International Workshop / Expert consultation ***Extreme Discharges***

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Large scale simulation of land use change effects on floods in the Rhine (results from the LAHOR-project)

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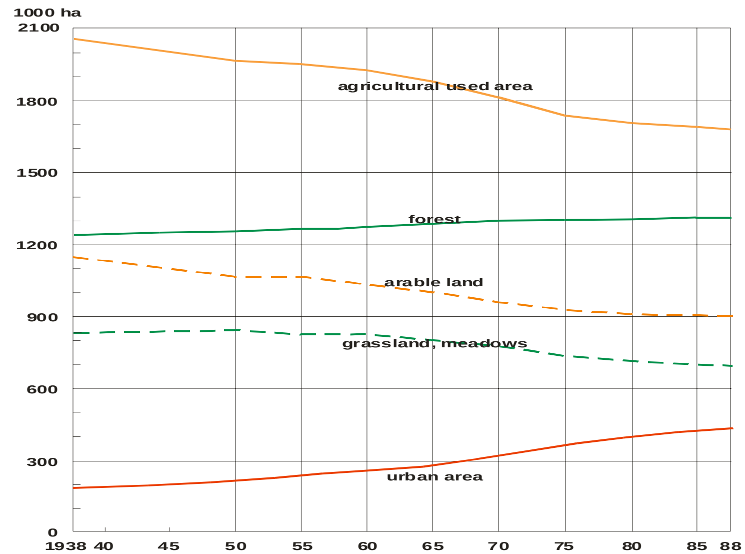
Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

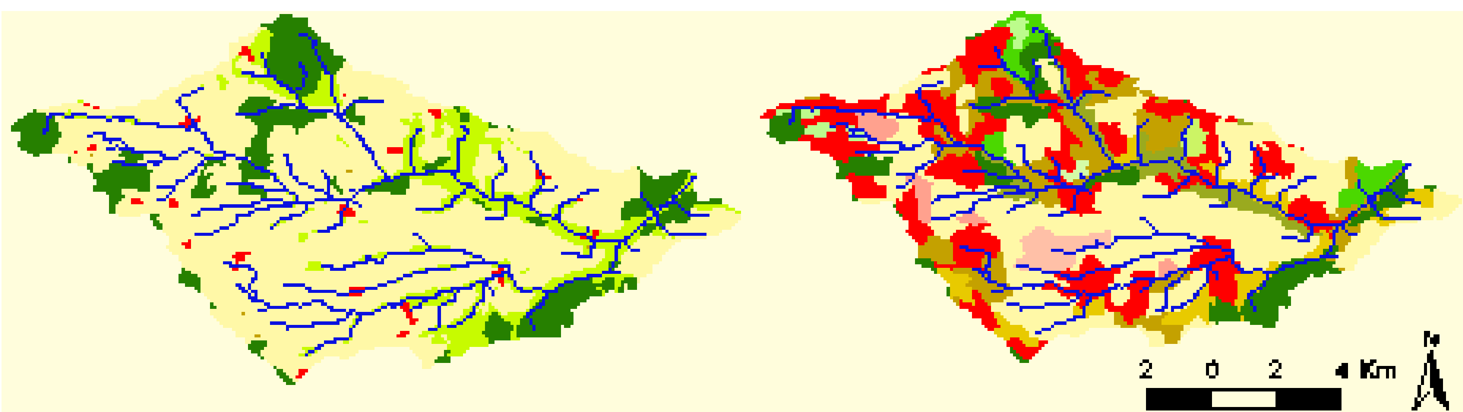
Major land-use changes in the Rhine basin during the last century

1) Urbanisation

- ***doubling of urban areas (housing, industry, traffic etc.) during the last 60 years***

- ***Example: Körsch-Catchment 1850 → 1990***





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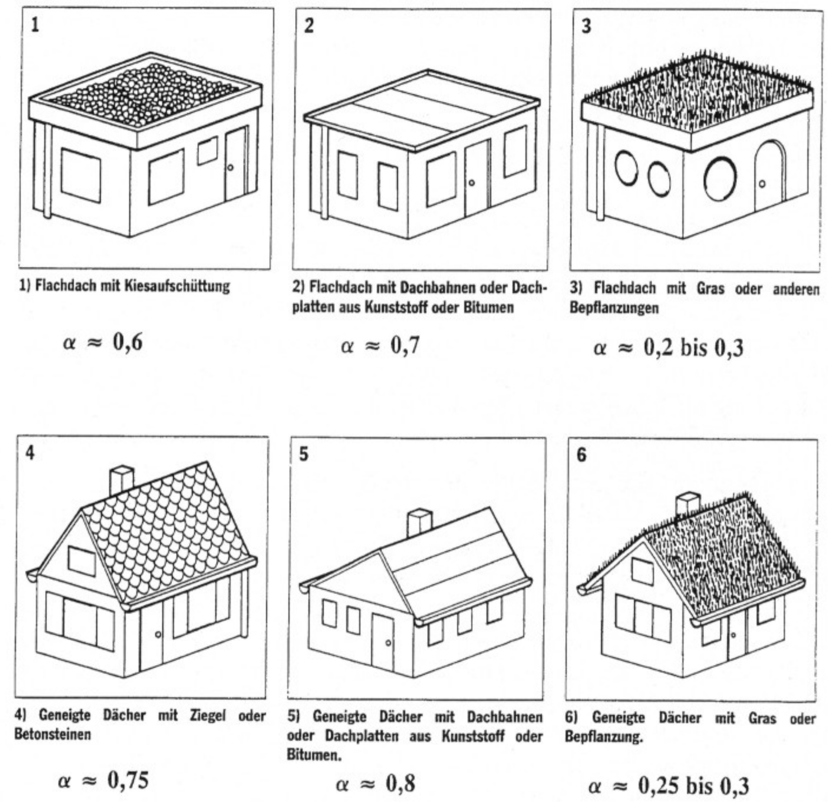
Major land-use changes in the Rhine basin during the last century

2) decentralised management urban storm water

- ***retention on roofs etc.***
- ***Small scale retention in the landscape***



Jahresabflussbeiwerte α.

Major land-use changes in the Rhine basin during the last century

3) change in management practice of farm land

- ***conventional tillage vs. Ecological oriented tillage***

- ***rationalisation of farm land***

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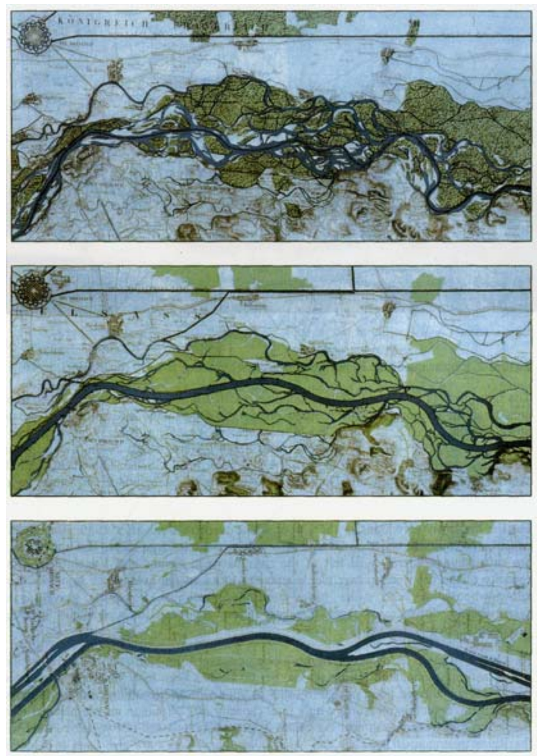
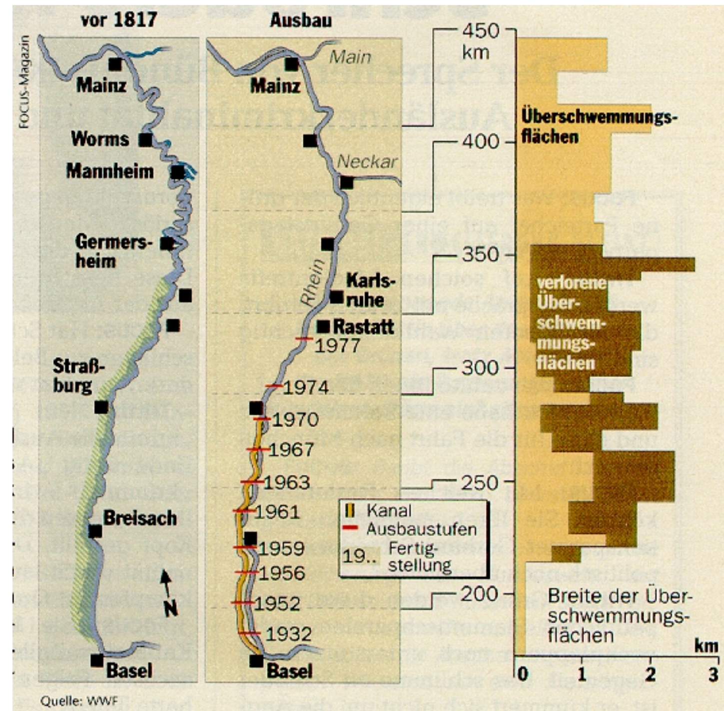
Major land-use changes in the Rhine basin during the last century

4) river training and river channelling





- *faster flood wave propagation*
- *reduced retention in flood plains*

The modelling concept

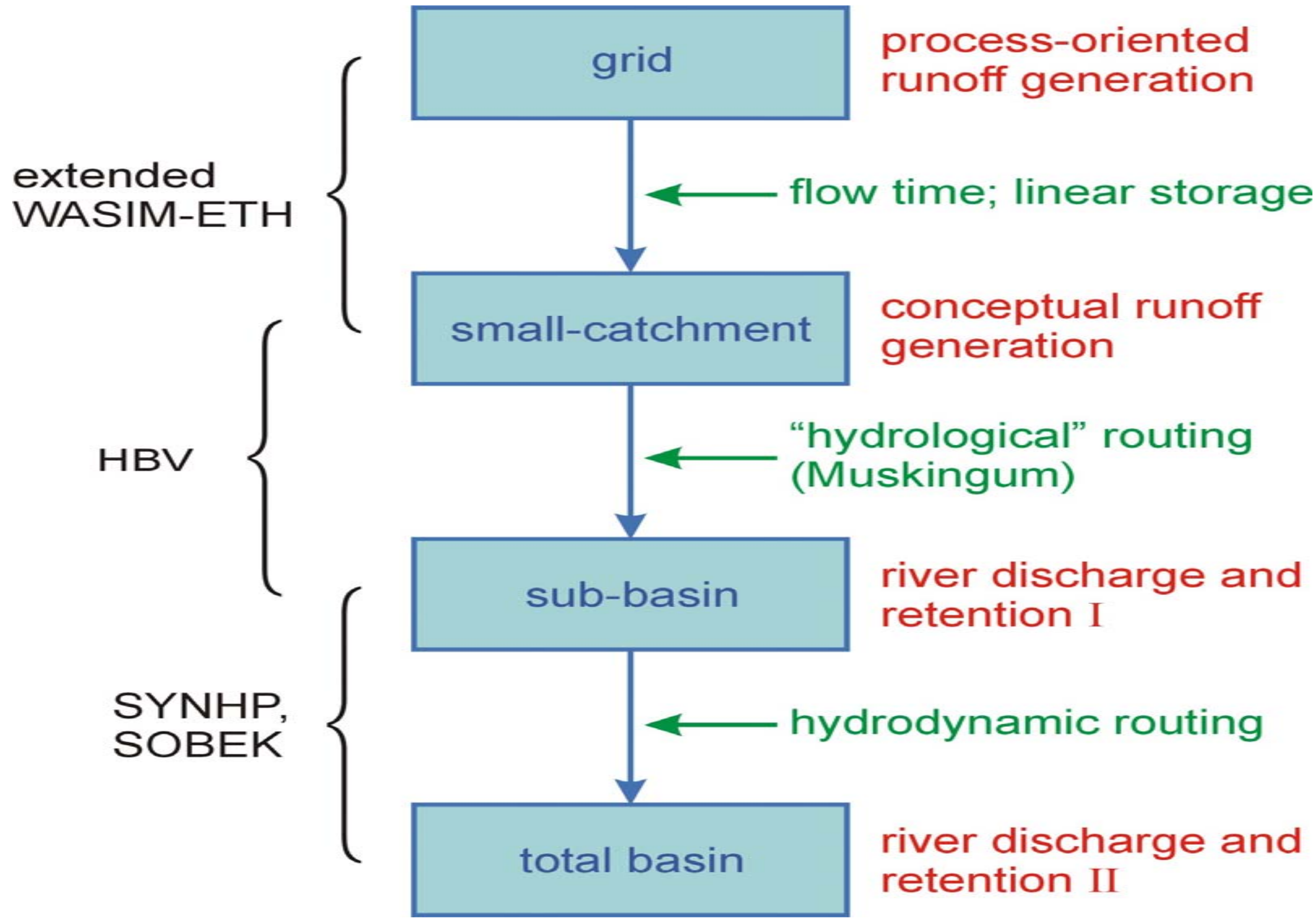
1) *storm runoff generation influenced by different land use ➔ meso scale hydrological modelling in selected sub-catchments*

2) *regionalization of runoff generation ➔ macro scale hydrological modelling in all sub-catchments*

3) *flood routing and retention in flood plains ➔ hydrodynamic routing in the main river system*

Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

The modelling approach: nested and scale-specific models



Results I

The Lein Sub-Catchment:

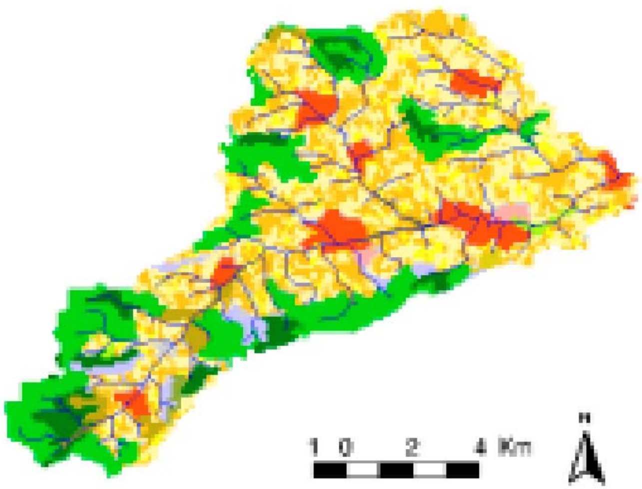
Area: 115 km²

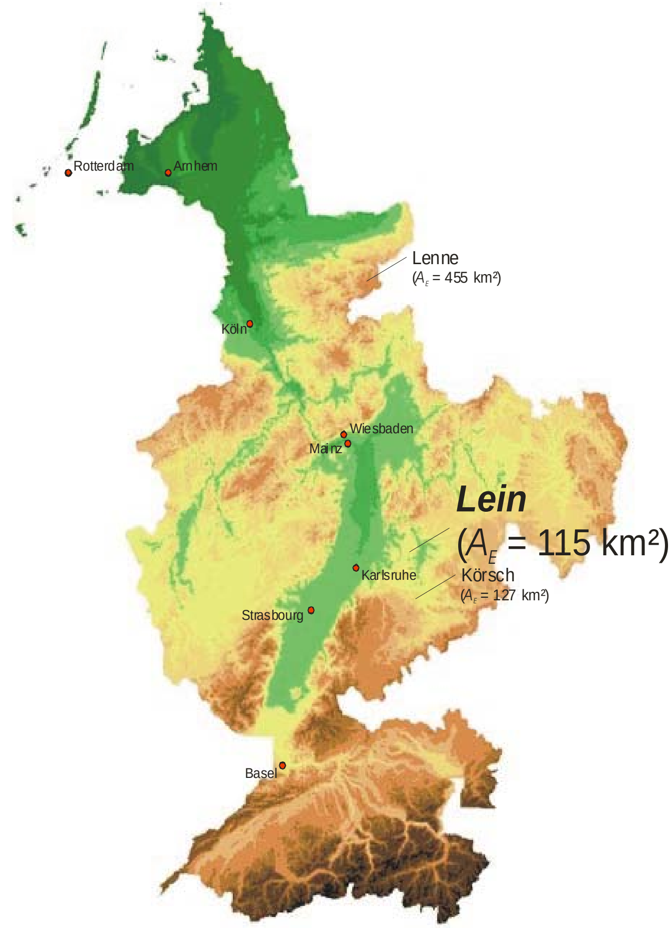
Location: Kraichgau (SW-Germany);

land use: intensive agriculture

soils: deep loess soils

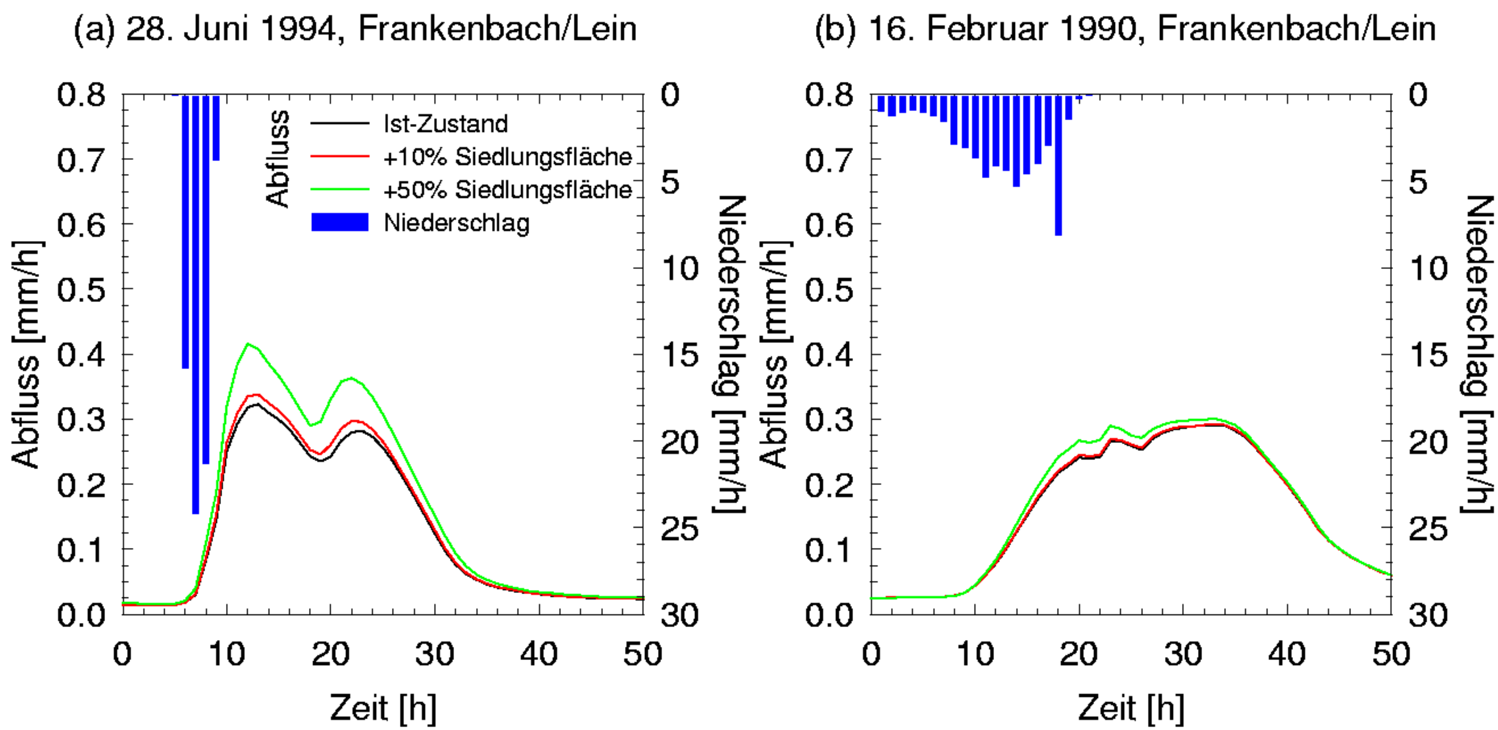
hydrological model: extended WASIM-ETH





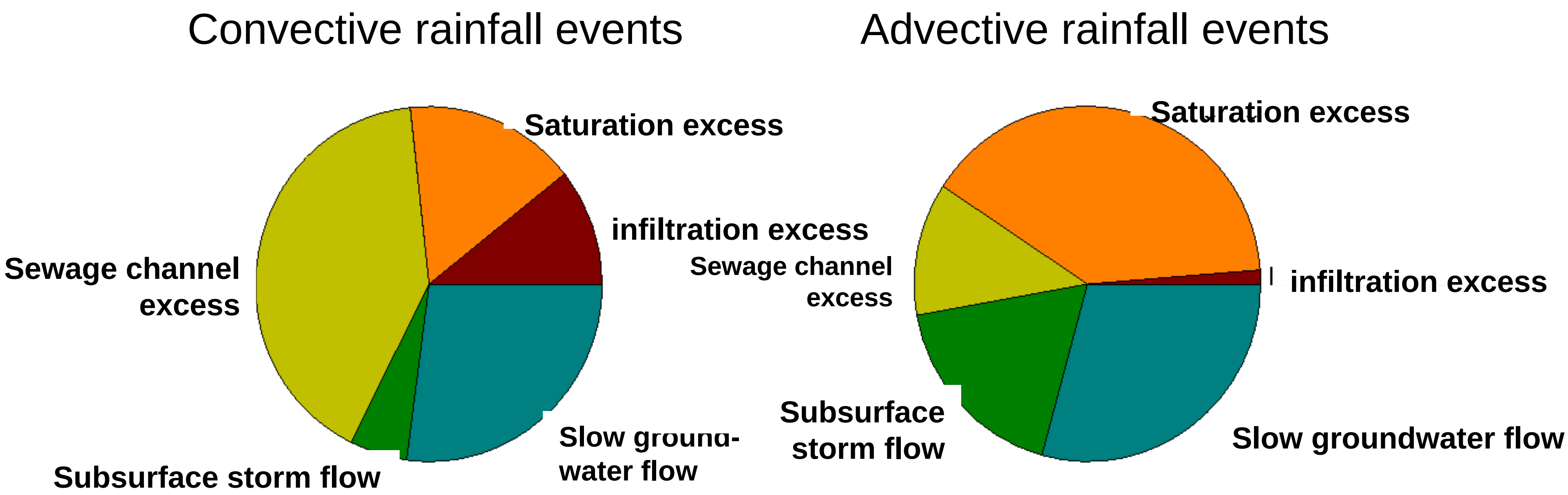
Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results I: The Lein sub-catchment



Simulate storm runoff after (a) a convective rain event (b) an advective rain event; present land use and urbanisation scenarios

Results I: The Lein sub-catchment



Lein-sub-catchment: runoff generation processes for different rainfall event types

Results I: The Lein sub-catchment

Simulated increase in runoff volume and peak (advective events) due to a 50% increase of settlement and industrial areas in the Lein catchment; the events are sorted by the urbanization impact on runoff volume

Year, month	*Increase in runoff compared to present conditions*		*Simulated baseflow contribution to volume [%]*	*Duration [h]*	*Return period approx. [a]*
	Maximum [%]	*Volume [%]*			
1990, February	3,4	3,7	19	150	2
1993, December	5,9	2,7	17	250	8
1997, February	3,9	2,7	19	150	7
1982, December	1,7	1,5	27	225	3
1983, May	0,6	0,9	39	300	4
1988, March	0,0	0,0	52	650	3
Mean	*2,6*	*1,8*	*29*	*290*	*4,5*

Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results II: The Lenne sub-catchment

The Lenne sub-catchment

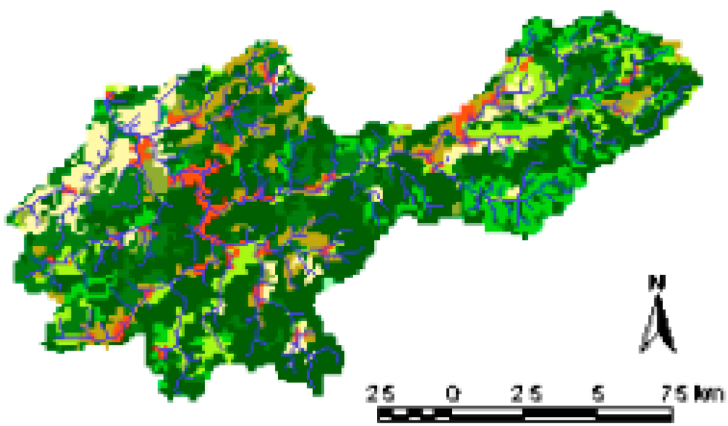
Area: 455 km²

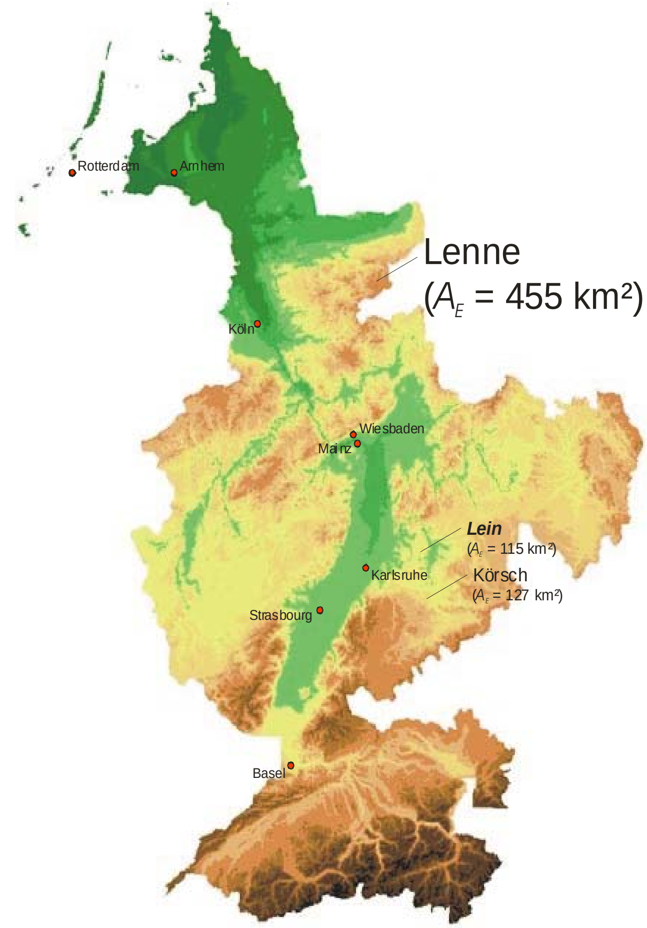
Location: Sauerland (W-Germany);

Land Use: mainly forest and pasture; few settlement

soils: shallow, permeable

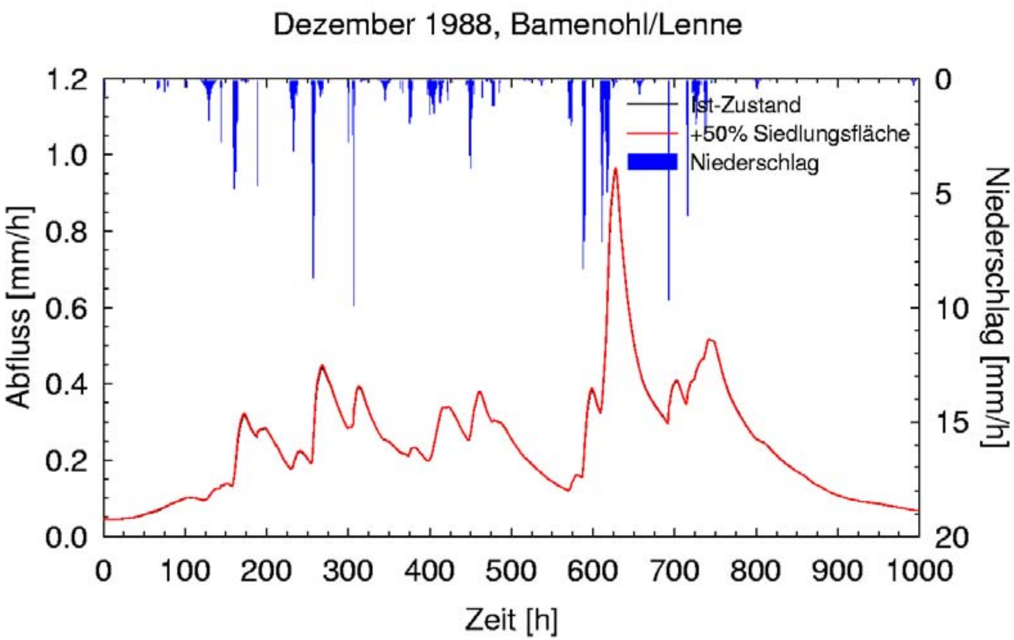
hydrological model: extended WASIM-ETH

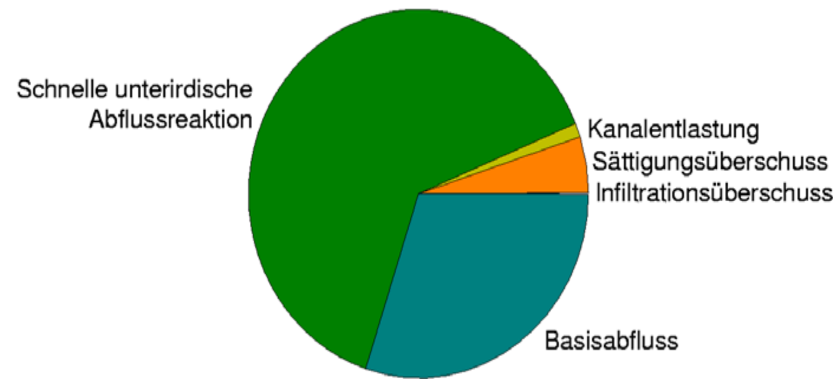




Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results II: The Lenne sub-catchment





Simulate storm runoff after an advective rain event: present land use and urbanisation scenarios

Results III: Regionalization of runoff generation

Rhine basin from Maxau to Lobith:

Area: 110 600 km²

hydrological model: extended HBV-IWS

(extended for urban areas, specific parameterization of storage processes for different land-use)

catchment sub-division:

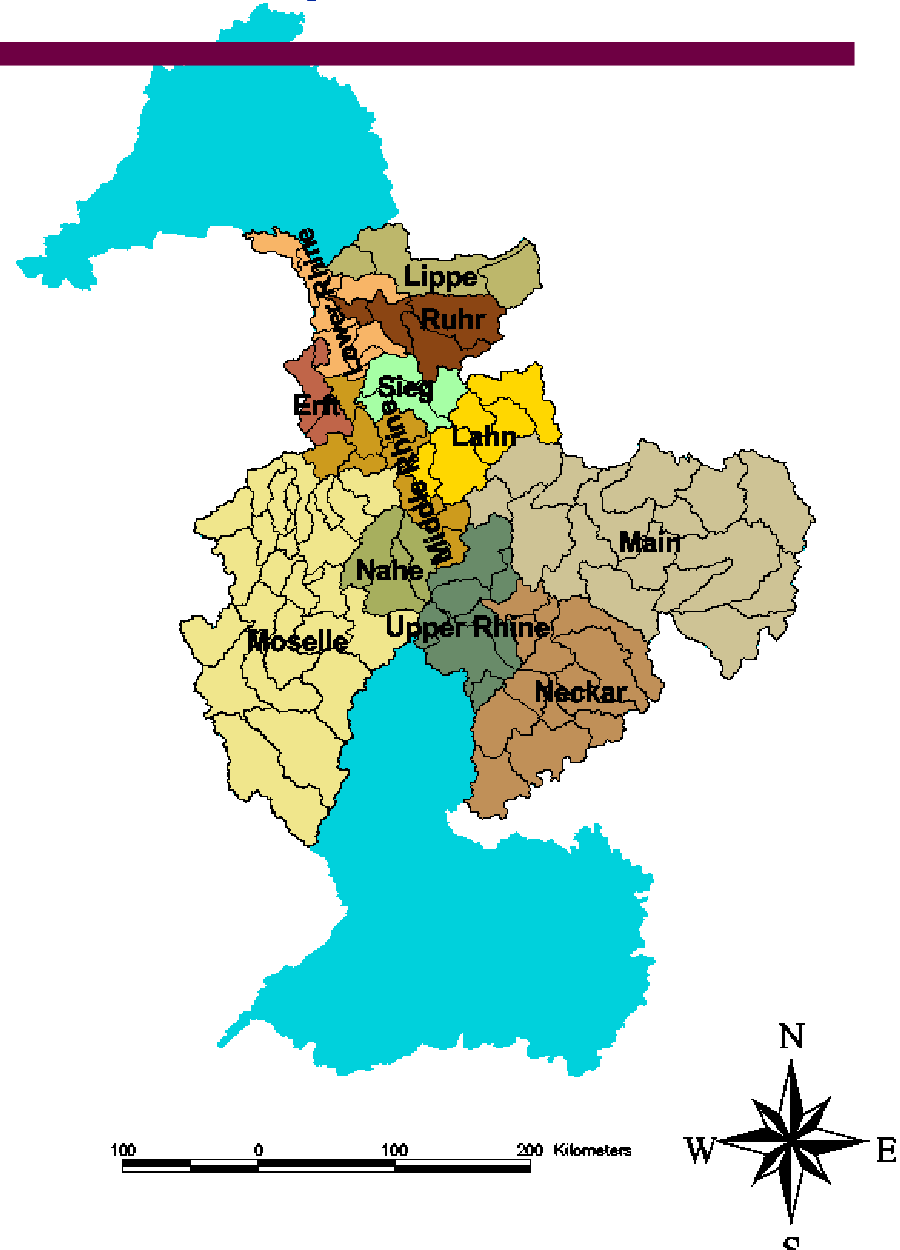
96 sub-catchments

12 major sub-catchments

hydro-meteorological data base:

1514 precipitation stations

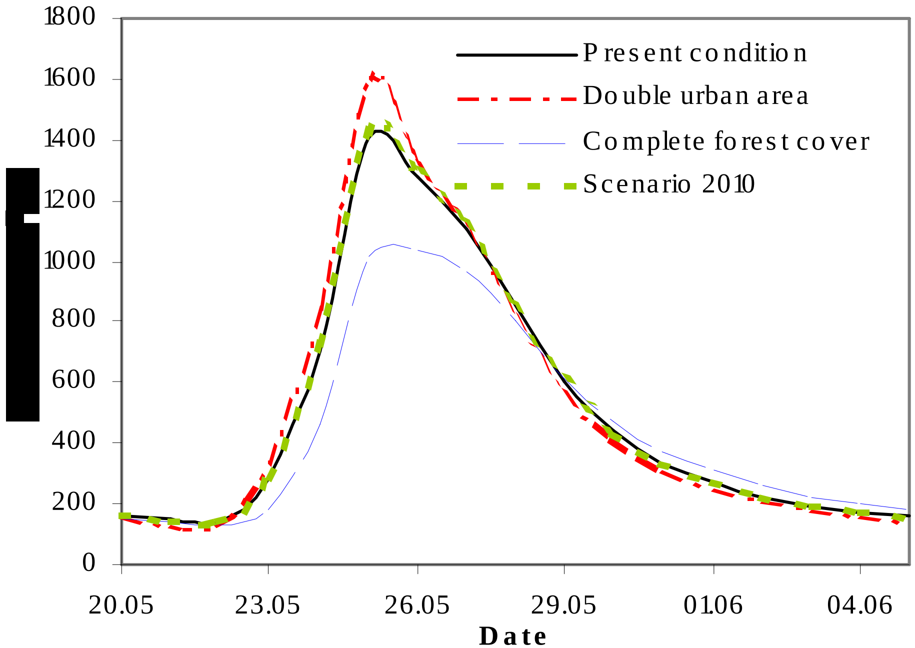
313 climate stations



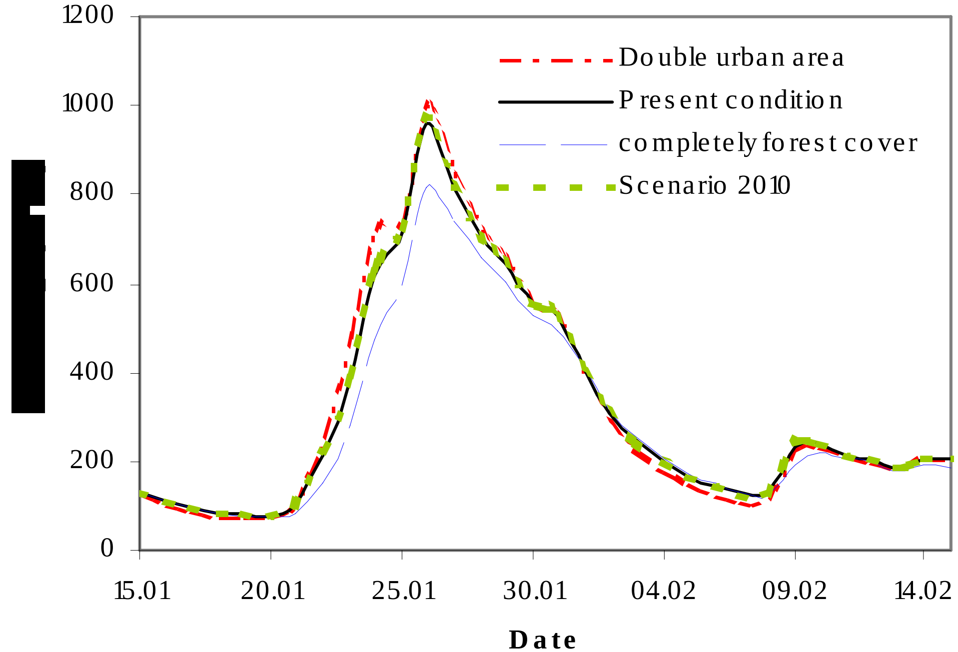
Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results III: Regionalization of runoff generation

a) Summer 1983 event



b) Winter 1995 event



Neckar catchment (Gauge Rockenau, 2,665 km²)

Simulated runoff for different land-use scenarios due to an intense summer rainfall of shorter duration and a winter precipitation of lower intensity and longer duration

Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results IV: Effects of land-use changes on the macro-scale

River network from Maxau to Lobith:

total length of simulated river stretches:

~ 1100 km

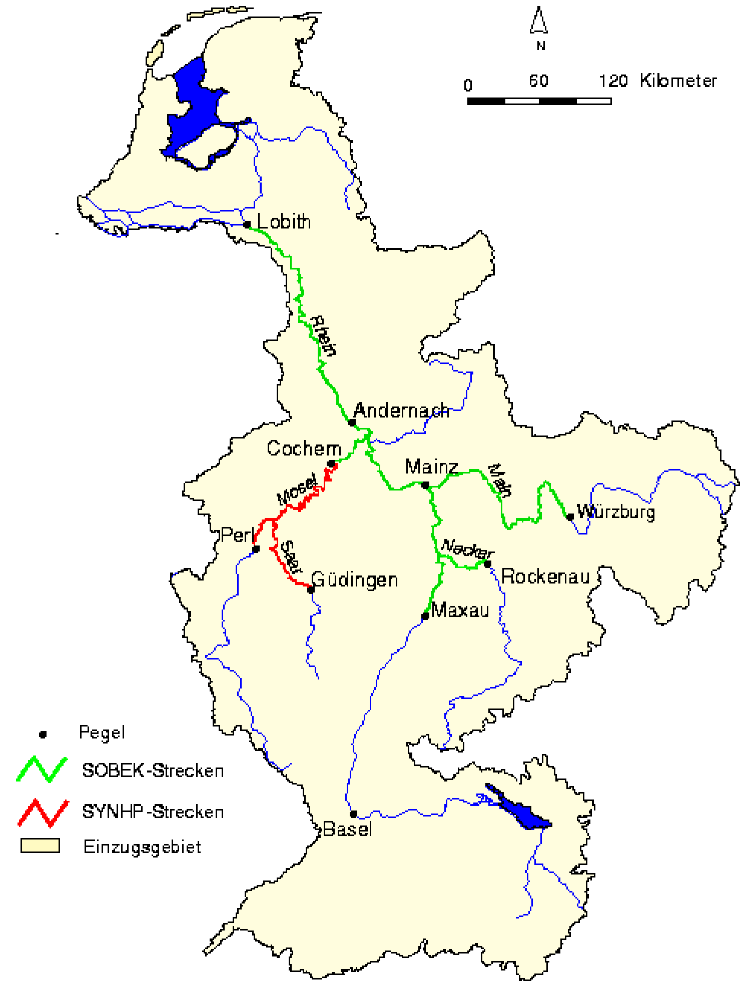
routing model:

SOBEK (1D-fully hydro-dynamic)

SYNHP (hydrological routing)

42 simulated scenarios:

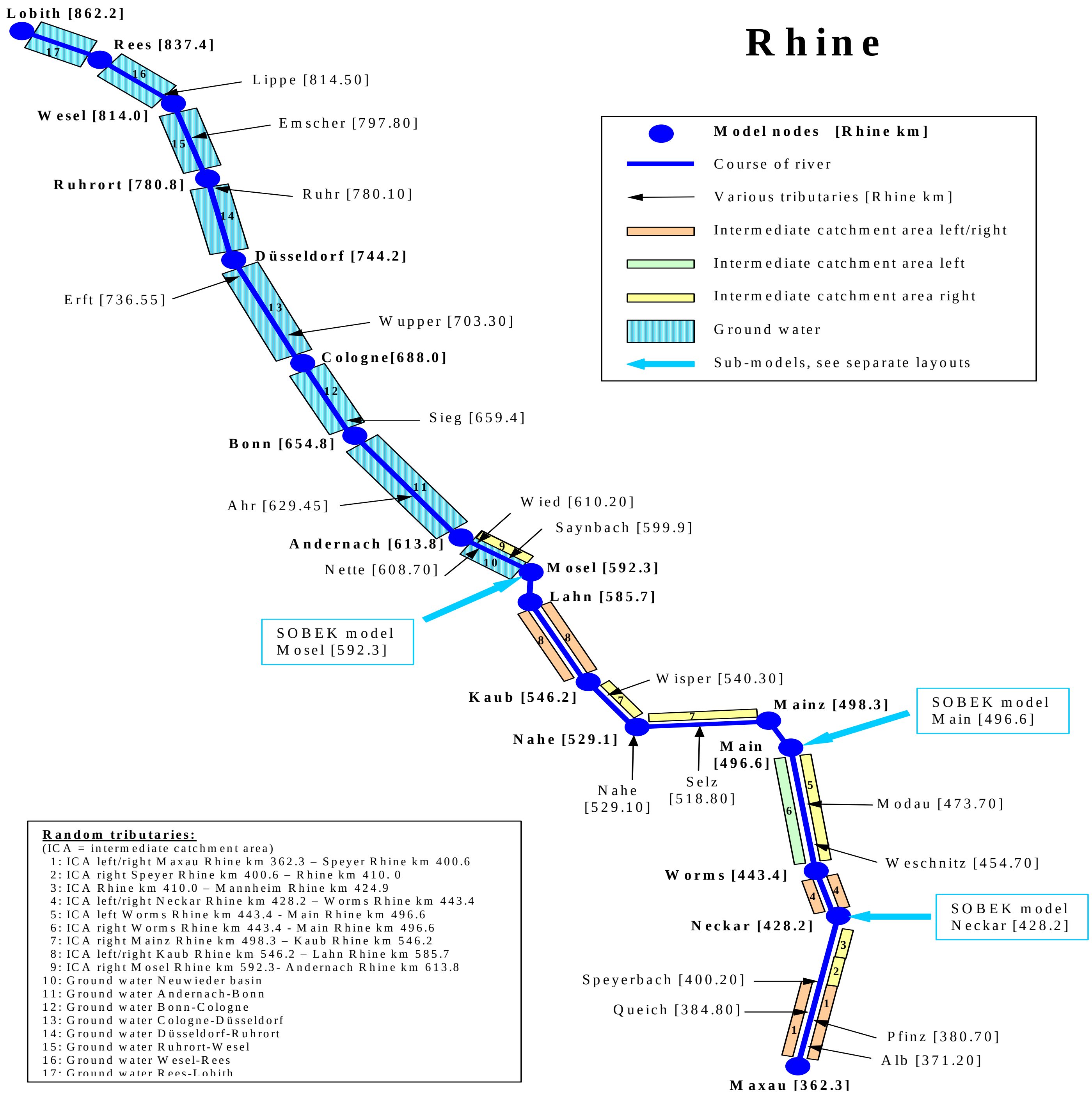
- ☞ land-use change
- ☞ extreme precipitation scenarios
- ☞ retention in polders and flood plains



Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

The Rhine River:

***river nodes and stretches*; groundwater and catchment inflows**



Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

The Rhine River:

simulated retention measures on the Rhine below the Maxau gauging station

Retention area		Operation	Volume [10^6 m^3]
Name	**Position (Rhine km)**		
Upper Rhine			
Wörth/Jockgrim/Neupotz	368	Moving the dike back and retention polder*	16.2 (12 +4.2)
Elisabethenwört	381.3 – 383.0	Retention polder*	11.9
Mechtersheim	388.4	Retention polder*	7.4
Rheinschanzinsel	390.4	Retention polder*	6.2
Flotzgrün	392.6	Retention polder*	5.0
Kollerinsel	409.9	Retention polder*	6.1
Waldsee/Altrip/Neuhofen	411.5	Moving the dike back and retention polder*	9.1 (7.9 +1.2)
Petersau/Bannen	436	Moving the dike back	1.4
Worms Bürgerweide	438	Moving the dike back	3.4
Mittlerer Busch	440	Moving the dike back	2.3
Bodenheim/Laubenheim	490	Retention polder*	6.4
Ingelheim	517	Retention polder	3.8
Total for Upper Rhine below the Maxau gauging station			**79.2**
Lower Rhine			
Cologne-Langel	668.5 – 673.5	Retention polder	4.5
Worringer Bruch	705.5 – 708.5	Retention polder	8
Monheim	707.5 – 713.5	Moving the dike back	6.9
Itter-Himmelgeist	723.5 – 727.5	Moving the dike back	2
Ilvericher Bruch	750.5 – 754.5	Retention polder	8.1
Mündelheim	760.5 – 769.5	Moving the dike back	3
Orsoy Land	797.5 – 803.5	Moving the dike back	10
Bislicher Insel	818.5 – 823.5	Raising the dike	-
Lohrwardt	832.5 – 833.5	Moving the dike back and retention polder	12.9 (10.3 +1.6)
Grietherbusch	837.5 – 847.5	Dike adaptation	-
Bylerward	845.5 – 854.5	Retention polder*	10
Total for Lower Rhine			**65.4**
Total volume of the measures taken into account in the model			**approx. 145**
Total retention polder volume			**approx. 108**

*) controlled retention polder

3 land-use and 3 meteorological scenarios

3 different land-use scenarios **in the catchment:**

- Scenario *D1:* 10% expansion of urban areas (“rather realistic scenario”)
- Scenario *D2:* increase of urban area of 10% (D1) ***plus*** controlled infiltration of urban storm runoff in 2500 km² urban areas, as recommended in the flood action plan of the IKSR
- Scenario *D3:* 50% increase of urban areas ("extreme scenario”)

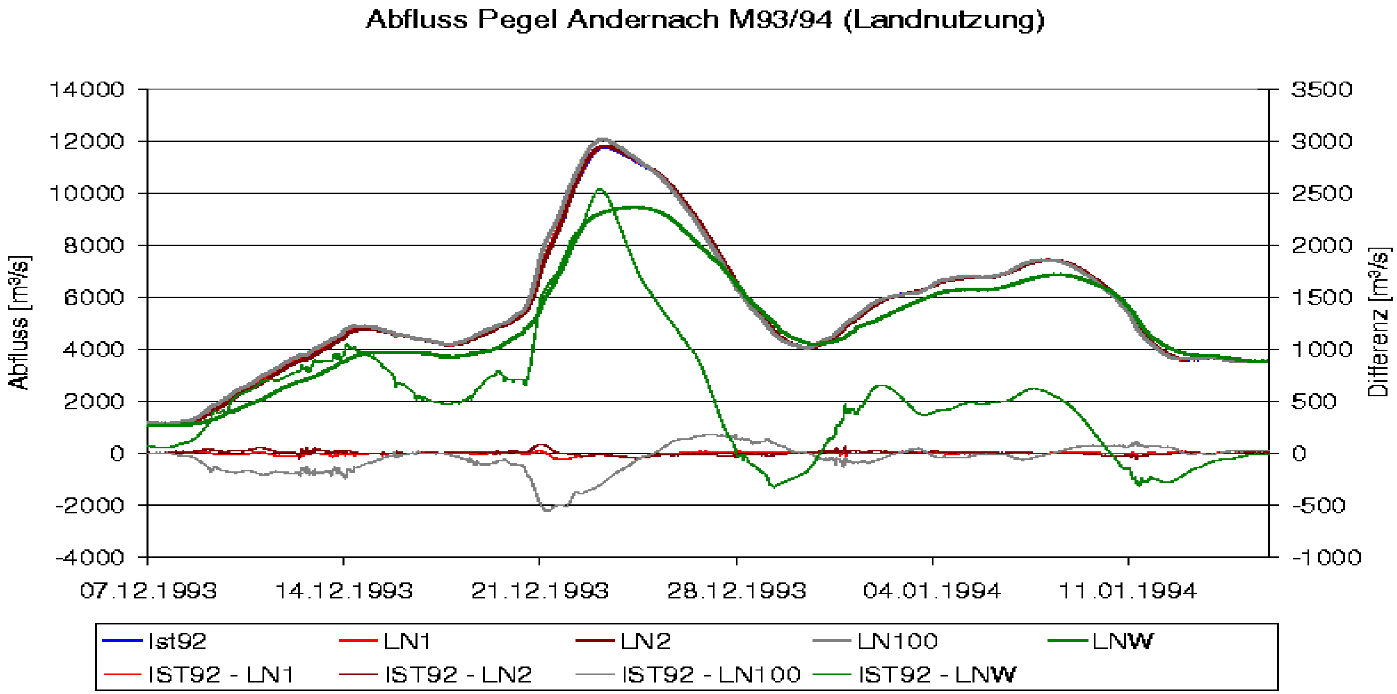
D1, D2, and D3 also consider the effects of the planned or already constructed flood defence works along the Rhine between Maxau and Lobith (flood polders along the Upper Rhine below Maxau, total volume 79.2 106 m³, and along the Lower Rhine, total volume 65.4 106 m³). The planned flood polders upstream Maxau (207.6 106 m³) have not been assessed in this study.

3 different scenarios of meteorological forcing**:**

- Scenario *M95*: Meteorological forcing (in its observed spatial and temporal distribution) of Jan/Feb 1995 which caused a flood in the Rhine with a return period > 100 years,
- Scenario *M95+*: Meteorological forcing of Jan/Feb 95 ***plus*** a 20% increase of precipitation
- Scenario *M95++*: Meteorological forcing of Jan/Feb 1995 ***plus*** a 20% increase of precipitation ***plus*** an additional pre-event snow water equivalent of 20mm

Multi-scale Modelling of Anthropogenic Effects on Floods in the Rhine Catchment

Results IV: Effects of land-use changes on the macro-scale



Rhine catchment: gauge Andernach (~ 100 000 km²);

simulation of the 1993 flood with present land-use and scenario land-use conditions

Results: Modelled changes in water level [cm] at 5 main gauging stations

Rhine gauging station (km below Lake Constance)	Meteorological Scenario		
	M95	M95+	M95++
Worms (km 444)			
D1	0 (0/0)	10 (0/10)	16 (0/16)
D2	0 (1/0)	9 (0/10)	16 (-1/17)
D3	0 (-1/1)	-10 (-1/-9)	15 (-1/16)
Kaub (km 546)			
D1	1 (-1/2)	8 (-1/9)	9 (-2/11)
D2	1 /-1/2)	8 (-1/9)	9 (-1/11)
D3	-5 (-7/3)	3 (-6/8)	3 (-9/11)
Andernach (km 614)			
D1	0 (-1/1)	5 (-1/6)	6 (-1/8)
D2	1 (0/1)	6 (-1/6)	7 (-1/8)
D3	-5 (-7/2)	1 (-5/6)	2 (-6/8)
Köln (km 688)			
D1	0 (-2/1)	5 (-1/6)	4 (-2/6)
D2	1 (0/1)	5 (-1/6)	5 (-1/6)
D3	-8 (-9/2)	-1 (-7/6)	-3 (-9/7)
Lobith (km 857)			
D1	2 (-1/3)	2 (-1/3)	2 (-1/3)
D2	2 (-1/3)	3 (-1/3)	2 (-1/3)
D3	-1 (-5/3)	-2 (-6/3)	-5 (-8/3)

Conclusions

- The nested and scale-specific modelling approach applied in this study is an adequate methodology
- Land-use changes may significantly influence floods in small catchment (in case of convective rainfall)
- In large catchments the impact is (very) small, e.g. about 5-15 cm (rising limb), 0-5 cm (peak)
- controlled retention in polders reduces flood peaks nearby the retention but very little far downstream

Thank You !

- UBA
- EU (INTERREG IIc)
- BfG, RIZA, Uni S, PIK, CHR

Final report:
Bronstert, A., Bárdossy, A:, Bismuth, C., Buiteveld, H., Busch, N., Disse, M., Engel, H., Fritsch, U., Hundecha, Y., Lammersen, R., Niehoff, D., Ritter, N., (2003): Quantifizierung des Einflusses der Landoberfläche und der Ausbaumaßnahmen am Gewässer auf die Hochwasserbedingungen im Rheingebiet. Reports of the CHR, Series II, No. 18, 78pp.