Further development of FLEMOps for the modelling of damage to residential buildings caused by high groundwater levels

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Background

Flood mitigation measures at the surface cause an increasing importance of losses due to high groundwater levels. Although problems are severe, losses caused by high groundwater levels are often neglected in loss assessment studies. However, reliable damage models are required to evaluate the cost-effectiveness of mitigation measures and to support a comprehensive risk management.

Objective

The city of Dresden in Germany has initiated the research project "MULTISURE - Development of Multisequential Mitigation Strategies for Urban Areas with Risk of Groundwater Flooding" which aims at the development of assessment methods for the hazard, the damage potential and the risk due to interactions of riverine and groundwater flooding.
The aim was the adaptation of the Flood Loss Estimation MOdel for the private sector – FLEMOps for high groundwater levels . FLEMOps is based on empirical flood loss data which has been collected after the flood in the Elbe- and Danube-catchments in 2002. It is a new, innovative, rule based model which takes into account several impact factors besides the water depth, such as building type and quality as well as contamination and precaution. It is applicable on the micro-scale, i.e. single buildings, and on the meso-scale, i.e. land use units (Fig. 1). FLEMOps for groundwater flooding was successfully validated at the micro- and meso-scale and a sensitivity analysis was undertaken in Dresden.

Concept and input data

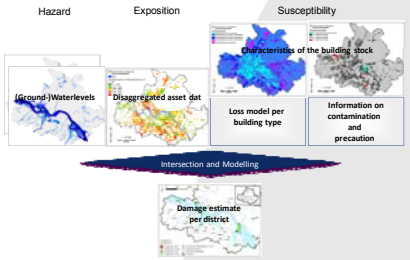

Figure 1 Sketch of the meso-scale validation including necessary input data

Damage model development

The micro-scale model (Fig. 2 & Table 1) was based on groundwater flood damage data collected after the 2002 flood in Germany (Kreibich & Thieken 2008). The model was scaled to the meso-scale to enable a regional application on basis of land use units (Figure 1 & Table 2).

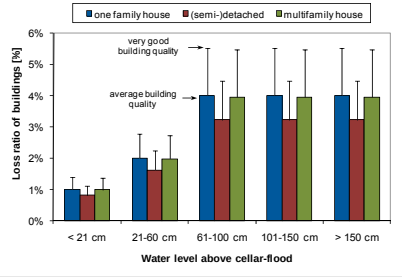

Figure 2 FLEMOps for groundwater flooding – first model stage

Table 1 FLEMOps+ second model stage using scaling factors

		Precaution		
		no	good	very good
Contamination	no	1.09	0.70	0.55
	medium	1.34	0.86	0.68
	heavy	1.34	0.86	0.68

Table 2 Mean composition of residential buildings in 5 clusters (EFH: one-family home, RDH: (semi-)detached house, MFH: multifamily house)

Cluster	Share EFH [%]	Share RDH [%]	Share MFH [%]	Description
1	12.00	5.13	82.87	Dominated by multifamily houses
2	31.35	24.58	44.07	Mixed (high share of MFH)
3	37.51	46.19	16.30	Mixed (high share of RDH)
4	68.51	21.43	10.05	Mixed (high share of EFH)
5	92.25	4.81	2.94	Dominated by one-family houses

Validation

FLEMOps for groundwater flood damage was successfully validated on the micro-scale (Table 3) using data from a survey in Dresden (KREIBICH et al. 2009). The meso-scale validation (Table 4 & Fig. 3+4) based on official flood damage data of the 2002 flood in Dresden points to a very good suitability of the meso-scale approach.

Table 3 Micro-scale validation: Analysis of confidence interval and error statistics for the estimation of damage ratios for buildings

Data for validation	Confidence interval	
Mean loss ratio	2.5% - percentile	97.5% - percentile
0.02900	0.00798	0.05432

Estimation	FLEMOps	FLEMOps+
Mean loss ratio	0.02750	0.02124
Within confidence interval	yes	yes
Mean bias error (MBE)	-0.00009	-0.00020
Mean absolute error (MAE)	0.00042	0.00042
Root mean square error (RMSE)	0.00428	0.00478

Table 4 Comparison of official and modelled damage data of residential buildings due to the 2002 flood in Dresden in million €

	FLEMOps	FLEMOps+	BEAK CONSULTANTS 2006	KORNDÖRFER 2006	SAB 2005
Groundwater flood damage	62.8	44.0	71.5		
Riverine flood damage	276.6	254.5			
Total flood damage	339.4	298.4		304.0	239.8

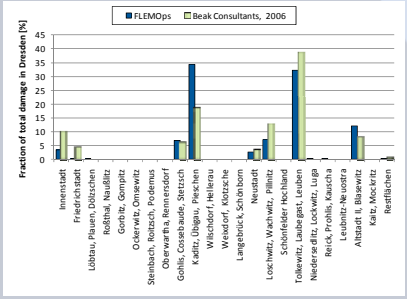

Figure 3 Relative comparison of modelled damage with FLEMOps and of BEAK CONSULTANTS (2006) due to groundwater flooding during and after the 2002 flood: Fraction of groundwater flood damage per district in Dresden

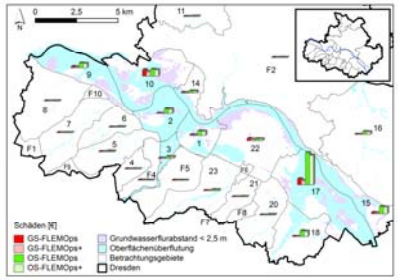

Figure 4 Spatial distribution of the modelled damage to residential buildings due to groundwater and riverine flooding in 2002 in Dresden (Data source: Environmental Agency of the city of Dresden: riverine flood inundation areas/depth, groundwater levels, districts)

Sensitivity analysis

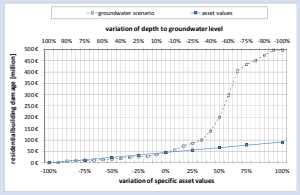

Figure 5 Sensitivity curves for the modelling of groundwater flood damage to residential buildings based on a groundwater flood scenario.

Table 5 Sensitivity indices (SI; DE ROO 1993) separated into sensitivity classes for the modelling of groundwater flood damage to residential buildings based on a groundwater flood scenario.

Sensitivity		Relative change of	
SI classes	Evaluation	Depth to groundwater level	Specific asset values
0,00 ≤ SI < 0,05	low	> -1,2 to 0,0%	0,0 to < 2,5%
0,05 ≤ SI < 0,20	medium	> -5,0 to -1,2%	2,5 to < 10,0%
0,20 ≤ SI < 1,00	high	> -20,0 to -5,0%	10,0 to < 50,0%
SI ≥ 1,00	Very high	≤ -20,0%	≥ 50,0%

Conclusions

The multi-factorial flood loss model FLEMOps was further developed for groundwater flood damage. The model was successfully validated on the micro- and meso-scale using survey data as well as official damage data. Therefore, particularly with meso-scale FLEMOps a model is developed, which is able to provide reliable information on groundwater flood damage for large regions with relatively little effort. Thus, FLEMOps is an efficient tool for groundwater flood risk analysis.

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