Flood Risks in Urban Areas - Data Analysis, Communication and Mitigation

Michael JESKULKE, Holger HOPPE, Christian MASSING, Antje STOKMAN, Michael KOCH, Katrin BEHNKEN, Dietmar GATKE, Katharina THIELKING and Jens WURTHMANN, Germany

Key words: Urban Flooding, Risk Analysis, Information System, Mitigation, Integrated Storm Water Management, Water Sensitive Urban Design

SUMMARY

The increased frequency of heavy rainfall events leads to urban flooding, which induces immense damage and thus results in substantial costs in the urban area and in some cases even bodily injuries. The underground sewage systems cannot cope with extreme precipitation events. Enlargement and remediation of sewage systems and the construction of - generally underground - storm water retention basins alone cannot solve the problem efficiently. Consequently, urban drainage and urban planning authorities have a joint responsibility for recognizing surface run-off in terms of surface and underground flow paths, and also area utilization schemes adapted to the latter. The overall goal is to develop new forms of collaboration and to establish integrated planning processes bearing the needs of “risk management” and “water-sensitive urban design” in mind. If spatial information is made accessible by means of web-based information systems, these processes can be supported in a reasonable fashion.

The paper presents a methodology that coordinates and substantiates the interlinking of data analysis, hydraulic modelling, flood risk mitigation and urban development to establish integrated concepts for flood risk management. These guidelines for action and for a web-based information system are being elaborated as part of the two research projects entitled SAMUWA (2014-2016; Hoppe et al., 2016; Deister et al., 2016) and KLASII (2015-2017) in the cities of Wuppertal and Bremen.

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1. STRUCTURE OF URBAN FLOOD PREVENTION AS SUPPORT FOR ACTION PLANNING

In order to coordinate urban flood prevention measures, it has been proved to be useful to differentiate between three essential modules - risk management, water sensitive urban design and public relations. Risk management includes the ascertainment of potential risks, the correlation between risks and the potential damage involved, and the development of measures to be taken in collaboration with all stakeholders. Risk management can be seen as a short-to-medium-term process designed to mitigate the risks affecting vulnerable infrastructure and in areas of high risk. In contrast to this, water-sensitive urban design stands for introducing potential remedies such as high infiltration rates, options for green roofs or creating open spaces for surface water retention. The overall goal is to let these potential remedies be known in public planning procedures in order to mitigate risks preventively. On the basis of such an approach, measures involving water-sensitive urban design will take effect in the medium to long term. Additionally, it is necessary to inform the public about potential risks and to increase precautions to be taken by house-owners for example. Public measures cannot reduce risks completely, especially not if rare, heavy rainfall events are involved. Therefore house-owners should be aware of the risk and protect themselves with, e. g., back pressure safety installations, waterproof windows, or by waterproofing light shafts for cellars. A total communication concept is needed to inform the public and to give guidelines for action.

Each of the three modules presented has its own requirements and includes various tasks with the involvement of different authorities. Therefore, it is necessary to structure operating cycles, develop guidelines for action and establish workflows. Furthermore, it is important to generate and organize fundamental data as a decision-making support tool and especially to make them available to all stakeholders. In relation to this matter, the two research projects entitled KLASII (2015-1017) and SAMUWA (2014-2016; Hoppe et al., 2016) involve different approaches aimed at supporting urban flood prevention. While KLASII is focused on the development of a web-based information system for organizing and providing data to support flood prevention processes in the city of Bremen (Germany), SAMUWA deals with the elaboration of guidelines for action to improve collaboration between water resources management and urban development bodies (Deister et al., 2016). In the case study of Wuppertal-Varresbeck (Germany), a gradual (five-step) methodology was developed that harnesses flood prevention so as to provide an impulse for water-sensitive urban design.

2. A WEB-BASED INFORMATION SYSTEM AS A SUPPORT FOR URBAN FLOOD PREVENTION(KLAS)

2.1 Structure and technical implementation

In order to support urban flood prevention processes, a web-based information system was developed. The structure of the system developed is aligned with the three urban flood prevention modules presented in Section 1. This permits purposeful provision of data, even if thematic overlaps are possible. For every module, useful content has been determined and acquired (see Fig. 1).

Risk management	Water-sensitive urban design	Public relations
Flood risks: • flow accumulation (based on DEM) • sink watersheds (based on DEM) • sink points (based on DEM) • results of a 1D hydrodynamic sewer system model • results of hydrodynamic 2D surface model • results of hydrodynamic interlinked 1D-2D sewer system surface model • flood hazard maps **Vulnerability:** • important infrastructure facilities (e. g. electricity supply, subways, local public transport) • building and land use (e. g. hospitals, kindergartens)	**Hydrological characteristics** • groundwater level • infiltration **Protection areas** • nature reserves • flora, fauna and habitat guidelines • water protection areas • Water Framework Directive **Potentials of:** • green roofing • renaturation of streams • open spaces for flood prevention **Drainage system** • sewer system • street inlets	**Contents:** • information about flood risks (flood hazard maps) **Support of** • information on flood risks for property owners • information flyer (backwater protection, examples of measures taken) • information events • consulting services
Basic data: topographical maps, aerial photos, digital elevation model, land registers	**Basic data:** topographical maps, aerial photos, digital elevation model, land registers	**Basic data:** topographical maps, aerial photos, digital elevation model, land registers

Fig. 1: Content of the web-based information system aligned with the urban flood prevention modules

The main goals of the information system have been defined as the central management of data, ensuring that the data are up-to-date, the user-specific provision of data and access to data independently of the user's workplace and software. On the basis of these specifications and with the help of ArcGIS Online (Esri, 2017), a web-based information system that provides data via web apps has been constructed. Web apps can be accessed via URLs either from desktop PCs or mobile devices without any specific technical know-how. They organize spatial information as layers and offer various easily-usable functions such as legends, address searches and print functions.

To learn more about the preparation, handling and communication of data, for each of the three modules different pilot projects were carried out. The following sections give an overview of two of these projects and illustrate results and the substantial discussion points.

2.2 Pilot project 1: Risk management for transformer stations

Important infrastructure facilities such as transformer stations should be protected against flooding. Power failures and supply bottlenecks could be the result of the absence of precautions. Due to this, in KLASII it was investigated how risks for transformer stations can be assessed. To accomplish such an assessment, an appropriate approach was developed in cooperation between authorities, dewatering planners and the local energy supplier. As a basis, the results of a municipality-wide flood risk assessment were made available in the form of surface water levels. Because of the huge number of transformer stations in the Bremen urban region, the first step was to prioritize flood risks and to identify stations exposed to high risk. Initially focused on a small district of Bremen named Findorff, a strategy was developed to determine, for each transformer station, a specific water level corresponding to the individual risk. While determination in the case of freestanding transformer stations could be carried out easily by a spatial intersection of the water levels with the geographic coordinates of these stations, it was more difficult to determine the water level for transformer stations that are located within buildings. Furthermore, there was no information about the exact location of the station within the buildings or about the type of station concerned. That is why an algorithm was developed to determine, first, the maximum water levels for a building and then assign the determined value to the transformer station inside. By classifying water levels according to specific hazard categories, it was possible to determine for which transformer stations priority protection concepts should be evolved. In order to verify the results, site visits were made in collaboration with the local electricity supplier. Such visits were not only suitable for assessing the flood risk and the vulnerability in each case but also for developing a mutual understanding between the various parties involved. The provision of the results as a web app allowed a simple data exchange to be made between all stakeholders and enabled an online map to be used during site visits (see Fig. 2). In future, the results of this collaboration, the data produced and the information system can be used not only to assess the flood hazards to which existing transformer stations are exposed but also to support planning processes with regard to new facilities.

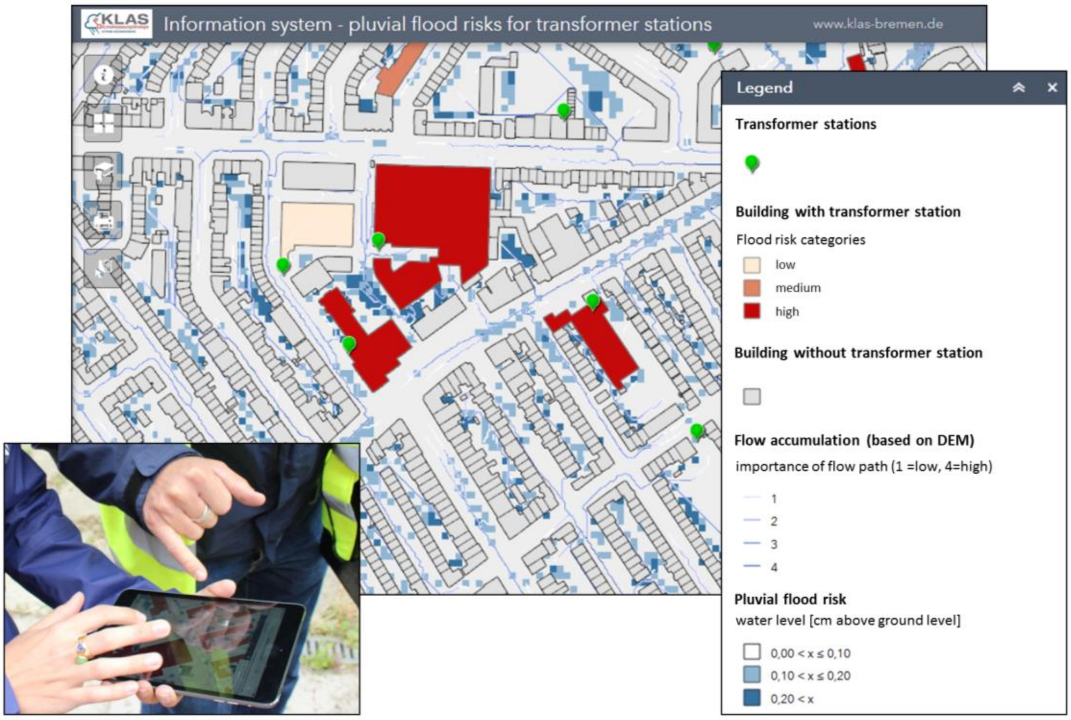

Fig. 2: Online map (web app) as a support tool for site visits

2.3 Pilot project 2: Information on flood risks to property owners

Informing the public or individual non-professionals about flood risks requires the development of a comprehensive communication concept (Behnken et al., 2017). The challenge is to explain complex scientific content in a simple and intelligible way. In KLASII a methodology was developed to inform citizens about flood risks to their property. The overall goal was to sensitize people to the topic of heavy rainfall and to increase self-precautions on the part of threatened property owners.

The methodology is composed of three interconnected modules: an overview map (web app) for sensitizing the public, detailed information of flood risks to the particular property with maps and explanations (available at the owner's request) and a personal on-site consultation on the part of the local drainage company. This approach was the result of various discussions about legal issues (data protection law), economic issues (claims for compensation, potential increases in insurance premiums) and substantive issues (map contents, explanatory texts). The overview map, which is freely accessible in the form of a web app via the web-based information system, is intended to make people aware of the subject and then get them to ask for detailed information about their property (see Fig. 3). For reasons of personal privacy, flood-endangered areas are only roughly recognizable on this map. To get more information, the property owner has to make an application to the authorities. Afterwards the authorities create a form and send it back to the owner by post. This ensures that only authorized persons receive information. The form consists of maps showing the flood risks for the particular property at a resolution of 1 x 1 m (grid) (see Fig. 3), explanatory texts and details of important contact persons. The goal of the detailed information is to encourage property owners to use personal consultations offered by the local drainage company. The consultants check both the property drainage system and the risk of flooding and provide recommendations for the implementation of appropriate protective measures. The methodology presented has been successfully tested in practice and is now to be introduced as an integral part of the urban flood prevention system in Bremen.

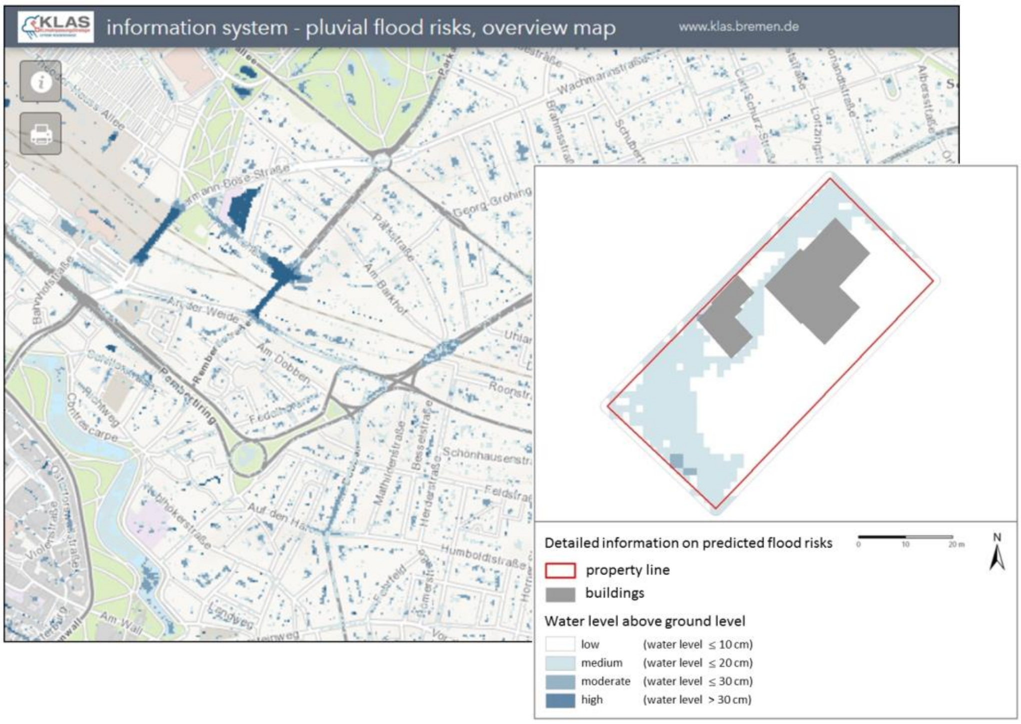

Fig. 3: Overview map (web app) and detailed information on flood risks to the particular property as part of a form

3. FLOOD PREVENTION AS AN IMPULSE FOR THE DEVELOPMENT AND DESIGN OF URBAN SPACES WITH A HIGH QUALITY OF LIFE(SAMUWA)

3.1 Status quo and background

The relationship between water resources management and urban development bodies is still characterized by a low degree of understanding of the interrelationships between water infrastructure systems, urban spaces and receiving waters (Graham and Marvi, 2001; Picon, 2005).

Based on the historically developed ideal of “clean urbanism” (De Meulde and Shannon, 2008), the design of urban spaces is aimed at discharging storm water as rapidly as possible into the underground storm-water and combined sewer system. It is necessary to awaken a new appreciation of the interrelationships between water infrastructure systems, urban spaces and receiving waters. The aim is to optimize the spatial organization of the city in the interplay between topography, surfaces, underground flow paths and land use schemes. The combination of underground and surface flood prevention measures with urban development projects being planned creates synergy options aimed at the multifunctional design of urban spaces. This enables urban development value added to be generated, while simultaneously permitting improvements of adaptability to the climate (Hoyer et al., 2011; Stokman et al., 2015). Using a case study, a methodology has been developed to use findings from urban flood prevention to support appropriate development and planning processes in urban areas. The particular work steps are described in the following sections.

3.2 Guidelines for action - a five-step methodology

3.2.1 Step 1: Definition of the spatial frame of reference and ways of understanding the water system in an urban context

To understand the water system in its urban context, a key question that poses itself is that of the spatial scope of the study: urban planners are used to thinking in terms of municipal administrative boundaries, but the latter are not oriented towards water catchment area boundaries and the corresponding flow paths of the water. By this means, an integral, multi-dimensional frame of reference is created that has "water-sensitive urban development" as its purpose.

3.2.2 Step 2: Risk analysis – urban flooding

In a multi-step analytical procedure, it is examined whether there are risky areas in the municipality, highly vulnerable to being flooded, and if so where and to what extent (see Fig. 4). The basis is ideally a municipality-wide risk assessment (Gatke et al., 2015). These areas can be subsequently examined, simulated and assessed at greater depth by means of various local detailed topographical and hydrological analyses, e.g. also using an interlinked 1D-2D sewer system-surface model. The simulation shows what paths the rainwater takes during a rainfall event and the spatial spread of the water. By subsequently superimposing the existing area and building utilization and infrastructural facility plans on these vulnerable zones, the possible impact of floods, and consequently the damage and risk potential, can be ascertained.

3.2.3 Step 3: Development of a water-related urban planning model

A water-related model, viewed from an urban planning perspective, is developed on the basis of the risk assessment (step 2). The overall urban development plans and existing development scenarios provide the groundwork for this. Existing development trends are followed up and viewed in greater depth, thus allowing the potential and challenges associated with urban planning and the design of open spaces to be utilized optimally in combination with flood risk mitigation and rainwater management (see Fig. 5).

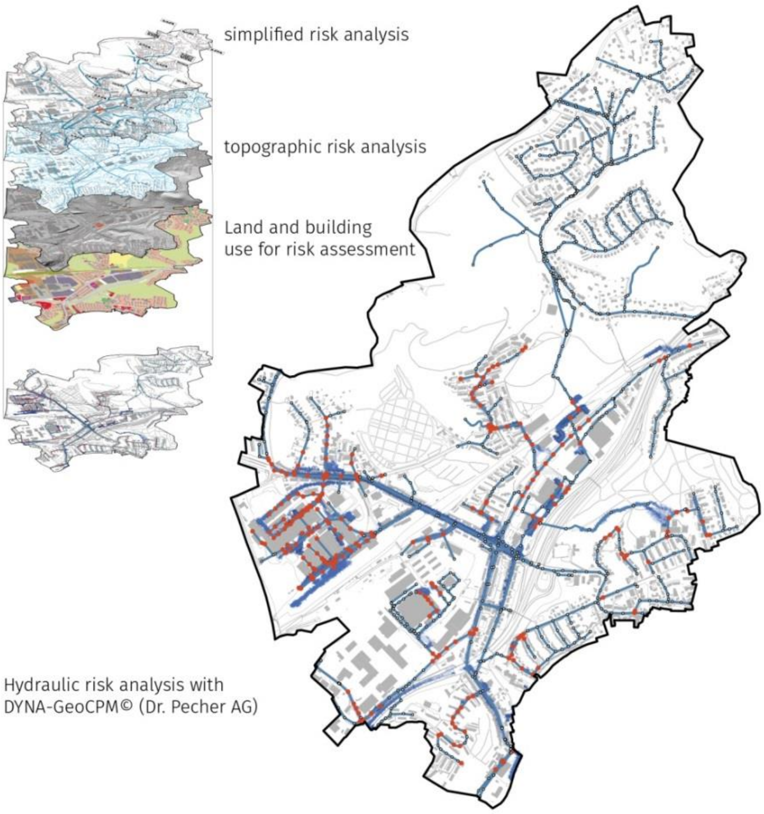

Fig. 4: Risk analysis of the project area (Dr. Pecher AG/ Institute of Landscape Design and Ecology, Stuttgart)

3.2.4 Step 4: Establishment and prioritization of focus areas

In a subsequent step, sanitary water engineering and urban planning aspects are very closely interlinked with one another: the water-related urban development model (Step 3) is superimposed on the areas highly vulnerable to flooding (Step 2). In addition, further items of information and aspects, such as any hydraulic remediation of the sewage system needed, traffic projects and the urban climate, are also included in the analysis.

The aim is to identify focus areas by revealing any possible links between the necessity for flood prevention measures and strategic urban development projects or measures capable of being executed in the short term as part of ongoing projects and also measures being taken by other development authorities (see Fig. 6).

3.2.5 Step 5: Development of integrated action and design-related concepts

For the focus areas and spheres identified, water resources management and urban design measures are subsequently developed and put into concrete form.

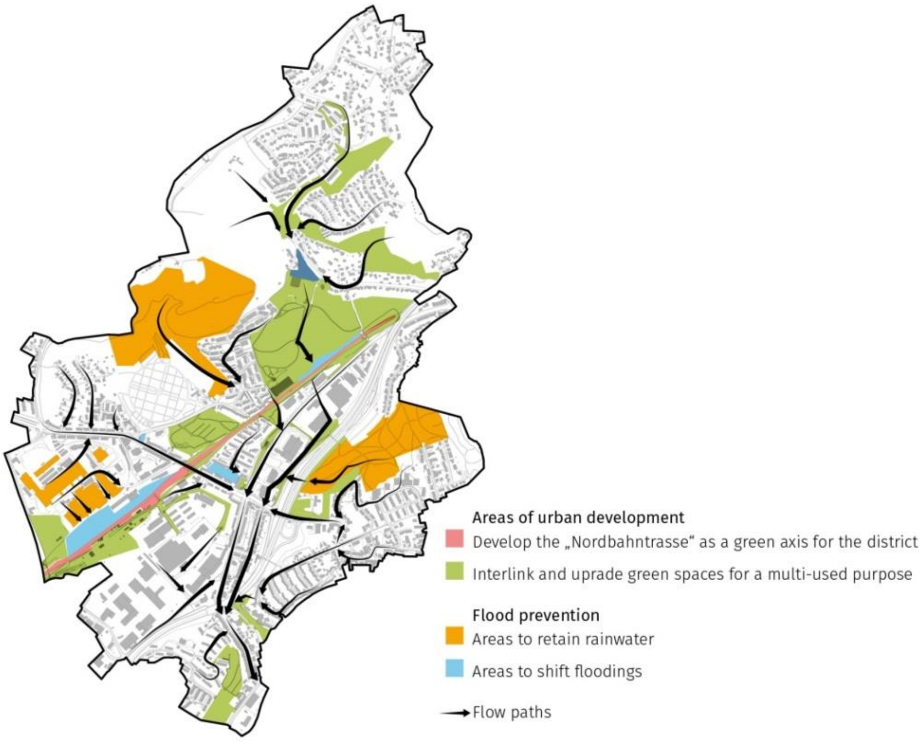

Fig. 5: Map of a water-related urban development model for the project area (Institute of Landscape Design and Ecology, Stuttgart)

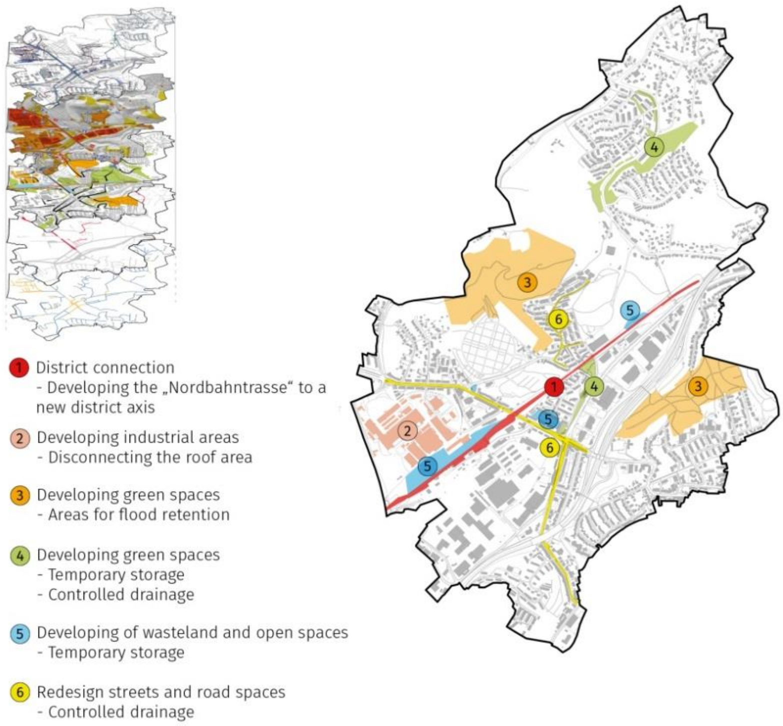

Fig. 6: The process of superimposing the maps containing the results of Steps 2 and 3 and the focus areas thus ensuing (Institute of Landscape Design and Ecology, Stuttgart)

4. CONCLUSIONS

Flood protection is to be understood as a joint community task, which requires cooperation between various protagonists. The provision and preparation of basic data is just as important as the development of a mutual, professional understanding between the parties involved. The research projects presented in this paper, deal with different strategies to develop forms of cooperation and to promote the interdisciplinary development of flood protection measures. In case studies, it has been shown that the strategies and concepts developed can already be used as effective tools to advance integrated planning processes.

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BIOGRAPHICAL NOTES

Michael Jeskulke studied Environmental Engineering at the Ruhr-University in Bochum and finished his degree in February of 2013. In his master's thesis, he focused on a simplified approach to ascertaining flood risks for large catchment areas using 1D/2D linked sewer-systems -surface models. As a postgraduate, he entered into employment and worked as a project engineer for the consulting engineers Dr. Pecher AG. Still working for this company, he is engaged in modelling and analyzing flood risks, mitigation of flood risks and the development of information systems aimed at finding new methods of collaboration between different stakeholders involved in prevention against flooding.

CONTACTS

Michael Jeskulke, M.Sc.
Dr. Pecher AG
Klinkerweg 5
40699 Erkrath
Germany
Tel. +49 2104 9396 26
Fax +49 2104 33153
Email: Michael.jeskulke@pecher.de
Website: www.pecher.de

Dr.-Ing. Holger Hoppe
Dr. Pecher AG
Klinkerweg 5
40699 Erkrath
Germany
Tel. +49 2104 9396 95
Fax +49 2104 33153
Email: holger.hoppe@pecher.de
Website: www.pecher.de

Dipl.-Ing. Christian Massing

WSW Energie & Wasser AG
Bromberger Straße 39-41
42281 Wuppertal
Germany
Tel. +49 202 569 4475
Fax +49 202 569 4486
Email: christian.massing@wsw-online.de
Website: www.wsw-online.de

Prof. Dipl.-Ing. Antje Stokman
Universität Stuttgart
Keplerstr. 11
70174 Stuttgart
Germany
Tel. +49 711 685 83380
Fax +49 711 685 83381
Email: antje.stokman@ilpoe.uni-stuttgart.de
Website: www.ilpoe.uni-stuttgart.de

Dipl.- Ing. Michael Koch
Freie Hansestadt Bremen
Der Senator für Umwelt, Bau und Verkehr
Contrescarpe 72
28195 Bremen
Germany
Tel. +49 0421 361 5535
Email: michael.koch@umwelt.bremen.de
Website: www.bauumwelt.bremen.de

Katrin Behnken, M. Sc.
Freie Hansestadt Bremen
Der Senator für Umwelt, Bau und Verkehr
Contrescarpe 72
28195 Bremen
Germany
Tel. +49 421 361 18383
Email: katrin.behnken@umwelt.bremen.de
Website: www.bauumwelt.bremen.de

Dipl.-Ing. Dietmar Gatke
hanseWasser Bremen GmbH
Birkenfelsstraße 5
28217 Bremen
Tel. +49 421 988 1153
Fax: +49 421 988 1998

Email: gatke@hanseWasser.de
Website: www.hanseWasser.de

Dipl.-Ing. Katharina Thielking
hanseWasser Bremen GmbH
Birkenfelsstraße 5
28217 Bremen
Tel. +49 421 988 1162
Fax: +49 421 988 1998
Email: thielking@hanseWasser.de
Website: www.hanseWasser.de

Jens Wurthmann, Geograph (M. A.)
hanseWasser Bremen GmbH
Birkenfelsstraße 5
28217 Bremen
Tel. +49 421 988 1222
Fax: +49 421 988 1916
Email: wurthmann@hanseWasser.de
Website: www.hanseWasser.de