Damage and loss prediction model based on the vulnerability of building types

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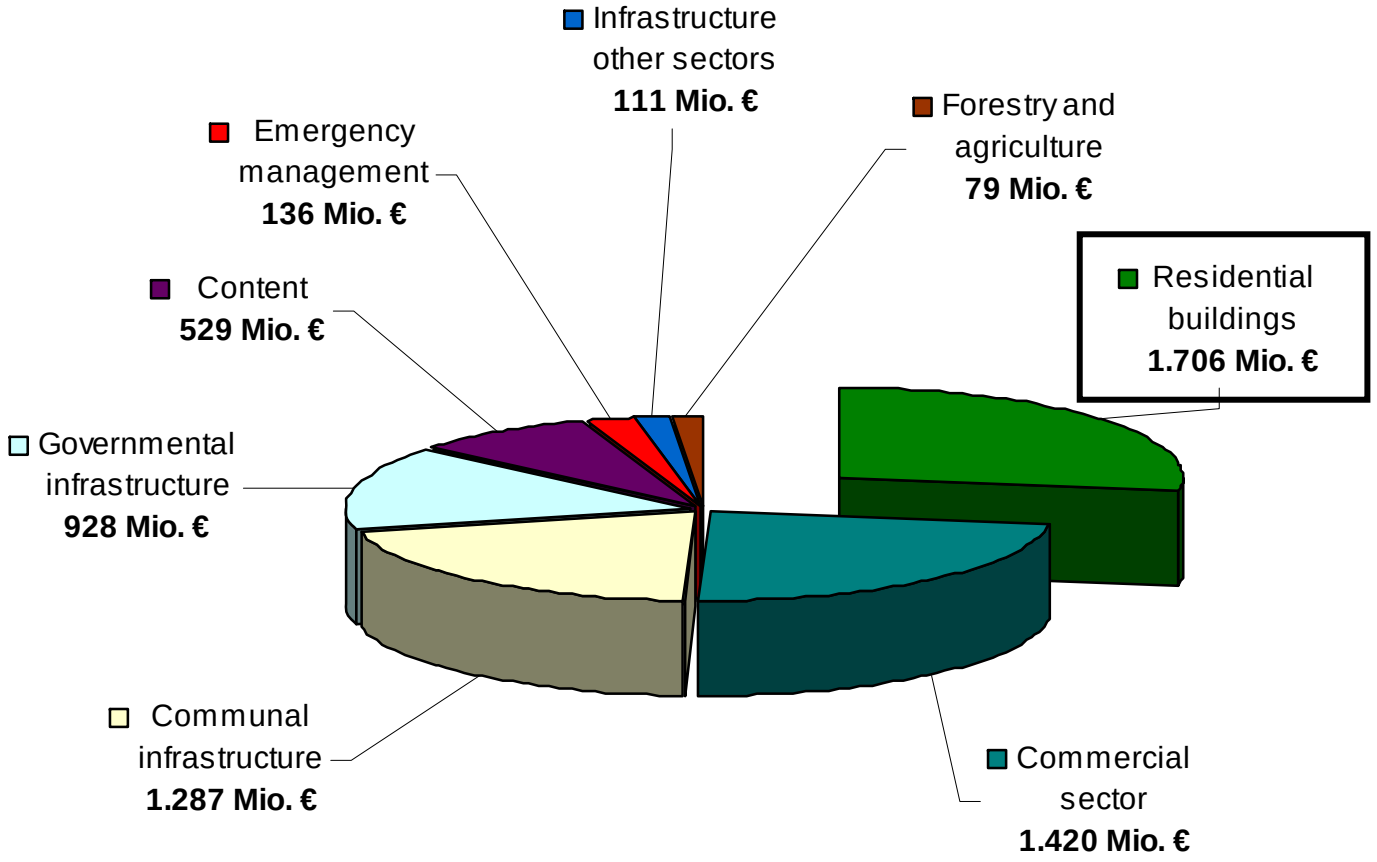
Institute for Catastrophic Loss Reduction

Motivation

Reasons for the study

Distribution of losses in Saxony after the flood 2002*



*** after Sächsische Staatskanzlei (2002)**

Reasons for the study

Building type: masonry
Damage grade: D2

Primary influence factor:
Inundation level

Building type: masonry
Damage grade: D2-3 (slight settlements)

Primary influence factor:
Inundation level

Reasons for the study

In addition to **Flood Action Side**, the impact of structural parameters (**Resistance Side**) has to be considered.

Can the procedures developed for the **Risk Analysis of Earthquakes** be adapted to **Flood Risk Analysis** procedures?

If “yes”:
➔ **Development of a Damage and Loss Prediction Model** based on an **Engineering Evaluation System of Buildings**

Reasons for the study

„Step 1“

Building type: clay
Damage grade: D5

Special influence factor:
Flow velocity and circulations

Building type: masonry with clay mortar
Damage grade: D5

Primary influence factor:
Inundation level
Flow velocity

Reasons for the study

„Step 1 + 1/2“

Building type: clay

Inundation level
Flow velocity
Duration
Building type

Building type: masonry

Inundation level
Flow velocity
Duration
Building type

Reasons for the study

Building type: masonry

Inundation level
Flow velocity
Duration
Building type

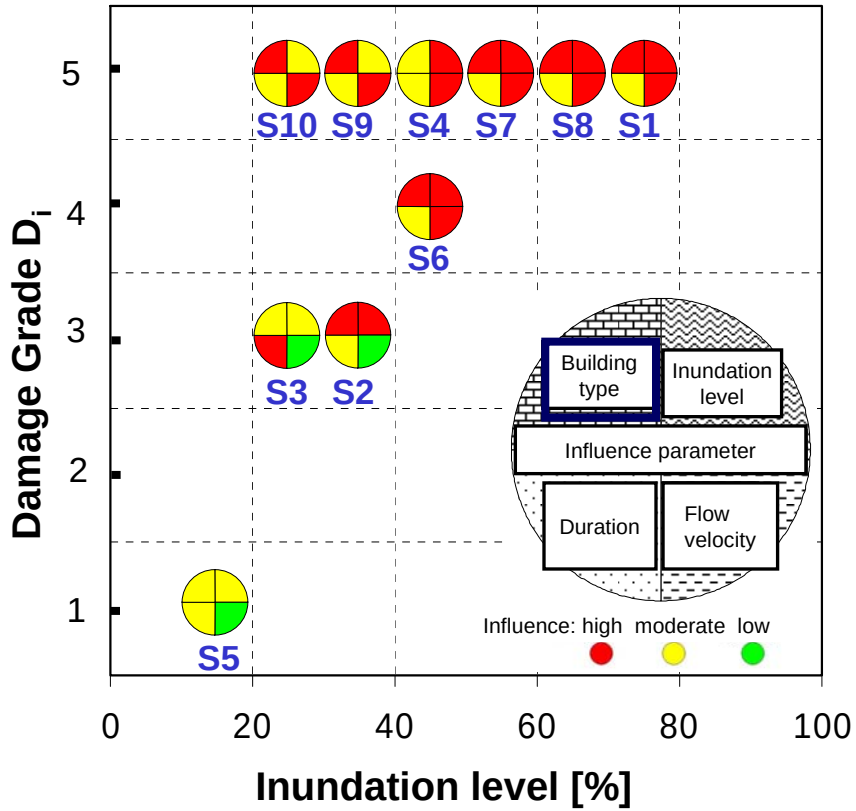
Building type: masonry (clay mortar)

Inundation level
Flow velocity
Duration
Building type

Basic elements

First approach

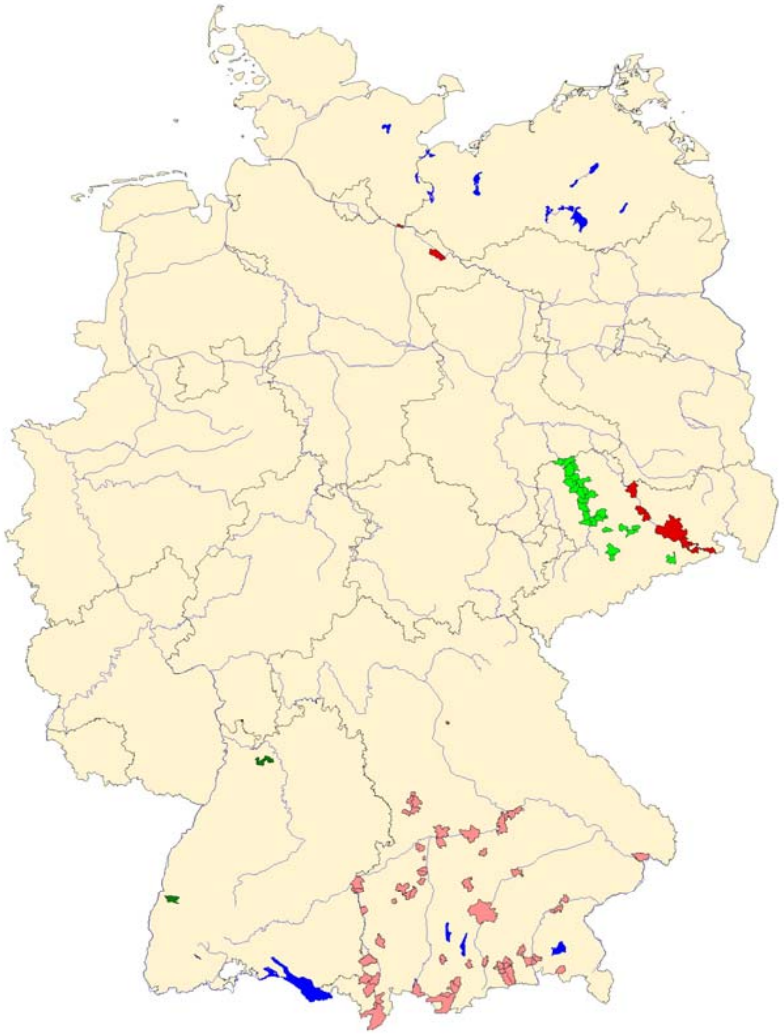
Classification of different damage cases (samples S1 - S10)



Basics of the Study

Engineering Evaluation System of Buildings

Data base



Dataset 1: EDAC – questionnaire

- Saxony August 2002
- Baden Württemberg 1978 - 1994

Dataset 2: MEDIS – telephone interview

- Bavaria September 2005
- Saxony April 2006

Basic elements

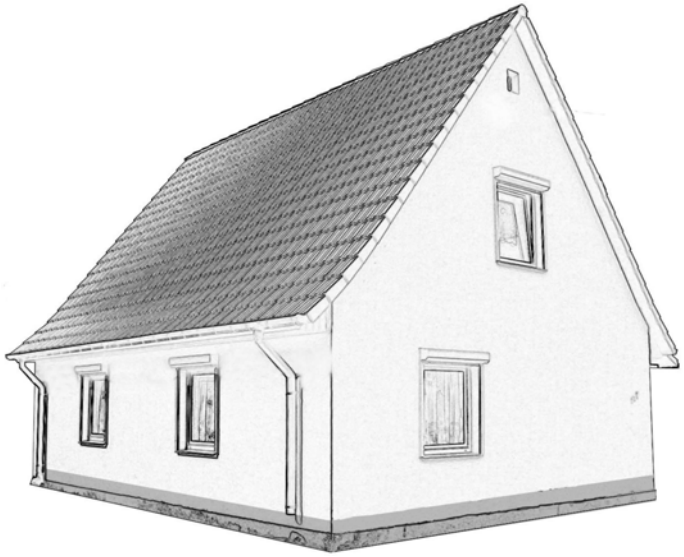
Criteria	Observed effect / measure	Damage grade D_i				
		D1	D2	D3	D4	D5
Building physical damage	**Penetration** of supporting and non-structural walls and the floor slabs	💻	×	×	×	×
Chemical damage	**Pollution** (mud, excrements …)	×	×	×	×	×
	Contamination (oil, chemicals)		×	×	×	×
Structural damage	Impressed doors and windows		×	×	×	×
	Slight cracks in structural elements		×	×	×	×
	Major cracks / deformations in structural walls and slabs			💻	×	×
	Settlements			×	×	×
	Partial failure of primary structural elements				💻	×
	Collapse of major parts of the building					💻
Rehabilitation measures	Cleaning of penetrated elements	💻	×	×	×	×
	Replacement of extension elements		💻	×	×	×
	Replacement of non-structural elements			×	×	×
	Replacement of structural elements				×	×
	Demolition of building required					×

„New Step“

Basic elements: Definition of Damage Grades

Damage grade D1

Drawing



Example

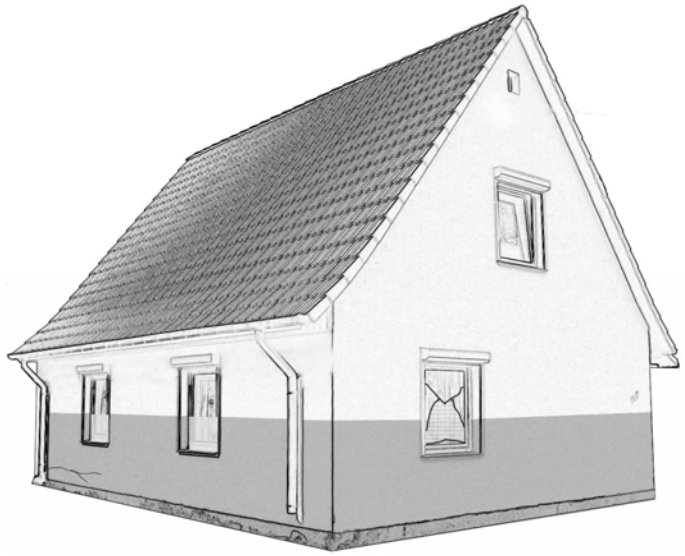
No structural damage
Slight non-structural damage

Only penetration and pollution

Basic elements: Definition of Damage Grades

Damage grade D2

Drawing



Example

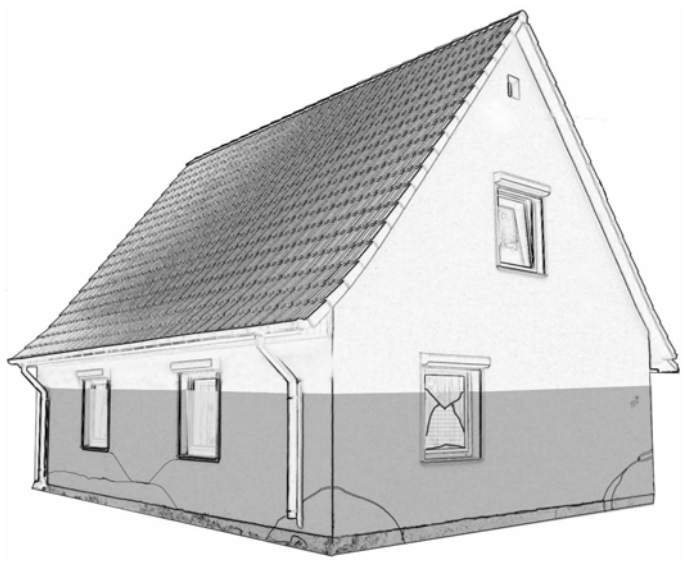
No to slight structural damage
Moderate non-structural damage

Slight cracks in supporting elements
Impressed doors and windows
Contamination
Replacement of extension elements

Basic elements: Definition of Damage Grades

Damage grade D3

Drawing



Moderate structural damage
Heavy non-structural damage

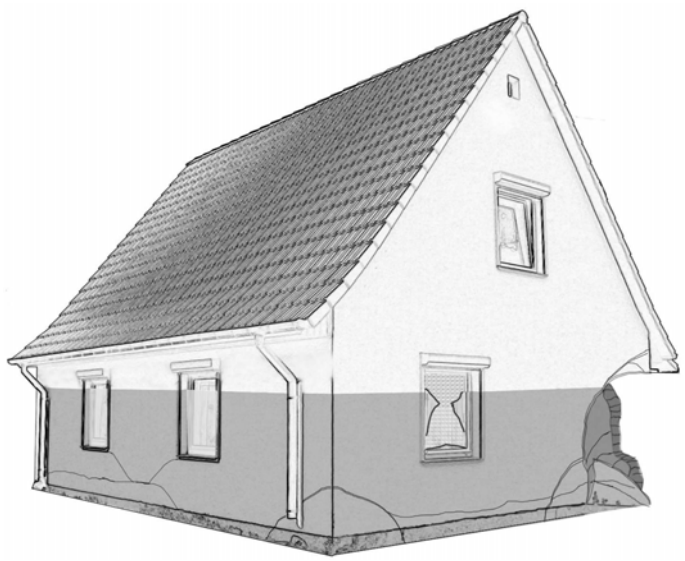
Example

Major cracks and/or deformations in supporting walls and slabs
Settlements
Replacement of non-structural elements

Basic elements: Definition of Damage Grades

Damage grade D4

Drawing



Example

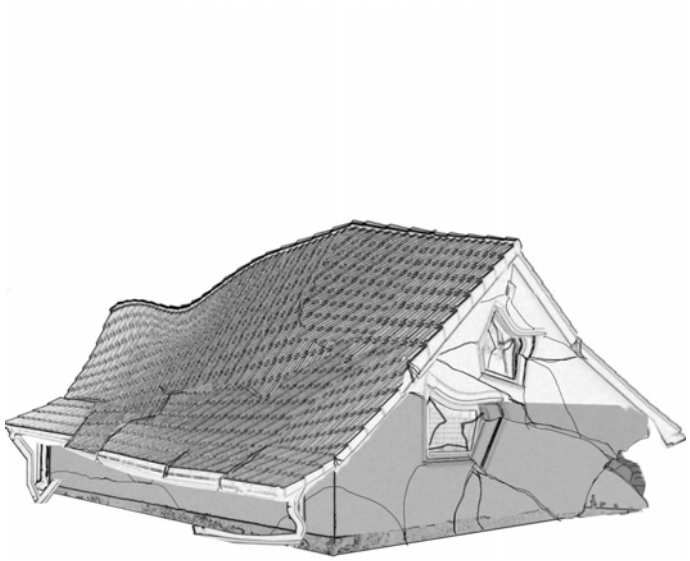
Heavy structural damage
Very heavy non-structural damage

Structural collapse of supporting walls, slabs
Replacement of sructural elements

Basic elements: Definition of Damage Grades

Damage grade D5

Drawing



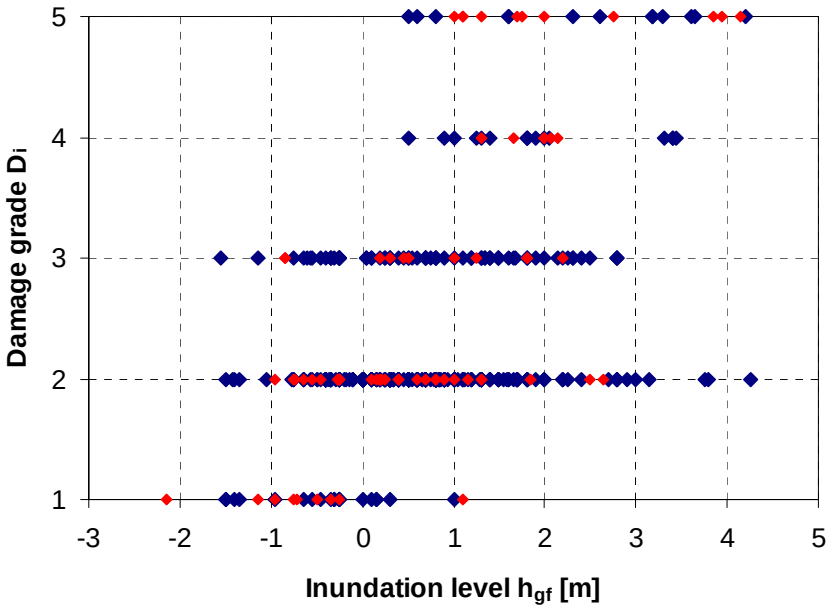
Example

Very heavy structural damage
Very heavy non-structural damage

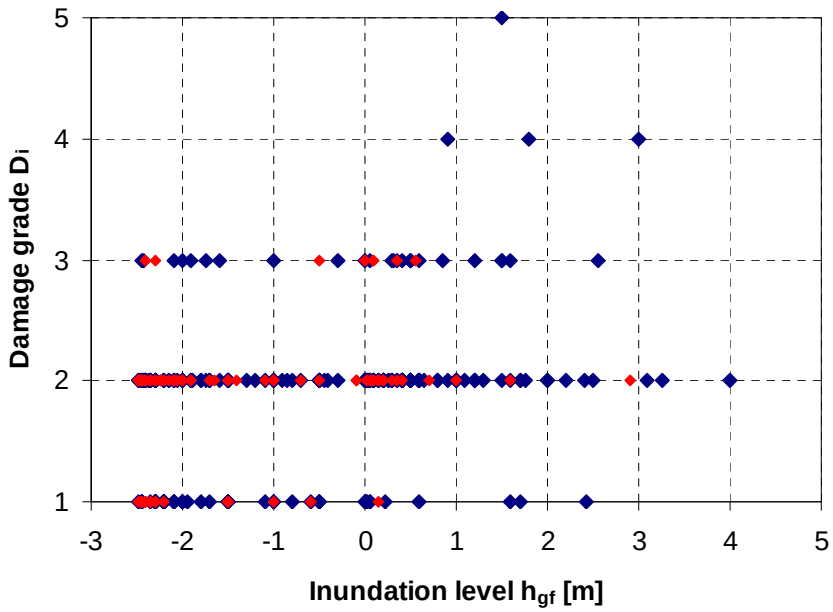
Collapse of the building or of major parts of the building
Demolition of building required

Basic elements

Dataset 1 „EDAC“



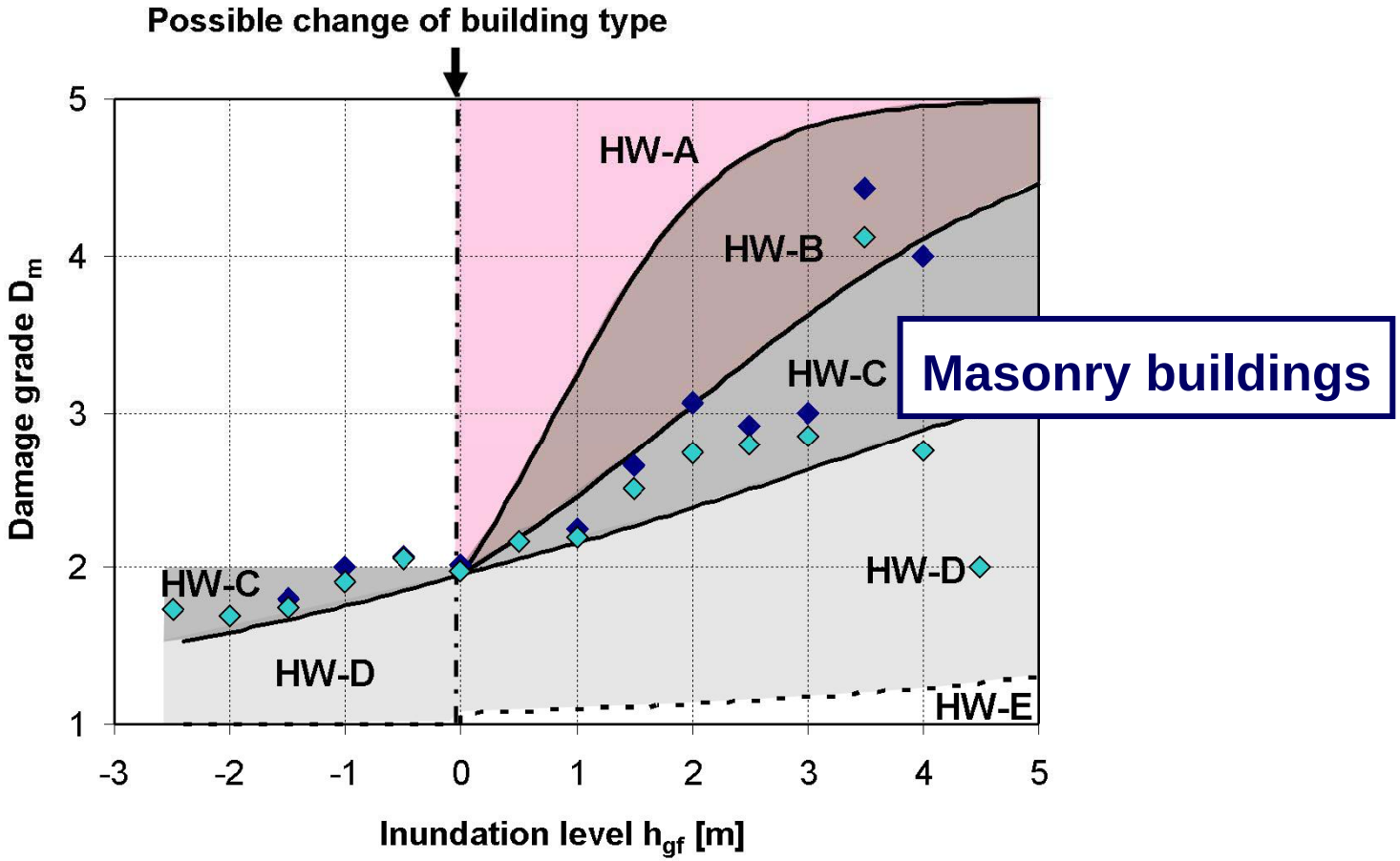
Dataset 2 „MEDIS“



Main building type (masonry)

Other building types

Basic elements



Masonry buildings

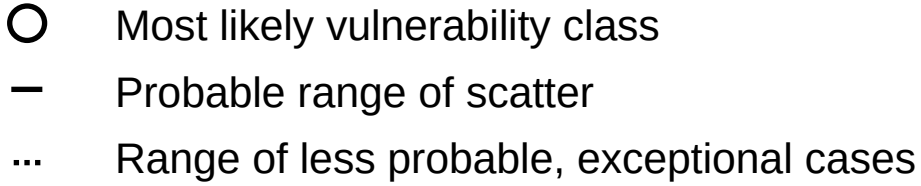
◆ Dataset „EDAC“

◆ Dataset „EDAC + MEDIS“

Basic elements

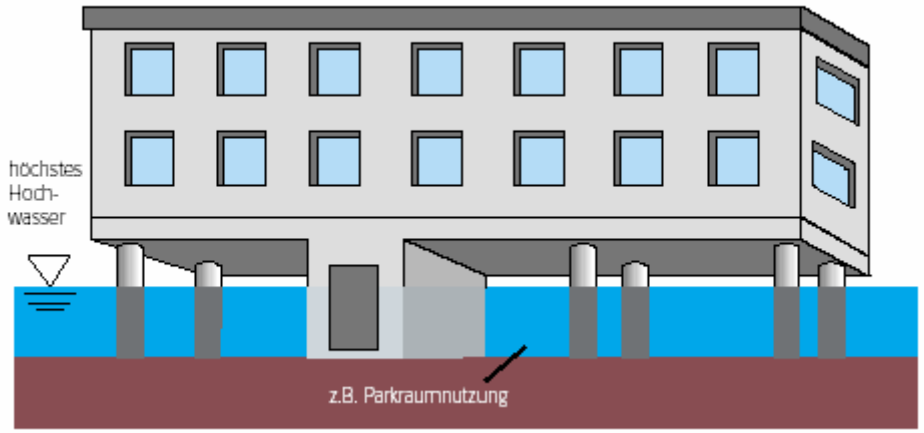
Classification of building types in vulnerability classes

Classification of building type		Flood vulnerability class HW-VC				
Main building type	*short*	A	B	C	D	E
Clay	*Clay*					
Prefabricated	*PF*					
Framework	*FW*					
Masonry	*MW*					
Reinforced concrete	*RC*					
Flood resistant designed buildings	*FRD*					



Basic elements

Flood vulnerability class HW-E



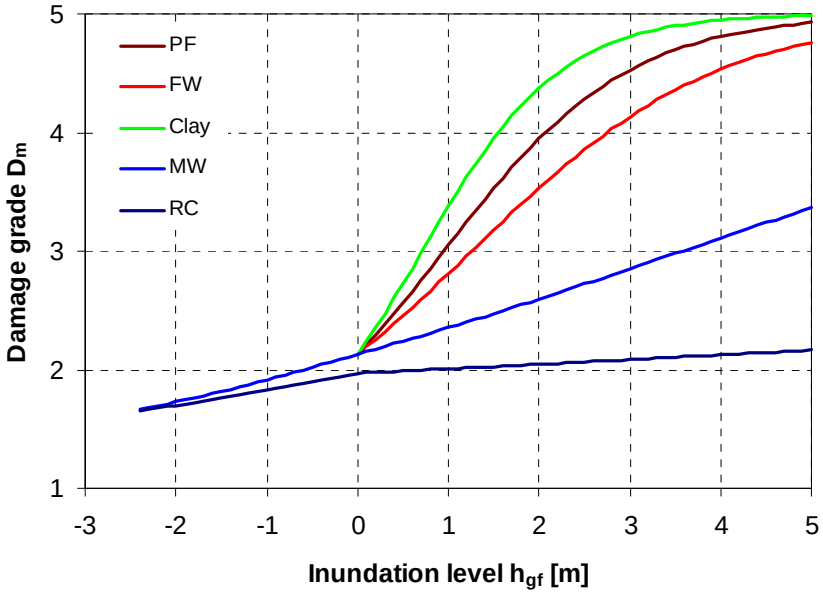
Bundesministerium für Verkehr, Bau- und Wohnungswesen:
Planen und Bauen von Gebäuden in hochwasser-gefährdeten Gebieten

Bauhaus-Universität Weimar
Institute for Foundations and Soil Mechanics

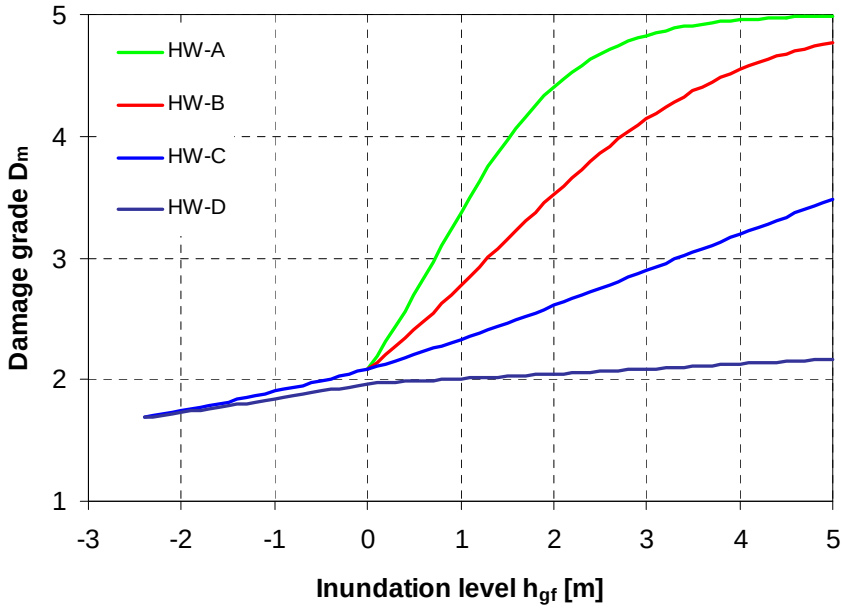
Basic elements

Specific Vulnerability Functions of type: $D_m = f(h_{gf})$

Building types



Flood vulnerability classes



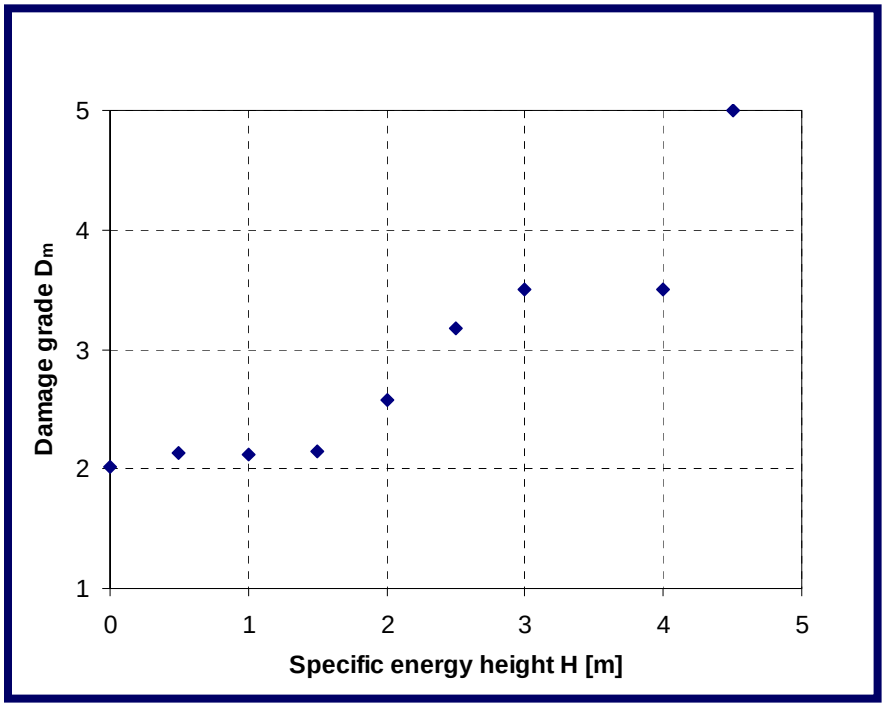
D_m - Mean damage grade

h_{gf} - Inundation level over ground floor

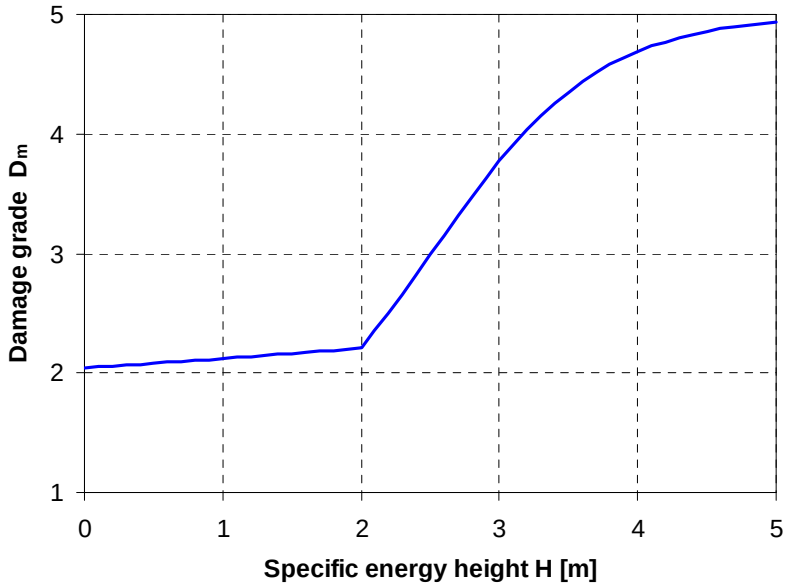
Basic elements

Specific Vulnerability Functions of type: $D_m = f(h_{gl}, v_{fl})$

Damage grades D_m



Buildings (without specification)



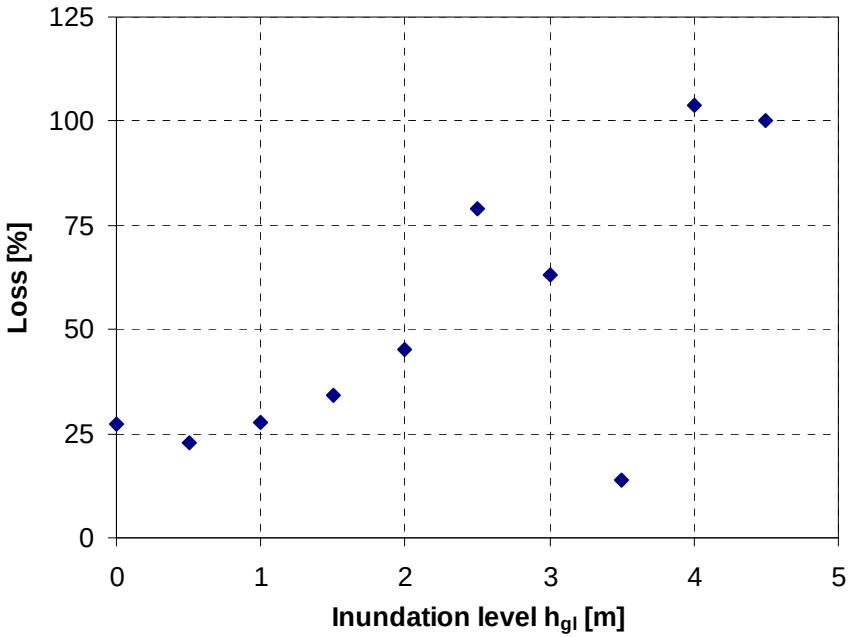
$H = h_{gl} + (v_{fl}^2/2g)$

h_{gl} - Inundation level over ground level

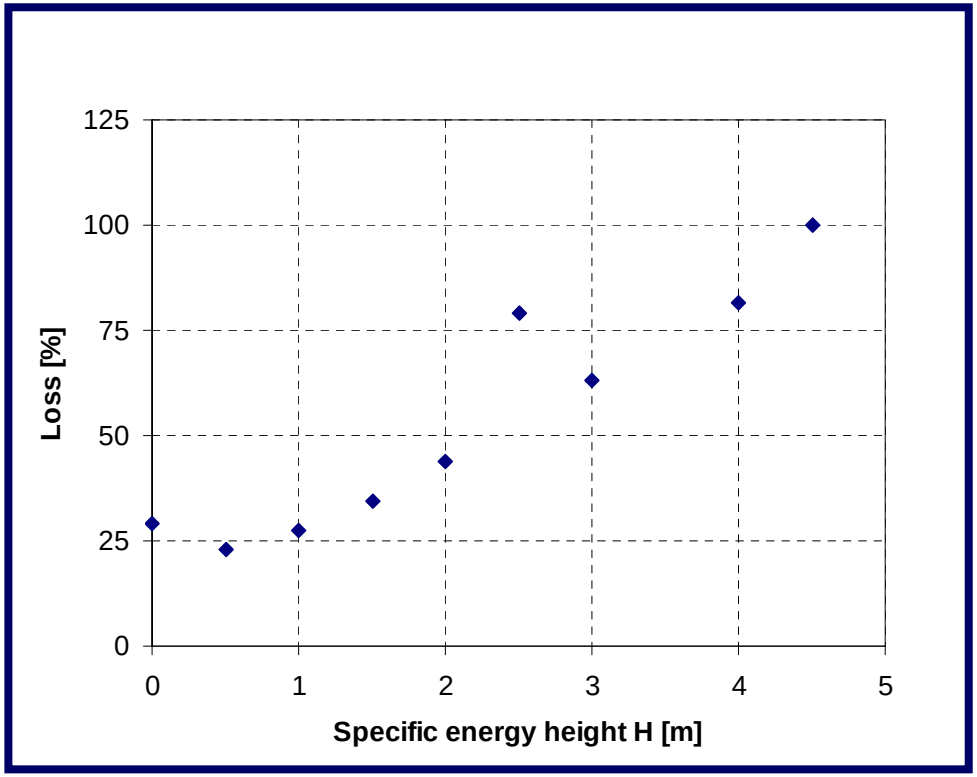
v_{fl} - Flow velocity

Basic elements

Losses (MDR) and impact parameters



h_{gl}

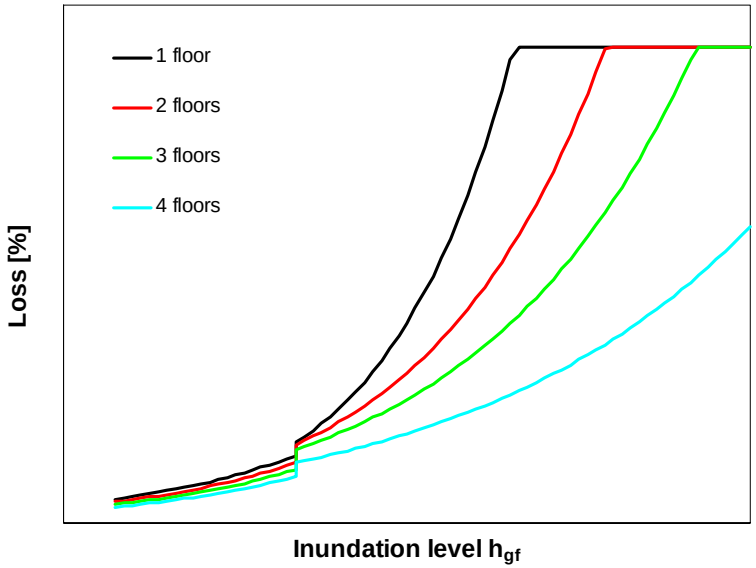


$H = h_{gl} + (v_{fl}^2/2g)$

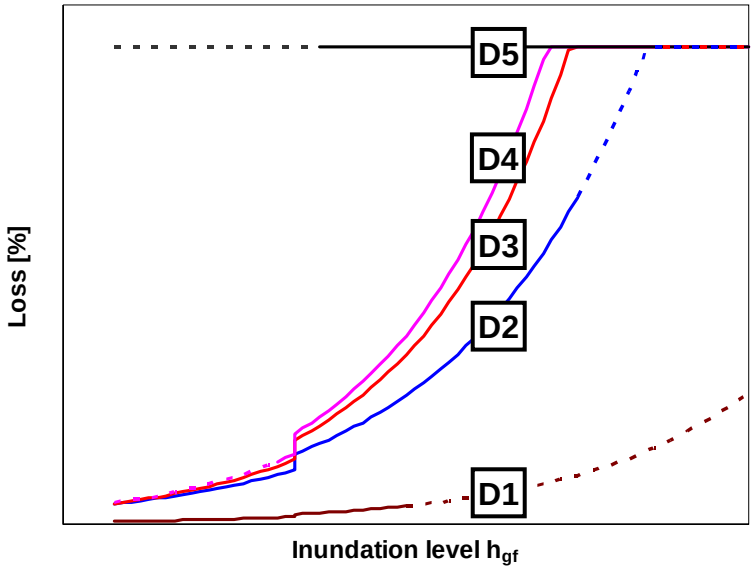
Basic elements

Specific Damage Functions (SDF i)

SDF 1b: Example for HW-C, with cellar

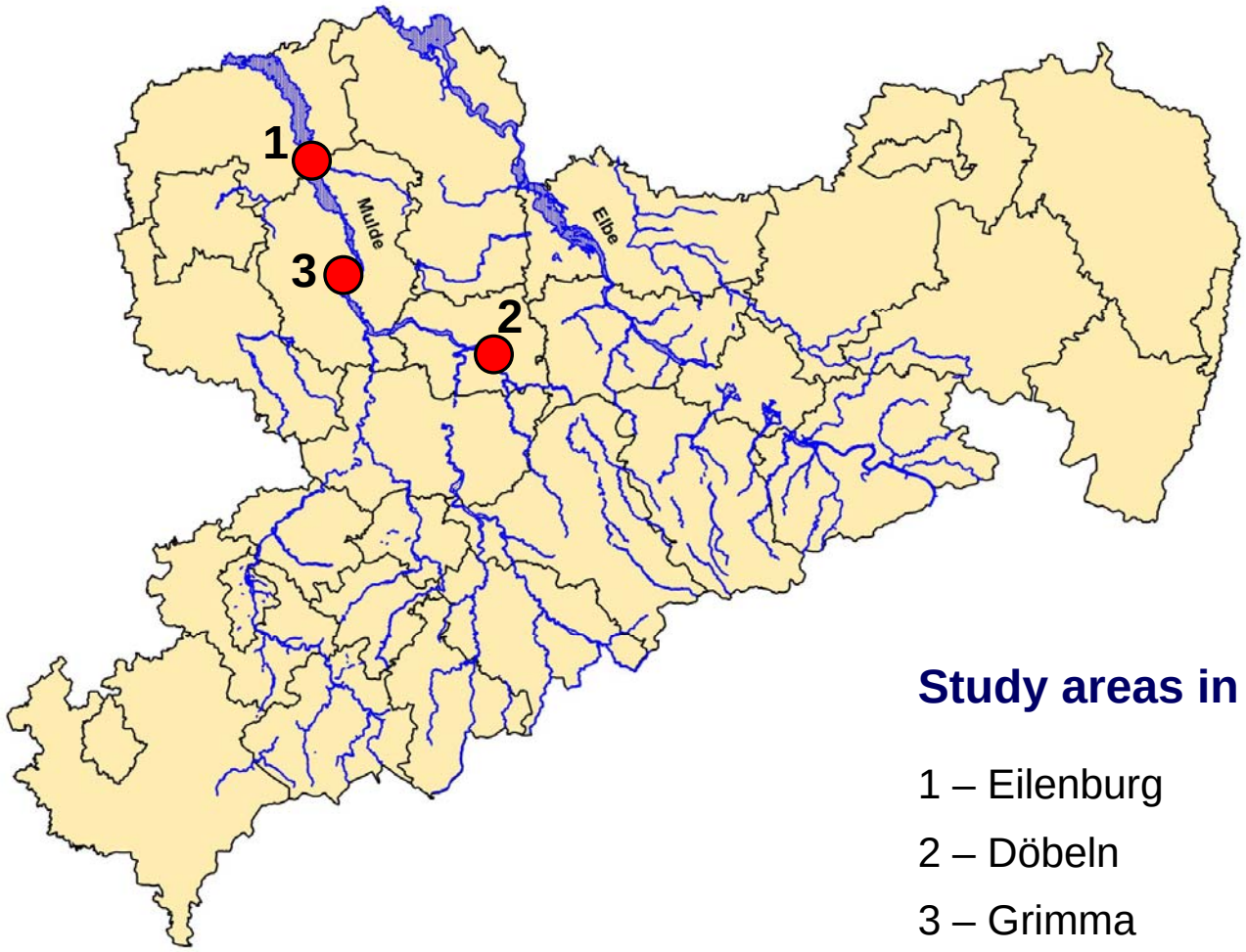


SDF 2: Example for floor number n, with cellar (under preparation)



Case studies

Case studies



Study areas in Saxony

1 – Eilenburg

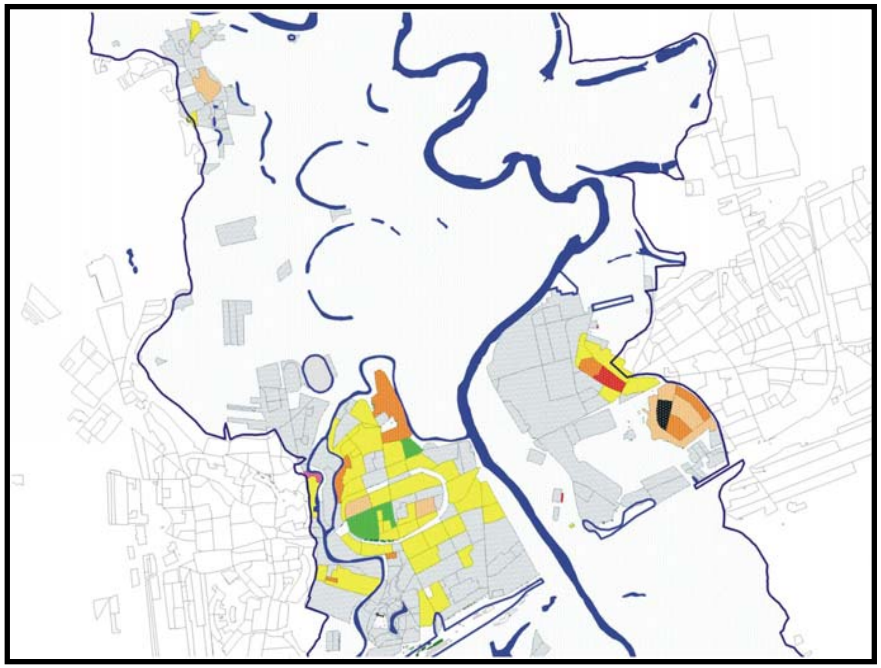
2 – Döbeln

3 – Grimma

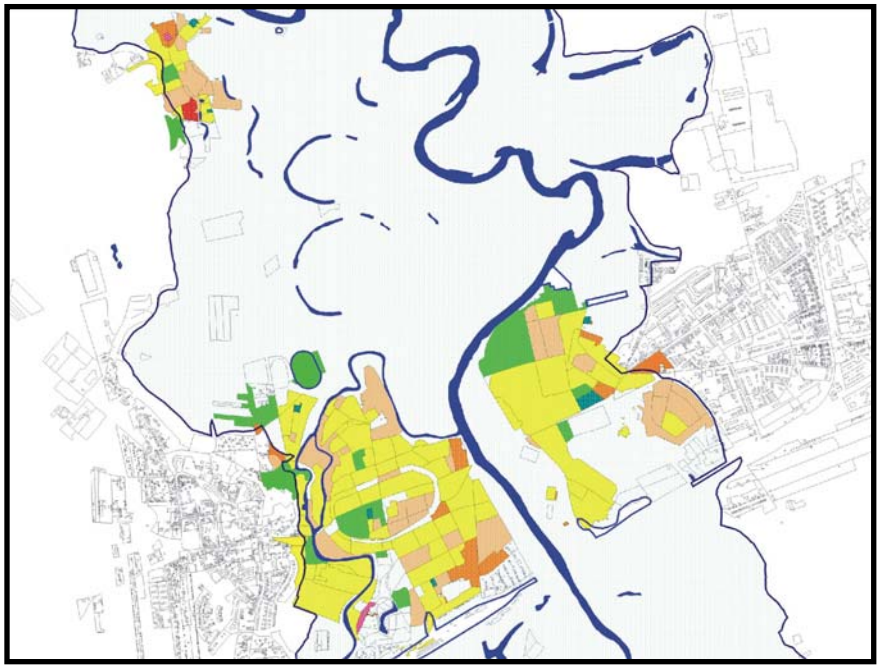
Case studies

Study area 1: Eilenburg

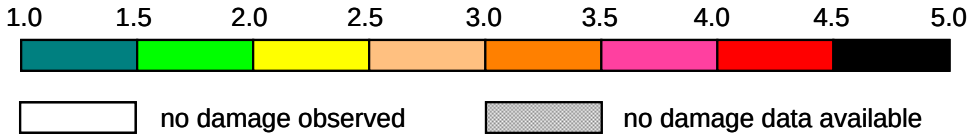
Observed damage grades



Re-Interpretation



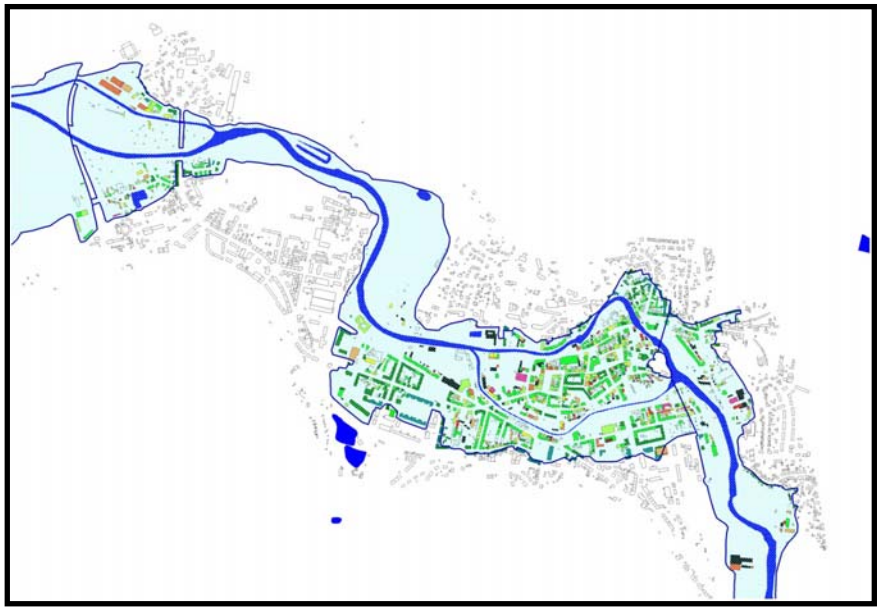
Mean damage grades in the ATKIS- land use areas (MD_m):



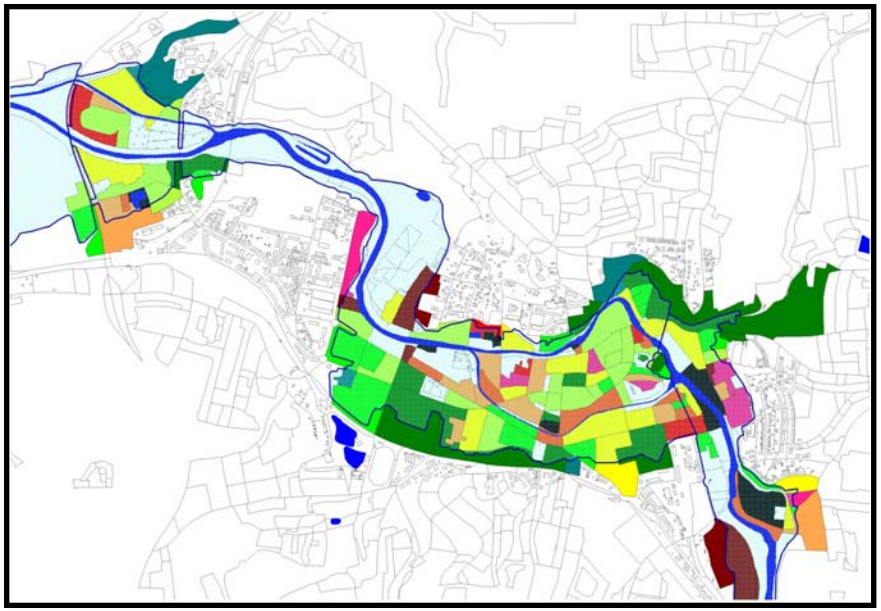
Case studies

Study area 2: Döbeln

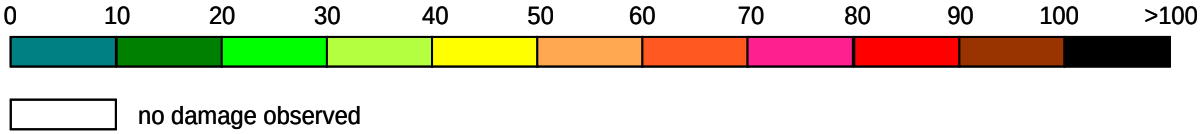
Single Buildings



ATKIS-land use areas



Mean Damage Ratio
(MDR) in [%]

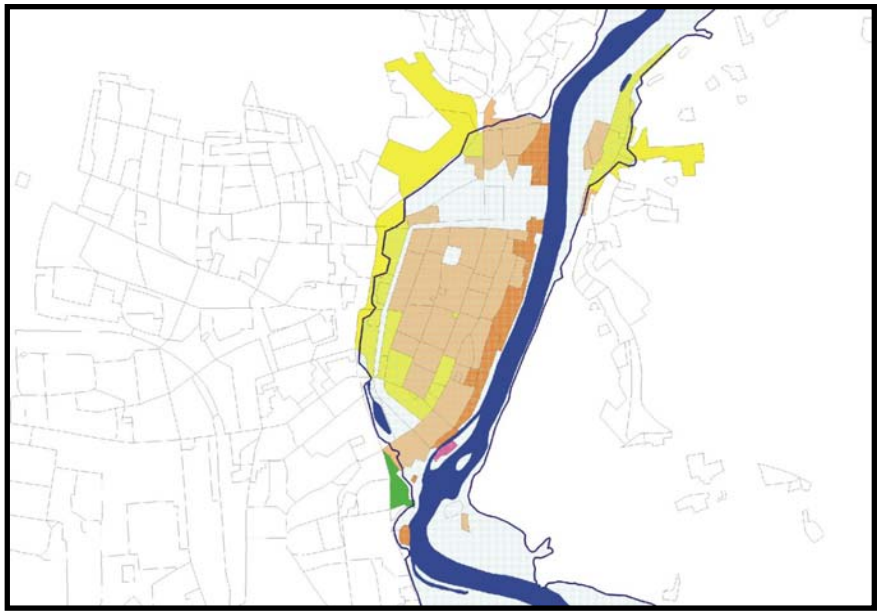


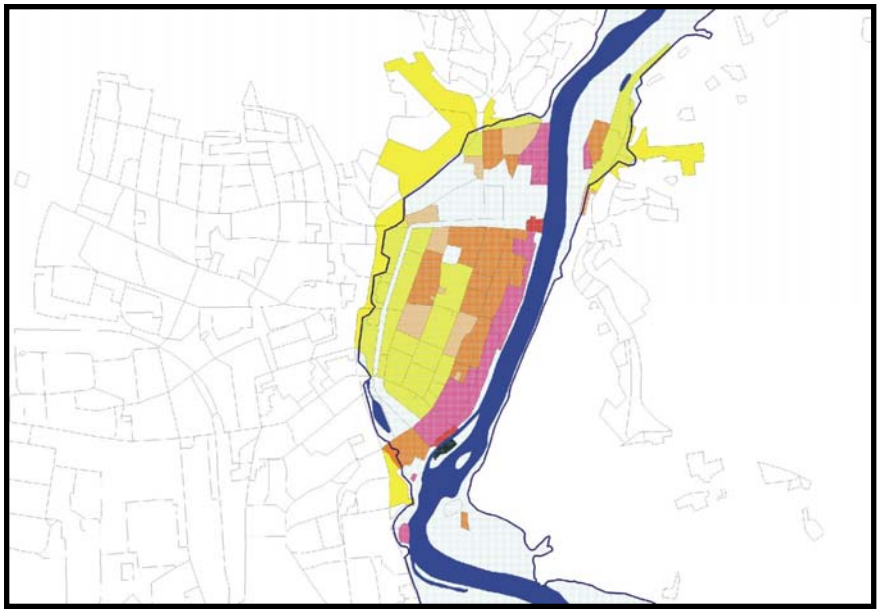
Case studies

Study area 3: Grimma

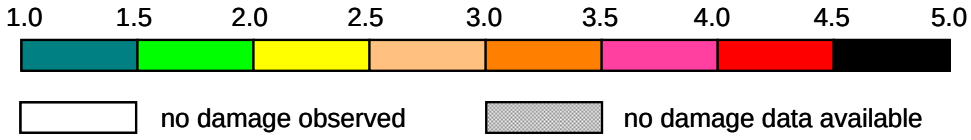
Consideration of the inundation level; $D_m = f(h_{gf})$

Consideration of inundation level and flow velocity; $D_m = f(h_{gl}, v_{fl})$





Mean damage grades in the ATKIS- land use areas (MD_m):



Case studies

Study area	Level	Reference	Losses in [Mio. €]	
			Reported	**EDAC – loss model**
1	Microscale	Residential building stock	**83.3**	**89.9**
		Total building stock	**146.0**	**166.3**
2	Microscale	Residential building stock	**61.9**	**71.8**
		Total building stock	**145.0**	**149.4**
3	Mesoscale	Residential building stock	**58.5**	**62.2**

Conclusions

Conclusion (I)

Result:
Damage and loss prediction model based on an **engineering evaluation system of buildings** including:

- a unified definition of global structural **Damage Grades** (Di)
- Specific **Flood Vulnerability Classes** (HW-A to HW-E)
- **Specific Vulnerability Functions (SVF)** of type:
  Dm = f (hgf)
  Dm = f (hgl, vfl)
- **Specific Damage Functions (SDF)** of type**:**
  Loss [%] = f (hgf, HW-VC, n, poc)
  Loss [%] = f (hgf, Di,)

Conclusion (II)

The **Results and developed Tools:**

- enable the reinterpretation of damage and loss parameters,
  ➔ are suited for **damage and loss prediction**

- enable the identification of critical zones
  ➔ are suited for **disaster management decisions**
  (short- and long-term)

Thanks for

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Coordination

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