Maps for natural risk management

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Abstract: Natural risk management requires maps that support analysis, assessment and handling of natural risks. It also needs maps which are suitable means for common societal decision making between different stakeholders. The paper[1] presents exemplarily some existing concepts of flood hazard and flood risk maps. They were evaluated in interviews with different stakeholders to get information how these maps can support the stakeholders' different tasks. The results will form a basis for the design of an information system for co-operative risk management.

1. BACKGROUND

The damages that natural and man made-hazards cause have been growing in the last years. For that reason disaster management becomes of particular importance. A long time, disaster management was predominately regarded as the protection of hazards, where the mean focus was on the technical protection against natural hazards, like building dikes against flood. However, this concept has its limitation: a complete protection against hazards is rather impossible. In the 1980th a new idea about disaster management evolved, the idea of risk management (HOLLENSTEIN 1997). From this point of view disaster management has to be regarded as a cycle of mitigation, preparedness, event management, and recovery of hazards. An essential issue in this concept is to deal with risk; a broad understanding of a natural hazard's risk in a certain area is fundamental due to this concept (PLATE, MERZ 2001). Therefore, an effective disaster management requires a comprehensive analysis, assessment and mitigation of risks. Furthermore, disaster management has to change into a process of common societal decision making (SCHANZE 2004). No single authorities should make an isolated decision any longer, but all stakeholders, who have to deal with disasters and their impact, have to develop co-ordinated and harmonized disaster management concepts and activities.

Risk management requires maps that depict information about spatial patterns of hazards, of vulnerability, and of risks at different regional levels and for different societal groups. Maps are important information means in the whole risk management process to get knowledge, to make decisions, to communicate information, and to raise awareness. For that reason the creation of risk maps is a point of research in many disciplines that have to deal with natural hazards like hydrology or seismology. Methods to define the risk in a particular area and for a specific hazard are developed in these disciplines. But also cartographers play an important role in making maps for a comprehensive risk management. They have to design maps that support different actors in performing their tasks and decision making and they have to depict risk information in a way, that laymen develop an understanding about risk and risk mitigation. Finally, they have to assist a co-ordinated risk management. At present, different hazard and risk maps exist that are characterized by different content and data processing as well as different -and sometimes wrong- cartographic design. These maps will be investigated how they are suitable means to support the various stakeholders in risk management.

2. RISK AND RISK MANAGEMENT

The risk of a specific hazard in a defined area is the central idea in modern disaster management concepts. What does this "risk" mean? In colloquial sense it characterizes the possibility to come to danger; in a scientific context it describes the combination of hazard and vulnerability, where "hazard" means the process that causes damages and "vulnerability" defines the exposition to a specific hazard (KUHLMANN 1995). In this paper "risk" is used in the scientific sense.

Risk management is a new approach to deal with natural disasters. It is derived from security science and has brought the turn from pure security thinking to an interdisciplinary risk culture that deals with risk on different levels and involves all stakeholders. (KUHLMANN 1995). Risk management consists of three sub processes: risk analysis, risk assessment, and risk handling. In the *risk analysis* process risks have to be identified and qualified. The goal is to get an overall overview to that what could happen. Due to this, it is necessary to look at former events, that took place, but also to consider scenarios, like worst case scenarios, to develop an idea about the potential risk. The analysis' results should be an estimation about the hazard itself and its influence on society, real values, and environment. *Risk assessment* deals with risk acceptance and protection against hazards. This is a complex process, where the right to protection and the proportion between expenditure and benefit have to be balanced against each other. *Risk handling* includes the reduction of risks as far as possible and the control of a rest risk, where no protection exists.

3. MAP TYPES FOR NATURAL RISK MANAGEMENT

3.1 General map types

Different maps were developed to support risk management in its various phases. They vary regarding to cartographic design, map content respectively considered data, aggregation of data and field of application. A systematic classification of these maps was made by MERZ and GOCHT (2003). They differentiated risk maps according to their complexity of content and distinguished following map types:

- Hazard maps. They visualise flood hazards and its spatial distribution (e. g. inundation areas with different flood probabilities, flood depth, flow velocity, flood duration, waterside erosion, mudflow sediment).
- Exposure maps. They present the spatial distribution of a hazard as well as the affected objects (e.g. flood zones of a 100 year flood and affected buildings).
- Vulnerability maps. They depict qualitative or quantitative values about the vulnerability of objects within the hazard area (e.g. the technical vulnerability of a factory with sensitive machineries or the social vulnerability of a hospital, which inhabitants need special help during a flood).
- Damage-risk maps. They show the damages in monetary values which a hazard causes (e.g. damage to be expected in a 100 year flood in Euro/m^2).

The use and the legal basis of these maps are quite different in various countries. In Switzerland for example, different types of risk maps are prescribed by regulations, their use for spatial planning is obligatory (LOAT et al. 1997). In Germany concepts of risk maps exist, too, but they were not regulated by law nationwide.

3.2 Actual map concepts for flood risk management

The following chapter presents some existing concepts of maps for risk management in Europe exemplary for floods and a particular area in East Germany[2]. They were used for an investigation of the usability of exiting risk maps for different actors in risk management (Chapter 4). Although some map design is wrong regarding to cartographic principles, we decided to keep the original design because it is already applied in practice.

Hazard Map (Switzerland)
The hazard map (Fig. 1) developed in Switzerland determines areas, "hazard zones", which are expelled from certain use due to the flood hazard. The hazard zones are aggregated on the basis of the flood probability and the potential flood intensity by means of the intensity-probability-matrix. The potential flood intensity depends on the flood depth, the flow velocity, the bank erosion and the mudflow sediment. The classification of the potential flood intensity (strong, average and weak) follows possible effects on areas of settlement (EGLI 1996; LOAT et al. 1997). The particular hazard zone (low, average or considerable) determines the application of different guidelines for spatial planning. The guidelines were primarily aligned with consequences of flood events on land use types. They were set up to support the migitation of possible effects of flood hazards to human beings and animals as well as to material assets. In the considerable hazard zone for example, no further buildings or constructions are allowed.

[2]All base maps: Raster data of the Topographic Map 1:10.000 with permission of the Landesvermessungsamt Sachsen; Permission-Nr.: 173/05. Each copy needs a permission of the Landesvermessungsamt Sachsen.

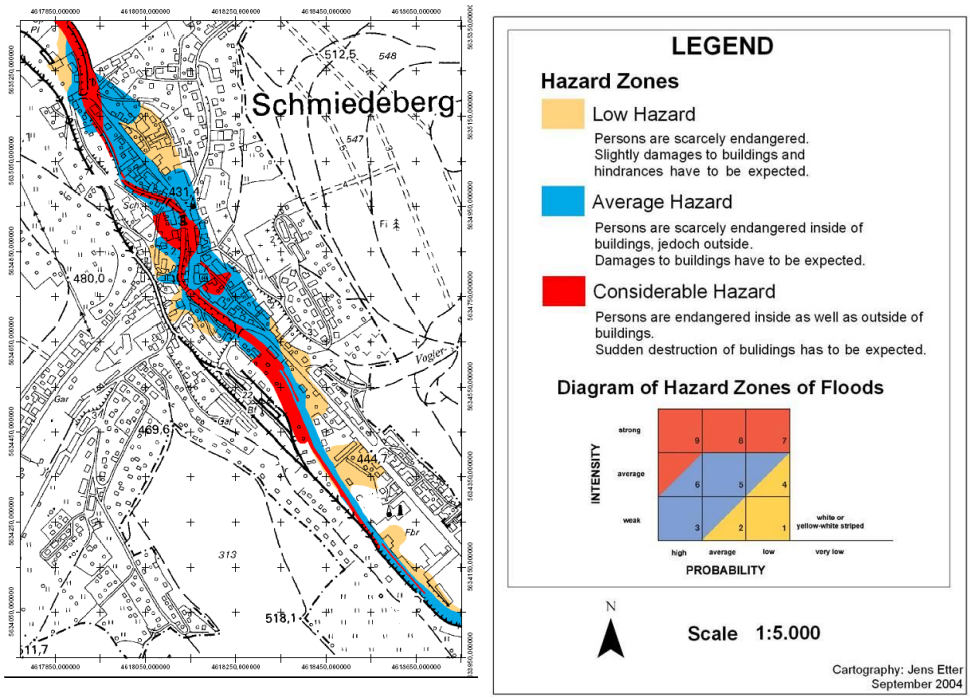

Figure 1: Example of the hazard map (Switzerland). Concept and cartographic design in accordance with the original map. (ETTER 2005)

Risk and Protection Deficit Map (Switzerland)

The risk and protection deficit map (Fig. 2) offers information about the potential risks to property and about areas with protection deficits. It bases on the hazard map described before. A protection deficit exists, if the intensity of the flood of a specific probability exceeds a defined threshold value ("protection aim"). The category of the particular object (e.g. industrial zone) specifies the applicable threshold value. The potential risk of a property is expressed as the expected annual damage to the property. The Risk- and Protection Deficit Map is used as basis of cost-effectiveness analysis of protection measures. The protection deficits illustrate under-protected areas and regions of high risks (EGLI 2001).

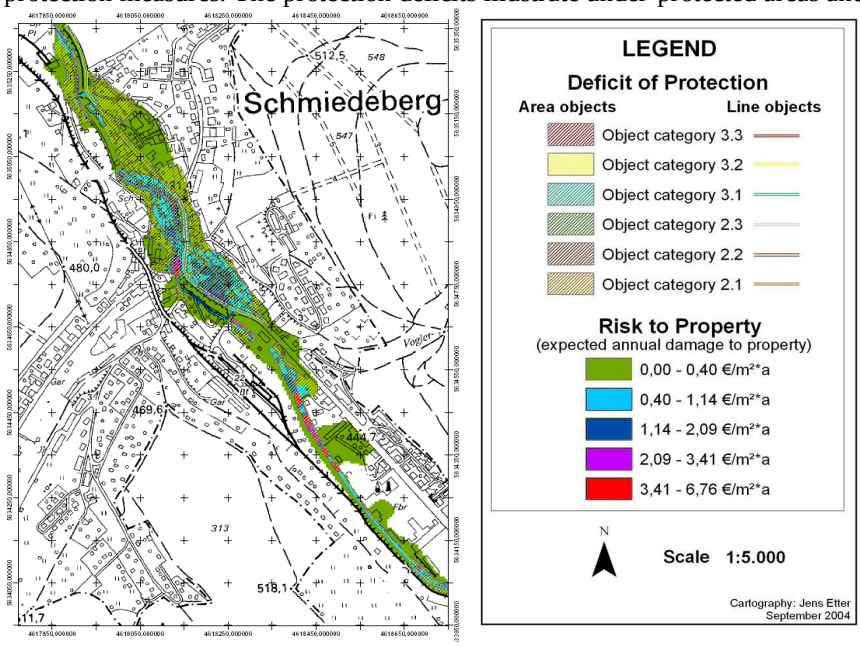

Figure 2: Example of the risk and protection deficit map. Concept and cartographic design in accordance with the original map. (ETTER 2005)

Risk Map of Insurance Companies (Germany)

German insurance companies developed the "Zone System for Localisation of Hazard Areas in Case of Flood, Retention and Heavy Rain (ZÜRS)". It allows the cartographic visualisation of so called "zones" in risk maps of insurance companies (Fig. 3). The zones are derived from probability of floods and consequent flood plains. The maps serve insurance companies for decisions about an insurability of objects (MÜLLER 2001; FALKENHAGEN 2004).

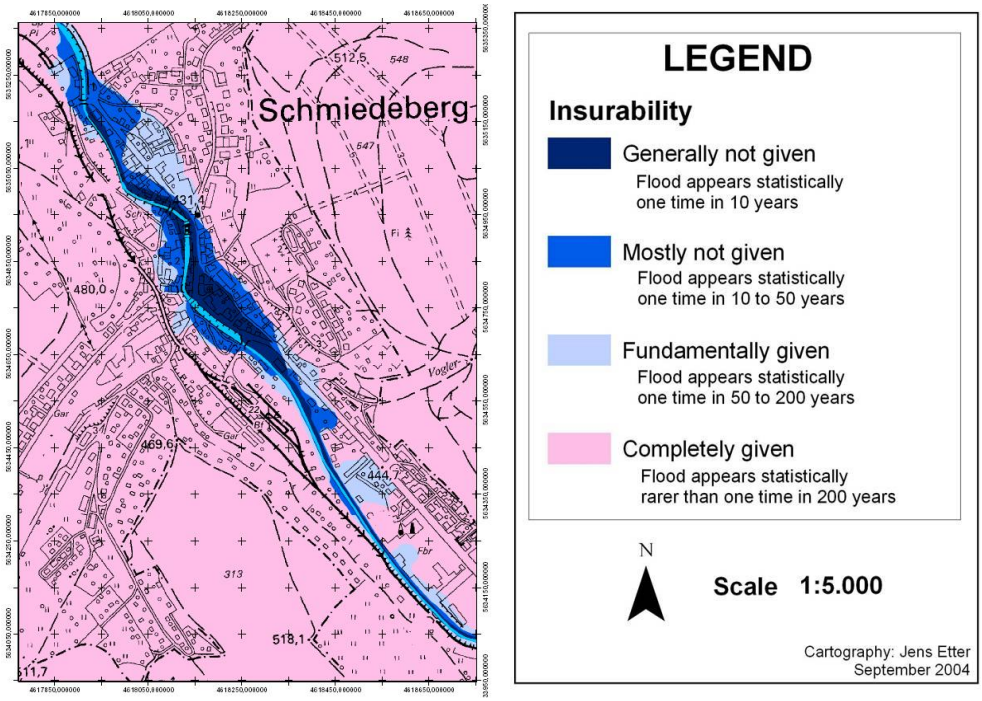

Figure 3: Example of the risk map of insurance companies (Germany). Concept and cartographic design in accordance with the original map. (ETTER 2005)

Risk of Damage Map (Germany)

The risk of damage map (Fig. 4) visualises the spatial distribution of potential risks of damages. The potential risk of a damage is expressed as the expected annual damage to a property. It is divided into different risk zones. The potential risk of damage is apprehended as the interaction of flood hazard and vulnerability. The vulnerability is calculated by application of damage functions which determine the damage of a single object depending on the flood depth. The Risk of Damage Map supports the economic assessment of flood prevention measures within the scope of cost-benefit analysis. In addition, it can be used as basis of the calculation of insurance premiums (MERZ et al. 2003).

Rhine Atlas - Hazard Map and Map of Potential Damages to Property (Switzerland, Germany, France, Netherlands)

The International Commission for the Protection of the Rhine (Internationale Kommission zum Schutz des Rheins (IKSR)) published the Rhine Atlas in 2001. The objectives of the Rhine Atlas are to illustrate existing flood risks and thereby to reinforce flood awareness of the general public. In addition, the Rhine Atlas is the basis for flood mitigation measures within the scope of the "Action Plan Rhine" (IKSR 2001). The Rhine Atlas covers the whole Rhine river catchment. It contains "Rhine Atlas – Hazard Maps" and "Rhine Atlas – Maps of Potential Damage to Property".

Rhine Atlas – Hazard Map

The "Rhine Atlas – Hazard Map" (Fig. 5) visualises the inundation areas of a 10 year and a 100 year recurrence as well as the flood plain and the flood depth of an extreme flood event in classes (<0,5 m, 0,5 - 2 m, 2 – 4 m, >4 m). The classification of the flood depth follows the expected effects of static flood events on persons and material assets (e.g. the danger to loss life and a high probability of total destruction of material assets exists in the case of a flood depth with more than 4 m). Additionally, the Rhine Atlas – Hazard Map gives information about the affected and endangered persons in case of an extreme flood event (IKSR 2001).

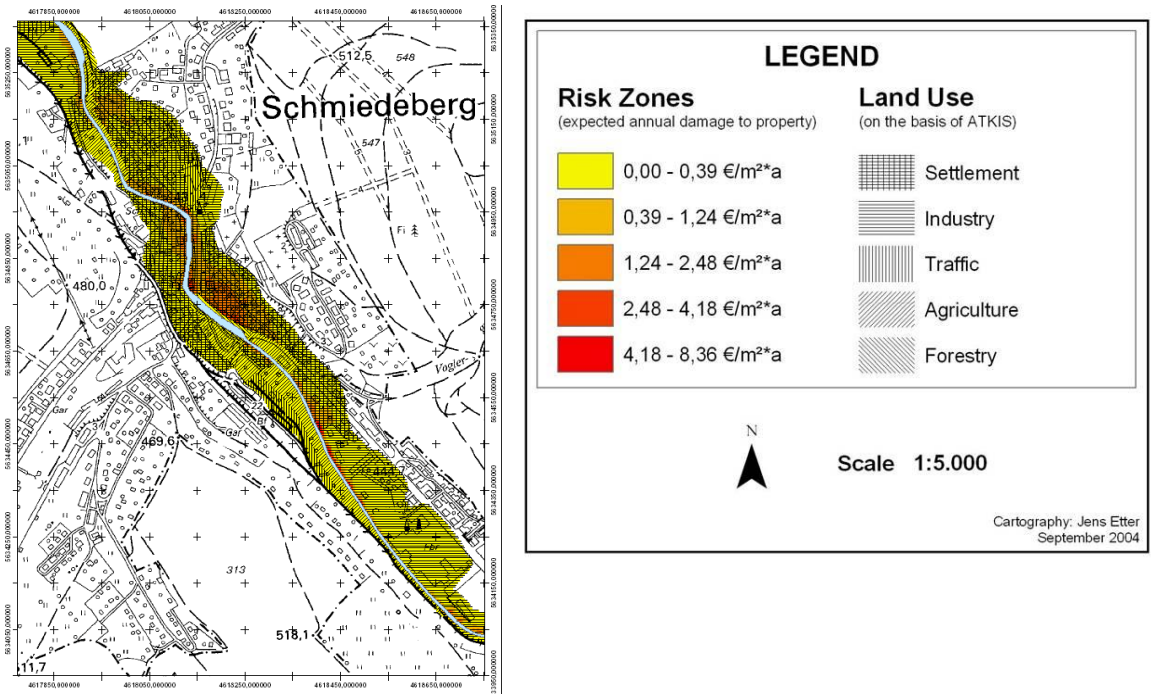

Figure 4: Example of the risk of damage map (Germany). Concept and cartographic design in accordance with the original map. (ETTER 2005)

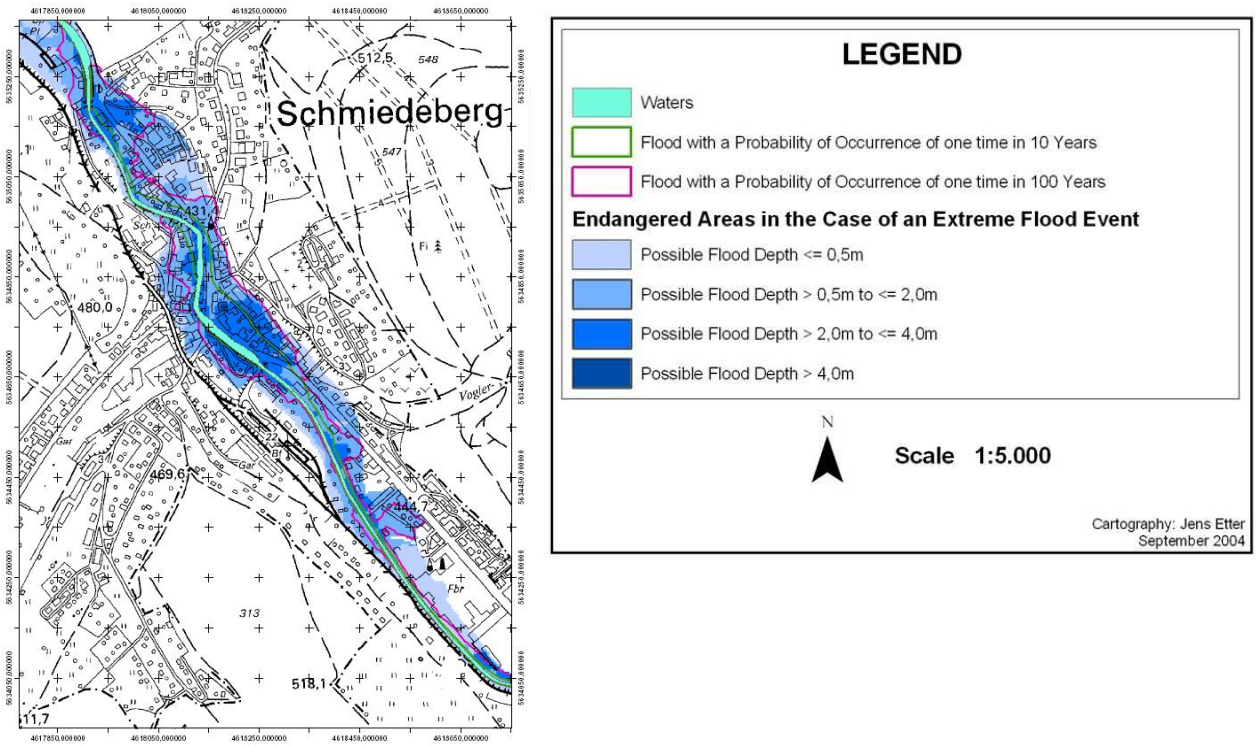

Figure 5: Example of the Rhine Atlas hazard map. Concept and cartographic design in accordance with the original map. (ETTER 2005)

Rhine Atlas – Map of Potential Damages to Property

The „Rhine Atlas – Map of Potential Damages to Property“ (Fig. 6) provides information about possible damages of an extreme flood event. On the basis of specific property assets and flood depths of an extreme flood event, potential damages are calculated by means of damage functions. The possible damages are differentiated according to land use (IKSR 2001).

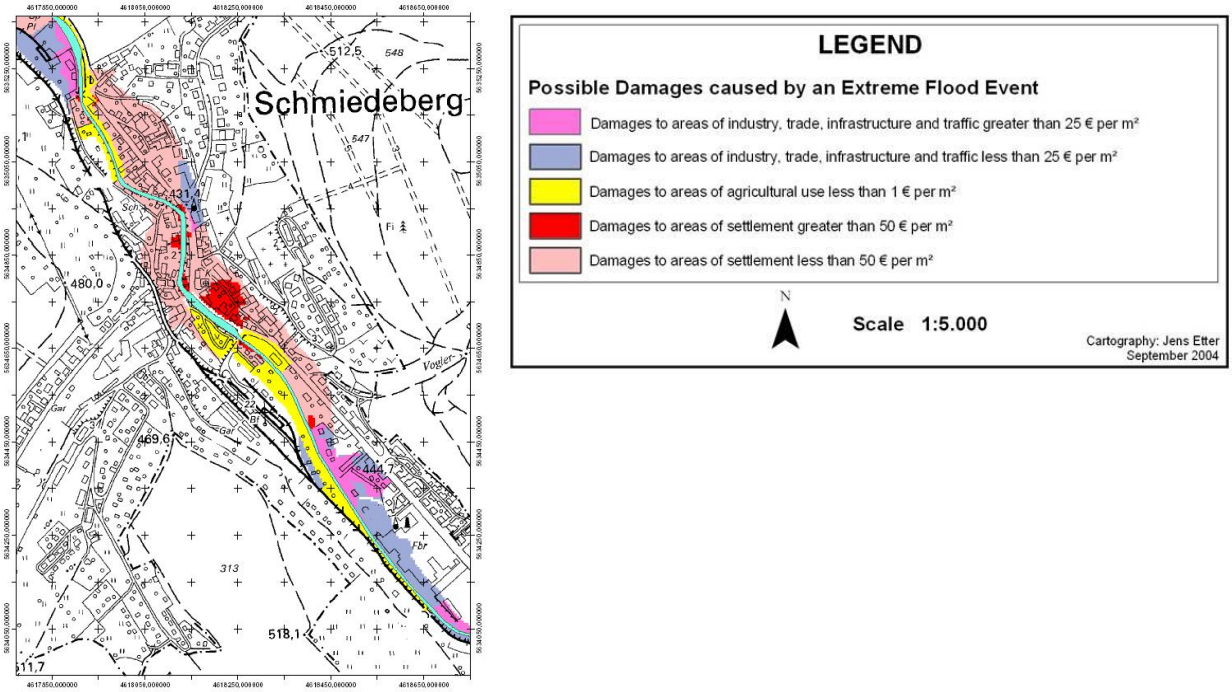

Figure 6: Example of the Rhine Atlas map of Potential Damages to Property. Concept and cartographic design in accordance with the original map. (ETTER 2004)

4. ACTOR- ORIENTED RISK MAPS

The culture of risk which is a core-idea in modern risk management requires a broad societal co-operation of all stakeholders as well as co-ordinated and harmonized decisions and activities. The project "Co-operative flood risk management using an environmental information system", which is located at the Leibniz Institute for Ecological and Regional development, aims to develop a theoretical, methodological and technical framework of regional co-operation in flood risk management. Different aspects of this cooperation, like its organization and shape, have to be examined. From a cartographer's point of view, the most interesting question is, yet, how the information system and its maps should be designed to support the involved stakeholders in performing their tasks and co-ordination.

4.1 Basic principles of actor-oriented maps

In the last years, the tasks maps are used for as well as the map users in the sense of an acting person, attract attention in cartographic research (BOLLMANN 1996, DRANSCH 2003). Modern interactive information systems, especially on the internet, allow creating different maps for specific requirements of actors with their varying knowledge and tasks. Thus, the technical equipment to realize *task*- and *actor-oriented* maps exists. But we are still lack of knowledge how to design these maps that they really support the different actors and their needs.

Cartography developed several methods for map design which are based on aspects of semiotics, communication, perception and map function (IMHOF 1972, BERTIN 1974, MCEACHREN 1994). For an actor-oriented map design, however, it is necessary to incorporate and accentuate the map user's task and related activities. Thus, an actor-oriented cartography has to take a closer look to activities and to develop principles for an actor-oriented map design. Activity theory can give a good framework for this (DRANSCH 2003).

According to that theory an activity can be described as a process in which actions are planned, executed and evaluated. Human activities are always initiated by and directed to a specific goal. The goal determines and structures each activity. Activities are inextricably linked with a certain situational context. The context shapes the action goals, it defines the community of persons who are involved in an activity and their roles, finally it determines the rules and circumstances that effect an activity. Activities are performed with the help of artefacts. For that reason, artefacts have a particular significance: They are mediators between the intended goal and the activity's result. The artefacts' properties and characteristics decisively influence the way in which an activity can be performed and also its quality. They also determine if the goal can be fulfilled at all. Artefact and action stand in a strong relationship to each other. The artefact's properties determine the action; the action, conversely, defines the artefact's properties. Activities also

influence a person's knowledge and vice versa. Thus, an actor's knowledge is closely related to his activities (NARDI 1996). According to this concept maps are regarded as *artefacts* that are used to execute activities. Consequently, map design has to consider all aspects related to activities as mentioned above (DRANSCH 2001).

4.2 Actor-oriented flood risk maps - a case study

In the context of flood risk management an actor-oriented approach of information presentation was applied by Dapp (2002). He distinguished several groups of actors and described their demands on actuality, accuracy and processing of information. Although his presentation is on a generalized level, it gives a direction about the different actors' needs. Dapp's work is a good contribution to the actor-oriented design of maps for flood risk management, but it needs to be improved, it has to be elaborated in more detail. In our research work we want to do some of this elaboration. We started with the evaluation of existing flood hazard and flood risk maps which were introduced in chapter 3. Different institutional actors were asked in an interview if the existing maps are suitable artefacts for their specific tasks, and how the maps should be changed to become a more useful artefact for their work and decision making. The investigation should bring more clarity into the different users' needs and give details how an interactive map-based information system for flood risk management should be designed.

The case study
Setting
The investigation was carried out in the context of the project "Co-operative flood risk management using an environmental information system" mentioned above. This project is geographically located in the Weisseritz catchment. The Weisseritz river is a left tributary of the river Elbe in Saxony, Germany with a catchment size of 386 sqkm. In August 2002 the Weisseritz inundated large urban areas and the countryside along the river. In the project the most important stakeholders of flood risk management were identified and 25 institutions agreed to work together. From this group a representative selection of institutions should be interviewed. Following stakeholders/actors were selected:

- Local government
- Water management authority
- Environmental department
- Forest department
- Regional planning authority
- Building authority
- Local pressure group

The maps for the interviews were derived from the map concepts introduced in chapter 3. Several maps were realized in accordance to the respective method and cartographic design on a scale of 1:5000 for "Schmiedeberg", a certain area in the Weisseritz catchment (see Fig. 1-6). As mentioned already, although some map design is wrong regarding to cartographic principles, we decided to keep the original design because it is already applied in practice. For the realisation of all maps we used the tools and methods of Geographical Information Systems.

The interviews itself were organised as *expert interviews,* a data collection method where a specific person who assumes responsibility for something or who has privileged access on information will be asked (Meuser et al 1991).The interview was also organised in a structured form. First of all the experts were asked about their experiences with flood hazard and risk maps. The second complex of questions dealt with the tasks and decisions the particular institution is concerned with in flood risk management. The central part included questions about the usability of the particular hazard and risk maps realized for Schmiedeberg in the context of the expert's or institution's tasks. The person should evaluate the different concepts and make contributions to improve the maps. Finally, we wanted to get some opinions of the experts about a dissemination of hazard and risk maps for the public. This aspect is quite sensible because risk maps show the vulnerability of real estates and can influence their estimated value.

Result
A summary of the experts' interviews are given in Table 1. It shows

- the actors and their general experience with hazard and risk maps,
- the tasks
- the maps which are suitable for the specific tasks and the proper scale,
- completions or modifications of the maps' content or design,
- the experts' opinion about publishing flood hazard and risk maps.

Actor	Familiar maps	Tasks	Suitable maps/ Scale	Completion, Modification	Opinion to publish maps
Environmental department	Hazard map (Switzerland)	Responsible for flood protection, Determining flood areas	Rhine Atlas hazard map, Rhine Atlas map of potential damages to property, Risk of damage map (even better than the one before) Scale: not to large because of make-believe security	"Hot Spots" = areas with high danger, Flow velocity of extreme floods	All information should be published with the exception of risk maps of insurance companies
Regional planning authority	none	Determining areas for preventing flood protection	Risk and protection deficit map, Risk of damage map, Rhine Atlas hazard map, Rhine Atlas map of potential damages to property Scale: 1: 100 000	Land use, Natural flood plains, Dams and storage reservoirs with capacity values, Areas for bed load, Areas with a specific damage potential, Areas that could be flooded in case of a breaking dyke Suggestions for changes in land use	Information should be published
Local Government	Maps of local Water Management Authority, (scale too small)	River development, Bank reinforcement	Hazard map (Switzerland), Rhine Atlas hazard map, Rhine Atlas map of potential damages to property, Risk of damage map Scale: large scale	Risk and protection deficit map is incomprehensible, Up-to-date information is necessary	Publication of Rhine Atlas hazard map
Building Authority	Hazard map (Switzerland)	Urban land use planning, Construction licensing procedure	Hazard map (Switzerland), Rhine Atlas hazard map Scale: 1:5000 – 1:10000	Flood depth at different flood events,	Publication of hazard maps, They should be created for different flood events
Forest Department	none	Forest development, Condition of riverine	Rhine Atlas hazard map Scale:	"Hot spots" = Areas with high flow velocity and great flood depth	Rhine Atlas hazard map. Important: not to

		vegetation, Determining areas of forestation	1:5000 – 1:10000	Flood depth necessary for stabilization of forest areas Protection deficit map would be useful for natural objects	present all sort of information but the relevant information
Water Management Authority (Dams and storage reservoirs)	Rhine Atlas hazard map		The maps are not useful, because they have their own flood information system		Information about hazards and risks are necessary for the public
Local Pressure Group	none	Water erosion reduction; Water storage in the ground	All maps with exception of risk of damage map	Maps should not be restricted to valleys, they should also depict the affecting hinterland	Risk and protection deficit map

Table 1: Results of the expert interviews with different stakeholders

In summary the interviews show that little experience exists about hazard and risk maps among the stakeholders up to now. The only map they are familiar with is the Rhine Hazard map. The interviews make also clear, that the maps which were developed for risk management are suitable in a various degree for all stakeholders. Especially both Rhine Atlas maps and the risk of damage map are good means for most of the stakeholders. The protection deficit map was mentioned only twice, it seems to be too complicate and it depicts only anthropogenic but no natural objects. The map of insurance companies is not suitable in this context because it is to specific. Additionally, the different tasks require information that goes beyond the existing maps; this information should be presented, too. Also maps in different scales are necessary. A publication of hazard and risk information is discussed diversely. All stakeholders agree that public needs information about hazards to raise awareness of flood events and direct responsibility, and to get knowledge about floods, flood velocity and depth. However, they differ if it is useful to show different risk of damages for properties and single houses.

Appreciation
This investigation is a first step to improve knowledge about task- and actor-oriented maps in risk management. Further investigations are necessary, which address all aspects of task- and actor-oriented maps presented in chapter 4.1, and which involves also the public as an important stakeholder. Only this comprehensive consideration can give an entire insight in the actors' requirements and form a basis for an information system that supports effectively a common societal decision making process. In another research work we already started with an inquiry of the public and its demands on information about flood risk management to complete the investigation described in this paper. A further point of importance in terms of a well created information system is the redesign of most of the introduced maps according to cartographic principles.

5. CONCLUSION

Modern risk management which has to deal not only with analysis, assessment and mitigation of risks but also with many stakeholders and a common societal decision making process requires appropriate information about hazards and their impact to cope with all these demands. The hazard and risk maps, introduced in this contribution, serve as good information means. The case study pointed out that existing maps are suitable for the various stakeholders in dependence of the tasks that have to be performed. Additional information is necessary that goes beyond that which is presented in existing maps already; it should be visualized, too. The investigation made also clear, that cartographers have to be involved in the map making process to design maps that are correct according to cartographic principles. If the concept of modern risk management described above should become a successful instrument against natural hazards, various issues have to be considered. Certainly one issue is a suitable, and understandable form of information presentation. For that reason, cartographers should increase their work on hazard and risk maps in co-operation with hazard specialists in future.

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