Institute for Environmental Studies (IVM)

Effects of Flood Control Measures and Climate Change in the Rhine Basin

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Deltares
Enabling Delta Life

KNMI

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Outline

Rhine basin

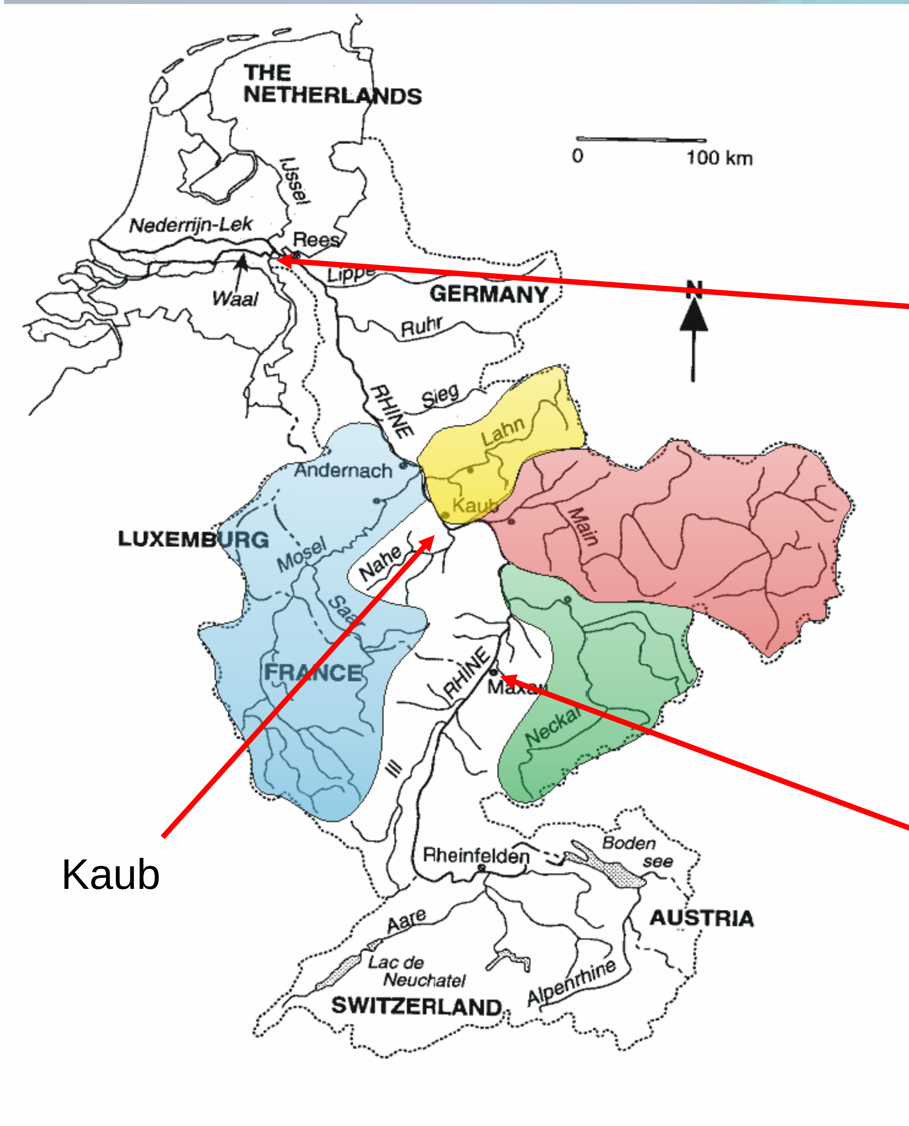
Background

Goal and method

Results

Conclusions

Rhine basin



	Area (km^2)	Mean Q (m^3/s)	Min Q (m^3/s)	Max Q (m^3/s)
Rhine, Lobith	160,800	2,206	788	12,885
Mosel	28,229	334	10	420
Lahn	5,917	48	0	730
Main	27,310	176	44	1,991
Neckar	13,971	141	3	2,105
Rhine, Maxau	50,624	1,297	379	4,430

- Length: 1,320 km
- 58 million inhabitants (10 million flood plain)

Background

Recent floods → major damages

- IKSR – Flood Action Plan
- D – NL Working Group on Floods
- EU Flood Directive

↓

- Measures are planned and implemented
- Risk assessments

Climate change

- Research available (Kwadijk 1993, 1998; Middelkoop, 2001; Kleinn, 2003, 2005; Te Linde, 2007)

↓

- Uncertainties remain
- Do not take into account effect of measures
- Assumption – *infinite dike height*

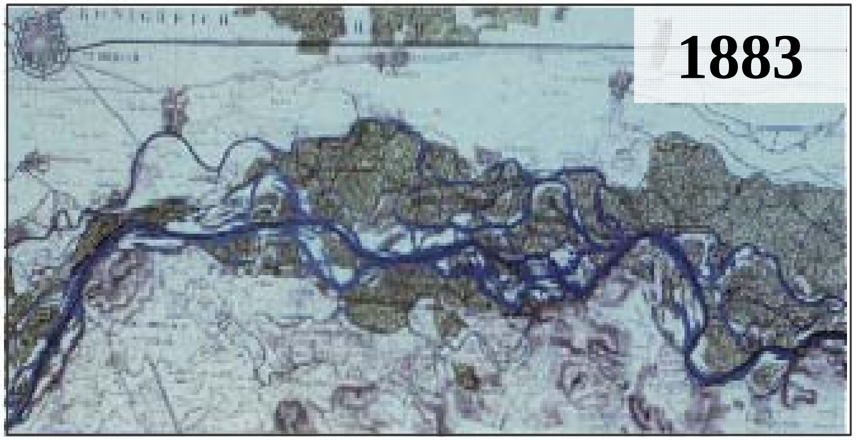
Background

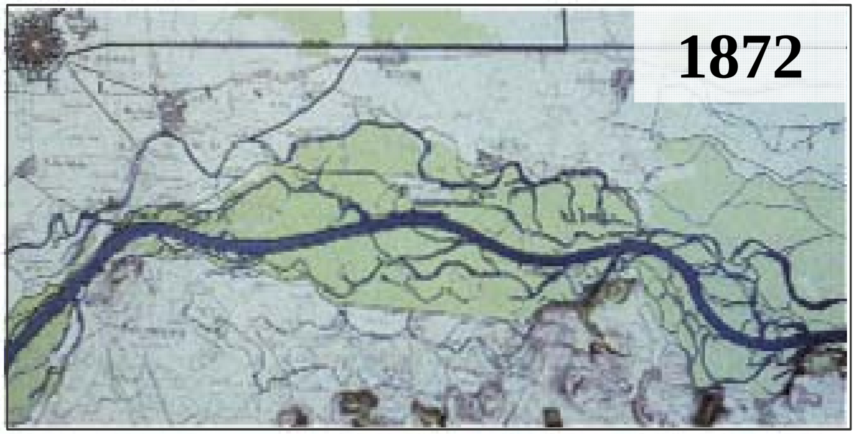
Recent floods → major damages

Date	Area	Fatalities	Damage (Mio USD)
…			
Dec 1993	Lower Rhine	14	1,800
Jan 1995	Lower Rhine	28	3,500
…			
May 1999	Upper Rhine	??	???
Aug 2005	Upper Rhine	7	800
…			

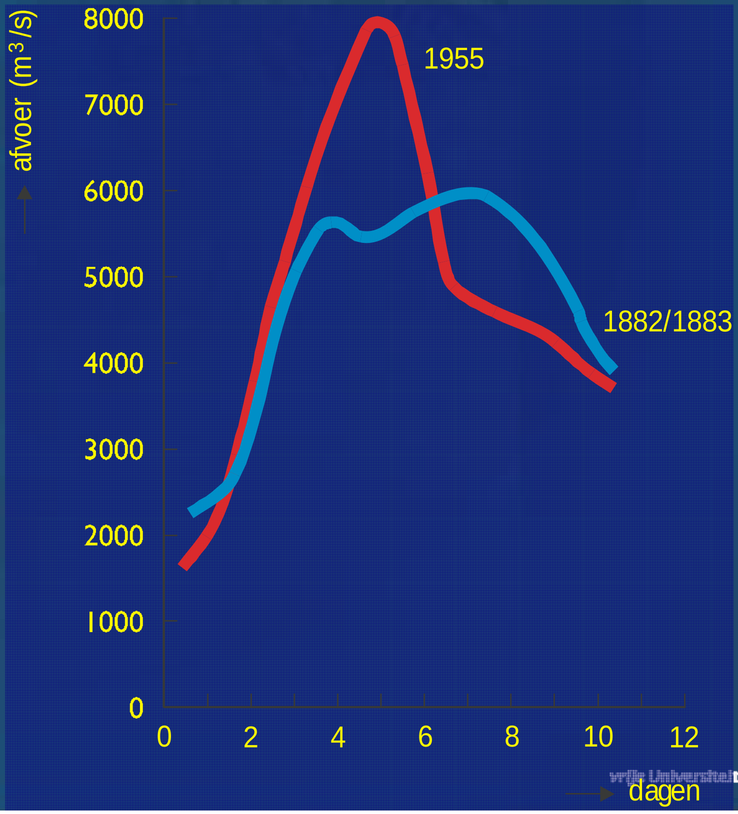
(Source: http://www.cru.uea.ac.uk/cru/projects/stardex/ and http://www.dartmouth.edu/~floods/Archives/.)

Human impact





- Reduced flood plain storage capacity (narrowing / urbanisation)
- River straightening → 100 km shorter



Goal

ACER

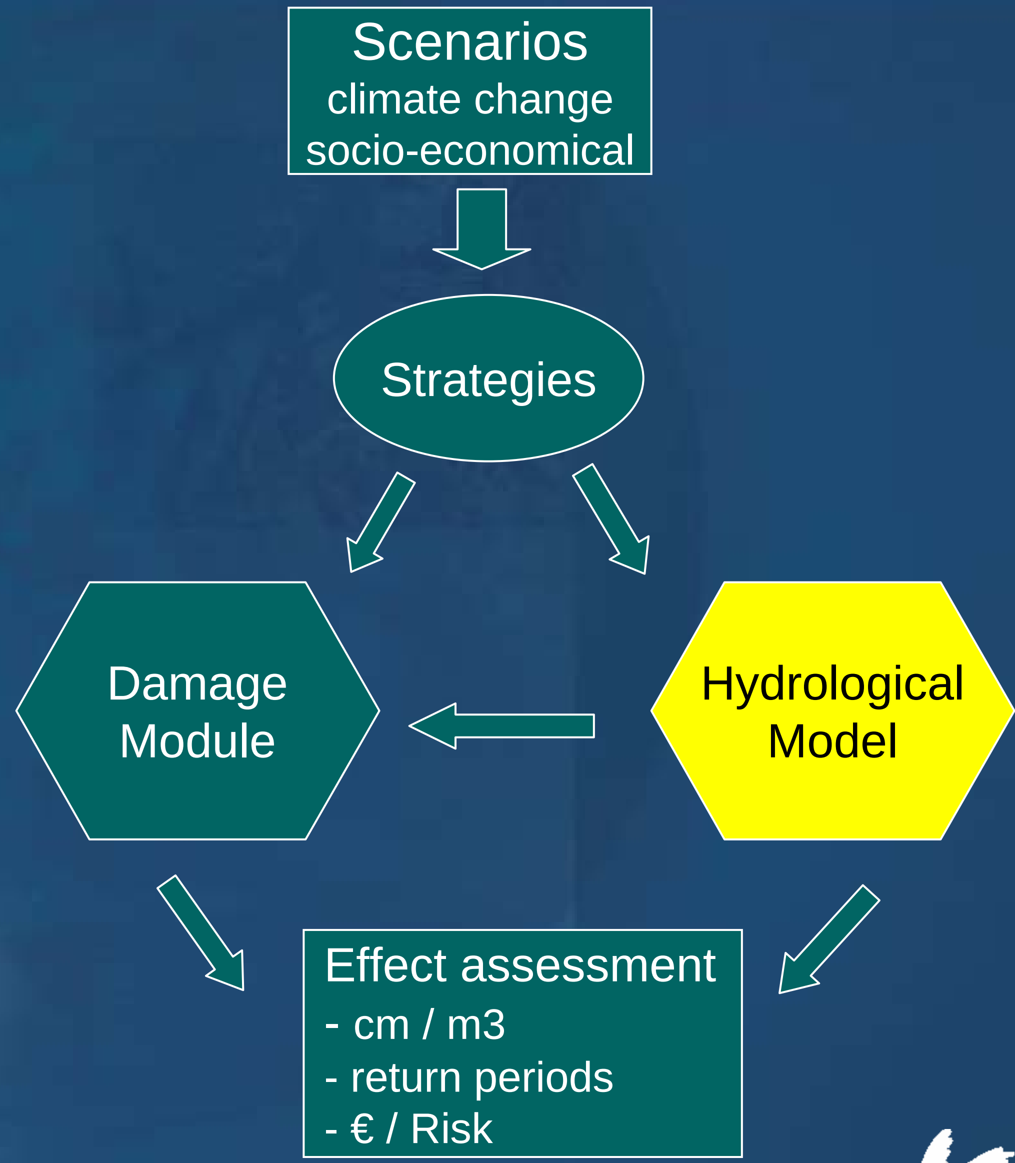
Compare

- effect of flood control measures
- effect of climate change

on

- discharges
- return periods

of extreme events



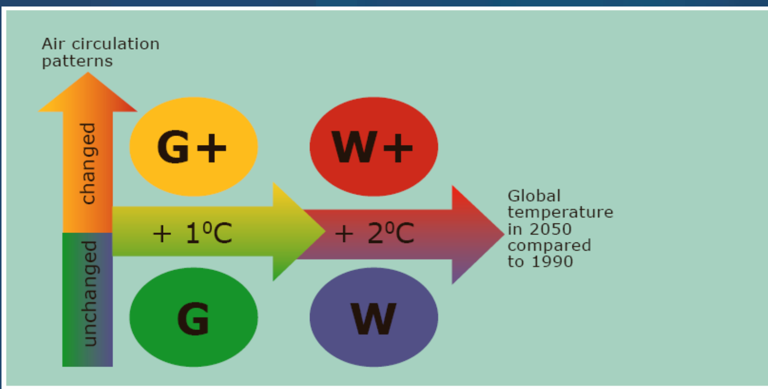
Method - Climate change scenarios for 2050 (KNMI, 2006)

- Based on 5 GCMs
- Two steering parameters
  - Global temperature
  - Strength of seasonal mean west circulation

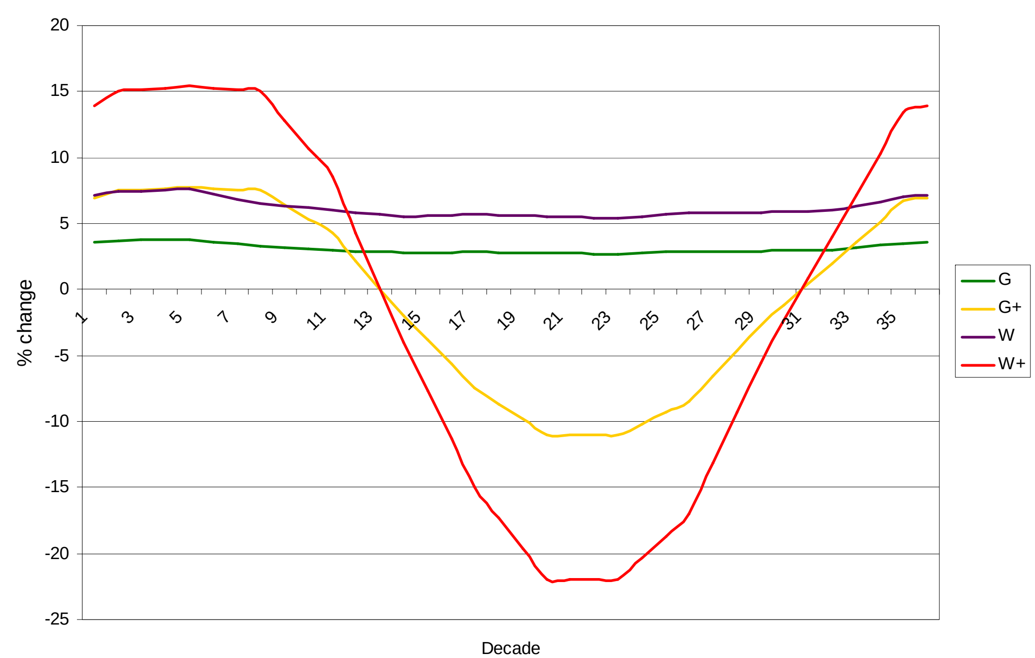
- Historical data transformed
- Delta method

$$T_{scen,d*}(t) = T_{his,d}(t) + \left(\overline{T}_{scen,d} - \overline{T}_{his,d}\right)$$

$$P_{scen,d*}(t) = P_{his,d}(t) \times \left(\frac{\overline{P}_{scen,d}}{\overline{P}_{his,d}}\right)$$



G	Moderate*	1°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
G+	Moderate +	1°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds
W	Warm	2°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
W+	Warm +	2°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds



Method - Climate change scenarios for 2050 (KNMI, 2006)

BUT

- Applied to complete Rhine basin

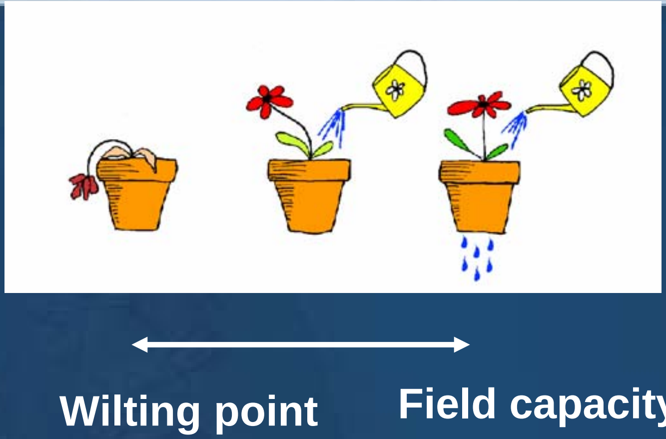
  (while they are developed for NL + NW part of D)
- Delta method does not take into account:
  - Possible changes in variance / extremes
  - Possible changes in number of wet / dry days

- KNMI produced direct RCM output (bias-corrected)
- RACMO:
  - SRES-A1B emission scenario
  - forced ECHAM5-GCM member 3
  - spatially distributed

Method - Hydrological modelling

Rainfall - runoff (HBV / VIC)

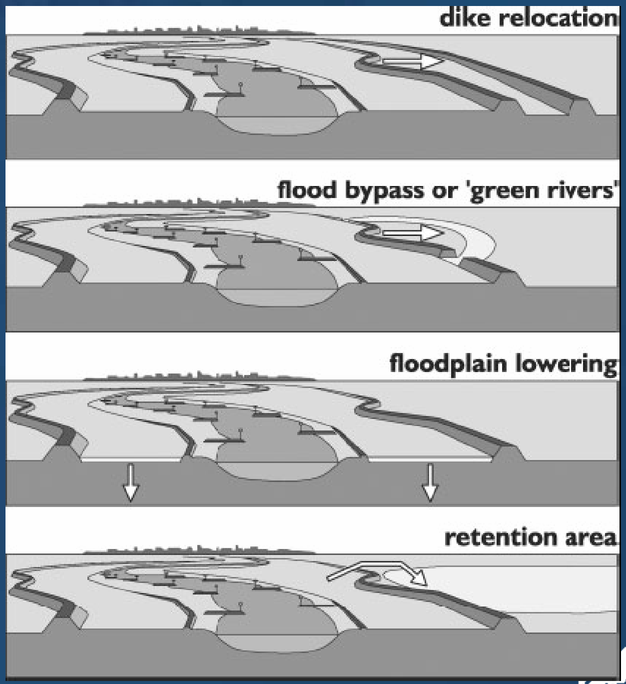
- Implementing climate change scenario
- Landuse change



1D Hydrodynamic model (SOBEK)

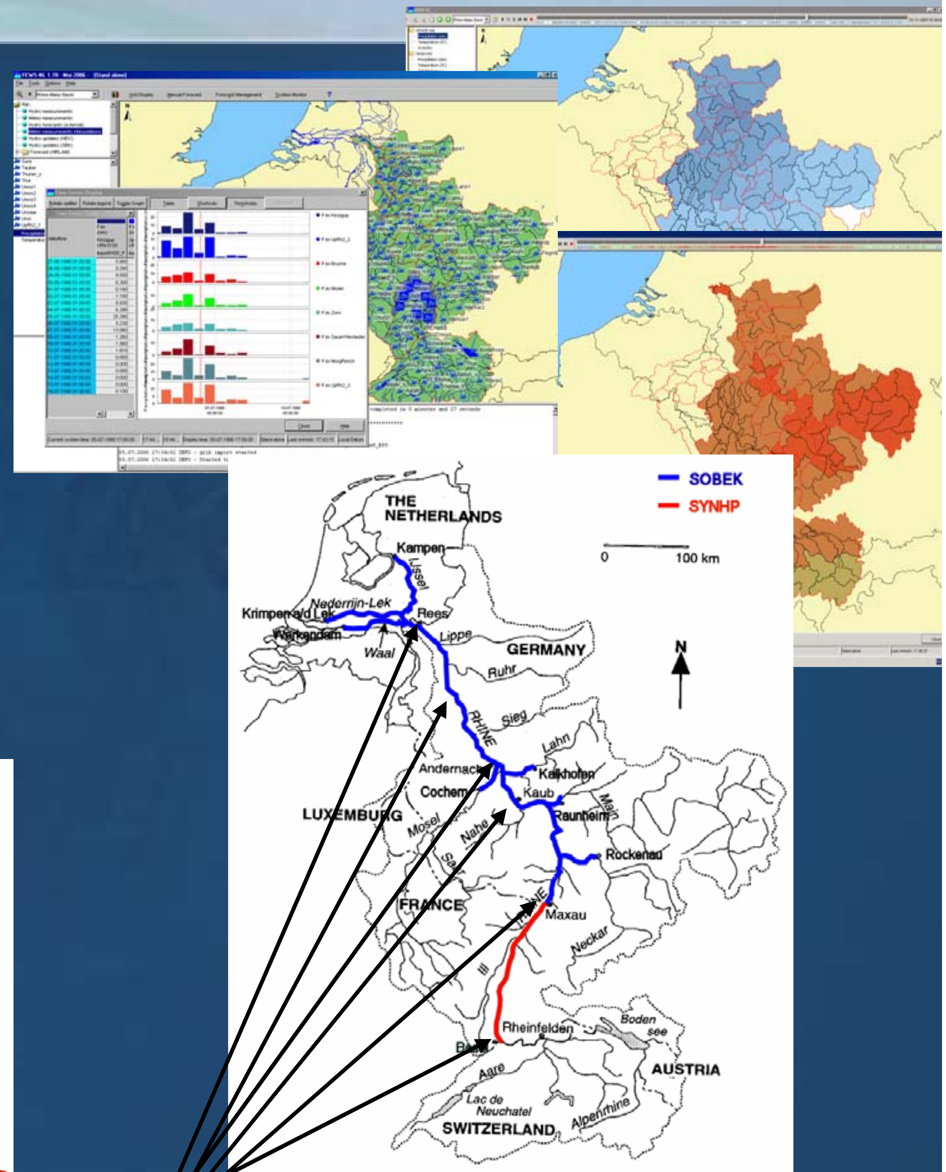
Measures

- Dike heightening
- Dike relocation
- Landuse change flood plain (friction)
- Bypass
- Detention area
- Flooding (calibrated on 2D model)

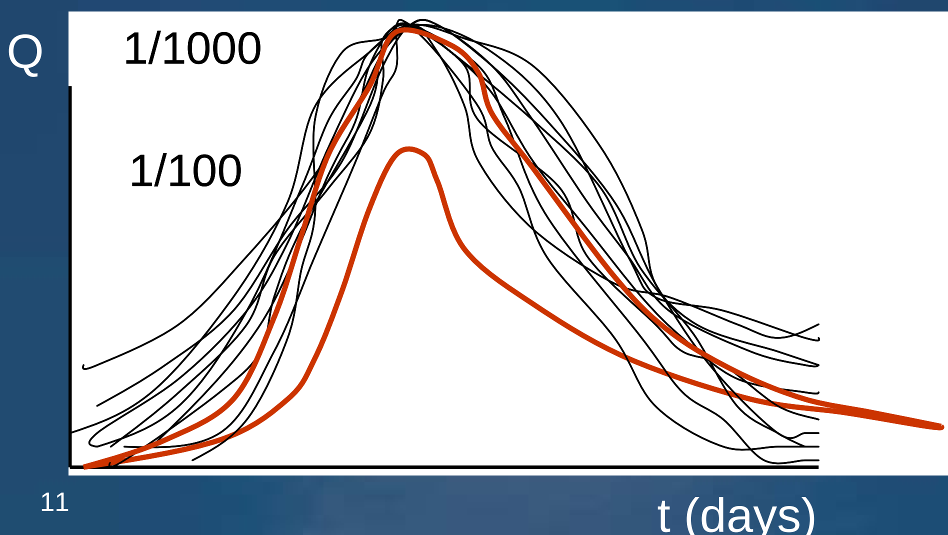


Method – stochastic rainfall generator

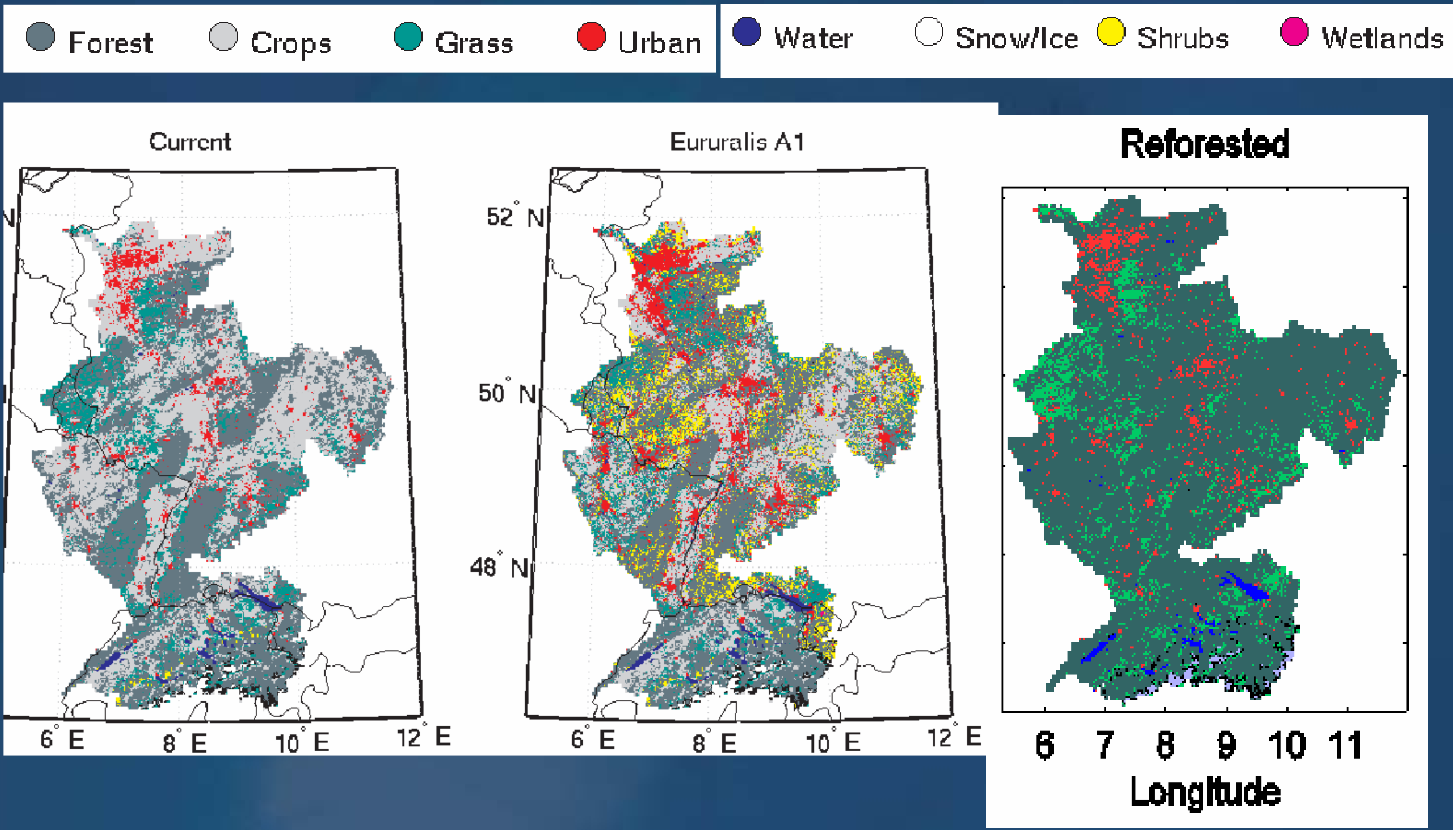
- 1,000 years Precipitation and Temperature (resampeld data)
- HBV + SOBEK → 1,000 years discharge data
- Estimate return periods (T) (1/200 - 1/500 - …)



X Locations

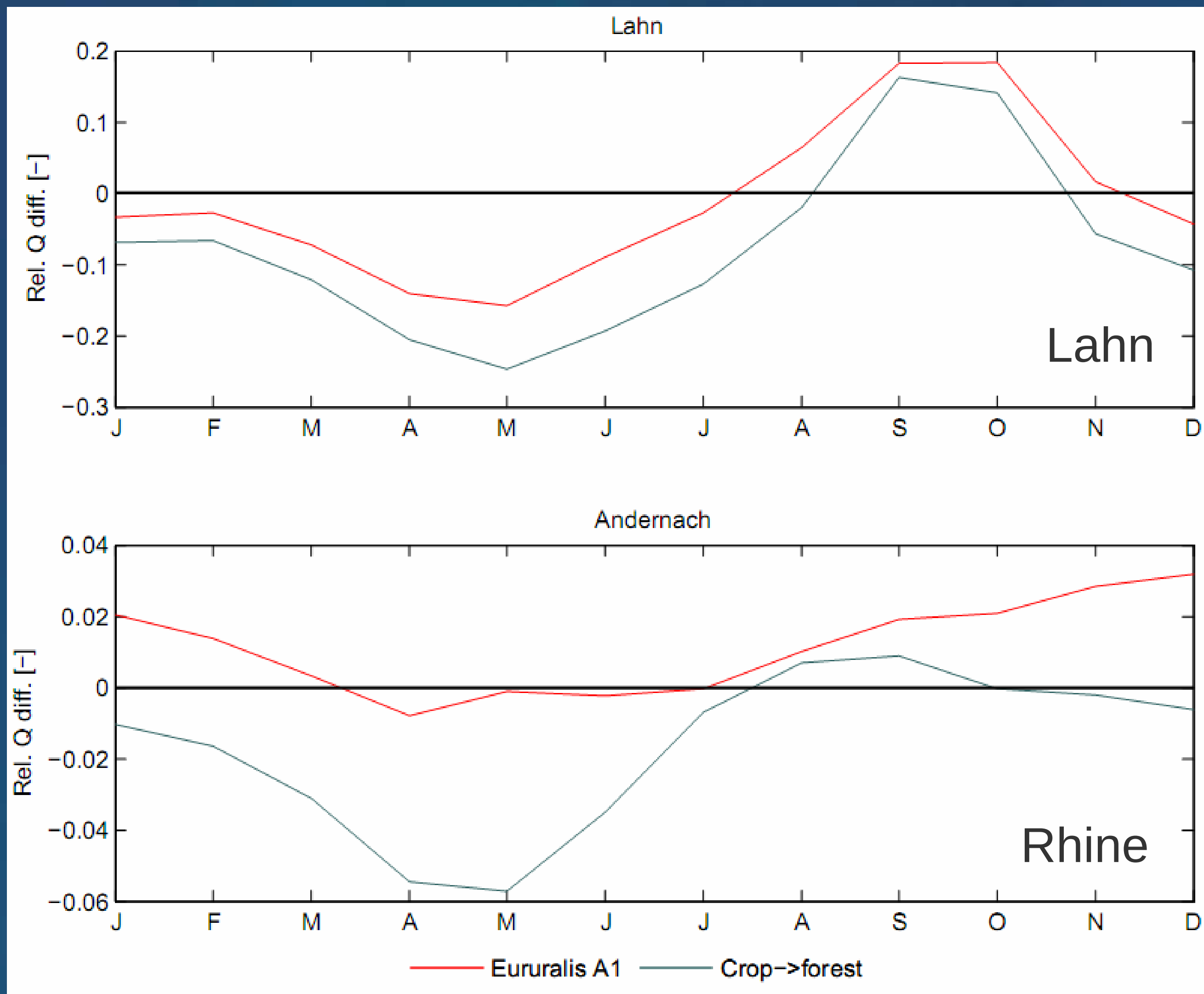


Landuse change



Landuse change

Effect on mean discharge



+ 20 %

- 30 %

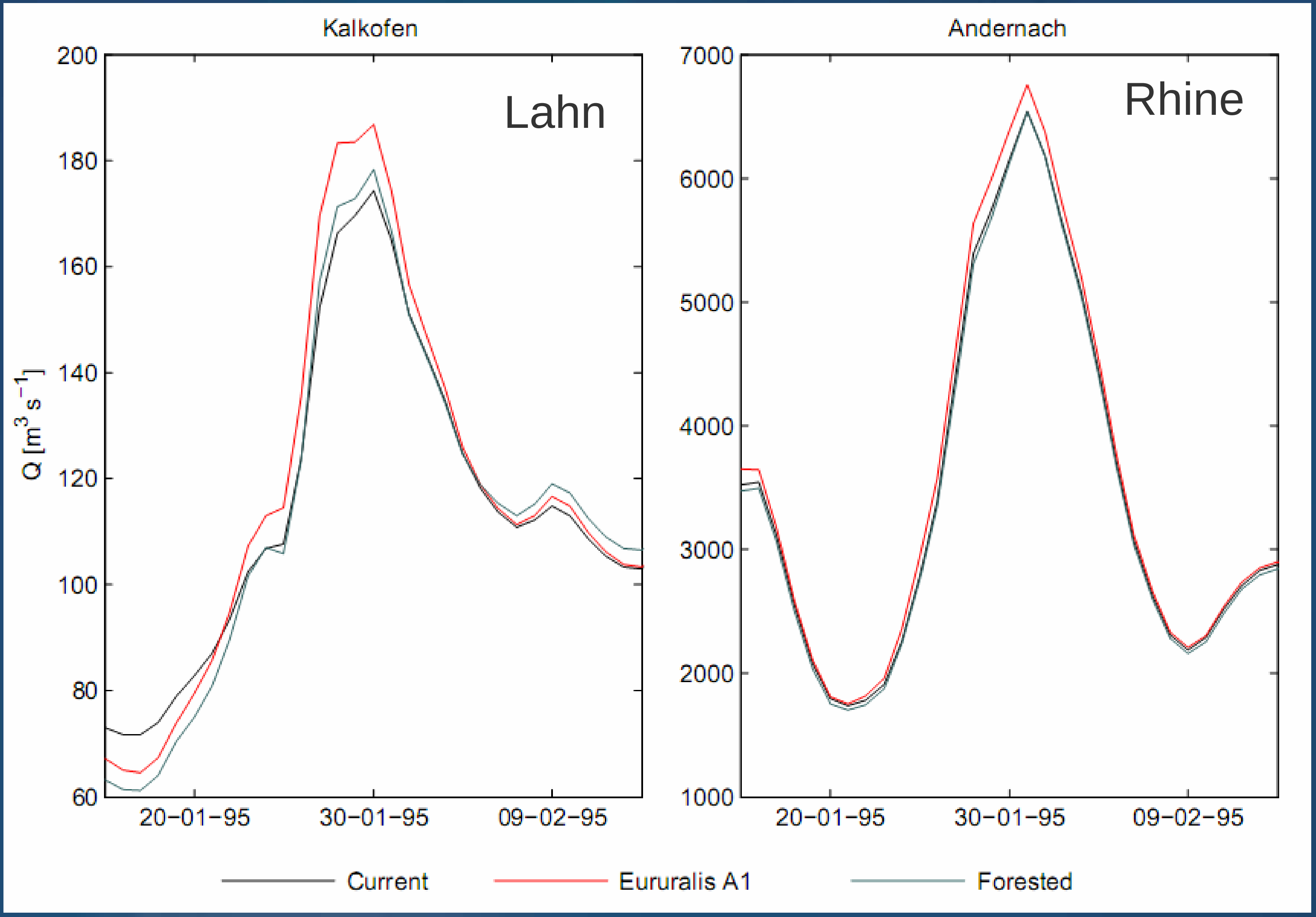
+ 4 %

- 6 %

(Hurkmans, 2008)

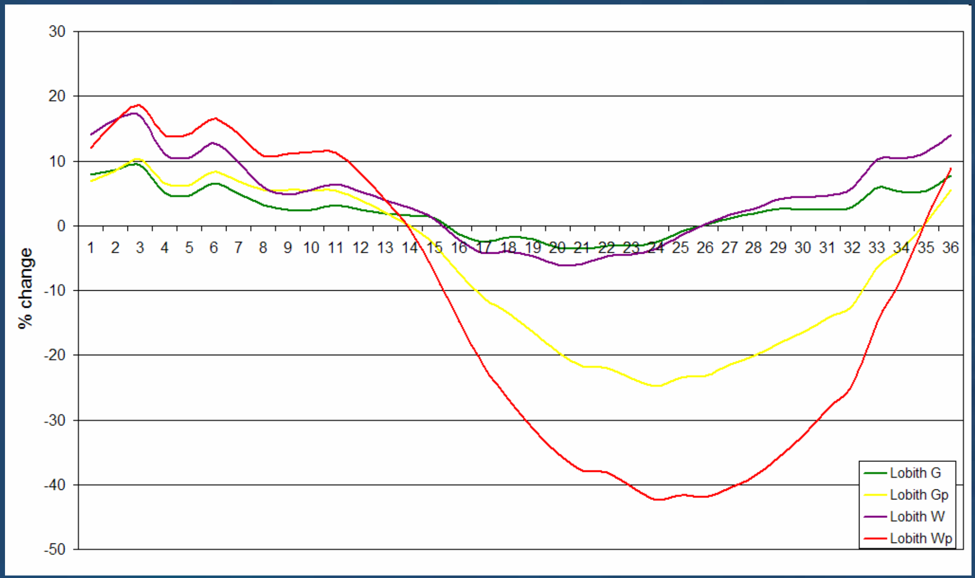
Landuse change

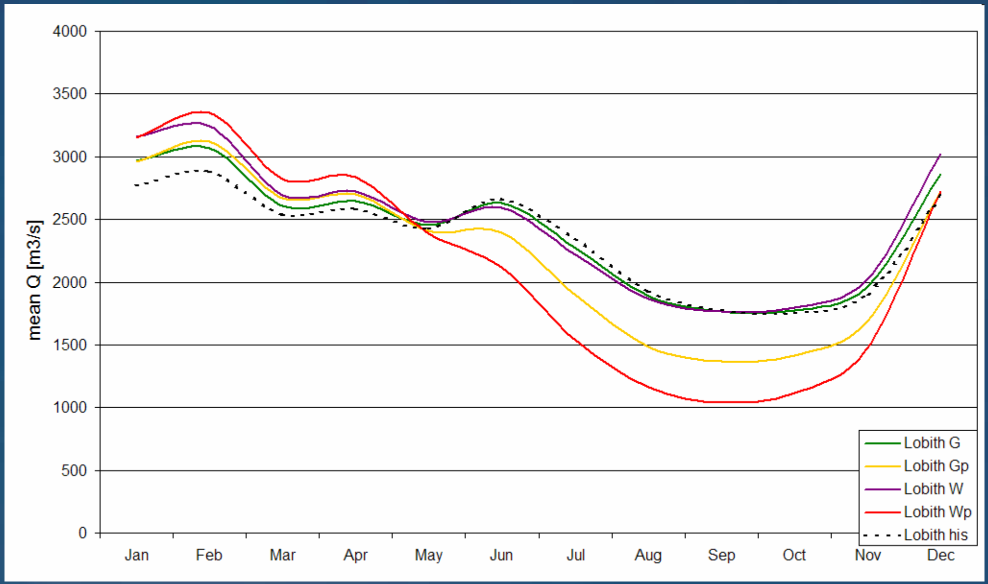
Effect on peak discharge



Climate change – change in mean discharge

Lobith





- Relative change
- Absolute change

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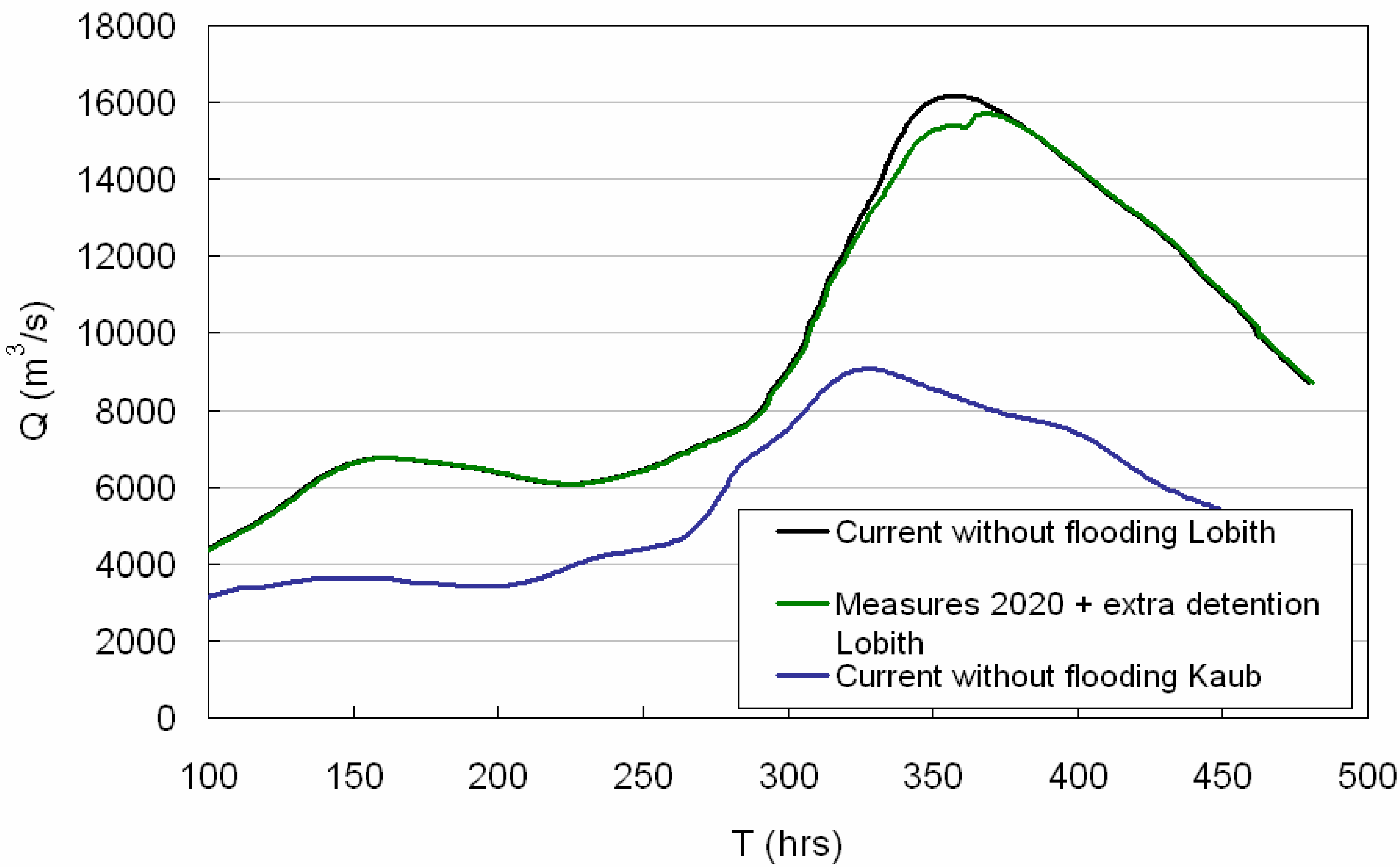
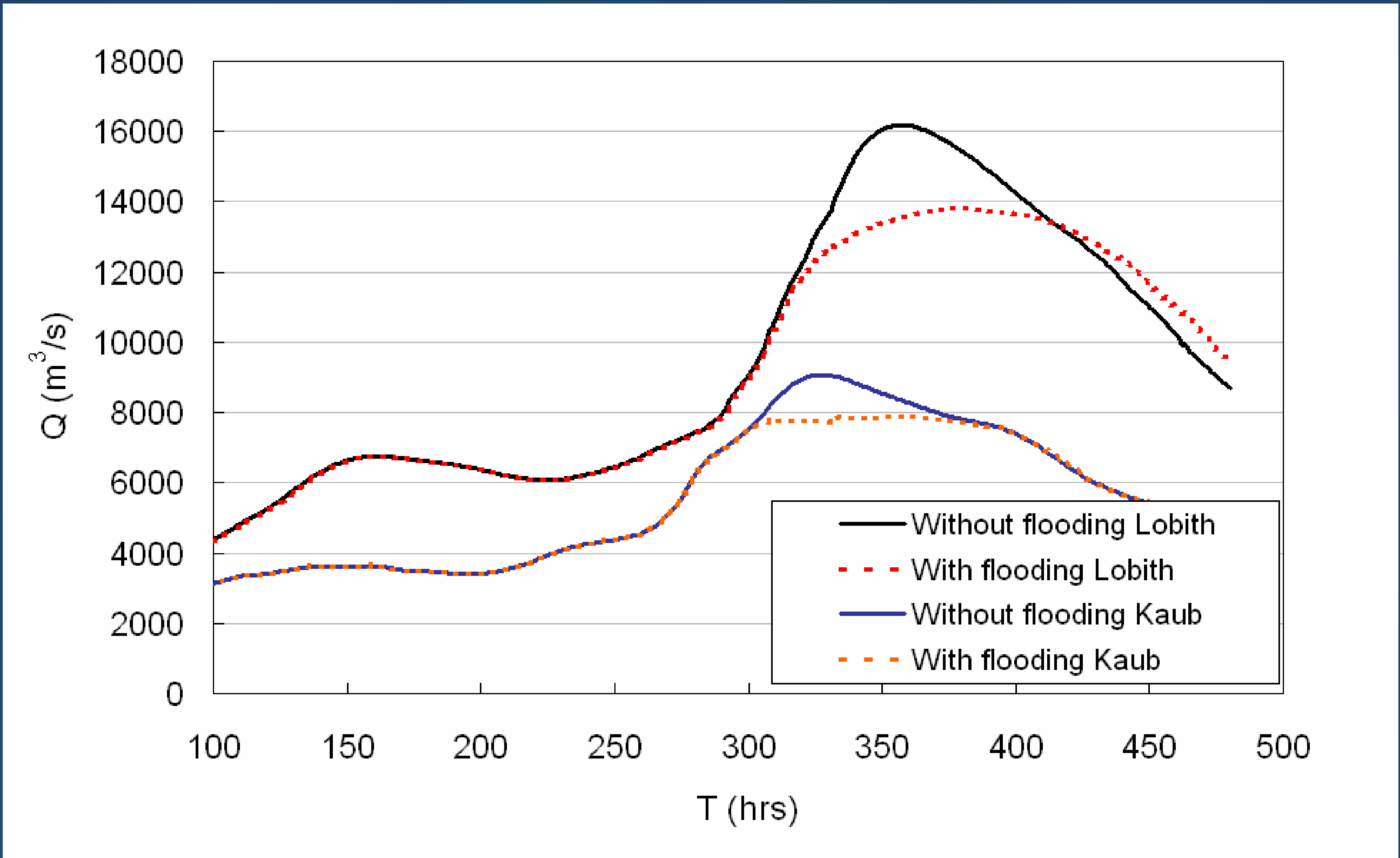
Infinite dike height: detention – flooding

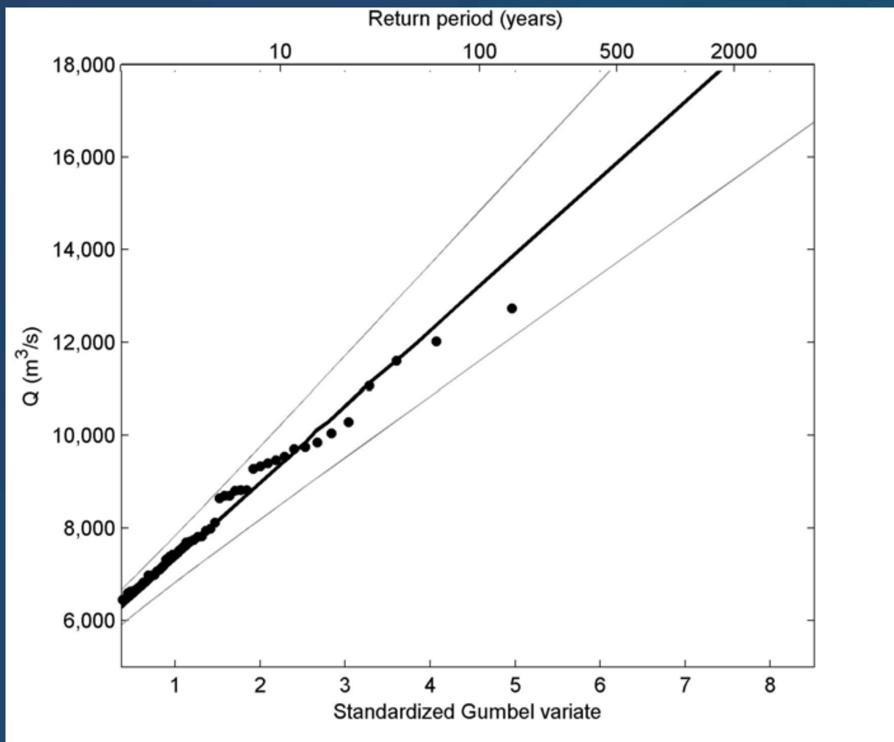


Infinite dike height: detention – flooding

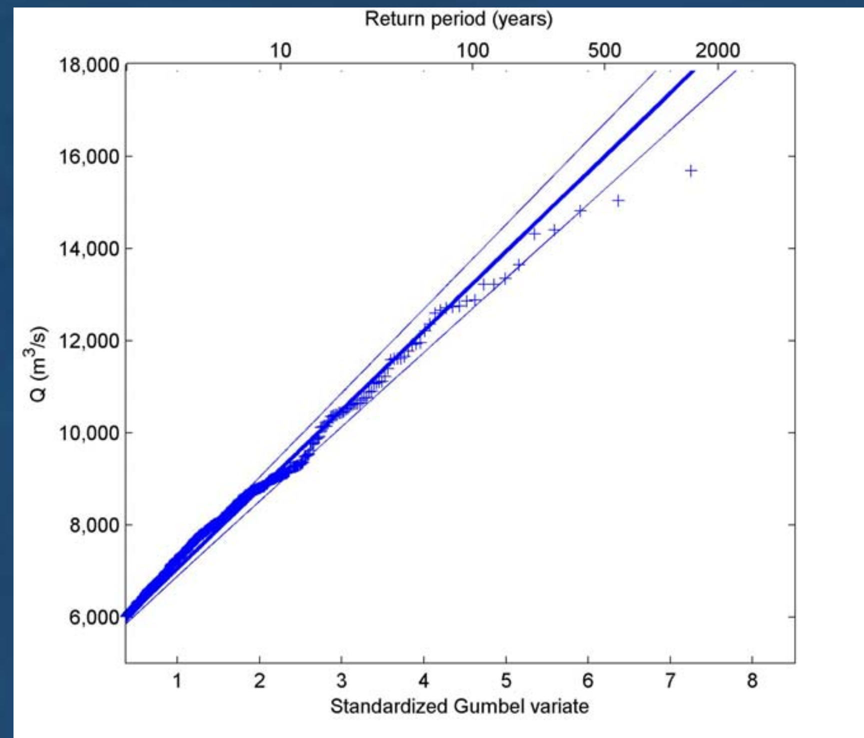


Extreme value distribution (Gumbel) yearly maximum Q

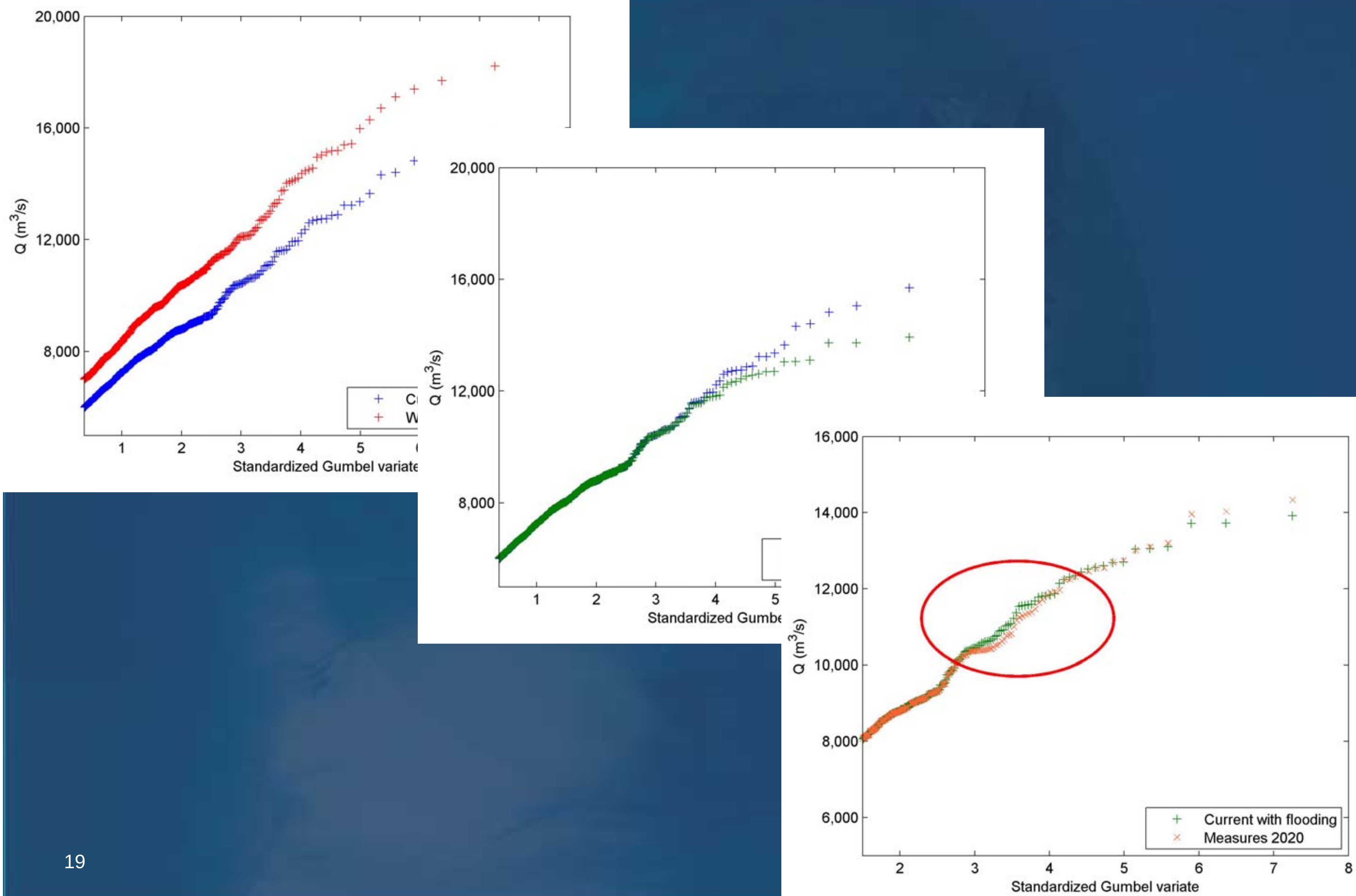
100 yrs observed



1000 yrs resampled



Climate change   Flooding / dike height   Detention



Conclusion

- Land use change → no effect on peak discharge
- Resampling
  - possibility to analyse ensemble of events / bandwidth
  - narrows confidence interval extreme value distribution fit
- Detention area
  - effect strongly depends on event size
  - planned areas are not effective at extreme discharges > ~ Q100
- Events > ~ Q100 → Flooding
- Dike heightening will increase extreme peak discharge downstream

- Climate change → peak events (flooding) expected to occur more frequently

Thank you

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www.klimaatvoorruimte.nl
www.adaptation.nl\acer