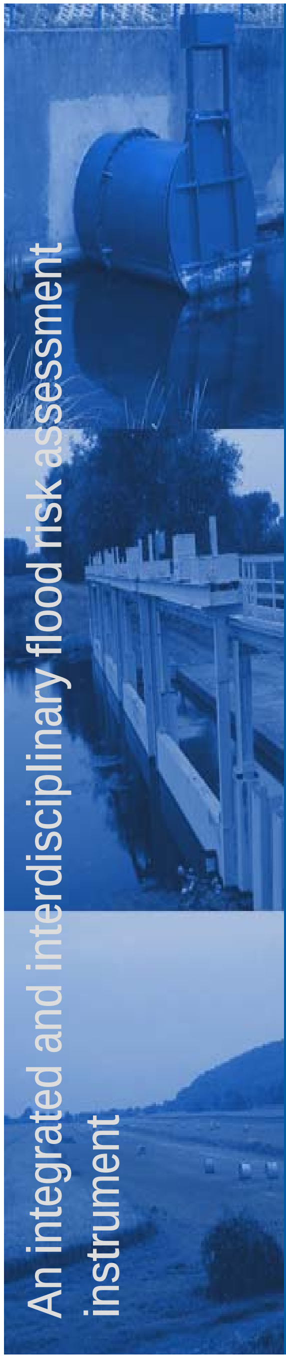


An integrated and interdisciplinary flood risk assessment instrument

DEVELOPMENT OF AN INTEGRATED AND INTERDISCIPLINARY FLOOD RISK ASSESSMENT INSTRUMENT

M. Pahlow[1], J. Dietrich[1], D. Nijssen[1], Y. Hundecha[1], B. Klein[1], C. Gattke[1], A. Schumann[1],

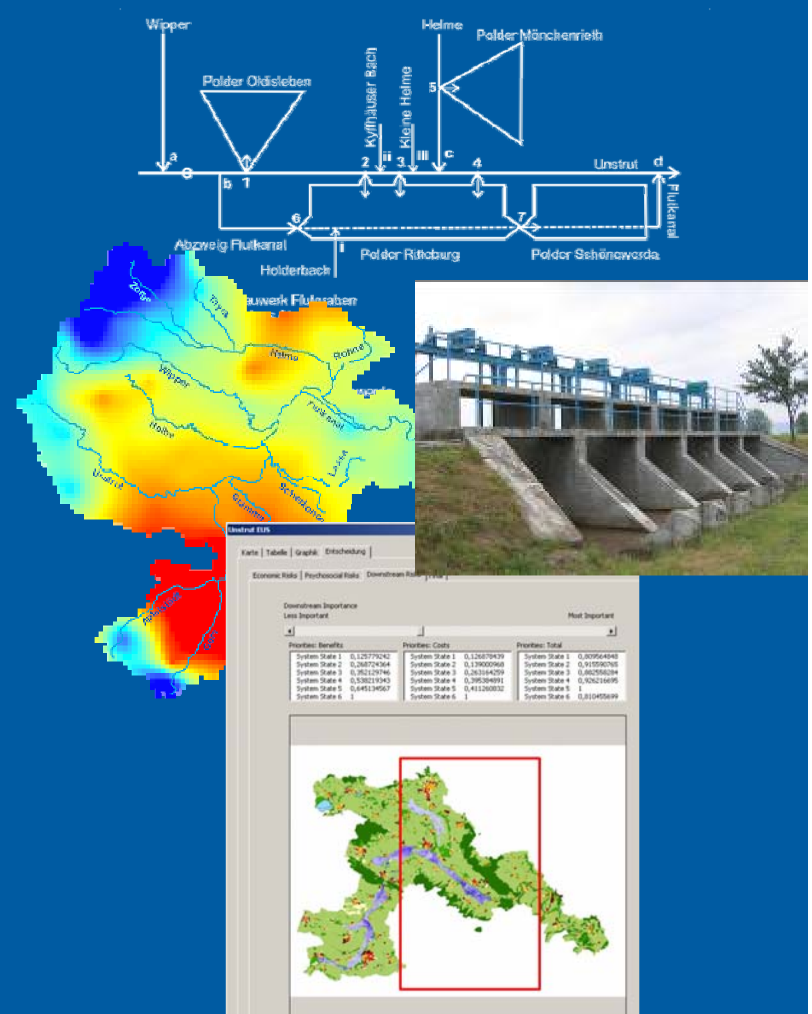
M. Kufeld[2], C. Reuter[2], J. Köngeter[2], H. Schüttrumpf[2],

J. Hirschfeld[3] and U. Petschow[3]

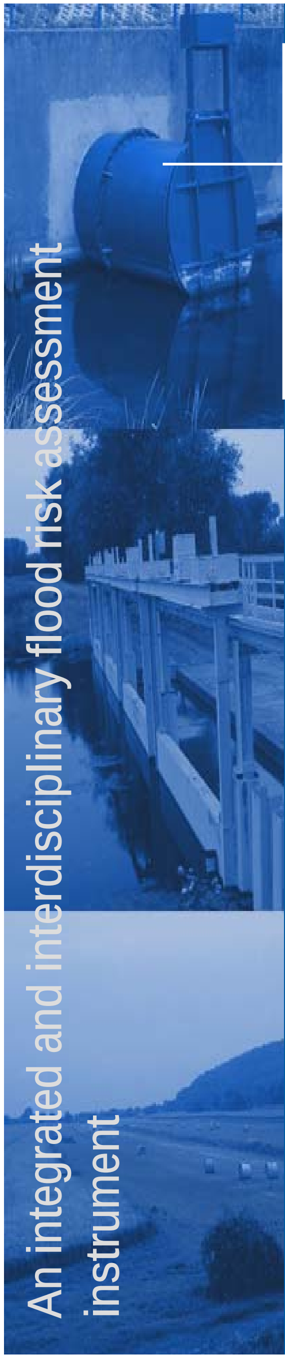
[1]Institute of Hydrology, Water Resources Management and Environmental Engineering, Ruhr-University Bochum, Bochum, Germany

[2]Institute of Hydraulic Engineering and Water Resources Management, RWTH Aachen University, Aachen, Germany

[3]IÖW, Institute for Ecological Economy Research, Berlin, Germany



A RIMAX- Research Project



Structure

I. Introduction

II. Specific Problems

III. Methodology

- I. Hydrological Loads and Risks
- II. Multiple Criteria Decision Making (MCDM) and DSS

IV. Results

12 Actions for Change

1. Employ integrated, comprehensive and systems-based approach
2. Employ risk-based concepts in planning, design, construction, operations, and major maintenance
3. Continuously reassess and update policy for program development, planning guidance, design and construction standards
4. Employ dynamic independent review
5. Employ adaptive planning and engineering systems
6. Focus on sustainability
7. Review and inspect completed works
8. Assess and modify organizational behavior
9. Effectively communicate risk
10. Establish public involvement risk reduction strategies
11. Manage and enhance technical expertise and professionalism
12. Invest in research

US Army Corps of Engineers®

Introduction

An integrated and interdisciplinary flood risk assessment instrument

Objectives

- Risk based approach in flood planning

- Evaluation of interacting flood retention facilities in river basins

- Consideration of hydrological complexity by imprecise flood probabilities

- Spatial distributed characteristics:
    - Natural system (interactions of tributaries)
    - Spatial distribution of flood retention facilities
    - Spatial distribution of potential flood damages

Development of a DSS- prototype for interactive MCDM-based planning of flood retention facilities in river basins

An integrated and interdisciplinary flood risk assessment instrument

Structure

I. Introduction

II. **Specific Problems**

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Problems

Safety versus Risk-Oriented Approach in Planning

Safety-Oriented Approach

Choice of design flood Q_{design} (e. g. 100 year flood)

↓

Design

Technical flood control fully functional for $Q \leq Q_{design}$

↓

Assumption: No risk of failure for $Q \leq Q_{design}$ and negligible beyond Q_{design}

Risk-Oriented Approach

100 % safety can not be achieved by technical means

↓

Risk of failure

Hydrological Risk
Operational/Technical Risk

↓

Risk Management required

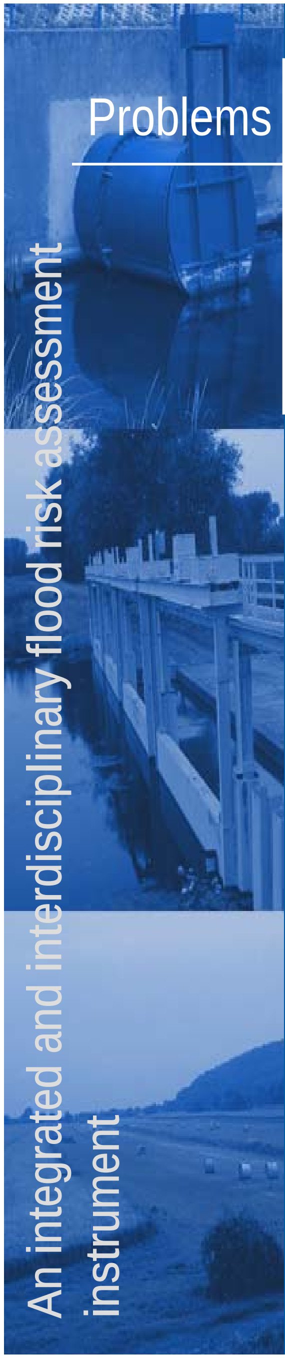
Problems | Risks, Interactions, Spatial characteristics

Natural Risk

- Hydrological variability and complexity results from interactions between watersheds and meteorological conditions
- Probability distribution functions of flood peaks describe only one part of multivariate statistical processes

Performance of technical flood retention facilities

- Depends on complex characteristics of floods



Problems | Hydrological Risk of flood protection by technical retention

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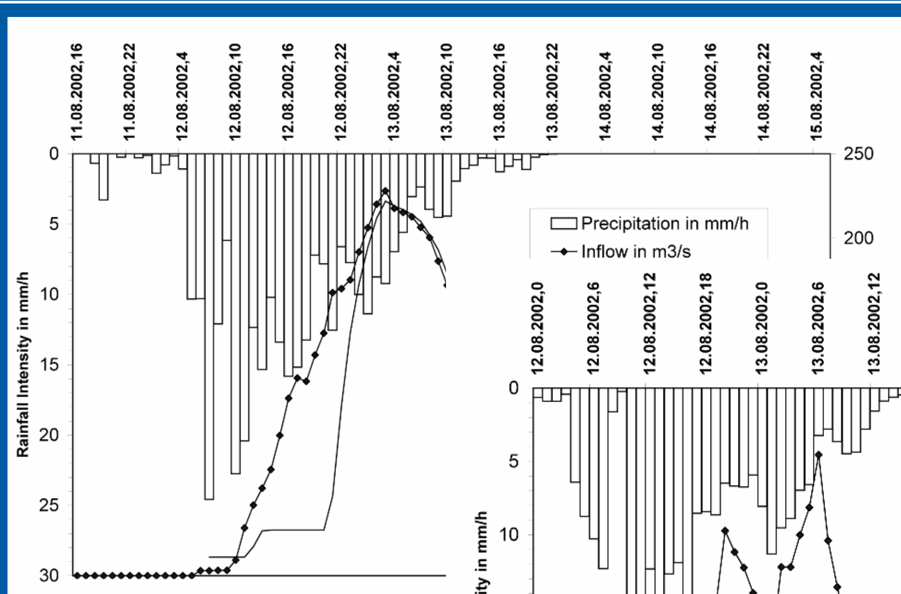
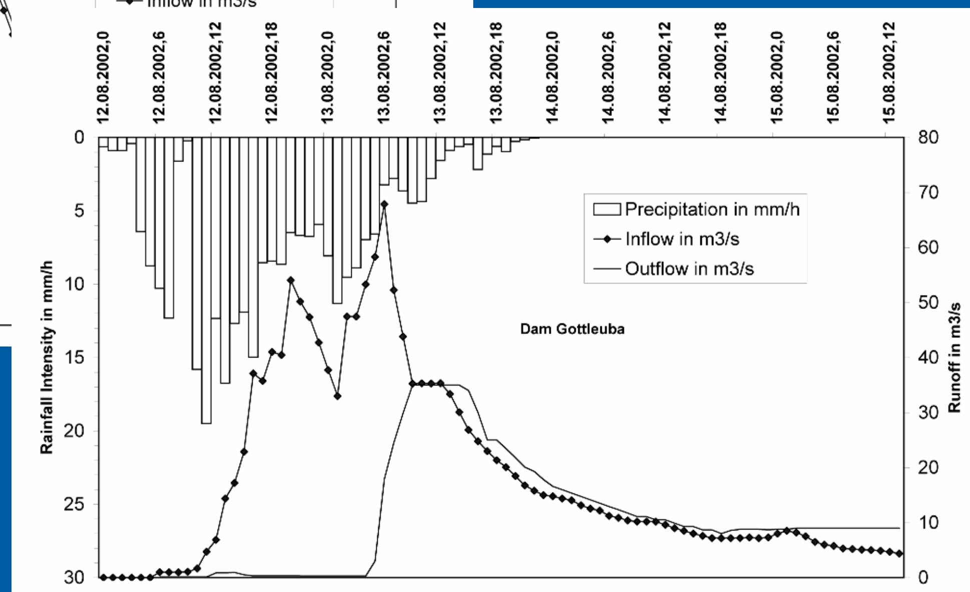
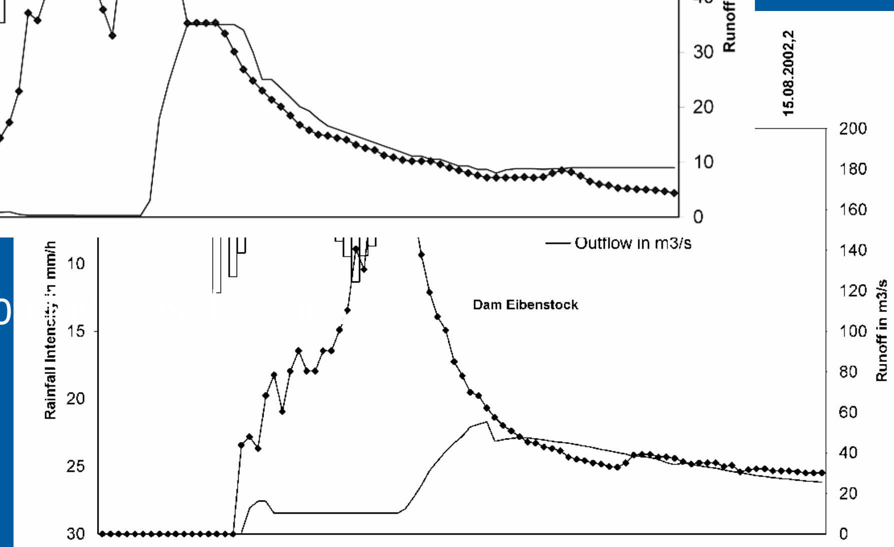


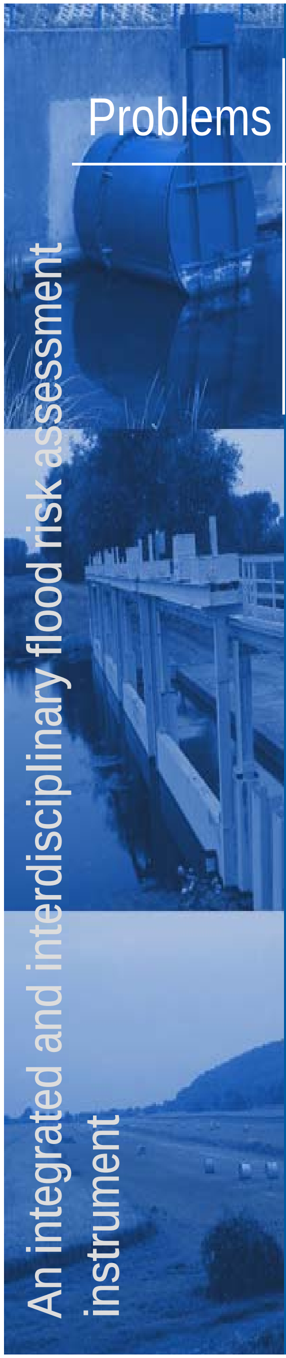
No flood protection





Flood protection by technical retentio
on characteristics of events!

Full flood protection



Problems | Risks, Interactions, Spatial characteristics

Natural Risk

- Hydrological variability and complexity results from interactions between watersheds and meteorological conditions
- Probability distribution functions of flood peaks describe only one part of multivariate statistical processes

Performance of technical flood retention facilities

- Depends on complex characteristics of floods
- Risk of unexpected flood situations depend on technical parameters, flood characteristics, operation

Consideration of spatial structures in decision making

- Differences between local and regional goals in flood protection
- Local and regional interests of decision makers and stakeholders
- Flood protection as a spatial open process

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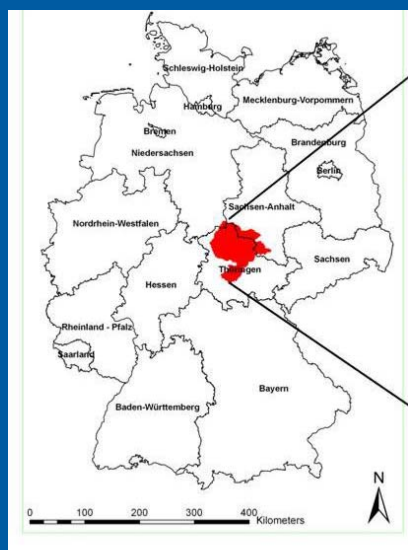
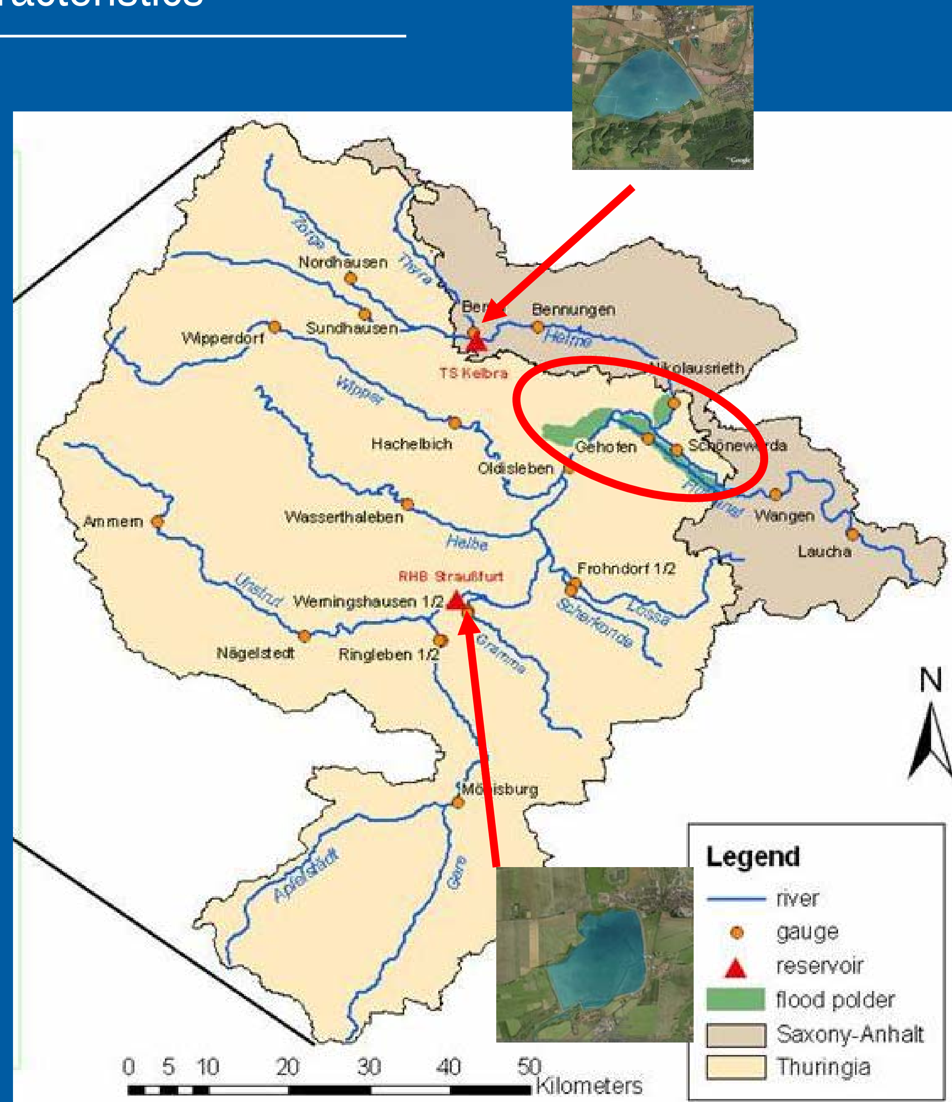
Problems | Risks, Interactions, Spatial characteristics

Unstrut River Basin, divided by two Federal States: Thuringia and Saxony-Anhalt





Watershed: 6.343 km²

Storage Volume:

approx. 100 Mio. m³: 2 dams,1 flood channel, 4 polders

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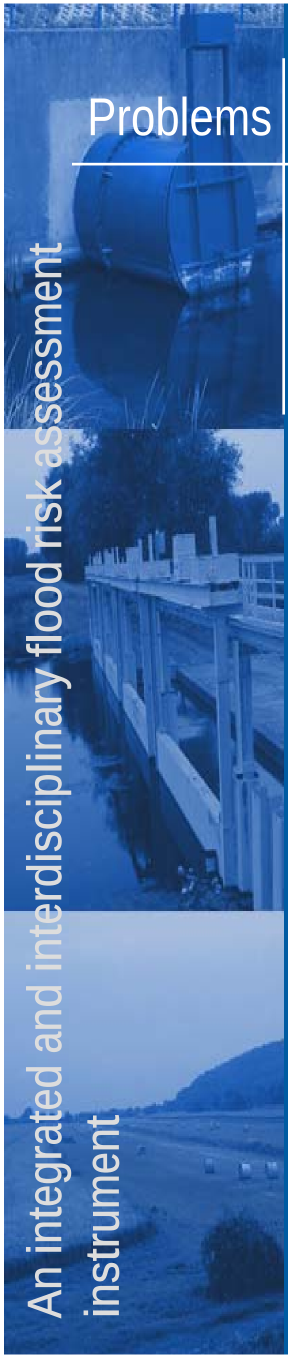
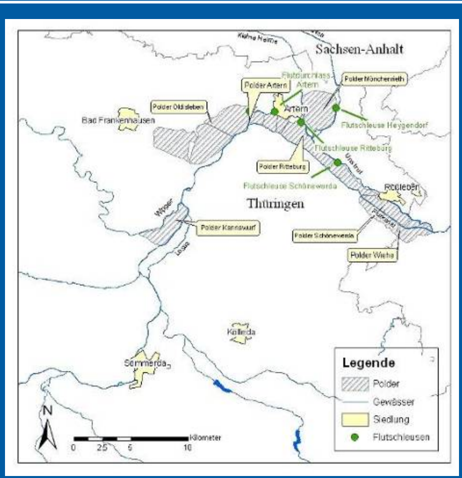
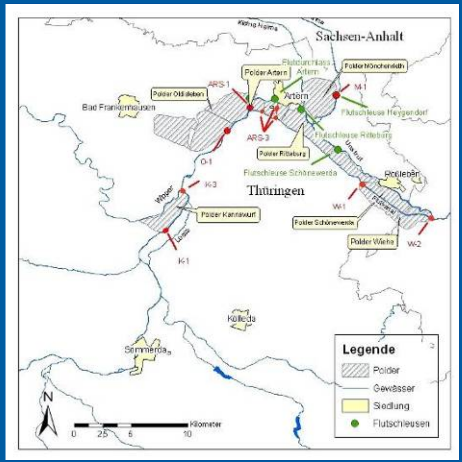


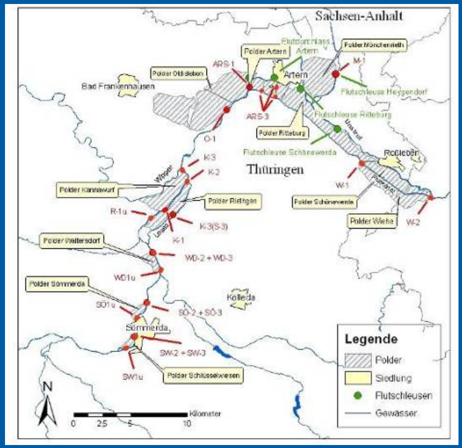
Problems | Planning of flood retention by new and extended polders



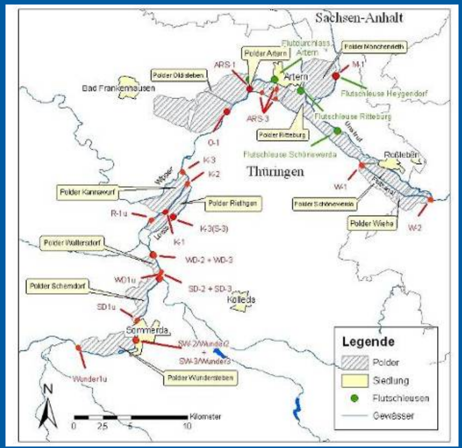
System State 1:Status Quo



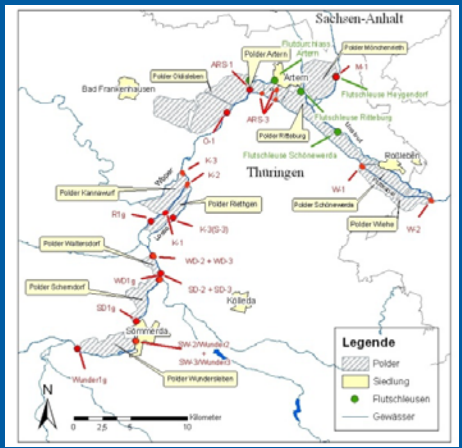
System State 2:
Current system is fully functional



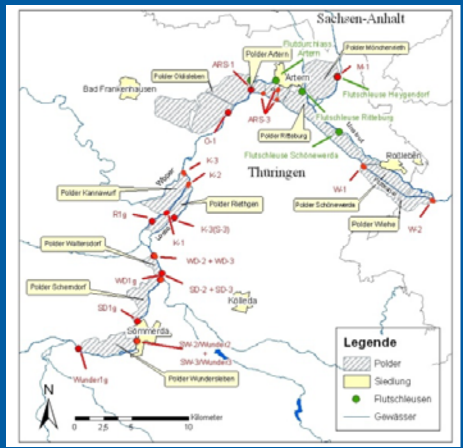
System State 3:
System State 2 + new (small) polders upstream



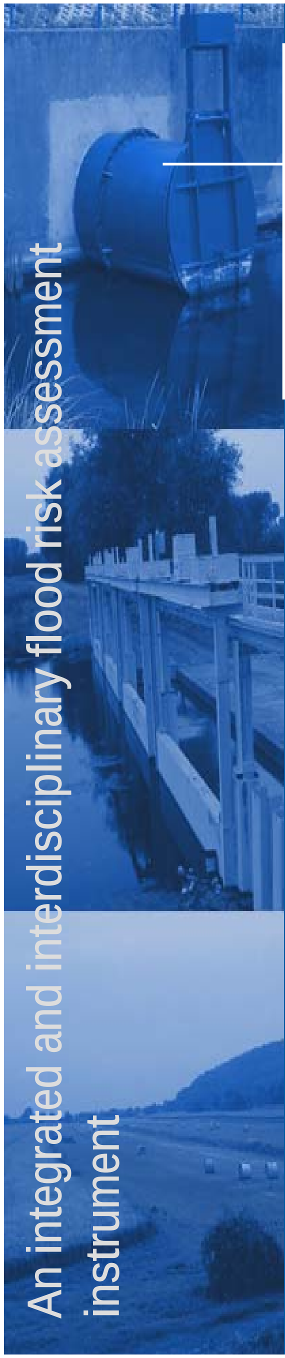
System State 4: State 2+ new (large) polders upstream



System State 5: System State 4 + controlled operation



System State 6:System 5 + increased inlet structures



Structure

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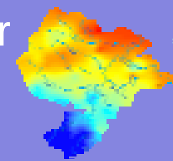
An integrated and interdisciplinary flood risk assessment instrument

Tuesday, 6 May 2008, 16:00 a.m., Room E
Presentation
by Pahlow et al.
“Assessment and optimization of flood control systems: The Unstrut River case study“

Wednesday, 7 May 2008, 11:00 a.m., Room B
Presentation by Klein et al.
“Probabilistic Analysis of Hydrological Loads to Optimize the Design of Flood Control Systems“

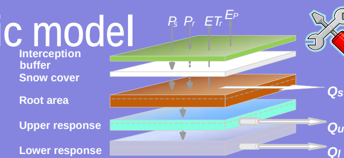
Thursday, 8 May 2008, 8:00, Room E
Presentation by Kufeld et al.
“Interlinked modelling of large floods by combining one and two dimensional diffusive wave approaches”

Rainfall Generator



Rainfall distribution
- Spatial variability
- Temporal variability

Hydrologic model



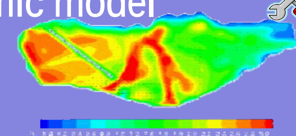
Technical Operation
- Dam

Probabilistic Analyses

Hydrological Load

Scenarios

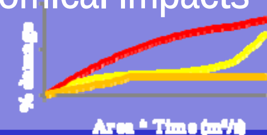
Hydrodynamic model
(Polder, River)



Technical Operation
- Polder

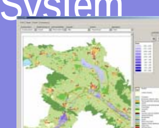
Inundation
- Area
-Depth & velocity
- Max depth x velocity

Socio-Economical Impacts
(Damage Functions)



Socio-Economic
- Agriculture & Industry
- Residential Housing

Decision Support System



MCDM
- Risk
- Differentiation of Alternatives

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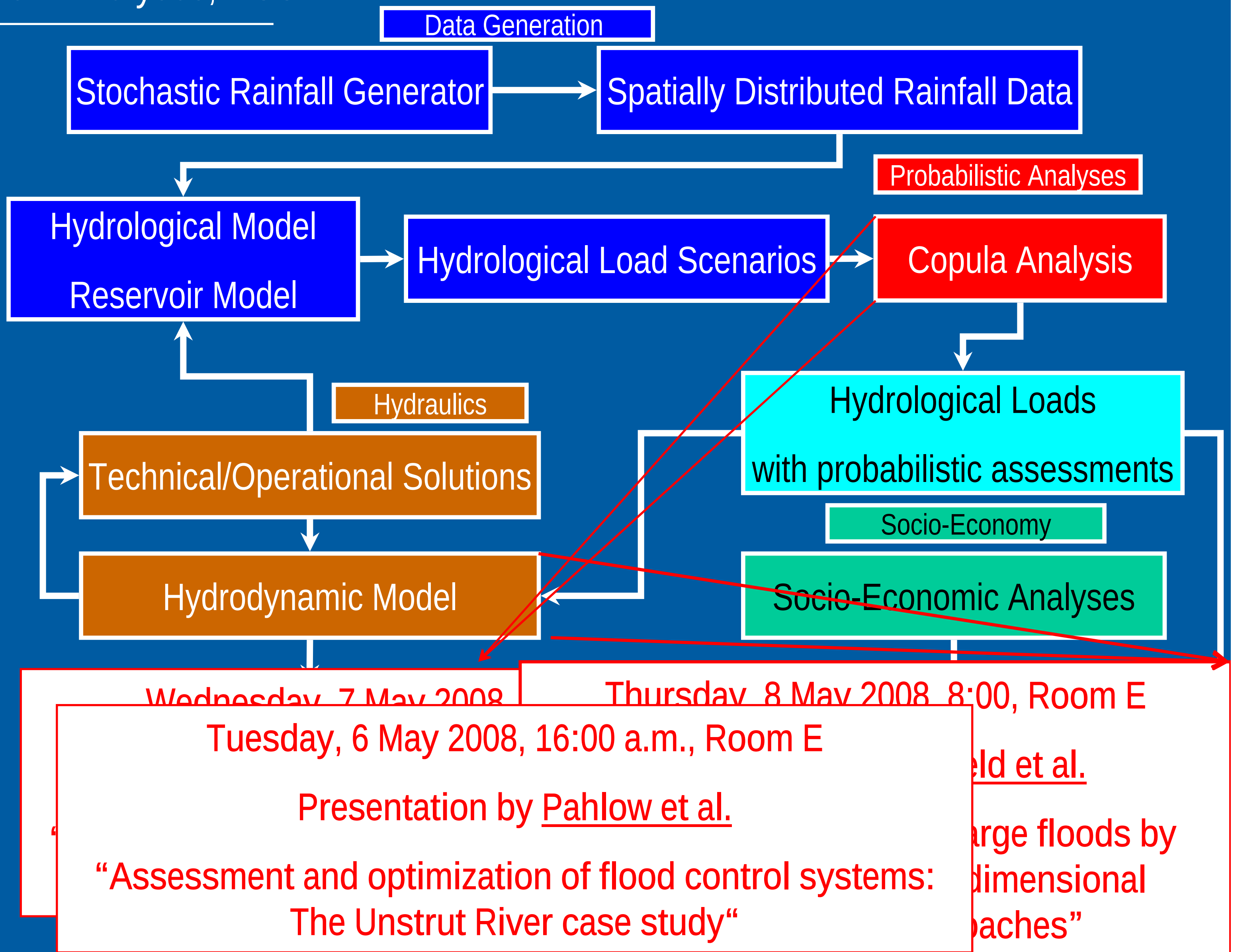
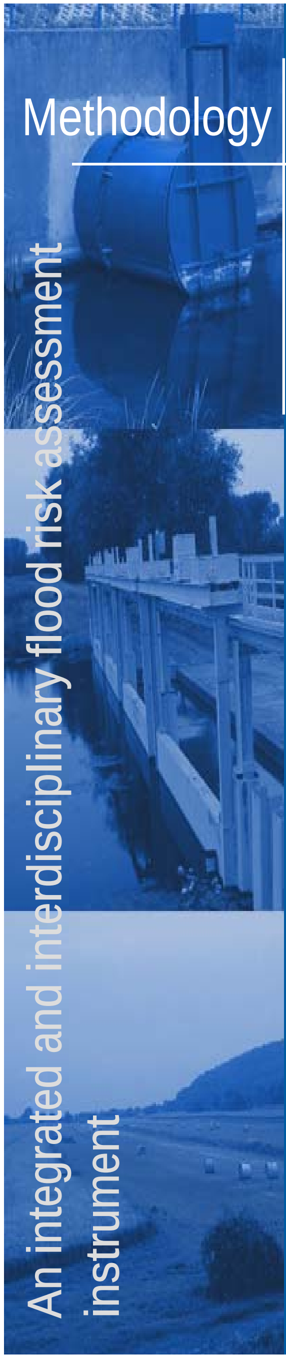
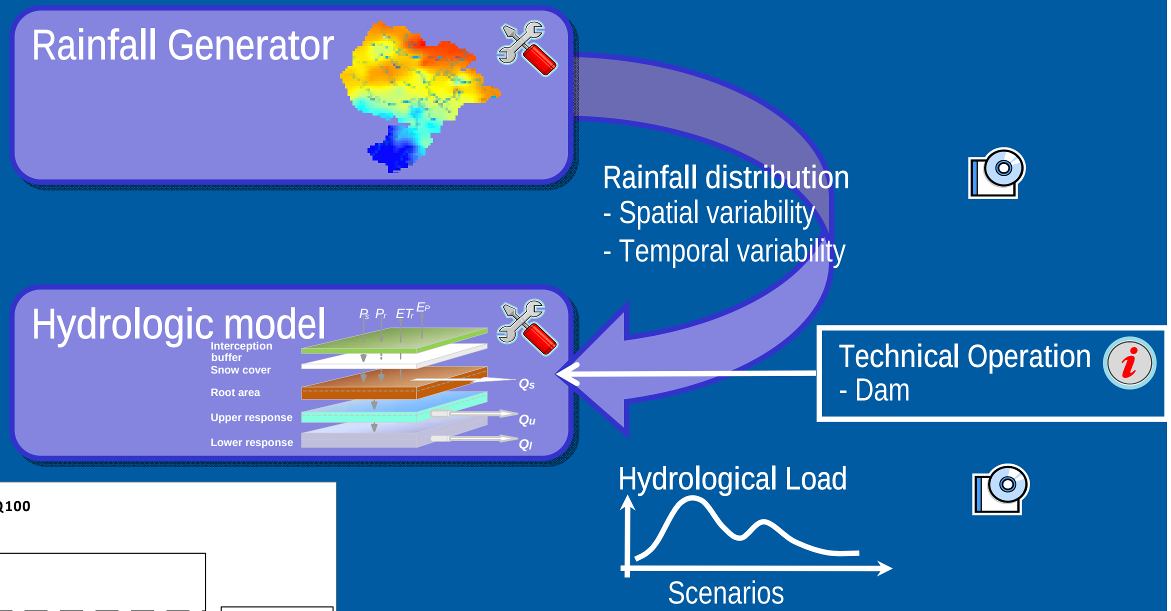
Methodology | System Analyses, DSS

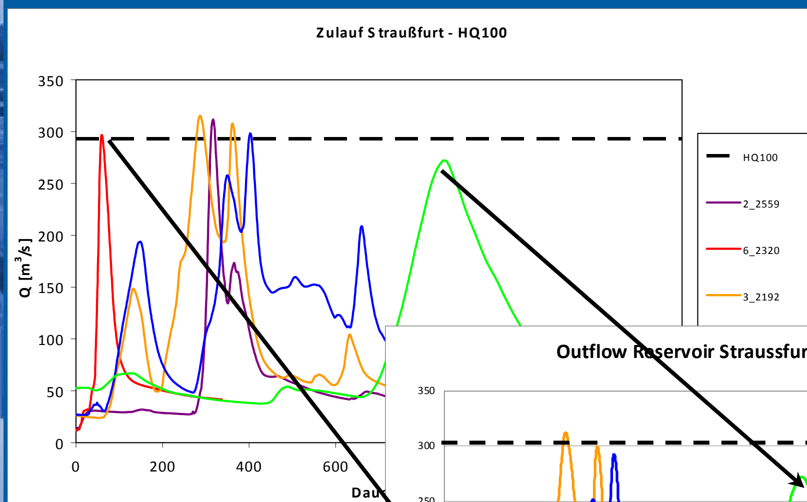


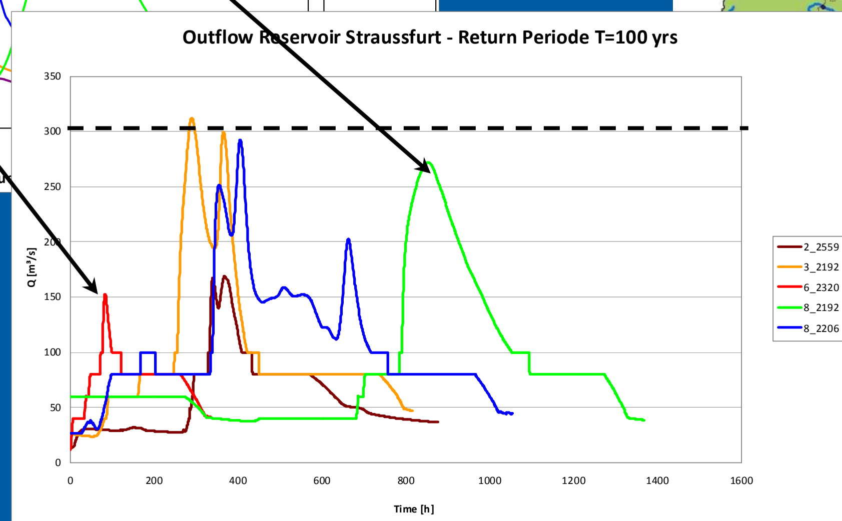
Methodology | Hydrological Loads

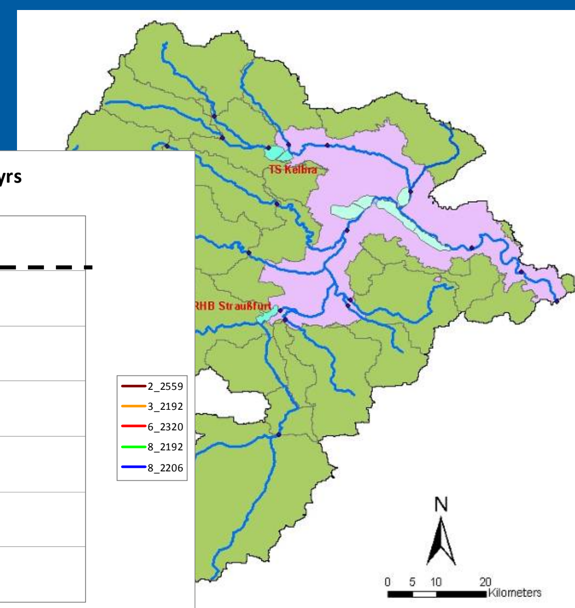
Effects of reservoirs











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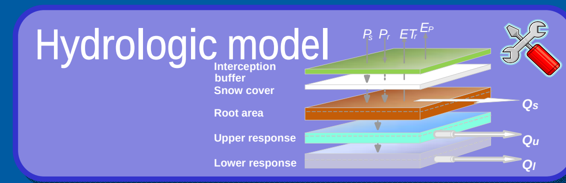
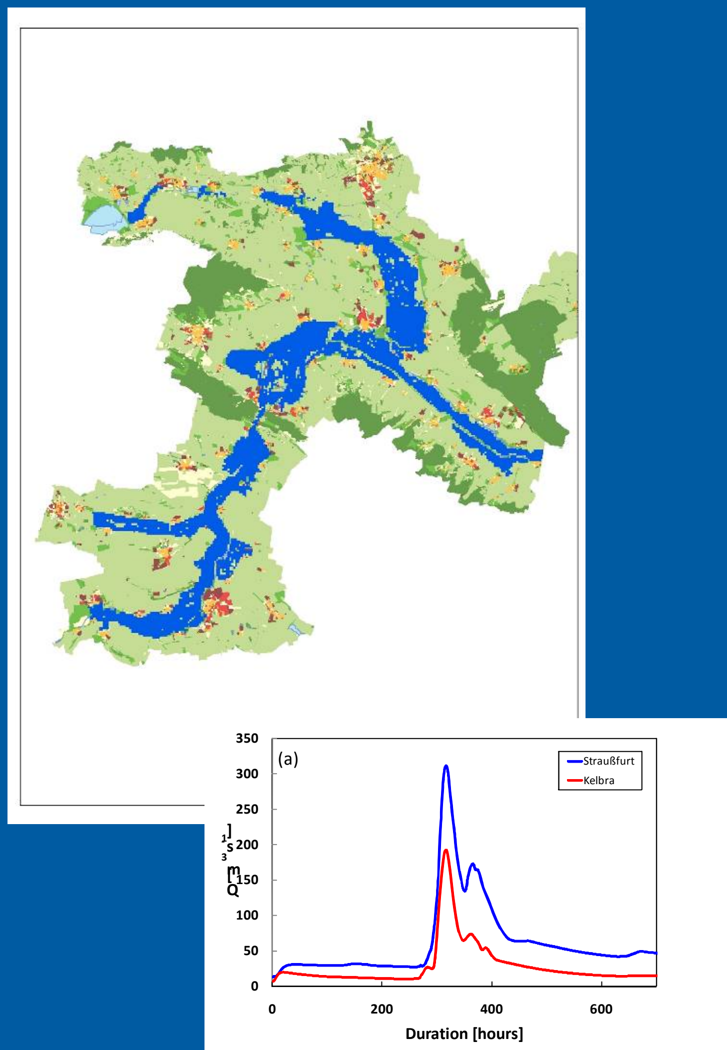
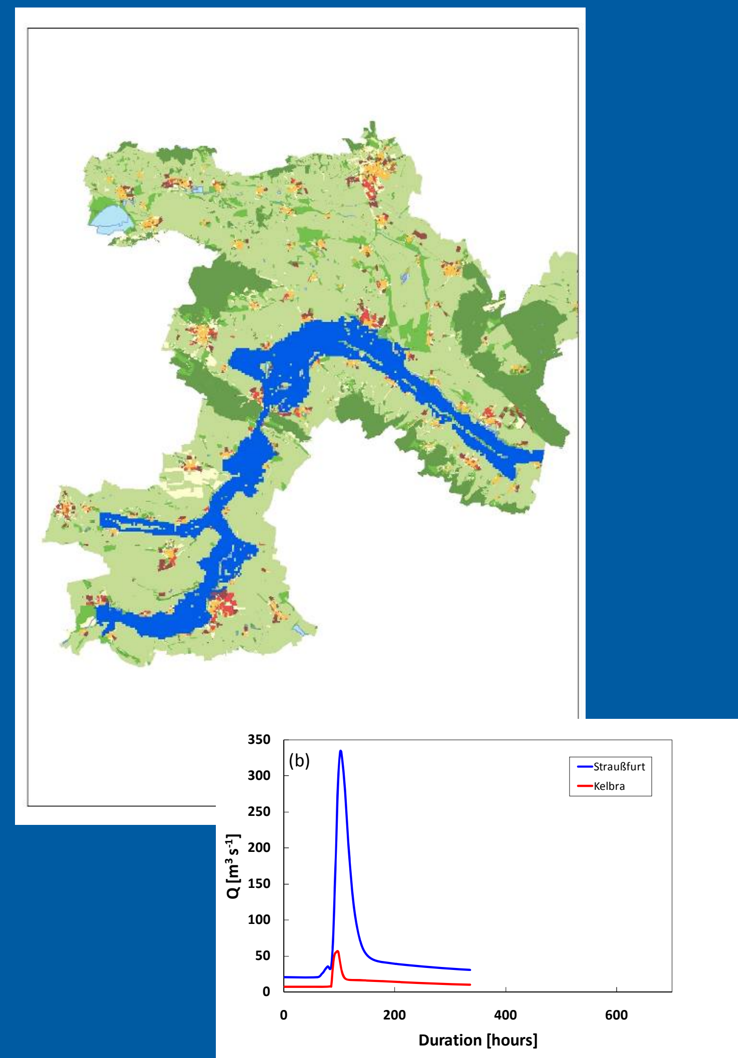
Methodology | Hydrological Loads

Interactions of tributaries







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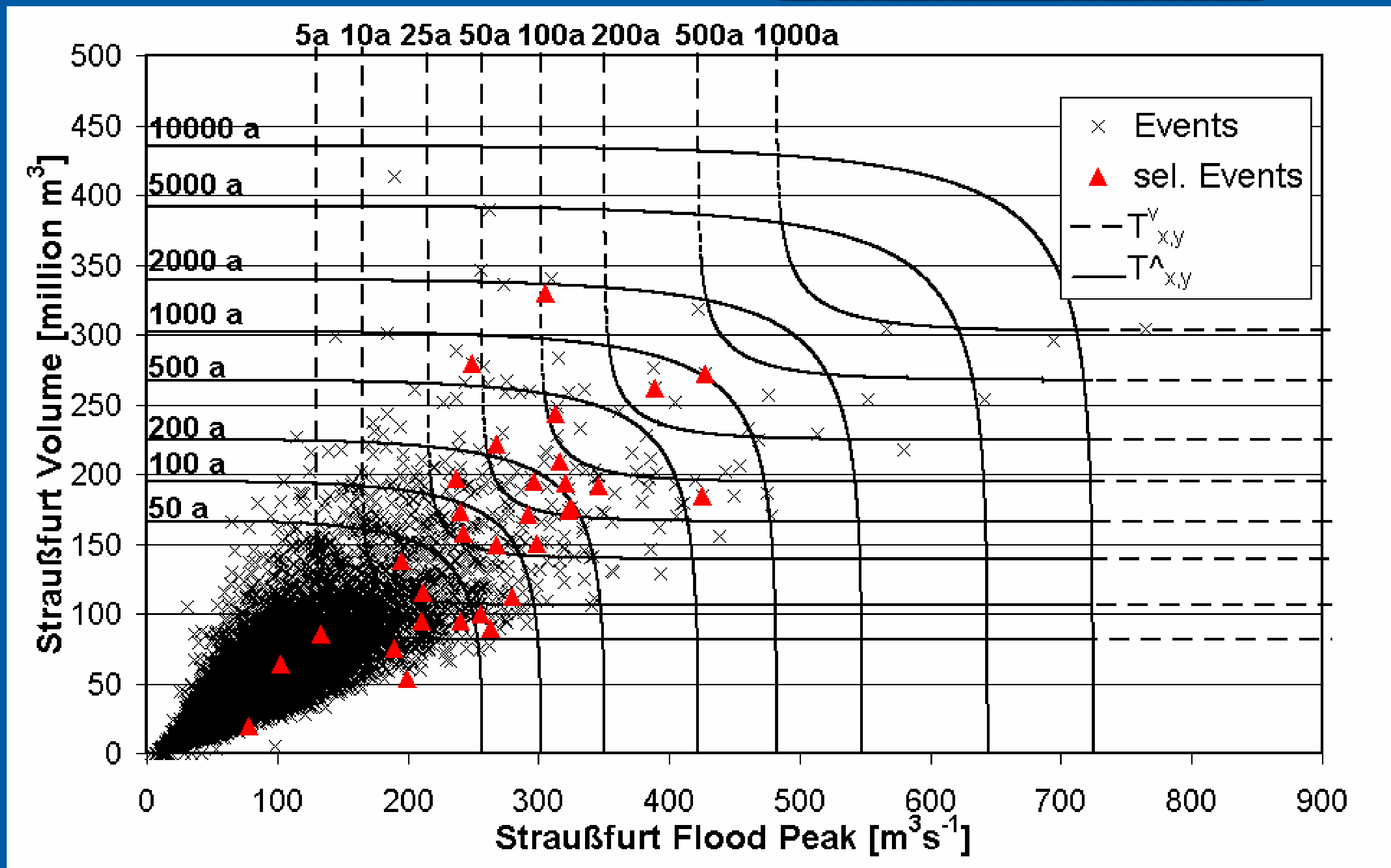
Methodology | Hydrological Loads

Copula

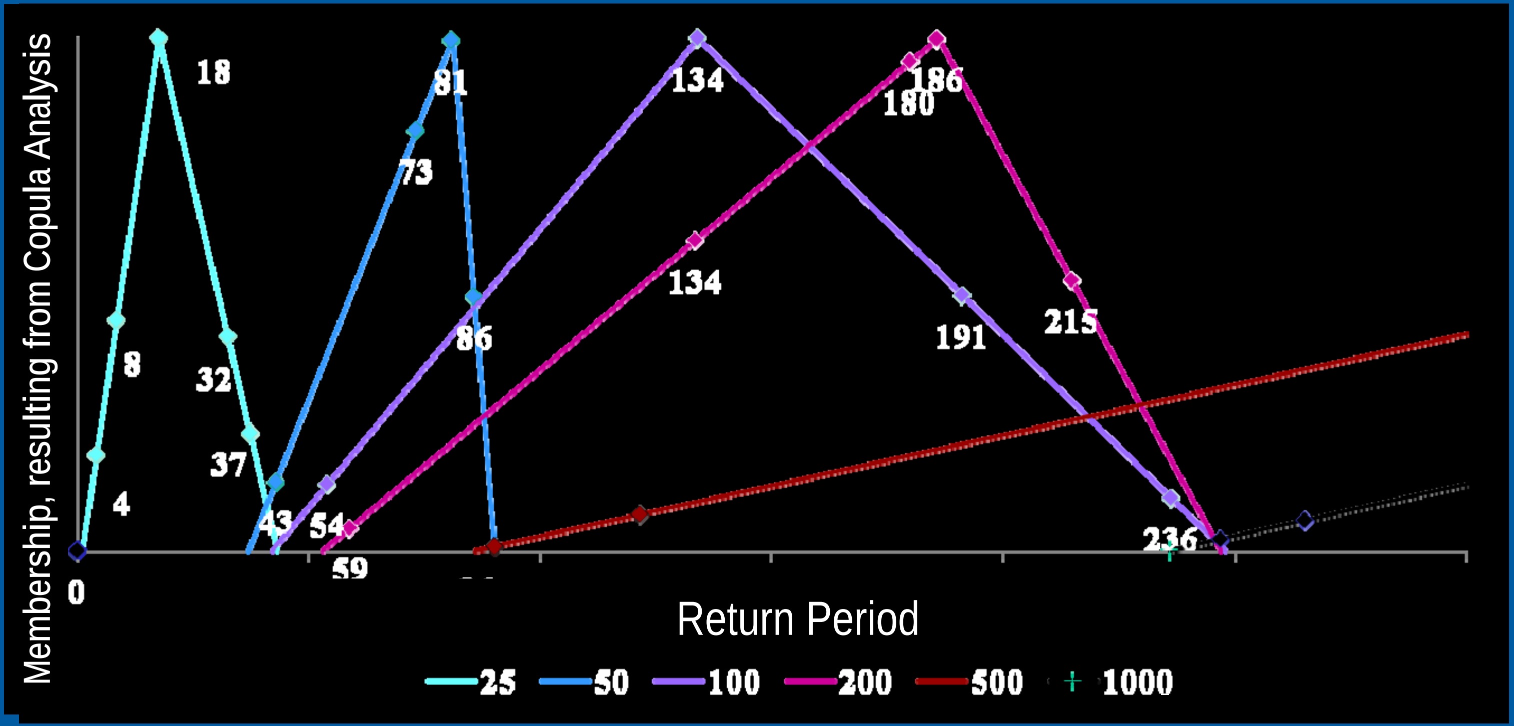
Probabilistic Analyses



Multivariate statistics for reservoir sides: Copula analyses of peak and volume

Probabilistic Analyses

Uncertainties of Return Periods



Scenarios with the same return period of flood peaks differ in their Copula return period:

Fuzzy representation, considering these differences in probabilities

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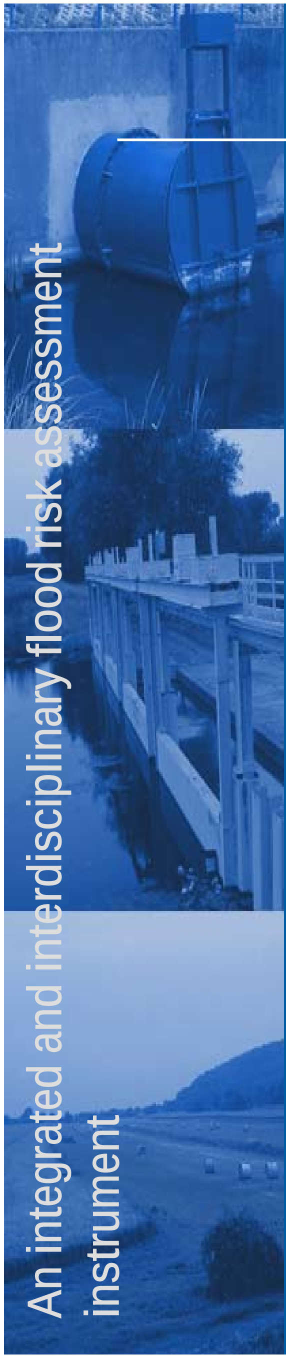
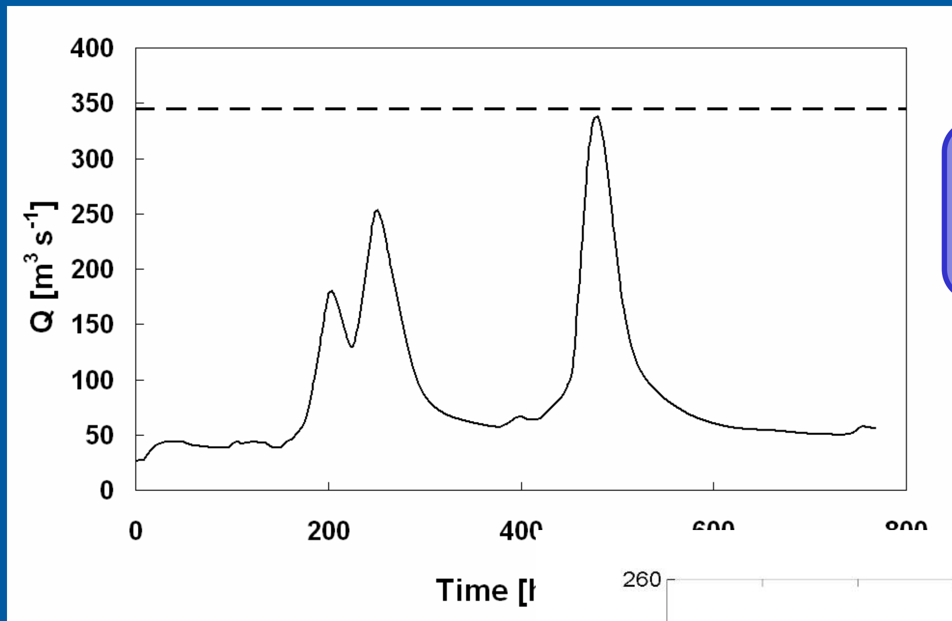
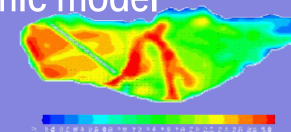
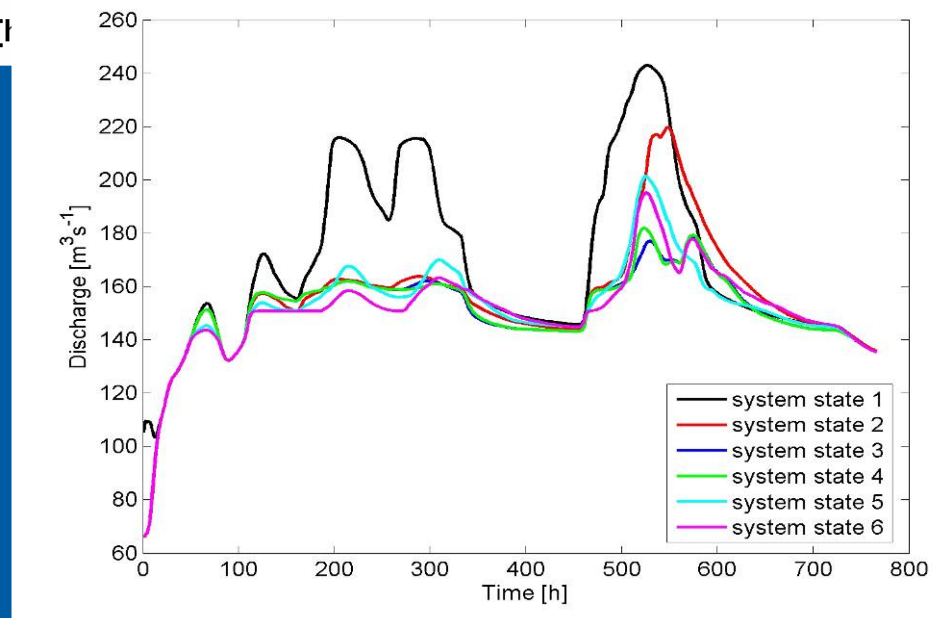


Straußfurt 1_2837 return period 200 years



Hydrodynamic model
(Polder, River)





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Structure

I. Introduction

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IV. Results

Methodology | DSS

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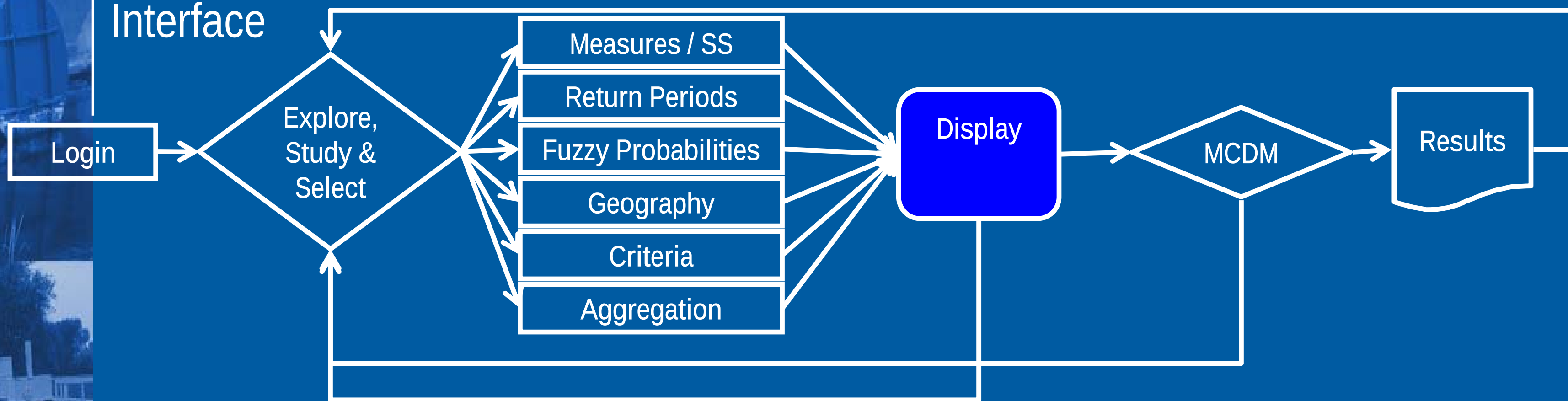
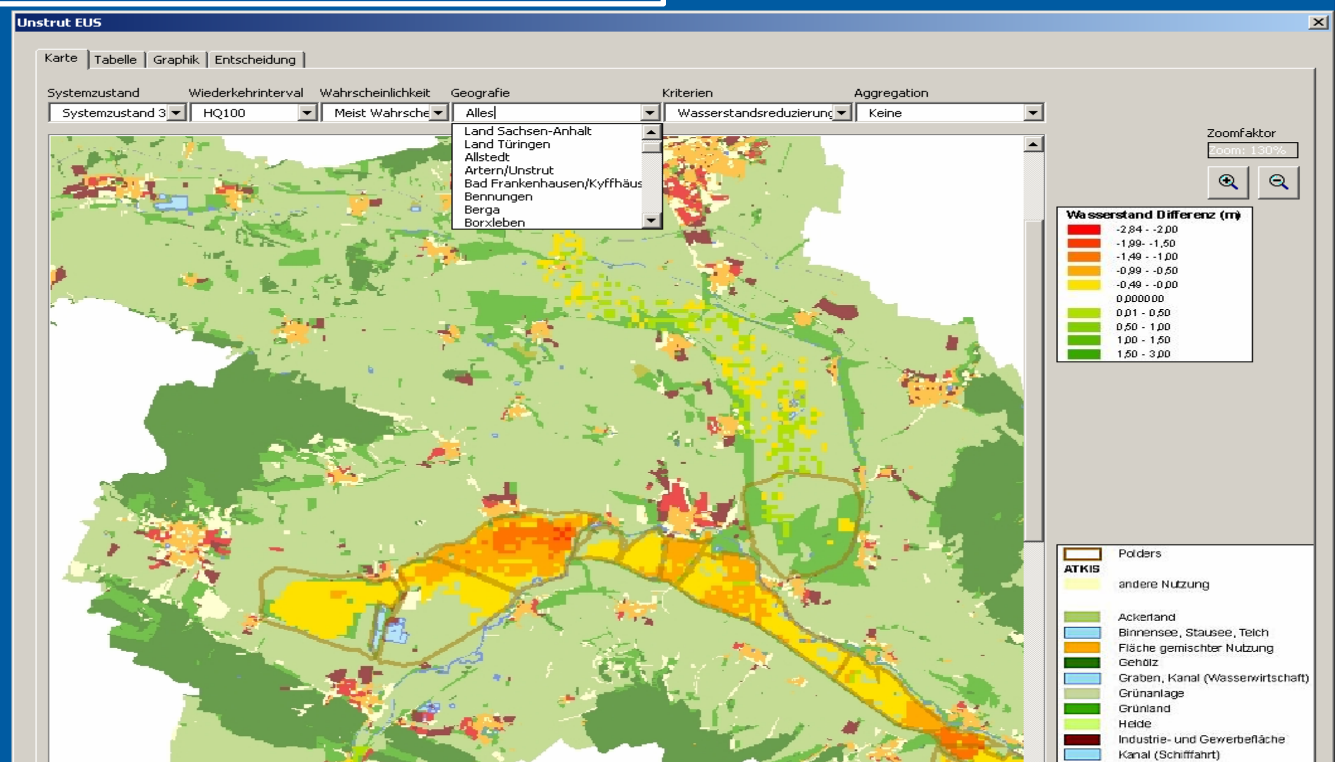
Interface





A RIMAX- Research Project

Tool Selection

Flood Management Problems:
- extremely complex
- time-bound
- multi-faceted
- conflicting priorities
- dynamic preferences
- high decision stakes
- limited technical information
- difficult tradeoffs

Operational/Technical Requirements:
- combining tangibles & intangibles
- allowing fuzzy data
- calculating feedback & interdependence
- easy to use
- possibility to build-into DSS

MCDA

- Utility theory
- PROMETHEE
- ELECTRE
- AHP/ANP
- TOPSIS
- CP
- NAIADE
- …

AHP/ANP

Saaty, 1990, 2005

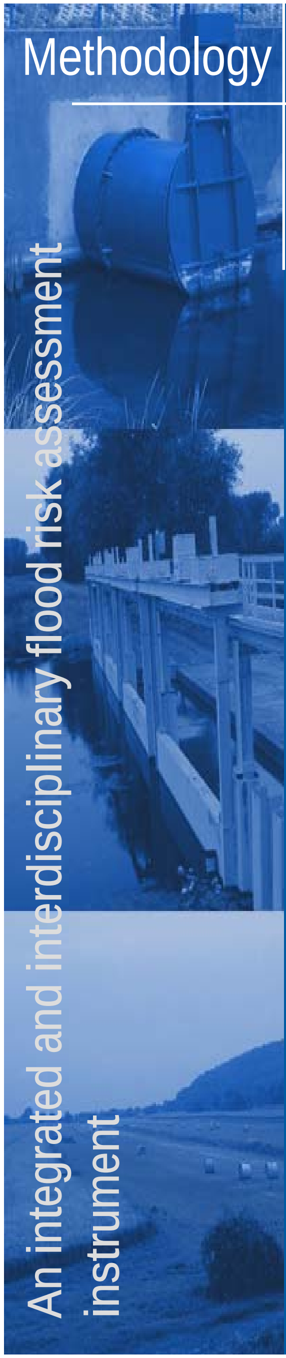
Analytic Network Process

An integrated and interdisciplinary flood risk assessment instrument

Decision Making with Dependence and Feedback

Two parts:

- First: a control hierarchy or network of objectives and criteria that control the interactions in the system under study;
- Second: many sub-networks of influences among the elements and clusters of the problem, one for each control criterion



AHP Criteria

Benefits:

Psycho-social benefits
P1: Reduction of Risk of Affected People
P2: Reduction of Risk at “Hot Spots of Vulnerability”
P3: Reduction of Risk of Psychological damages

Economic Factors
D1: Reduction of Risk of Direct Damages
D2: Reduction of Risk of Indirect Damages (traffic, regional development, unemployment, ecological damages, market situation)

Downstream Effects
G1: Hydraulic Benefits for locations downstream: Gauge at outlet

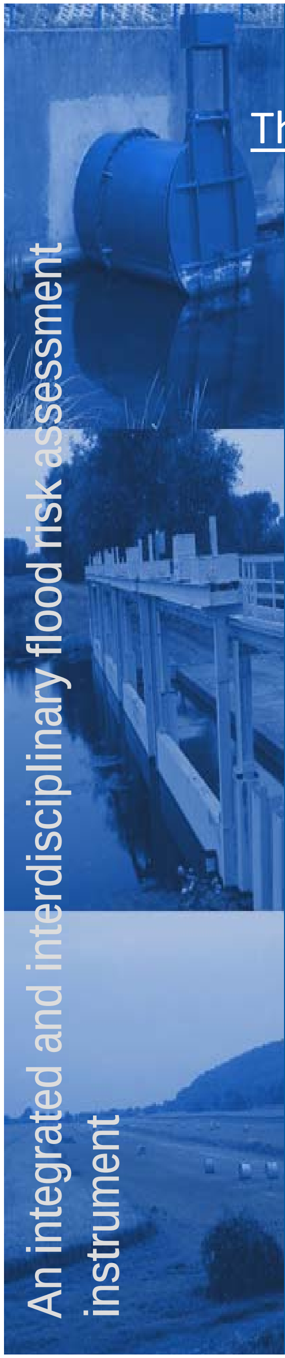
Costs:

C1:Cost of Operation and Maintenance
C2: Construction Costs
C3: Implementation Costs (esp. relocation and land-use changes)

Opportunities **(Considered not yet) :**
Social: Personnel/ Employment in Flood Protection ?
Ecological: substitution of intensified agriculture in polder areas (may arise a risk to use retention areas caused by new ecological developments !)

Risks:
Ecological: Contamination of polders by flooding
Economic: Socio- economic risks caused by reduced carrying capacity of agriculture

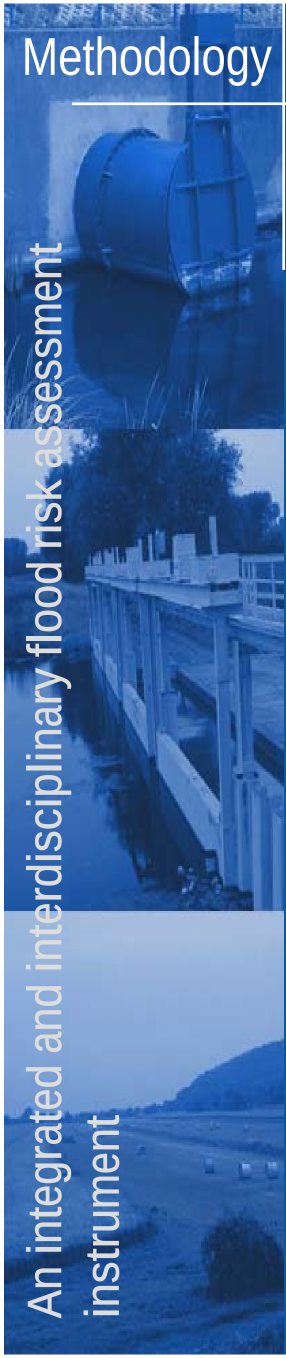
Downstream- Upstream Risk Trading



The Fundamental Scale: Numerical Ratings Associated with Pairwise Comparisons

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate Importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong Importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated Importance	An activity is favoured very strongly over another; it´s dominance demonstrated in practice
8	Very, very strong	
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation

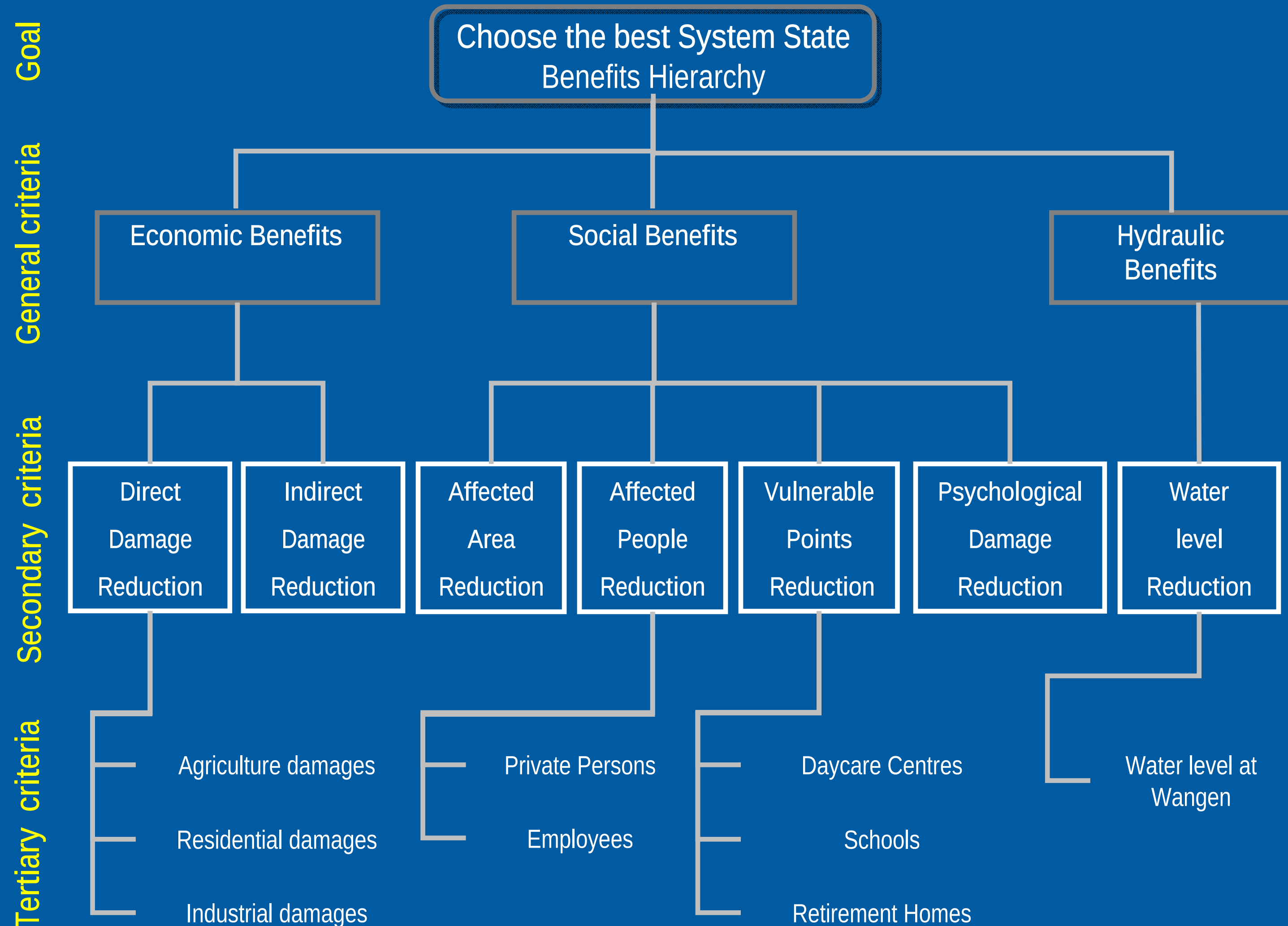
(Saaty and Vargas, 2006)



Methodology

MCDM

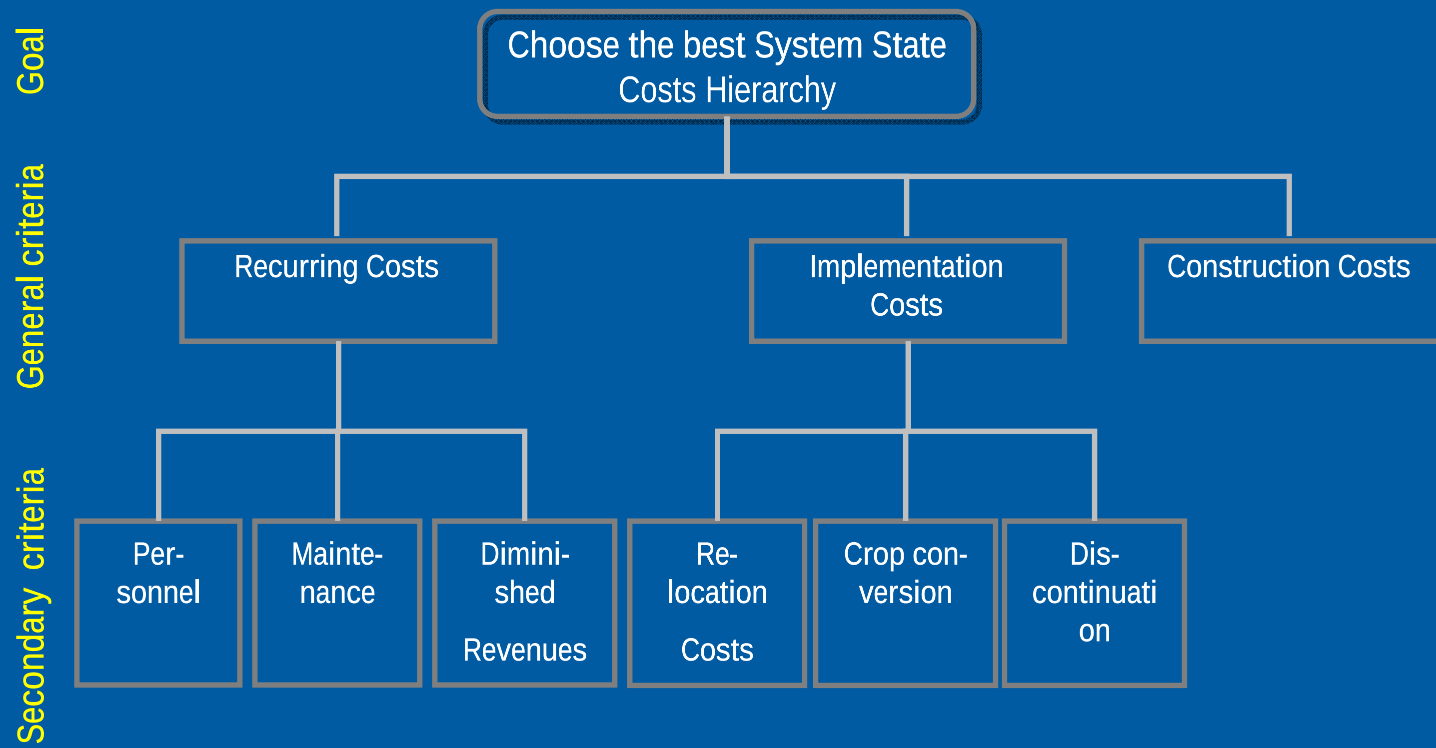
Hierarchic order of criteria



Methodology

MCDM

Hierarchic order of criteria



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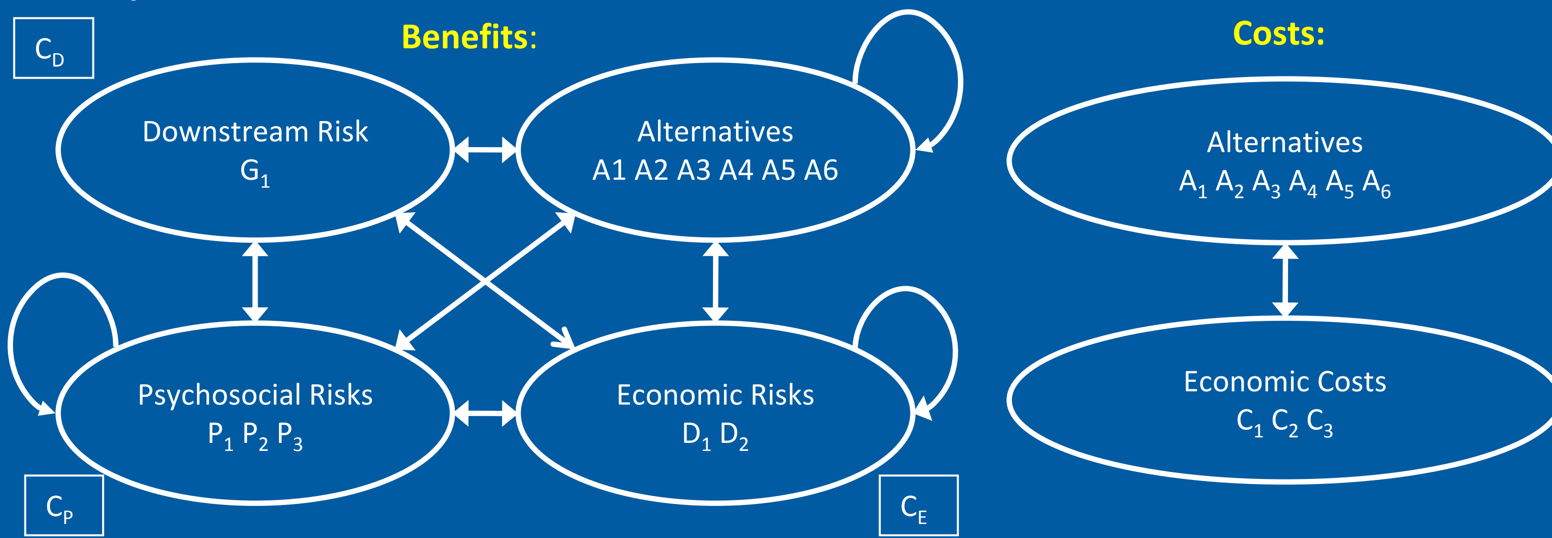
MCDM

Interdependencies of criteria



Benefits:
P1: Reduction of Risk of Affected People
P2: Reduction of Risk of Vulnerable Points
P3: Reduction of Risk of Psychological Damage

D1: Reduction of Risk of Direct Damage
D2: Reduction of Risk of Indirect Damage

G1: Hydraulic Benefits: Flood reduction downstream

Costs:
C1: Recurring Costs
C2: Construction Costs
C3: Implementation Costs

MCDM - AHP Criteria

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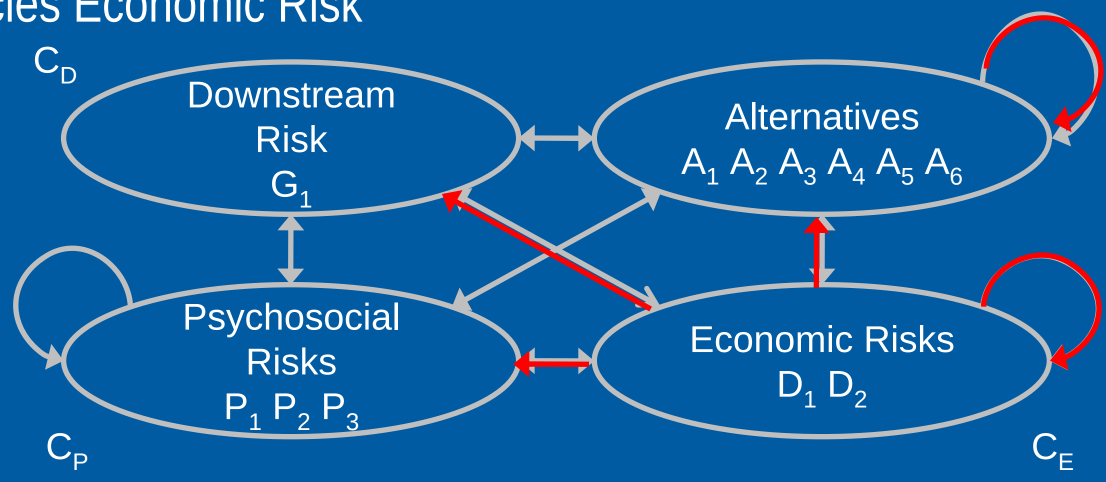
Dependencies Economic Risk



Interrelatedness of Alternatives: dependency of alternatives on/of another

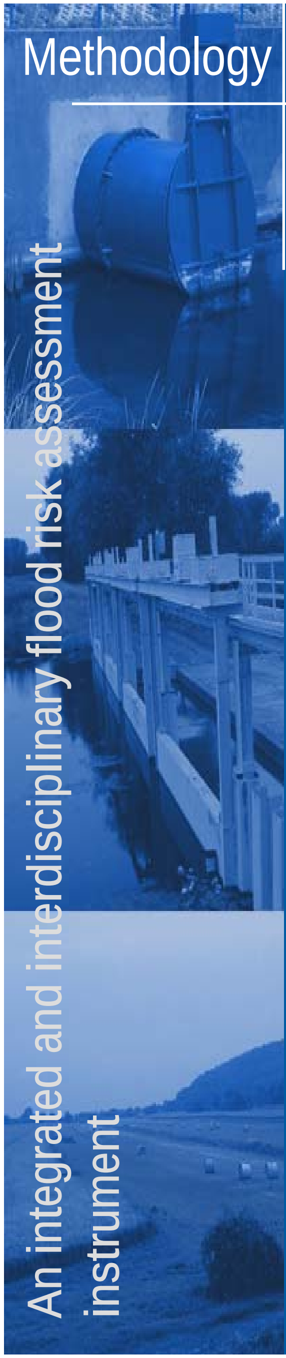
- Construction of new Polders encompasses optimisation of existing facilities
- Enlargement of Inlets encompasses optimisation of inlet management

Dependencies of Economic Risks: Categorising influence of different criteria on economic risk

- Alternatives: compare relative influence of each alternative on economic risks
- Psychosocial Risks: relative influence of affected number of people, vulnerable places, …
- Downstream Risk: influence of downstream risk on (indirect) economic risks

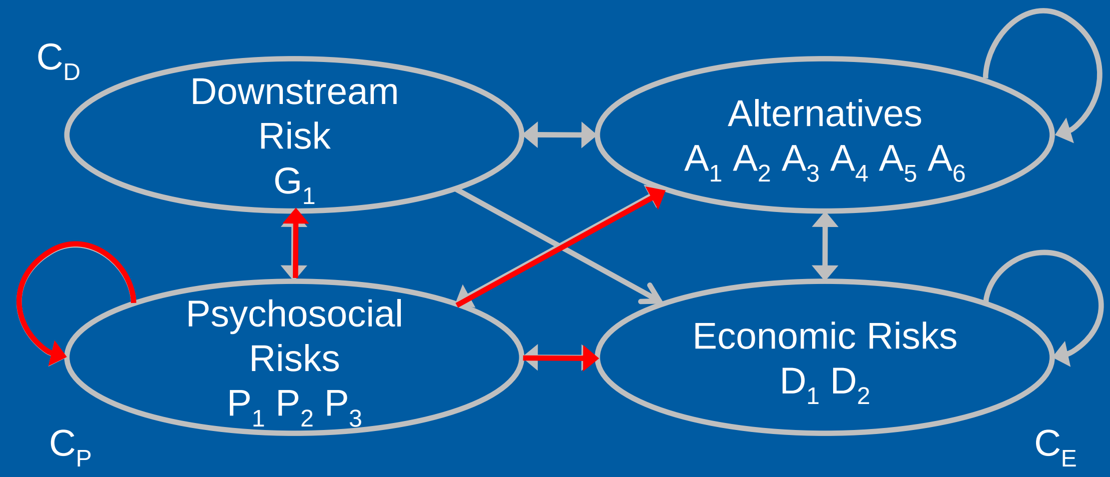
Interrelatedness of Economic Risks: dependency of economic risks on another

- Indirect damage is related to the intensity of direct damage



MCDM - AHP Criteria

Dependencies



Dependencies of Psychosocial Risks: Influence of criteria on psychosocial risks

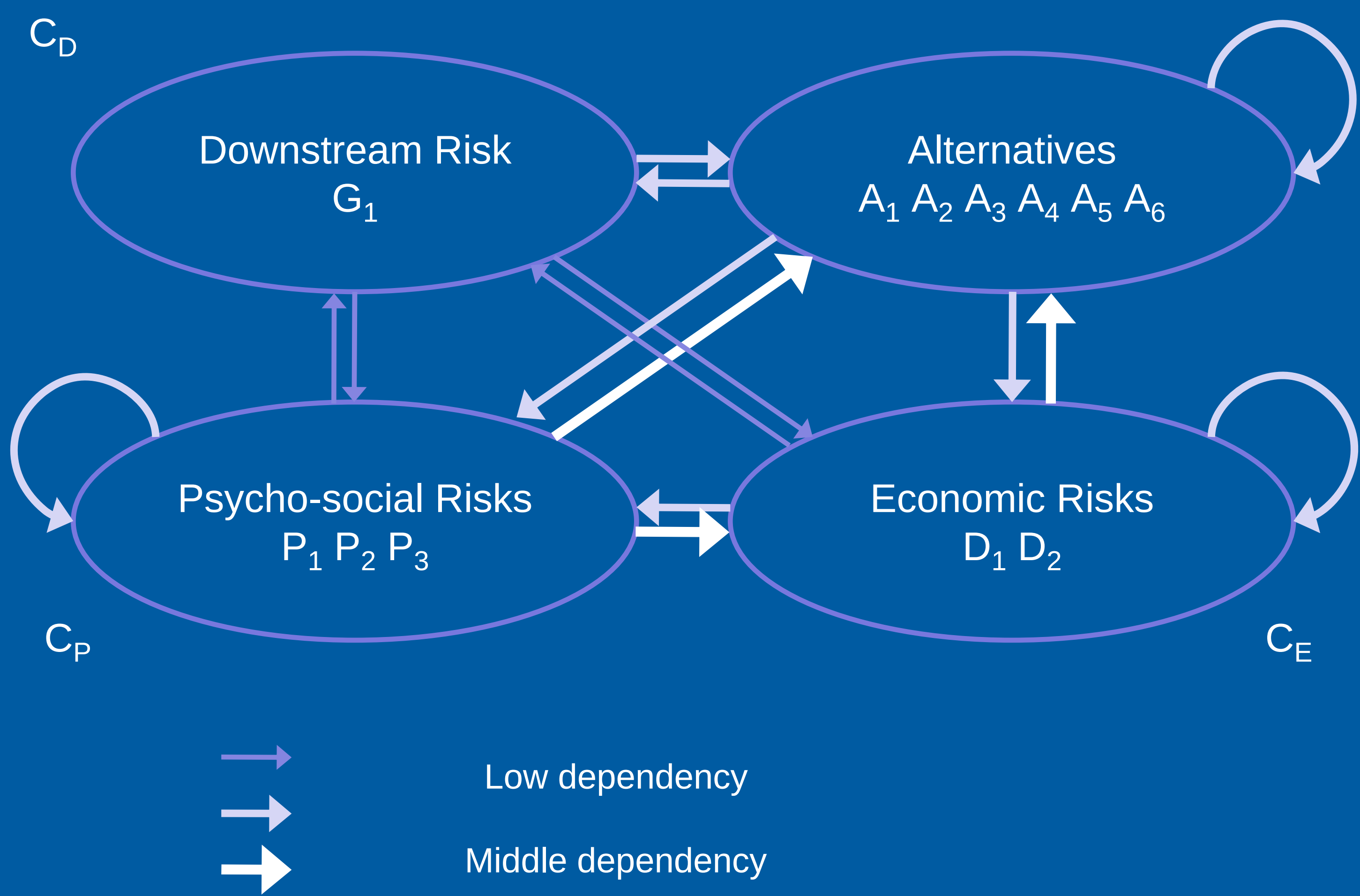
- Alternatives: compare relative influence of each alternative on psychosocial risks
- Economical Risks: relative influence of direct and indirect damages on psychosocial risks
- Downstream Risk: possible influence of downstream risks on psychosocial risks upstream

Interrelatedness of Psychosocial Risks: dependency of psychosocial risks on another

- Number of people is related to the number of affected vulnerable points
- Psychological damages is related to number of people and affected vulnerable points

MCDM - AHP Criteria

Dependencies

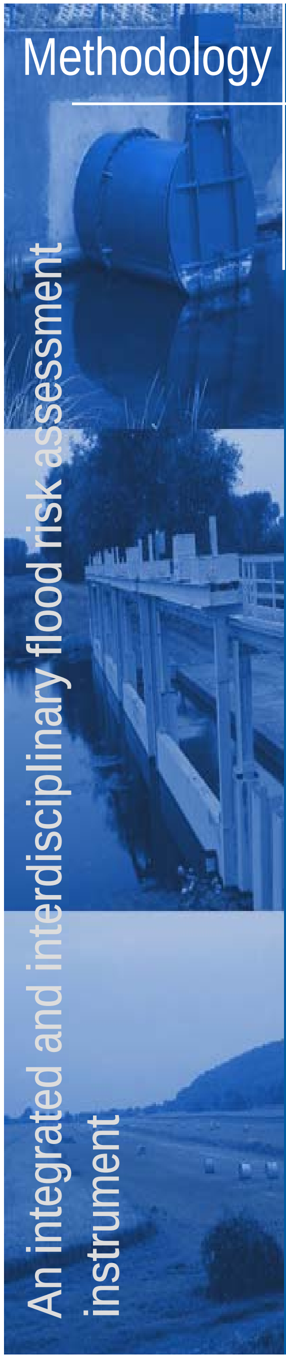


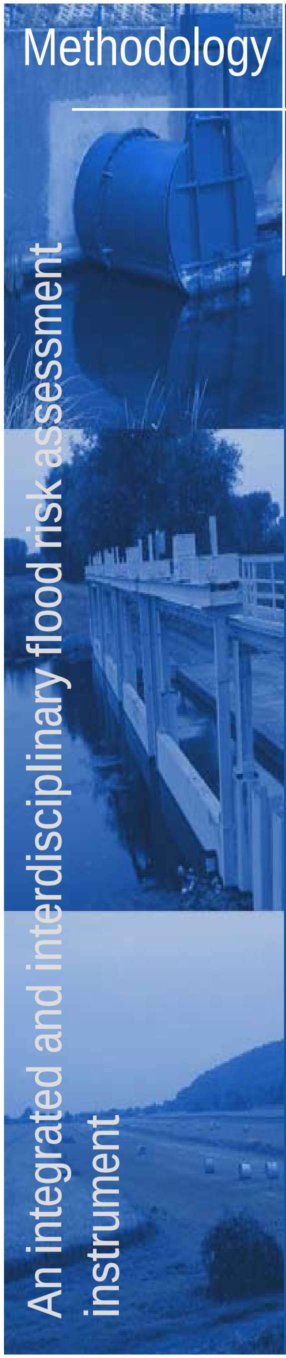
Low dependency

Middle dependency

High dependency*

* Note: Dependency can be altered by the Decision Maker





MCDM ANP Individual Comparisons

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
		xperience and judgement slightly favour one activity over another
		xperience and judgement strongly favour one activity over another
		An activity is favoured very strongly over ... rated in
		ity over ... order of

Goals

With Respect to **Benefits**	Economic Risks	PsychoSocial Risks	Downstream Risks	EigenVec	Global Priorities
Economic Risks	1,000	2,000	4,000	1,000	0,537
Social Risks					
Downstream Risks					
Inconsistency Inde					

Alternatives

With Respect to: Risk of Direct Damages	System State 1	System State 2	System State 3	System State 4	System State 5	System State 6	EigenVec	Local Priorities
System State 1	1,000	0,500	0,400	0,333	0,200	0,143	0,120	0,045
System State 2								
System State 3								
System State 4								
System State 5								
System State 6								
Inconsistency Index:								

Psychological Risks

Interdependency Psychosocial Risks	Affected People	Vulnerable Points	Psychological Damage	Normalised Matrix		
Affected People	0,000	0,200	7,000	0,000	0,583	0,500
Vulnerable Points						
Psychological Damage						

Economic Risks

With Respect to: Pschychological Damage	Direct Damages	Indirect Damages	EigenVec
Direct Damages	1,000	7,000	1,000
		1,000	0,143

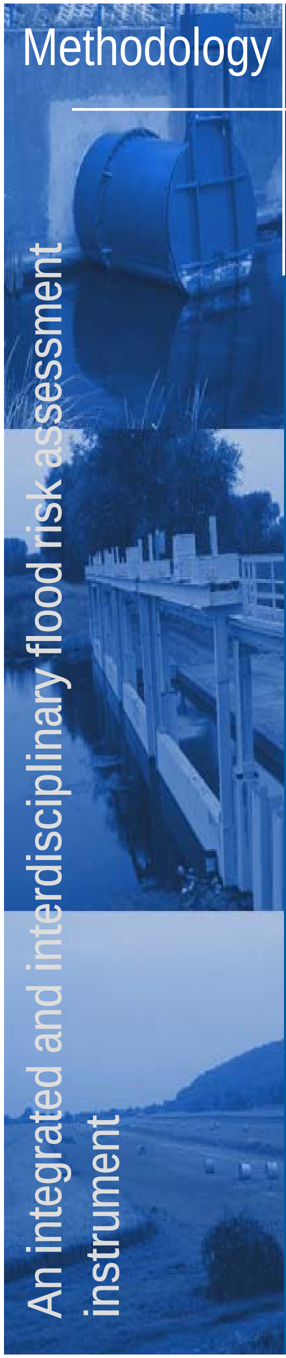
Costs

Alternatives

With Respect to: Construction costs	System State 1	System State 2	System State 3	System State 4	System State 5	System State 6	EigenVec	Local Priorities
System State 1	1,000	1,000	0,500	0,500	0,500	0,143	0,124	0,063
System State 2	1,000	1,000	0,500	0,500	0,500	0,200	0,133	0,067
System State 3	2,000	2,000	1,000	0,500	0,500	0,200	0,191	0,096

Methodology

MCDM ANP Results



Priorities Benefits

Ideal Form	
System State 1	0,12598
System State 2	0,27068
System State 3	0,35386
System State 4	0,53945
System State 5	0,64608
System State 6	1

Priorities Costs

Ideal Form	
System State 1	0,12688
System State 2	0,139
System State 3	0,26316
System State 4	0,39538
System State 5	0,41126
System State 6	1

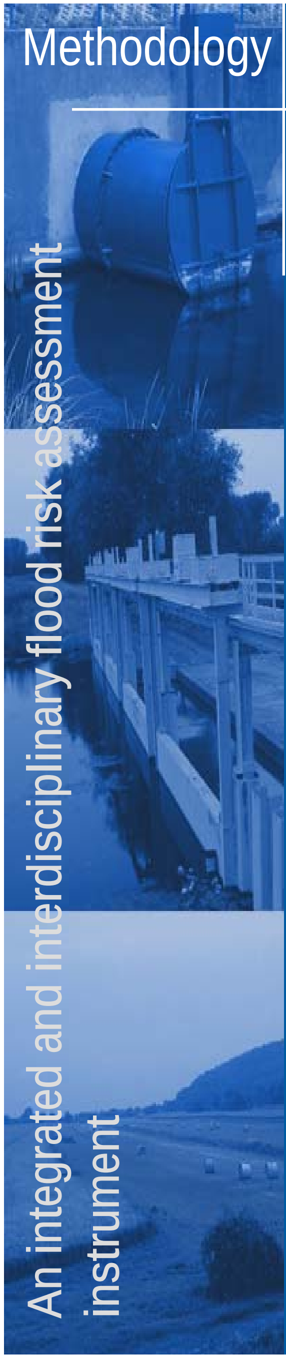
Priorities of the Criteria

Ideal Form	
Direct Damage	0,31388836
Indirect Damage	0,10302344
Reduction Risk Affected People	0,23998598
Reduction Risk Vulnerable Points	0,1797751
Reduction Risk Psycholgical Damages	0,07276836
Reduction Risk Downstream	0,09055875

Priorities General = bB+c(1-C) b= 1c= 1

Total		Normalised	
System State 1	0,9991	System State 1	0,8091027
System State 2	1,13167	System State 2	0,9164662
System State 3	1,0907	System State 3	0,8832823
System State 4	1,14406	System State 4	0,9265006
System State 5	1,23482	System State 5	1
System State 6	1	System State 6	0,8098322

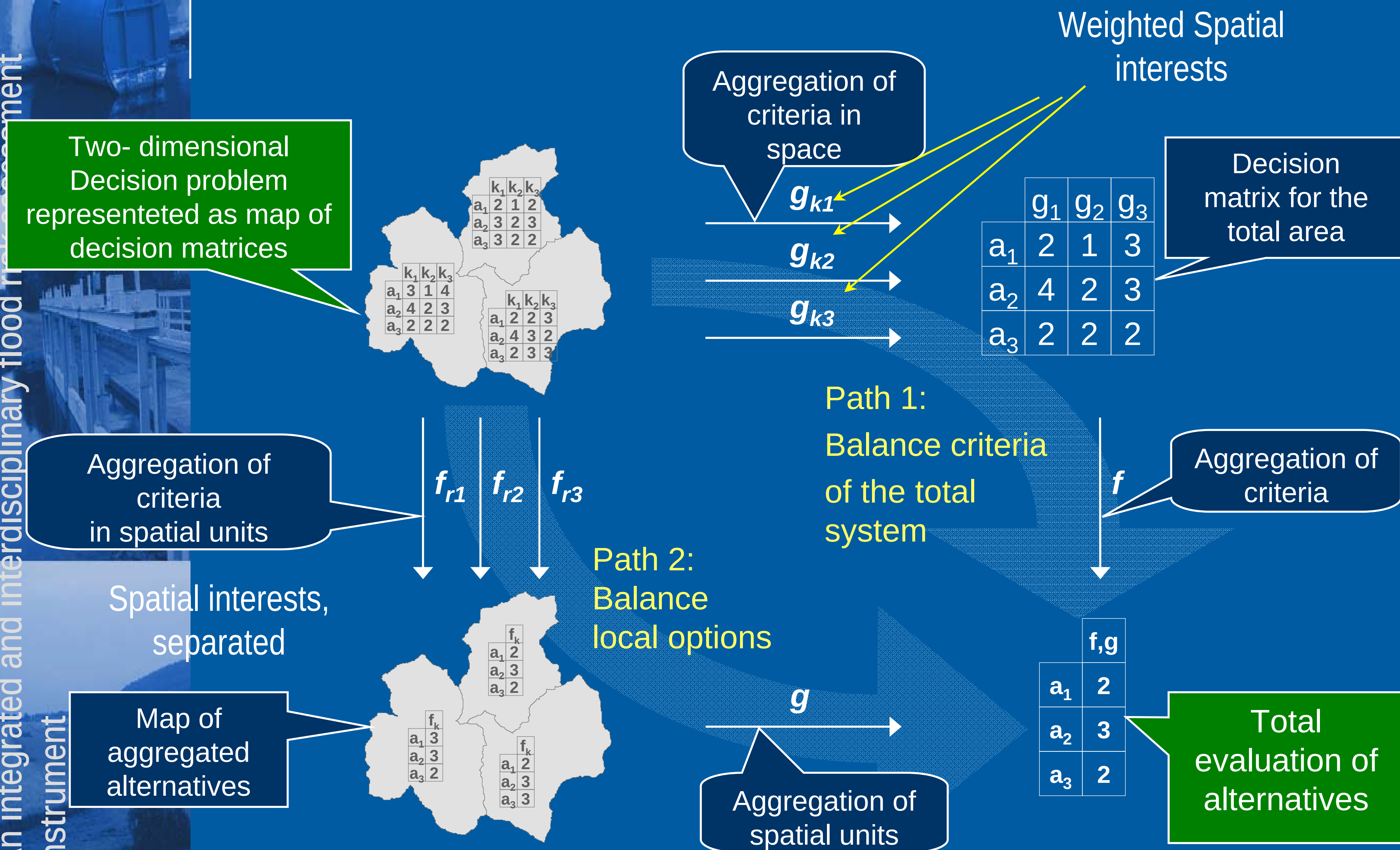
MCDM ANP Supermatrix



Benefits		Economical Risks		Psychosocial Risks			Downstream	Alternativen					
Unweighted Supermatrix		D1	D2	P1	P2	P3	S1	A1	A2	A3	A4	A5	A6
		Direct Damage	Indirect Damage	Reduction Risk Affected People	Reduction Risk Vulnerable Points	Reduction Risk Psychological Damages	Reduction Risk Downstream	System State 1	System State 2	System State 3	System State 4	System State 5	System State 6
D1	Direct Damage	0,000	1,000	0,500	0,875	0,875	0,000	0,750	0,750	0,750	0,750	0,750	0,750
D2	Indirect Damage	0,000	0,000	0,500	0,125	0,125	0,000	0,250	0,250	0,250	0,250	0,250	0,250
P1	Reduction Risk Affected People	0,785	0,105	0,000	0,583	0,500	0,000	0,455	0,405	0,405	0,405	0,405	0,405
P2	Reduction Risk Vulnerable Points	0,149	0,258	0,972	0,000	0,500	0,000	0,455	0,481	0,481	0,481	0,481	0,481
P3	Reduction Risk Psychological Damages	0,066	0,637										
S1	Reduction Risk Downstream	0,000	1,000										
A1	System State 1	0,045	0,046										
A2	System State 2	0,071	0,072										
A3	System State 3	0,100	0,100										
A4	System State 4	0,180	0,176										
A5	System State 5	0,225	0,228										
A6	System State 6	0,378	0,379										

Benefits		Alternatives					
Limit Supermatrix		A1	A2	A3	A4	A5	A6
		System State 1	System State 2	System State 3	System State 4	System State 5	System State 6
A1	System State 1	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137
A2	System State 2	0,0295	0,0295	0,0295	0,0295	0,0295	0,0295
A3	System State 3	0,0386	0,0386	0,0386	0,0386	0,0386	0,0386
A4	System State 4	0,0589	0,0589	0,0589	0,0589	0,0589	0,0589
A5	System State 5	0,0705	0,0705	0,0705	0,0705	0,0705	0,0705
A6	System State 6	0,1091	0,1091	0,1091	0,1091	0,1091	0,1091
D1	Direct Damage	0,2133	0,2133	0,2133	0,2133	0,2133	0,2133
D2	Indirect Damage	0,0700	0,0700	0,0700	0,0700	0,0700	0,0700
P1	Reduction Risk Affected People	0,1631	0,1631	0,1631	0,1631	0,1631	0,1631
P2	Reduction Risk Vulnerable Points	0,1222	0,1222	0,1222	0,1222	0,1222	0,1222
P3	Reduction Risk Psycholgical Damages	0,0495	0,0495	0,0495	0,0495	0,0495	0,0495
S1	Reduction Risk Downstream	0,0615	0,0615	0,0615	0,0615	0,0615	0,0615

Spatial aggregation of criteria



	g_1	g_2	g_3
a_1	2	1	3
a_2	4	2	3
a_3	2	2	2

	f,g
a_1	2
a_2	3
a_3	2

after van Herwijnen & Rietveld (1999)

An integrated and interdisciplinary flood risk assessment instrument

ANP Results

Unstrut EUS

Karte | Tabelle | Graphik | Entscheidung

Economic Risks | Psychosocial Risks | Downstream Risks | Final

Downstream Importance

Less Important — Most Important

Priorities: Benefits

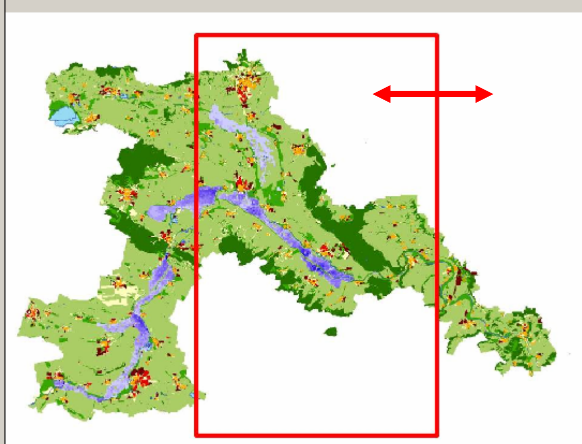
System State 1	0,125779242
System State 2	0,268724364
System State 3	0,352129746
System State 4	0,538219343
System State 5	0,645134567
System State 6	1

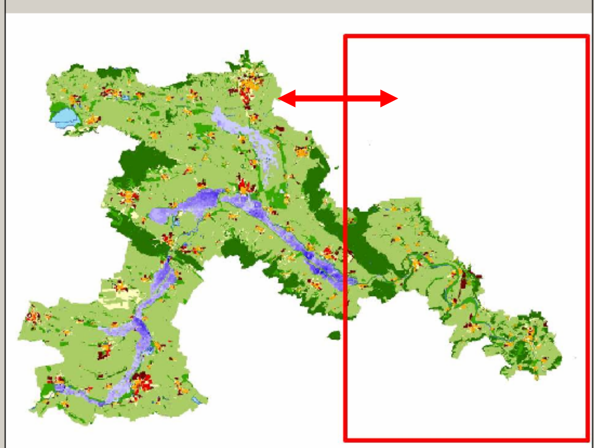
Priorities: Costs

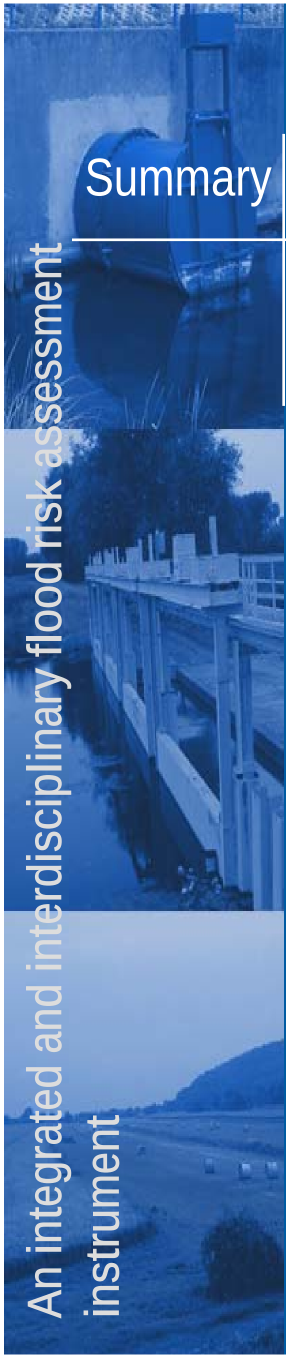
System State 1	0,126878439
System State 2	0,139000968
System State 3	0,263164259
System State 4	0,395384891
System State 5	0,411260832
System State 6	1

Priorities: Total

System State 1	0,809564848
System State 2	0,915590765
System State 3	0,882558284
System State 4	0,926216695
System State 5	1
System State 6	0,810455699







An integrated and interdisciplinary flood risk assessment instrument

Summary

DEVELOPMENT OF AN INTEGRATED AND INTERDISCIPLINARY FLOOD RISK ASSESSMENT INSTRUMENT

- Hydrological Risk:
  - Modeling of the river basin to generate the data base, Copula Analysis, Imprecise probabilities, 6 classes of return periods with 5 realizations of floods with different characteristics,
  -
- Spatial interdependencies:
  - Upstream – downstream preferences
- Interactions of criteria and alternatives
  - ANP
- Further Steps:
  - Integrating of uncertainties
  - Integrating of operational risks of flood retention structures

An integrated and interdisciplinary flood risk assessment instrument

Summary | MCDM

„Decision-makers don‘t know what they want until they know what they can get“
(Loucks et al. 2005)

From our point of view:

- They should also know what they can't get !

Thank you for funding:

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rimax Risk management of extreme flood events

Thank you for support:

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Thank you for your attention !