 2000 AD	40	400

1911-2006: 2 observed discharges $> 3000 \text{ m}^3\text{s}^{-1}$ (1926 and 1993)

Deforestation scenario



Preliminary Results



Recent mean $Q_{def} <$ Holocene mean Q_{def} in all cases (*t-test*: $p < 0.001$)

Recent: decreasing Q_{def} (*Mann-Kendall*: $p < 0.001$)

$$Q_{def} = \sum(Q_{threshold} - Q_{day}), \text{ if } Q_{day} < Q_{threshold}$$

where,

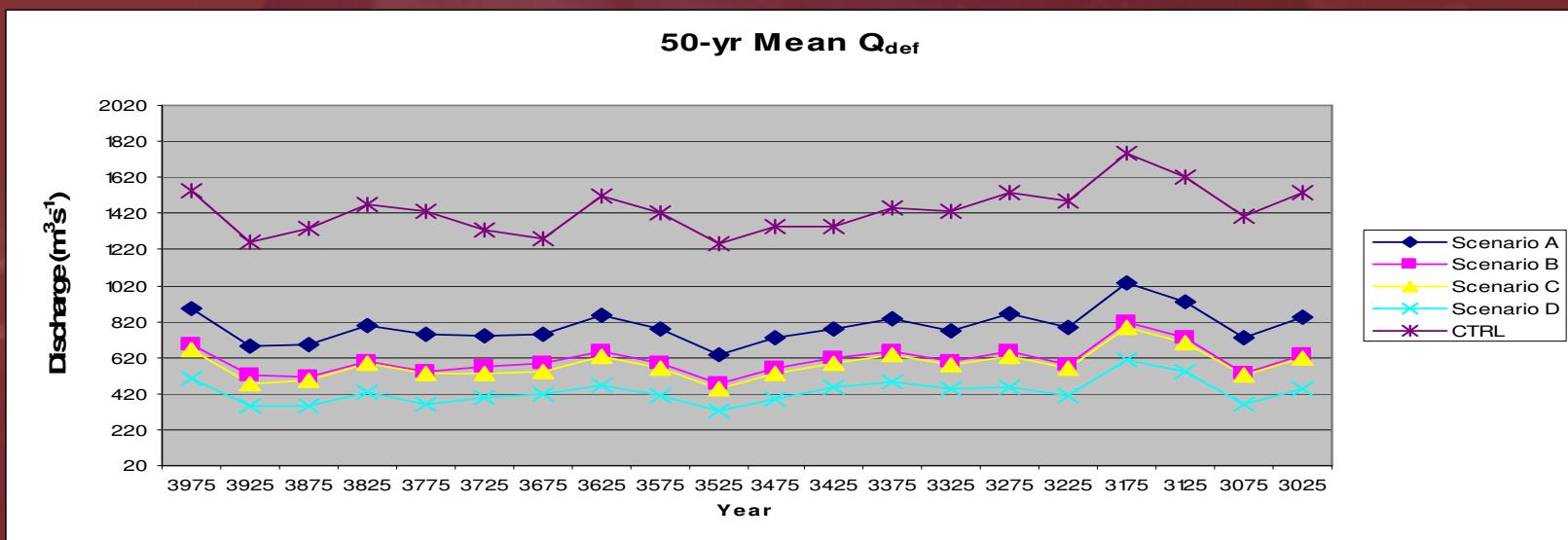
Q_{def} = discharge deficit

$Q_{threshold}$ = discharge threshold (here $60 \text{ m}^3 \text{s}^{-1}$)

Q_{day} = discharge on a particular day



Deforestation scenario



Conclusions

- Mean discharge higher in 1000-2000 AD than 4000-3000 BP (dominant mechanism: decreased AE)
- AE lower due to land-use change (direct influence and resulting decrease in temperature)
- Last century: relatively large increase in mean discharge despite increased AE: enhanced precipitation of more importance in future?
- Floods more frequent in recent than in Holocene, and probably more frequent still since industrial era (reduced WHC?)
- Significant increase in flood frequency under deforestation scenarios
- Frequency and magnitude of low-flow events **lower** in recent than in Holocene (decreased AE in summer due to deforestation)