Chance at foresight - risk of misuse?

An empirical study of scenario simulation for natural hazard risk management

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Vorgelegt von

Stina Kjellgren

aus Kiaby, Schweden

Hauptberichter:	Prof. Dr. Ortwin Renn
Mitberichter:	Prof. Dr.-Ing. Michael M. Resch

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Contents

Contents ii

Summary v

Zusammenfassung viii

Acknowledgements xi

List of Figures xii

Abbreviations xiii

1 Introduction **1**
1.1 Outlining the research interest 4
1.1.1 Research questions and study design 7
1.1.2 The choice of flood maps in Baden-Württemberg 8
1.2 Previous literature on flood hazard maps 10
1.3 Purpose and disposition 20

2 Simulation beyond the science sphere **22**
2.1 Definition and characteristics 22
2.1.1 What is simulation? 23
2.1.2 What makes simulation 'special'? 26
2.1.2.1 The epistemology of simulation 27
2.1.2.2 Visualization of results: Seeing is believing? 32
2.2 The simulation-policy/practice interface 35
2.2.1 Perceived risks 36
2.2.1.1 The 'over-critical' approach 37
2.2.1.2 The 'under-critical' approach 39
2.2.2 Solution suggestions 41

3 The science-policy nexus and research utilization **45**
3.1 Science in the policy sphere 45
3.2 What is research use? 47
3.2.1 Typologies of research utilization 47
3.2.2 Use, misuse and non-use of research 51

3.3 Explaining research use . . . 54
3.3.1 Credibility, saliency and legitimacy . . . 56
3.3.2 Further affecting factors . . . 60
3.3.3 The role of uncertainty . . . 63
3.4 Implications for the empirical study . . . 66

4 Flood hazard maps in Baden-Württemberg 69
4.1 Simulating flood hazard . . . 69
4.1.1 The *how* of flood scenario simulation . . . 70
4.1.2 Sources of simulation uncertainty . . . 72
4.2 The case of Baden-Württemberg . . . 74
4.2.1 Flood risk management and its challenges . . . 74
4.2.2 Flood hazard mapping in Baden-Württemberg . . . 80
4.2.3 Special features: legal status and linkage . . . 85
4.2.4 Intended areas of application . . . 87

5 Method and material 91
5.1 The study interest and research questions . . . 91
5.2 Research design: Exploratory case study . . . 92
5.2.1 Sampling . . . 95
5.2.2 Interviews . . . 101
5.2.3 Data analysis . . . 103

6 Utilization of flood hazard maps 105
6.1 (Non-)Usage per management field . . . 105
6.1.1 Technical protection . . . 105
6.1.2 Emergency management . . . 112
6.1.3 Non-structural alleviation . . . 121
6.1.4 Risk communication . . . 127
6.2 Complementary observations . . . 136

7 Factors affecting application 139
7.1 Reasons for (non-)use per management field . . . 139
7.1.1 Technical protection . . . 139
7.1.2 Emergency management . . . 143
7.1.3 Non-structural alleviation . . . 147
7.1.4 Risk communication . . . 152
7.2 Complementary observations . . . 160
7.2.1 Credibility and the presence of uncertainty . . . 163

8 Benefits and problems 172
8.1 Flood hazard maps as input to risk management . . . 172
8.2 Benefits . . . 172
8.2.1 Benefits of knowledge, guidance and persuasion . . . 173
8.2.2 Benefits of pressure and restriction . . . 177

8.3 Problems: under-usage and risk of negative implications 183
8.3.1 What about non-experts' handling of uncertainty? 188

9 Discussion 198
9.1 Discussion per research question 198
9.1.1 How flood hazard maps are used 198
9.1.2 Factors affecting whether flood hazard maps are used 205
9.1.3 Benefit and problems associated with flood hazard maps . . 212
9.2 Implications for the overall research interest 216

10 Excursion: Alpine hazard simulation in Austria 219
10.1 Motivation, method and material 219
10.1.1 Contrasts between alpine and riverine hazard simulation . . 221
10.2 Simulation as input to risk-management 223
10.2.1 Benefits... 224
10.2.2 ...and problems? 229
10.3 Different audiences' responses to simulated hazard assessments . . . 231
10.3.1 Regional development planners and local leaders 231
10.3.2 Private actors and publicly owned enterprises 236
10.3.3 Regional-level risk managers 240
10.4 Reflection on the original case study findings 247

11 Conclusion 249

A Translations of German quotes 262
A.1 Quotes in chapters 2-5 262
A.2 Quotes in chapter 6 263
A.3 Quotes in chapter 7 274
A.4 Quotes in chapter 8 283
A.5 Quotes in chapter 10 291

Bibliography 300

Declaration of Authorship 317

Summary

For the past few decades, the losses caused by natural catastrophes have risen continuously. Though changing hazard frequencies may explain *some* of this, it cannot be neglected that human and social drivers play a role too; hence, the importance of effective management strategies. A problem in this regard concerns that it is often difficult to get decision-makers to prioritize preparedness planning and risk management measures in times of calm, meaning that it is often not until disaster has already hit that necessary reforms are being implemented.

In theory, the possibility to simulate the likely outcomes of one or more natural hazard scenarios represents a promising prospect for change in this respect. By showing the consequences of being hit while there is still time to act, simulations – so it is proposed – will motivate decision-makers to take relevant steps and measures *in foresight rather than in hindsight*. At the same time, all models are simplifications of reality, meaning that all output will be associated with intrinsic uncertainties and predictive limitations. In this regard, it is often pointed to as a risk factor that actors in policy and practice without specific expertise in the field of modeling and simulation (so called 'non-experts') may nevertheless expect these to deliver certain research results in line with what has been achieved in relation to invariant natural phenomena in the hypothetico-deductive science tradition.

Based on the analysis of available social science literature, a misconception about the epistemological nature of simulation is proposed to be associated with two types of dangers. First, it can lead intended users to take an 'over-critical' approach to simulation results, meaning that unrealistic expectations about science's ability to deliver certain knowledge translates into low confidence in output associated with natural levels of uncertainty. The effect of this may be non-use, in which case potentially valuable insights will go unheeded. Second, a misconception about simulation's epistemological nature can lead intended users to take an 'under-critical' approach to simulation research. In practice, for example, public officials in government and administration sometimes satisfy with limited or nonexistent expressions of uncertainty and model and data assumptions, although this can lead

to blind spots. Because graphical representations of findings *look* convincing, so the reasoning goes, and because non-experts often lack experience in working with this type of research, they may accept these as 'the truth' without much critical reflection. As demonstrated by concrete empirical examples, the consequences of this can be suboptimal decision-making, either in the sense of not accounting for the implications of uncertainty or in the sense of – unintentionally – relying on research of questionable quality. Both possibilities concern a form of 'misuse' of available knowledge, and both can be extremely costly in their consequences.

In light of this analysis, it is relevant to explore how simulation-based information about the likely consequences of natural hazard scenarios are responded to and used by non-experts responsible for directing and managing the communal response to this threat. On the one hand, hazard maps and other forms of simulation-based hazard assessments can allow for better planning and decision-making in relation to technical protection, emergency management, non-structural alleviation and risk communication. On the other hand, there is also the risk of them not being used or – perhaps even worse – of them being misused.

The research questions that have guided this study concern how and why (or why not) graphical scenario simulation results are used in relation to risk management of natural hazards, and with what benefits and problems this is associated. As case study, the introduction of flood hazard maps to municipalities in the German state of Baden-Württemberg was selected. Qualitative data was collected through interviews with, on the one hand, local-level risk managers (mayors and civil servants) and, on the other hand, external experts (e.g. modelers, engineers and higher-level public officials) with insight into the state's mapping project and its implementation.

In a second step, following the realization that the interviewees in Baden-Württemberg did *not* regard uncritical acceptance of flood simulation results as a great cause for concern, a small excursion was made into the field of alpine hazard simulation in Austria. Here, a small number of additional interviews were carried out to see whether this finding would hold true for other simulation products and user groups as well. Together, the results are used to develop a theoretical argument as to how it can be that under-critical acceptance of simulation output does not always constitute a cause for concern.

Zusammenfassung

In den letzten Jahrzehnten sind die Verluste, welche durch Naturkatastrophen verursacht werden, kontinuierlich gestiegen. Zwar kann eine höhere Frequenz solcher Ereignisse einen Teil dieses Anstiegs erklären, es darf aber nicht übersehen werden, dass menschliche und soziale Einflussfaktoren ebenfalls eine Rolle spielen. Dabei ist es problematisch, dass es oft schwer ist, Entscheidungsträger dazu zu bewegen, Bereitschaftsplanung und Risikomanagementmaßnahmen in Zeiten der Ruhe zu priorisieren, was bedeutet, dass die notwendigen Reformen oft erst umgesetzt werden, wenn die Katastrophe bereits eingetroffen ist.

In der Theorie stellt die Möglichkeit, die voraussichtlichen Effekte von einem oder mehreren Naturgefahrenszenarien zu simulieren eine viel versprechende Perspektive für einen Wandel dar. Durch das Aufzeigen der zu erwarteten Konsequenzen während es noch Zeit zu handeln gibt, können Simulationen – so die Theorie – Entscheidungsträger motivieren, präventiv anstatt im Nachhinein relevante Schritte und Maßnahmen zu ergreifen. Zugleich sind alle Modelle Vereinfachungen der Realität und somit alle Ergebnisse von Simulationen mit eigenen Unsicherheiten und Einschränkungen verbunden. In diesem Zusammenhang wird als Risikofaktor oft genannt, dass Akteure in Politik und Praxis ohne Fachwissen bezüglich Modellierung und Simulation (sogenannte 'Nicht-Experten') trotzdem erwarten, dass simulationsbasierte Forschungsergebnisse sichere Voraussagen darstellen, so wie sie der Forschung in der hypothetisch-deduktiven Wissenschaftstradition gelungen sind.

Laut der Analyse der vorhandenen sozialwissenschaftlichen Literatur können falsche Vorstellungen bezüglich des epistemologischen Statuses von Simulationen auf zwei Arten negativ sein. Zunächst können sie bei vorgesehenen Anwendern dazu führen, eine "überkritische" Haltung zu simulationsbasierten Forschungsergebnissen einzunehmen, was bedeutet, dass unrealistische Erwartungen bezüglich wissenschaftlicher Möglichkeiten, bestimmte Erkenntnisse zu liefern zu geringem Vertrauen in 'normal' unsichere Ergebnisse führt. In der Folge werden verfügbare Ergebnisse nicht verwendet und möglicherweise wertvolle Erkenntnisse bleiben unbeachtet.

Zweitens können solche falschen Vorstellungen vorgesehene Anwender dazu bringen, eine "unterkritische" Haltung zu simulationsbasierter Forschung einzunehmen. Zum Beispiel zeigt empirische Forschung, dass Beamte in Regierung und Verwaltung trotz geringer oder nicht vorhandener Darstellung der Unsicherheit und der Modell- und Datenannahmen zufrieden sind, obwohl dies zu blinden Flecken führen kann. Weil grafische Darstellungen die Ergebnisse überzeugend *aussehen* lassen und weil es Nicht-Experten oft an Erfahrung im Umgang mit dieser Art von Forschungsergebnissen fehlt, besteht die Gefahr, dass sie unkritisch Simulationsergebnisse akzeptieren und diese als sicherer behandeln, als sie wirklich sind. Wie durch konkrete empirische Beispiele gezeigt worden ist, kann das zu suboptimaler Entscheidungsfindung führen, entweder weil die Auswirkungen von Forschungsunsicherheit übersehen werden oder weil man sich unwissentlich auf Erkenntnisse verlässt, deren Qualität Akteure mit mehr Wissen in Frage stellen würden. Beides stellt eine Art von Fehlanwendung dar und beides kann sehr teuer werden.

Angesichts dieses Problempotenzials ist es relevant zu erforschen, wie auf simulationsbasierte Informationen über die wahrscheinlichen Folgen von Naturgefahrenszenarien reagiert wird und wie sie durch Nicht-Experten für die Leitung und Organisation der Reaktion einer Gemeinschaft auf diese Art von Bedrohung verantwortlich eingesetzt werden. Einerseits können Gefahrenkarten und andere grafische Darstellungen vorhergesagter Ergebnisse zu besser informierter Planung und Entscheidungsfindung in Bezug auf technischen Hochwasserschutz, Katastrophenschutz, nicht-strukturelle Vorbeugung und Risikokommunikation führen. Andererseits gibt es auch das Risiko der Nichtbenutzung und – vielleicht schlimmer noch – der Fehlanwendung.

Die Forschungsfragen, die diese Studie geleitet haben sind wie und warum (oder warum nicht) visualisierte Simulationsergebnisse von Gefahrenszenarien in der Praxis eingesetzt werden und mit welchem Nutzen und welchen Problemen das verbunden ist. Als Fallstudie wurde die Einführung von Hochwassergefahrenkarten als Instrument für lokales Risikomanagement im deutschen Bundesland Baden-Württemberg ausgewählt. Qualitatives Datenmaterial wurde durch Interviews mit, einerseits, kommunalen Risikomanagern (Bürgermeistern und Verwaltungsbediensteten) und, anderseits, externen Experten (Modellierern, Ingenieuren und übergeordneten Beamten) mit Einsicht in das Gefahrenkartierungsprojekt generiert.

Nach der Erkenntnis, dass die Experten in Baden-Württemberg unkritische Akzeptanz *nicht* als allzu großen Anlass zur Sorge betrachten, wurde in einem zweiten Schritt ein kleiner Exkurs in den Bereich der alpinen Gefahrensimulation in Österreich gemacht. Hier wurde eine kleine Anzahl weiterer Interviews geführt, um zu sehen, ob diese Aussage auch für andere Simulationsprodukte und Anwender zutreffend ist. Zusammen werden die Ergebnisse genutzt, um ein theoretisches Argument dafür zu entwickeln, wieso unterkritische Anerkennung von Simulationsergebnissen nicht immer einen Grund zur Sorge darstellt.

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List of Figures

3.1 Use, misuse and non-use of research. Adapted from Cousins (2004, pp. 392). 53

4.1 Example flood hazard map depicting inundation depth for the HQ100-scenario: “Überflutungstiefen für HQ100” (LUBW, 007a) 82
4.2 Example flood hazard map depicting inundation extent for different HQ-scenarios: “Überflutungsflächen für HQEXTREM, 100, 50, 10” (LUBW, 007b) 82

5.1 Overview of interviewed risk managers 98
5.2 Overview of interviewed experts 100

9.1 Overview of main benefits identified 214

Abbreviations

SELECTED ACRONYMS:

DTM	**D**igital **T**errain **M**odel
GBP	**G**reat **B**ritish **P**ound
GIS	**G**eographical **I**nformation **S**ystem
ICS	**I**nstrumental **C**onceptual **S**trategic
KU	**K**nowledge **U**tilization
NWS	**N**ational **W**eather **S**ervice
STS	**S**cience and **T**echnology **S**tudies
USD	**U**nited **S**tates **D**ollar
1D	**O**ne-dimensional
2D	**T**wo-dimensional
3D	**Three**-dimensional

SELECTED TRANSLATIONS:

Administrative District Office	Landratsamt
Expert opinion	Gutachten
Flood fact sheets	Hochwasser Steckbriefe
Flood association	Zweckverband Hochwasserschutz
Legally binding development plan	Bebauungsplan
Preparatory land-use plan	Flächennutzungsplan
Regional Administrative Authority	Regierungspräsidium
Service for Avalanche and Torrent Control	Wildbach- und Lawinenverbauung

Chapter 1

Introduction

> *Misuse of predictions can lead to greater costs than if no prediction were provided.* (Pielke, 1999, pp. 98)

In April 1997, communities along the Red River of the North, USA, experienced extreme flooding. Most of the 1-2 billion USD worth of damage occurred in the two towns Grand Forks (North Dakota) and East Grand Forks (Minnesota), located at opposite sides of the river. Almost immediately after the flood, residents and policy makers in Grand Forks and East Grand Forks began to blame the disaster on the river stage forecast issued by the National Weather Service (NWS) (Pielke, 1999). This was based on a hydrological modeling system, which was used to produce values for two different scenarios. Under the assumption of average temperature and no subsequent precipitation, the river was predicted to crest at 14,5 meter (47,5 feet). Under the scenario of average temperature and *continued* precipitation, on the other hand, a river stage of 15,1 meter (49 feet) was forecasted. On April 22, after the protective dikes had already given way, the Red River finally crested at 16,6 m (54 feet), leading local, state and national officials to point to inaccurate flood forecasting as the cause of the disaster. Had the final flood crest been known in advance, so it was argued, Grand Forks could have been protected to almost any elevation (Pielke, 1999; Pielke and Conant, 2003, pp. 1351).

Yet, an analysis of the outlooks issued between 1982 and 1997 finds little support for the argument that the flood forecast was “inaccurate”:

> *Placing the 1997 outlook into historical context, indicates that the 1997 prediction was worse than average in terms of feet, but perhaps more importantly, better than average in terms of percentage.* The forecast error was neither unique or unusual, and in fact, because it was a forecast of a record event, arguably better than those issued in more typical years. (Pielke, 1999, pp. 89)

Though the NWS did not escape criticism, the main problem was not the quality of the forecast but rather its design and how it was interpreted. Interviews carried out with local leaders show that different people interpreted the flood stage outlooks in different ways, some of which were demonstrably incorrect:

> Some viewed the two numbers as a range: that the maximum flood stage would be between 47.5-49 feet. Others viewed the higher number as a maximum: a value that would not be exceeded. [...] Others viewed the flood outlook as exact, that is, "the crest will be 49 feet." Still others viewed the 49 foot outlook as somewhat uncertain; examples of the uncertainty ascribed to the outlook by various decision makers ranged from 1 to 6 feet. (Pielke, 1999, pp. 88)

Whereas the message that the NWS had intended to send was to expect unprecedented flooding, an ex-post resident survey in Grand Forks showed that 79,6 percent of the respondents had taken the forecasts to mean that no flood insurance was necessary (Pielke, 1999).

Regarding the forecast's content and design, Pielke (1999) finds it problematic that no sensitivity analysis was performed and that no quantitative uncertainty information was provided. Instead, a qualitative disclaimer was appended to the bottom of the flood stage prediction. This did not only make it difficult to assess the forecast's reliability but also implicitly placed the responsibility for deciding which river stage to prepare for with the forecasting agency rather than with the decision-makers in charge of crisis management. A more appropriate solution would have been to provide probabilities of different levels of inundation together with uncertainty information. But this is not what decision-makers wanted. What they desired was "an *accurate* forecast that the NWS will stand behind." (Pielke, 1999, pp. 94, emphasis added). Hence, Pielke concludes:

> Responsibility for the apparent misuse of the outlooks is shared. The NWS failed to communicate effectively the uncertainty of the predictions, *and* some local decision makers failed to appreciate the uncertain nature of flood forecasting. The result was that actions were taken based on a misinterpretation of what could have been useful information. (Pielke, 1999, pp. 89)

Though much has changed since 1997 in terms of how forecasts are issued, the Red River flooding is a good illustration of the problems associated with non-experts' use of predictive information as input to real-world decision-making. Particularly, it highlights the 'dilemma' of simulation: that *it can imply a great advantage to be able to act in foresight rather than hindsight at the same time as the complexity of simulation research makes it difficult for unpracticed users to interpret the output in a way that accounts for the presence of uncertainty.* As Pielke and Conant (2003, pp. 1355) put it, "[p]rediction products are difficult to evaluate and easy to misuse". Hence, although we tend to think of access to information as something good, whether access to predictive information is beneficial or not will not only depend on *whether* but also on *how* it is used.

If computer models are treated as 'answer machines' or 'truth generators', implicitly legitimated by the success of prediction in traditional reductionist science, it can lead to forms of application "that miss the true value of models and distort their outputs in damaging ways." (Wagner et al., 2010, pp. 330). For example, public officials in government and administration are noted to satisfy with limited or nonexistent expressions of simulation uncertainty and model and data assumptions although this can lead to blind spots (Wagner et al., 2010). Moreover, there is the risk of unrealistic expectations in models' predictive capacity keeping people from acting upon information in the present as they are holding out for more certain information to reduce political risk (Pielke and Conant, 2003).

Thus, the potential benefit of 'foresight' does not only depend on the quality of simulation research but also on users' approach to and application of this. If treated as a technique for illuminating dynamic and uncertain relationships in natural settings, simulation-based information can be highly valuable (cf. Wagner et al., 2010). But, in practice, other forms of use are common, too. Hence, the benefit of access to simulation technology and ability to generate predictions about complex natural phenomena cannot be taken for granted, but should be subject to empirical analysis.

1.1 Outlining the research interest

Statistics by Swiss Re for the period between 1970 and 2013 show that, with few exceptions, each year, natural catastrophes claimed more victims (dead or missing persons) and resulted in higher insured losses than man-made disasters. Both in terms of insured and uninsured losses, the costs associated with natural catastrophes and man-made disasters have risen continuously over the same period, with 2011 being a record year (Swiss Re, 2014).[1] While some of this can be attributed to an increase in hazard frequency, human and social drivers (such as population growth, land-use and settlement patterns, and the development and use of sensitive technology) play a large role, too (Haque and Burton, 2005).

In an article called "Knowing better and losing even more", White et al. (2001) contemplate how come the past decades' growth in research and knowledge on disaster prevention and drivers of risk has not been able to curb the trend of rising losses from natural hazards. According to their analysis, available knowledge is often *ineffectively* used, e.g. due to conflicting interests and lack of political will to resolve the same. As long as the losses are largely attributed to growing wealth and can be absorbed by an economically rich society, they write, the motivation to undertake actions is likely to be weak. Although one might think that the potential impact of a crisis would be sufficient to motivate political leaders and risk managers to devote considerable resources to prevention and preparedness

[1] Although the number of reported natural disasters in 2011 was below the average for 2001-2010, the number of people killed, injured, homeless or requiring immediate assistance during a period of emergency was the largest since 2003, while the estimated economic losses (USD 366.1 billion in 2011) were the highest ever registered, surpassing the last record year of 2005 (Guha-Sapir et al., 2012, pp. 23). According to the OECD (2003, pp. 30), it is especially the impacts of floods, storms and droughts which have risen steeply since the early 1960s.

planning, such optimism has to work against forces and circumstances of inertia; often, it is only once disaster occurs that a 'window of opportunity' for reform opens (cf. McConnell and Drennan, 2006). At the same time, Weichselgartner and Sendzimir (2004) note that the concurrent increases in losses and research raise doubt about the approaches and tools hitherto used for hazard assessment and disaster management.

In this perspective, simulation technology represents a promising prospect for change. Already, forecasts of floods, hurricanes and seasonal precipitation patterns have frequently contributed to save lives and reduce physical damage (Sarewitz and Pielke, 1999, pp. 127). Thanks to rapid technological development, new forms of applications are being developed as well. One such novelty is the simulation of one or more scenarios to explore the likely effects of being hit by a natural hazard (i.e. a kind of 'what if – what then' prediction).[2] This type of information can, for example, help public authorities identify hazard hotspots where a high risk of exposure coincides with high levels of vulnerability or valuable structures or activities. In contrast to forecasts of *oncoming* threats, simulation of hazard scenarios – for which we do not know when they will materialize or whether they will come exactly as assumed in the model – allow for more long-term planning of how to mitigate and adapt to risk; enabling people to act in the present to avoid damage later. The output is often displayed on a map or against a digital background resembling an aerial photo, providing the end-user with a visual representation of which areas the simulation model predicts to be at risk. In comparison to the manual documentation of a single historic disaster, simulation allows for the exploration of a range of different scenarios based on the current state of topography. As such, it allows for a more up-to-date hazard assessment and the exploration of scenarios which surpasses local memory. In a nutshell, it represents the possibility of 'seeing' what it would mean to be hit by a natural hazard without actually having to experience this, thereby offering a chance to act in foresight rather than hindsight.

At the same time, all models used to simulate hazard scenarios are simplifications of reality, meaning that the output generated by such models will always be

[2]Other novelties include agent-based modeling. This has, e.g., been used by Lewis (2010) to simulate traffic behavior to support evacuation planning. These will not be the focus of this study, however.

associated with intrinsic uncertainties and limitations. Writing about modeling and mapping software used to characterize the nature and extent of flood, wind and coastal hazards, Pine (2009, pp. 54) notes that it is highly important for users of environmental hazard models to understand how assumptions and variations in input data can affect output results, as errors in this regard "can lead to distortions [. . .] so that the hazard zone outputs do not reflect the real danger in the simulated hazard." Likewise, commenting on flood hazard mapping in the European Union, van Alphen et al. (2009, pp. 291) write:

> Flood mapping is not an exact science, but includes uncertainties regarding the natural phenomena and those associated with the data and modelling. [...] These uncertainties dictate the accuracy of the mapping products and need to be understood in order to know how closely the mapping represents what the users would see as an accurate representation.

In other words, information about limitations, assumptions and uncertainties, respectively the implication of these for the completeness and reliability of simulation-based predictions, needs to be communicated to end-users to avoid that mistaken conclusions are drawn about which areas should count as 'safe'. Yet, a research report by Meyer et al. (2009) claims that the uncertainty and imprecision associated with flood simulation used for risk assessments is often *not* communicated to decision makers. Instead, a non-existent precision of estimation is pretended, which "might facilitate the decision for the decision maker but reduces the scope of decision and could lead to a solution which is not optimal." (pp. 18). In short, this implies a *theoretical* risk of misguided decision-making if the uncertainty associated with scenario simulation of natural hazards is not properly communicated to or understood by end-users in risk management.

Hence, the interest of this study concerns the introduction of graphical scenario simulation results to support risk management of natural hazards *in practice*. On the one hand, a graphical representation of the likely outcome of a natural hazard can help public officials improve crisis preparedness and risk management while there is still time. On the other hand, people without expertise in the field of modeling and simulation are suggested to have difficulties when it comes to interpreting predictive information, in the worst case leading to misuse of what could have been valuable insights. Consequently, the research interest motivating this study is what benefits and problems the introduction of such tools are *actually* associated with. So far, there have not been any reports of misuse of, e.g., hazard maps similar to the descriptions offered for forecasts (i.e. Pielke, 1999) and other simulation products (e.g. Wagner et al., 2010). But is there still a risk to be cautious of? What are the perspectives of those working with these products in practice?

1.1.1 Research questions and study design

To guide the exploration of risk managers' use of visualized scenario simulation results (e.g. in the form of lines on a map), the following research questions were formulated:

- *How are risk managers in the public sphere using simulation-based scenario information about the predicted outcome of a natural hazard – if they use it at all?*
- *What affects whether or not predictive information is used?*
- *What benefits and/or problems are associated with the introduction of predictive information to an audience that lacks expertise in the field of modeling and simulation?*

In this respect, 'risk management' refers to all efforts to decreasing the probability for and/or potential consequences of being exposed to an unwanted event, focusing on both the risk agent and the potential target. According to Renn (2008, pp. 7), it refers to "the creation and evaluation of options for initiating or changing human activities or (natural and artificial) structures with the objective of increasing the net benefit to human society and of preventing harm to humans and what they value". The term 'risk manager' covers both elected decision-makers and employed administrators and practitioners carrying some kind of responsibility for or having being tasked with risk management activities.

To make the exploration of the research interest practically manageable, the study will focus on a single context and example of the phenomenon of interest, namely risk management in the German state of Baden-Württemberg and the introduction of simulation-based hazard maps depicting the predicted outcome of riverine flood scenarios. According to Yin (see 2009), a single case study design is motivated when a research area is relatively new and there is limited knowledge about relevant concepts and linkages, as it allows for in-depth study of the phenomenon of interest while drawing on data from different units of analysis. In principle, it reflects the belief that exploratory research is well-served by an approach that seeks to identify systematic components in one context before an effort is made to see if these are replicated also under other circumstances (cf. Esaiasson et al., 2005, pp. 186). Below, the choice of case study is enlightened in more detail.

1.1.2 The choice of flood maps in Baden-Württemberg

Beginning with why flood hazard maps are a product of interest, it can be noted that simulation technology is currently used to predict the outcome of a wide range of hazards, including different forms of flooding, avalanches, debris flow and torrents. Because the underlying physical processes of riverine and coastal flooding are relatively well understood, these are amongst the hazards for which simulation-based hazard mapping has been pursued the longest. In Canada, the portrayal of hydrotechnical information on topographical maps, including from simulation of design flood profiles, begun already in the 1970s (Burrell and Keefe, 1989). Yet, it is really only since a couple of decades that simulation of flood scenarios is possible from a computational perspective (de Moel et al., 2009, pp. 298). Early European examples include simulation efforts in Norway, England and Wales, and the German state of Bavaria during the second half of the 1990s (Petrow et al., 2006; Wagner, 2006).[3] What really sets modeling of flooding apart from that of other natural hazards is that it is only in respect to flooding that the production of hazard maps has been regulated at supra-national level. Through

[3] In Norway, severe flooding prompted a flood mapping project to be initiated in 1995, and in England and Wales maps documenting the flood lines of previous inundation episodes were complemented with simulation of a 100-year flood scenario in 1996 (Petrow et al., 2006). For as long, floodplain mapping based on 1D- and 2D-modeling of 100-year flood events has been pursued in Bavaria (Wagner, 2006).

the introduction in 2007 of the EU Floods Directive (2007/60/EC), all EU member states were required to produce and publish hazard and risk maps based on "the best available technologies" until the end of 2013. Resting on the three pillars of *information*, *cooperation* and *planning*, the directive calls for hazard maps showing the predicted extent, depth and – if appropriate – velocity of inundation associated with a frequent, mid-frequent and rare flood event.[4]

According to academic literature, the introduction of flood hazard maps as a EU policy tool reflects how the approach to the risk of flooding has changed in Europe and elsewhere in recent years (e.g. Meyer et al., 2009; Wagner, 2008). Not only are they seen as suitable tools for lessening exposed communities' reliance on structural protection measures (Petrow et al., 2006; Handmer, 1980), they are also thought to support a 'risk'-based rather than 'safety'-based management approach (Büchele et al., 2006; Wagner, 2008; de Moel et al., 2009, pp. 290). At the same time, reflecting that information provision to private individuals is not only about empowerment but also a way of transferring responsibility from a 'hollowed-out' state to active citizens (Taylor-Gooby and Zinn, 2006, pp. 16), the requirement for hazard and risk maps to be made publicly available is sometimes interpreted as a strategy for shifting some of the responsibility for flood protection and risk preparedness onto those at risk (Hagemeier-Klose and Wagner, 2009; Steinführer et al., 2009).

For the study at hand, this means that flood hazard maps are an example of a mandated risk management instrument. Even if there is no requirement to produce these with simulation technology, this is often the solution in practice. In effect, this means that all member states *have to* invest intellectual and financial resources in the production of this type of information, whether they want to or not. Considering how common this makes flood hazard maps, an empirical analysis of benefits and eventual problems is certainly called for.

[4]These are to be complemented by risk maps, specifying the expected adverse consequences, including the number of people and economic activities affected, sources of environmental pollution, etc. According to Wagner (2008, pp. 777), however, risk maps are generally a less relevant tool for most activities and users. Until the end of 2017, flood risk management plans covering all management measures and being developed for each river basin and coastal zone area (as opposed to for each state, region or municipality) are to follow. Each of these documents are to be updated every 6 years.

That the choice fell on Baden-Württemberg as the contextual setting in which to study non-experts' use of predictive information is, in contrast, primarily a result of pragmatism. Apart from geographical proximity facilitating data collection, Baden-Württemberg is also amongst the German states with the longest tradition of flood hazard mapping, with early attempts dating back to the end of the 1990s. Hence, it is a suitable setting for studying hitherto experiences of introducing scenario simulation as a policy tool for risk management. Additionally, it is an interesting circumstance that Baden-Württemberg chose to develop this kind of instrument prior to it becoming mandatory to do so through EU legislation, and that considerable efforts and financial resources have gone into its production and design. As will be discussed in chapter 3, pre-existing interest and involvement by actors in policy and practice are generally seen as favorable conditions for research use. At the same time, Baden-Württemberg is also one of the few cases in which some of the simulated hazard lines are given legal status after their publication, meaning that the introduction of predictive information is at the same time an imposition of strict land-use regulations. In that sense, there are not only favorable conditions in place but also a high potential for conflict.

Flood hazard maps are described as useful instrument for a wide range of actors, from private households to insurance companies. In this study, the focus is placed on local-level risk managers' use of flood hazard maps. This decision reflects both that the hazard maps in this state depict individual communities and that risk management is normally a municipal responsibility.

1.2 Previous literature on flood hazard maps

Academic writing on flood hazard maps can be divided into four different categories. First, a large body of literature is of a technical nature. To this count both descriptive overviews of methods and map designs currently applied across Europe (e.g. de Moel et al., 2009; van Alphen et al., 2009), and papers outlining methods not yet subject to standard use. To this latter category belong, e.g., Büchele et al.'s (2006) proposal of a methods for extreme flood events, Falconer et al.'s (2009) study of less well-understood sources of flooding, and Zerger's (2002) method for including and visualizing model uncertainty directly in hazard maps. This category is altogether of little interest to the study at hand.

The three remaining categories concern (a) analytical or empirical evaluations of map designs and design requirements, (b) studies of the knowledge production process associated with hazard mapping, and (c) studies concerned with the impact of flood hazard maps, focusing on land-use planning and communication.

a) Analytical or empirical evaluations of map designs or design requirements

Beginning with the first category, these studies often depart from the assumption that current map designs are suboptimal and that this explains why "maps often fail to attain their potential to fulfill the needs of different users, to raise awareness and provide a clear and understandable source of information for planning." (Meyer et al., 2012, pp. 1702). For example, Dransch et al. (2010) point out that, although one of the main uses of hazard and risk maps is as tools for risk communication, most maps have been designed for scientists and experts, not for laypeople. Likewise, empirical evaluations of current European practices find that several maps and online mapping tools are either too simple or too complex (Hagemeier-Klose and Wagner, 2009), and that their content fails to meet the requirements both of residents at risk and public officials (Meyer et al., 2012; Pardoe et al., 2011).

Independently of whether these evaluations concern an existing design or a suggestion for an alternative (e.g. Spachinger et al., 2008), what they have in common is that they point to different user groups having different needs and capacities, often paying particular attention to the general public. From this perspective, it is problematic when end-users are simply *assumed* to be willing and able users of hazard maps. Instead, representatives of different user groups should be invited to participate in the mapping and design development process. Such direct involvement does not only expand the knowledge on which the maps are based, but also fills the function of improving the usability and acceptance of maps among users.[5] Furthermore, different needs of different target groups mean that different designs

[5] As noted above, this is something where the state of Baden-Württemberg scores relatively high.

should be considered. For laypeople, it is suggested to be important that a map's message can be identified at the first glance. (In effect, this implies a low need for this group to consider simulation uncertainty. Yet it is not explained why this is of limited relevancy.) Professional risk managers, on the other hand, can often handle more complex tools and may also require functions that allow for further data processing.

More concretely, the recommendations found in this literature include:

- to avoid technical terminology;
- to include gauge level information so that people can compare the mapped water levels with past flood events;
- to include information (e.g. photos) from past flood events; and
- to use colors that people naturally associate with water, such as different shades of blue.

b) Studies of the knowledge production process associated with hazard mapping

The second category concerns studies, which – following in the footsteps of *Science and Technology Studies* (STS) – are interested in the processes through which knowledge is produced, negotiated and stabilized. Two examples of this are Landström et al. (2011) and Lane et al. (2011), both of which focus on the flood hazard maps commissioned by the Environment Agency of England and Wales. According to Landström et al. (2011), technical consultants' computer simulation of local flood hazard is best understood as a form of *virtual engineering*, since the work is geared towards solving a client's problem by articulating risks and possibilities in the digital space of the computer.

Based on ethnographic observation and in-depth interviews with actors in engineering consultancy firms, as well as with scientists at universities and national research centers, a detailed account of the practice of flood hazard mapping is presented. The result shows that, although the simulation is undertaken by private businesses, the work is shaped by the demands and protocols of the client, e.g. through the establishment of long-term contractual agreements and by requiring the consultants to use particular software packages. The latter point is of particular interest since it implies that part of the agency's trust in simulation output is linked to its level of standardization, rather than to its predictive skill: "Information produced in this practice can be trusted by clients because of the stamp of approval given to the software, not because specific knowledge claims have demonstrated their ability to withstand challenges from competing modelling approaches." (Landström et al., 2011, pp. 19). To some of the engineers, the requirement to use particular software packages implies a restriction in terms of what can be simulated; limiting their ability to produce truly useful output (Lane et al., 2011). Moreover, as virtual engineering becomes *the* way in which input to flood risk management is generated, it starts defining what society needs to know about flooding; unless numerically compatible with model requirements, other forms of evidence, such as local knowledge, will not be recognized (Landström et al., 2011).

What made several of the interviewed engineering consultants critical of current mapping practices was (a) the amount and quality of available data (e.g. in the form of historic flood records) since this is critical for calculating return periods; (b) that the mapping only considered inundation caused by water coming *out of* a river, although another common flood cause is rainwater flowing *towards* a waterway; and (c) that historical records were used to 'force' empirical adequacy, i.e. that the parameters were adjusted until the simulation output fitted the empirical data, even when a model contained poorly known processes and parameters (Lane et al., 2011). Finally, a paradox was perceived in the sense that a certain percentage had to be added to the calculated river flow to account for climate change, while it was excluded to take future changes in urban development into account. This was felt to imply that only some sources of instability were accounted for, meaning that flood hazard maps construct flood risk in particular ways; closing the analysis down rather than opening it up. In this respect, the occurrence of actual flood events was perceived to play an important role, unsettling some of the critically seen practices by "drawing attention to elements of flood risk excluded from or overlooked by a particular analysis." (Lane et al., 2011, pp. 1803). Representing a more general form of criticism, especially scientists at universities and national research centers considered the reviewed simulation practice to "rely on over-simplifying model structures and to lack critical perspectives on the parameterisations in the proprietary software packages." (Landström et al., 2011, pp. 18).

This shows that there is both internal and external critique against some of the hazard mapping practices currently in use in Europe. In Lane et al.'s (2011, pp. 804-805) view...

> what separates flood risk estimation from astrology has less to do with the separation of risk assessment and management than with the burden of social accountability attached to the risk management regimes of which the calculation of risk is inextricably a part. Such accountability requires an openness about the scientific and policy procedures that make flood risk estimations more (or less) reliable to those we entrust to produce and act upon them such that, unlike astrology, they can be put to the test of public interrogation, not least by those who have to live with their consequences.

Put differently, this suggests that what creates a demand for flood scenario simulation is not necessarily how good it is but that it makes things traceable; enabling others to scrutinize the basis of a hazard assessment; allowing for accountability both on behalf of those producing predictions and behalf of those using them for decision-making.[6]

c) Studies concerned with the impact of hazard maps on land-use planning and communication

Finally, the last category, which is also the one of most direct interest to the study at hand, concerns the use of hazard maps for risk management purposes and concrete impacts in the areas of land-use development and risk communication.

Many studies concerned with land-use impacts come from Canada, where an agreement for mapping and floodplain zoning and for the distribution of these maps to the public was signed by the governments of Canada and Quebec already in

[6] A similar perspective is found in Jamieson (2000), in which simulation is described as the latest successor in a long tradition of oracles, through which decision-makers try to reduce uncertainty and dictate 'rational' policy paths.

1976.[7] Referring to maps of the Greater Montreal region from the period 1978-1996, for example, Robert et al. (2003) study whether mapping and designation of floodplains helped reduce increases in flood damage potential in four selected municipalities. Flood mapping and designation, it is argued, should basically have led occupancy and economic value in floodplains to cease to grow, whereas no-flood-risk zones near water bodies should have seen a marked increase in the same values. In reality, however, a long list of automatically exempted undertakings together with withdrawal clauses included in the mapping agreement enabled municipalities to permit increased floodplain occupancy even after mapping and designation, with the result that...

> ...the pace of home construction is the same (or greater) in flood-risk zones as it is in no-flood-risk zones. The same is true for property values [. . .]. This means a considerably increased exposure to potential flood damage – contrary to the principle underlying the activities of designation, mapping and dyking. (pp. 382)

Another study from the Quebec area confirms this picture. Having looked at the construction development in floodplains in six municipalities along the Chaudière River for the period 1979-1997, Roy et al. (2003) find that, in spite of the designation carried out in 1979, total property value in floodplains increased in each study area over the selected time period. The ratio of new property values to total value in the floodplain ranged between 4,5 to 14,3 percent for most areas, but in one municipality property value increased with 64,3 percent due to a commercial sector being built in the flood-risk zone. Moreover, the study found that new buildings had been legally erected in the high-risk zone (i.e. the zone likely to be affected by a flood with a return period between 0 and 20 years), despite of the fact that construction in this area was officially prohibited (Roy et al., 2003, pp. 399). Referring to a report by Christin (1997) showing that 23 out of 25 municipalities in the Quebec area asked about the region's flood-risk mapping program

[7]It should be noted that, since hazard mapping based on scenario simulation is a relatively new phenomenon, especially the maps discussed in studies of Canada are sometimes based on a somewhat different methodology. For a description of one of the methods used to produce flood hazard maps in Canada in the 1970-80s, see Burrell and Keefe's (1989) article on flood risk mapping in the New Brunswick region.

had allowed for further development in floodplain areas, Robert et al. (2003, pp. 384) conclude that...

> ...in the Greater Montréal region as in other regions of Canada, flood damage reduction measures based on designation and mapping of floodplains had no impact on occupancy, have failed to reduce flood damages, and have not even halted increases in such damages.

In 2000, Shrubsole reported that Environment Canada is not renewing the 10-year agreements of which the mapping and designation projects were part and that there has not been any effective action by provinces and municipalities to update existing maps and extend the present coverage.

While similar studies are lacking in Europe, Wisner et al. (2004, pp. 204-205) note that, in the United Kingdom, "awareness of the significance of the flood plain does not mean that pressure for use of its 'cheap' flat land has diminished". On the contrary, severe housing shortage in some regions, coupled with a reduction in the planning powers of local authorities, has led to an increase in use of floodplains for housing developments, and an accompanying steep increase in insured flood losses following flood events. Hence, it seems somewhat uncertain what role it has played that flooded areas in England and Wales have been subject to hazard mapping since 1973 (see Petrow et al., 2006, pp. 719).

When it comes to Germany, studies of early mapping efforts criticize that there are no standards in place for considering flood hazard zones in land-use regulation. Instead, land-use regulation is largely left to municipalities, for which trade taxes is a main source of income. Since this implies that municipalities have much to gain from attracting businesses and enterprises to their areas, the result is an intrinsic conflict between the aims of reducing increases in flood damage potential and encouraging local economic development (Thieken et al., 2005). Data from Bavaria support this by showing that municipalities there resisted the changes made to the federal Water Resource Act (WHG) in 2005 out of fear for restrictions of their planning capacities (Wagner, 2009). Finally, a study by Petrow et al. (2006) of the lessons learned from the catastrophic Elbe flooding of 2002 warns that a too strong focus in hazard maps on the area at risk in case of a 100-year flood event can cause people to ignore the residual risk of more extreme events. By concentrating on a 100-year flood, the assessment of flood hazard is reduced to a question of whether an element is located 'inside' or 'outside' the 100-year flood line. Hence, flood mapping can potentially have the effect of increasing damage potential just outside the floodplain line, in a sort of 'land-use'-equivalent to the escalator effect.[8]

When it comes to the use of hazard maps as a tool for public authorities to raise public awareness about the risk of flooding, John Handmer (1980) used qualitative and quantitative methods to investigate the effect of access to hazard maps on local residents' risk perception in Canada. In Handmer's view, the use of flood maps for public information purposes relies on the implicit assumption that "maps are read and understood by the target audiences, and that they have the effect of improving their flood awareness and acceptance of government flood related programs." (pp. 84). His own empirical analysis, however, suggests that there is little substantive foundation for such an assumption.

More precisely, Handmer's findings show that direct distribution of flood maps to households was ineffective in increasing the recipients' flood risk perception.[9] In one of the case study areas, there was almost total ignorance of the flood maps' existence six months after local newspapers had covered and even reprinted parts of them. In another case study area, an interest group formed *against* local risk management efforts: "These people, and others in the flood plain, did not regard the maps as a source of information. Instead they saw them solely as part of a program to expropriate their property and as a waste of resources: 'the money would be better spent on building a dyke'." (Handmer, 1980, pp. 97). Amongst the interviewed officials, furthermore, there was uncertainty about what to do with flood maps, and a feeling of unhappiness about a tool that seemed to condemn half of the town to being flooded.

[8]For avalanches, such an effect is reported for regions in Austria and Switzerland, where damage potential increased the most just outside the designated risk zones prohibited from further development (Wagner, 2008, pp. 776).

[9]Although quantitative surveys could establish a difference in the respondents' flood risk expectations before and after the maps were distributed, there was no significant difference between the group to which maps had been distributed and the control group. Hence, the change in perception was attributed to the intense media campaign surrounding the release of flood maps rather than to the maps themselves.

That the results of mapping efforts will not always be welcomed or accepted is also shown by Burningham et al. (2008), who analyzed quantitative and qualitative data related to two projects intended to contribute to a more detailed understanding of flood awareness in England and Wales. In 2004, the Environment Agency, which is responsible for flood risk management activities (ranging from building flood walls to raising public awareness), collaborated with insurers to produce flood hazard maps using hydrological modeling. The maps pinpoint risky areas and households defined as being 'at risk' and target these by campaigns intended to raise people's risk awareness, as well as awareness of warning systems and appropriate behavior in case of flooding.

Results from the qualitative part of the study, however, found that people would often reject the maps' findings and/or the conclusion that they should be at risk. While some suggested that the maps were simply wrong, others pointed to the location of their property (e.g. on a hill) as putting them beyond flood risk. Yet others told of different actors drawing different conclusion on the basis of the same findings, making some inclined to see the whole effort to designate floodplains as a conspiracy between the Environment Agency and the insurance industry. On the whole, the awareness campaigns adopted a *deficit model* of public understanding of risk, assuming that the simple act of providing information about flood hazard would 'correct' people's low risk perception and lead to behavioral changes. In reality, though, people were often unwilling to accept the message provided to them, e.g. due to economical and psychological reasons or because the responsible authority enjoyed little credibility (Burningham et al., 2008).

When it comes to Germany, Wagner (2006) has studied the floodplain designation process in Tiroler Achen, in Bavaria, where his results show that floodplain maps were unsuccessful as public information tools. Based on documents, newspaper articles, interviews and observation, Wagner found that the designation process was accompanied by conflicts both between the two responsible authorities and between these authorities and the affected property owners. Due to insufficient, late and partially contradictory information, the authorities missed the chance to affect the public's conception of what a floodplain is or why it should be designated. As a result, people did not only fail to understand the purpose of the mapping process but also felt it to go against their values and interests, e.g. in terms of the right to free disposal of one's own property and in terms of reduced property values. To make the situation worse, local residents did not always find the maps credible. This was, for example, the case when areas depicted as inundated in the maps were noticeably larger or smaller than the areas that people remembered, and where it was not sufficiently clarified that such discrepancies can be natural, e.g. due to changes in the local terrain and due to the fact that not all sources of flooding are accounted for in hazard mapping. Where the conflict between the public authorities and those perceiving themselves to be affected by "arbitrary and excessive planning" stood in the foreground it overshadowed the message of certain areas being at risk to the extent that the mapping process could not be used to contribute to awareness raising (pp. 231). At the same time, Wagner doubts that the success was much greater in other areas. Out of 20 responsible authorities, only one provided material indicating active public relations work and, in interviews, active communication efforts were regarded with skepticism; it could lead to "overreactions" or it was best to "let sleeping dogs lie" (2006, pp. 239-240).

Based on the study of 60 communication practices across Europe, Höppner et al. (2012) suggest that promising tools for risk communication such as hazard and risk maps are rarely embedded in a more comprehensive and long-term communication strategy. For example, risk maps and forecasting systems are "not necessarily well advertised amongst the public through additional information materials or events." (pp. 1767). Finally, a quantitative study from Switzerland showed that 75 percent of the respondents did not know or did not think that flood maps were available for their area although these existed since several years (Siegrist et al., 2004, pp. 19).

Comments on the basis of the literature review

On the basis of this literature review, it may be suggested that:

- Lack of stakeholder involvement leading to unsuitable design is one of the explanations proposed for low levels of application of flood hazard maps;
- The role of simulation uncertainty for how risk managers respond to flood hazard maps, respectively for whether and how they use these, has not been focused on previously;

- Prior empirical work questions the effectiveness of flood hazard maps as tools for risk management and public risk communication;
- Although hazard maps are often described as promising information products *in theory*, there is little empirically-based understanding of what benefit this type of tool is actually associated with in practice;
- There has not been any prior focus on whether the problems noted in literature on other simulation products are also present for flood hazard maps;
- Beyond the technical literature and some studies of map-design, research on flood hazard maps has not focused on the case of Baden-Württemberg.

This means that there is potential for the study at hand to generate new and/or complementary insights in relation both to flood hazard maps and simulation usage more generally.

1.3 Purpose and disposition

The empirical study of municipal-level use of simulation-based flood hazard maps in Baden-Württemberg has two aims. The theoretical aim is to explore the role of uncertainty for whether and how simulation-based hazard assessments are used by non-experts to guide practical planning and management decisions. While academic literature often points to usage of simulation results by non-experts as something complicated and potentially ‘risky’, there is not enough literature on this phenomenon to be able to determine under which circumstances this is so and whether or when exceptions are possible. Furthermore, since the literature on flood hazard maps has so far focused on other aspects, we cannot know whether or in which ways the problems reported in literature on simulation in general also pertain to maps showing the results of hazard scenario simulation. Hence, it is the aim of this study to close this gap and to try to further our theoretical understanding of when and why simulation usage by non-experts requires caution.

In more practical terms, the study represents a chance to do research in a German region so far not very well-represented in the academic literature on flood hazard maps. In this regard, the aim is to formulate concrete recommendations, based on empirical analysis, for how to motivate use (as oppose to misuse or non-use) of this type of foresight information.

In the next chapter, it will be explained what simulation is, why it is sometimes understood as a controversial assessment method, what problems, more exactly, have been observed in regard to non-experts' dealings with simulation output, and what suggestions have so far been developed for how to respond to these difficulties. In chapter 3, focus will be shifted towards the science-policy nexus more generally. The questions raised in this section concern what research 'use' is, how it differs from misuse and non-use, and how this can be studied empirically. Moreover, theory and literature as to what affects whether research is used or not used will be reviewed to provide an idea of what to look for in respect to the second research question.

Before the method and material are described in chapter 5, chapter 4 will provide a more detailed overview of and information on the case of flood scenario simulation in Baden-Württemberg and the context of local-level risk management. In chapters 6-8, the results of the empirical analysis will be presented. The presentation of the results is divided into three chapters corresponding to each of the three research questions. Because the outcome of the analysis was somewhat unexpected in the sense that what has been described as problematic in academic literature on non-experts' use of simulation results was not found to be problematic for risk managers' use of flood hazard maps in Baden-Württemberg, an effort was made to assess whether this situation also applies to other instances of scenario simulation. Hence, chapter 10 presents the results of a small excursion into the world of alpine hazard simulation in Austria. Finally, the conclusion takes us back to the study's practical and theoretical purpose.

Chapter 2

Simulation beyond the science sphere

2.1 Definition and characteristics

Simulation is sometimes described as a third path to knowledge next to theory (or logical thinking) and experiment (e.g. Küppers et al., 2006, pp. 5). As a research method, its advantage does not only lie in that it enables us to study systems which are beyond our physical reach, or which it would be dangerous or immoral to experiment with, but also that the time and cost requirements are often lower compared to other methods of investigation. Furthermore...

> ...there is no limit to their complexity. When a complicated system defies mathematical analysis or when the inclusion of random variables with nonstandard distribution makes a statistical formula difficult to find, a simulation models may still be constructed. (Bobillier et al., 1976, pp. 7)

Apart from constituting an academic research method, simulations are run by corporations and public agencies and institutions. In these instances, computer models are, inter alia, run for the purpose of:

- Gaining insights into the operation or dynamics of a system;
- Informing strategies or decisions to improve system performance;
- Testing and optimizing new concepts before implementation;
- Supporting pedagogical activities or purposes (Hartmann, 2005; Chung, 2004, pp. 3).

In relation to environmental regulatory issues,[1] Wagner et al. (2010) describe simulations as providing a means for assessing, measuring and predicting exposure or harm, thereby generating insights which may trigger heightened or reduced regulatory activity. Simulation can also be used outside of rulemaking activities, however, e.g. for assessing problems, setting priorities, or evaluating existing rules. In American environment and health policy, models have become so entailed that if the use of computer models would be abandoned, regulation would be set back to pre-1970 levels (Wagner et al., 2010, pp. 297).

The aim of the following section is to provide a *basic* understanding of what 'simulation' is, why it is thought to have a distinct epistemology and why its use as input to policy and decision-making is subject to discussion.[2] In this respect, all simulations will be treated as if they are the same although there are really many different types and areas of applications.

2.1.1 What is simulation?

Though there is no scientific consensus about what the term 'simulation' really refers to, it is nowadays generally associated with science and technology, and with computation carried out on a digital computer (Thompson, 2000, pp. xi). In its widest sense, it can be understood to mean the imitation of a system, though

[1] E.g. water quality, air toxics, pesticides, toxic chemicals, hazardous waste facilities, forest planning and ecosystem management.

[2] Here and in the following, 'simulation' means theoretical computer simulation, implying that the target system of interest is mathematically simulated on a computer for the purpose of study and analysis. This can be compared to real-world or physical simulation, where a real physical or biological model is used to imitate a real physical or biological process (see Hartmann, 2005, pp. 2), or training simulation, where the aim is to develop or practice certain skills (see Chung, 2004, pp. 1-3).

a variety of more precise definitions can be found as well. To offer a sample, Robinson defines computer-based dynamic simulation used in private and public sector organizations as "[e]xperimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for the purpose of better understanding and/or improving that system." (2004, pp. 2), whereas Chung describes "simulationmodeling" of manufacturing, service and transportation systems as "the process of creating and experimenting with a computerized mathematical model of a physical system." (2004, pp. 1). Others have defined simulation without specifying the area of use as "the generation of pseudodata on the basis of a model, a database, or the use of a model in the light of a database." (Thompson, 2000, pp. xi), or as "the technique of constructing and running a model of a real system in order to study the behavior of that system, without disrupting the environment of the real system." (Bobillier et al., 1976, pp. 6). Finally, the definition offered by the Oxford English Dictionary (Murry et al., 1989) is broad enough to include both training simulation and physical models as well as theoretical computer simulations:

> The technique of imitating the behaviour of some situation or process (whether economic, military, mechanical, etc.) by means of a suitably analogous situation or apparatus, esp. for the purpose of study or personnel training.

While each of these definitions is slightly different, they all describe simulation as something that involves a model or the imitation of a target system. Hence, we shall take a closer look at these terms, too.

Beginning with the term *system*, this can be quite easily defined as "a collection of parts organized for some purpose" (Robinson, 2004, pp. 2) or as "a set of parts organized functionally to form a connected whole." (Bobillier et al., 1976, pp. 4). Robinson (2004, pp. 2) differentiates between four classes of systems:

- Natural systems, like an atom or the weather.

- Designed physical systems, like a house or a car.

- Designed abstracts systems, like mathematics or literature.

- Human activity systems, like a family, city or political system.

Though simulation is used to imitate systems within each of the four categories above, in this study, it is the simulation of natural systems that is of interest.

What a *model* refers to is less clear-cut. Having reviewed a number of different definitions of models, Spath (2009, pp. 50) suggests that:

> Ein Modell kann zwei verschiedene Dinge bedeuten, zum einen die Wiedergabe eines Sachverhaltes, in Form einer Abbildung [...], zum anderen eine Aussage über die Beziehung und Wechselwirkungen mehrerer Objekte untereinander (was sie mit den Theorien verwandt macht). [. . .] Die abstrakten Modelle bilden die Basis von Annahmen, auf der eine Simulation aufbaut. Eine Simulation stellt also die konkrete Umsetzung eines solchen Modells dar.

This can be compared with Thompson's (2000, pp. xii) definition of a model as "a mathematical summary of our best guess as to what is going on in a part of the real world", whereas Hartmann (2005, pp. 4) describes it as "a set of assumptions about some system", where "[s]ome of these assumptions may be suggested by a general theory (such as symmetry principles), others serve merely as (idealized) descriptions of a special object or system."

Thus, both Hartmann and Spath see a model as a set of assumptions about a system. If the purpose of the model is to study the behavior of a target system, the model must not only specify static properties of that system, but also assumptions about its time evolution (Hartmann, 2005). When the simulation is of a theoretical nature, these assumptions will be expressed in mathematical form – as suggested by Thompson's definition. For a model to be run on a computer, furthermore, these mathematical expressions must be made into numerical expressions. A computer model (or numerical model) can therefore be said to refer to the algorithms and equations used to capture the main characteristics of the target system. Sometimes, an abstract model of this kind that is stored in and manipulated by a computer will also be referred to as a computer program (Bobillier et al., 1976, pp. 7).

A last aspect to note, finally, is that, although a model allows us to study a system (i.e. by comparing observations of how the model reacts to changes in input data with observations from the empirical world), it is rarely possible, or even desirable, to imitate a system in all its detail. Hence, a model will commonly offer a simplified, approximate description of the target system.

Based on these elaborations, the term *simulation*, as it will be used in this study, can be understood as *the technique of imitating a system (on a computer) by means of a mathematical model, thereby allowing for the study of the target system's behavior without having to interrupt the environment of the real system.* This is also in line with how the McGraw-Hill Dictionary of Scientific and Technical Terms defines the main feature of simulation technology:

> The essential characteristic of simulation is the use of models for study and experimentation rather than the actual system modeled. In practice, it has come to mean the use of computer models because modern electronic computers are so much superior for most kinds of simulation that computer modeling dominates the field. (Parker, 2003, pp. 1480)

In practice, this means that existing theoretical knowledge of the behavior of underlying components (e.g. solid particles or parcels of fluid) are used to create a computer model with which to simulate a phenomenon of interest (e.g. complex natural phenomena like storms or flow of water) to help scientists investigate the interactions and influences involved (cf. Winsberg, 1999).

2.1.2 What makes simulation 'special'?

In the next two sections, the focus is on features that are often discussed as setting simulation technology apart from more traditional methods of inquiry. These concern (a) the epistemological character of computer models, and (b) that simulation results tend to come in the format of graphic images.

2.1.2.1 The epistemology of simulation

The questions of what represents reliable knowledge, respectively how this can be established, has long been a subject of discussion within the field of philosophy of science. The term epistemology (or 'the theory of knowledge') can be said to refer to the means by which we sanction belief in a specific outcome. What makes simulation special is that the traditional means by which we sanction belief in natural science theories and predictions based on deductive logic cannot be transferred to computer models and simulation output. As Winsberg (2001, pp. 447) puts it, the techniques used to justify simulation-based claims "are unlike anything that usually passes for epistemology in the philosophy of science literature."

To understand this statement, we must look at how empirical data is traditionally used to assess the credibility of reductionist natural science theory. A first thing to notice, in this regard, is that no amount of empirical evidence can ever *verify* a theory. This is because, no matter how much data we have, there is always the possibility that more than one theory can explain the same observations or that data contradicting the theory exists even if we have not found it. What empirical evidence *can* do is to help disprove or refute a theory (i.e. to falsify it), since a lack of correspondence between a theory's logical prediction and empirical evidence means that the theory was faulty. Because of this prospect, a match between prediction and evidence is thought to *confirm* the underlying theory even if it cannot prove it.

When it comes to simulation, modelers sometimes claim that a computer model has been "verified" when the simulation output reproduces empirical data. When a model is calibrated,[3] for example, one is satisfied when the model's output data matches empirical observations beyond those which were used to calibrate it. Yet, this does not mean that the model has been verified (Oreskes et al., 1994). First, it is not only a hypothetical possibility but a common situation that more than one model construct can produce the same simulation results. During the 2008

[3] When a model is calibrated, the independent variables are manipulated to obtain a match between the observed and the simulated distribution of the dependent variable. The aim is to 'tune' the model until it reproduces available data. Commonly, one part of available data is used for tuning, while the rest is saved to serve as a basis for comparison; if the calibrated model replicates the second part of the observational data, it supports the model's quality.

workshop *A new look at the interaction of scientific model and policymaking* at the University of Oxford, Pasky Pascual used the term 'model identifiability' to refer to the fact that different sets of model structures and parameters are often able to explain available data with reasonably similar descriptive accuracy (PFP, 2008, pp. 6). Second, the use of auxiliary hypotheses (i.e. additional assumptions, inferences and input parameters serving to make the model work) implies that there is always a risk that two or more errors in auxiliary hypotheses cancel each other out, in which case a faulty model may appear to be correct (Oreskes et al., 1994).[4]

Likewise, even if some modelers argue that a model can be "verified" by comparing a numerical solution with an analytical solution to demonstrate that the two match over a particular range of conditions, once the model is applied beyond the initial range of conditions – and this is mostly the very point of modeling – the numerical code would no longer be verified (Oreskes et al., 1994, pp. 642).[5]

More serious from an epistemological viewpoint, though, is that a lack of correspondence between simulation output and empirical data cannot be used to *falsify* a computer model. The reason for this is that, even though simulation modeling begins with theory, theoretical knowledge is just one of several ingredients that modelers use to produce simulation results:

> [I]f the model is derived from a set of approximations to a well-corroborated theory, then the simulation tests both the theory and the approximations in conjunction. When the results in simulation go against the underlying hypothesis but we have reason to believe those results, then we cannot be certain immediately what has been falsified, the theory or the approximation. (Weissert, 1997, pp. 110)

[4]The concept of auxiliary hypotheses can be compared with Winsberg (1999)'s view that modelers use 'tricks of the trade' to make models computationally tractable. A similar point to the one made here is found in (Bobillier et al., 1976, pp. 14), who argue that if the programming is consistent with the rules of the simulation language, then errors stemming from invalid data or incorrect logic will not prevent the model from working and thereby producing spurious results.

[5]Whereas an analytical solution (or closed form solution), refers to the exact solution of a set of equations by means of mathematical analysis, e.g. using calculus or trigonometry, a numerical solution uses algorithms (i.e. a step-by-step procedure for calculation) to produce an approximate solution, often with the help of a computer. Such a solution can be accurate to a certain digit of precision and is often as good as an exact solution for many applications.

> These models are a complex amalgam of theoretical or phenomenological laws (and the governing equations and algorithms that represent them), empirical input parameters, and a model conceptualization. When a computer model generates a prediction, of what precisely is the prediction a test? The laws? The input data? The conceptualization? Any part (or several parts) of the model might be in error, and there is no simple way to determine which one it is. (Oreskes, 2000, pp. 36)

This inability to use empirical data to falsify a model implies that the means by which we sanction belief in theory cannot be transferred to the case of simulation models. In extension, this also means that the high level of trust accorded to logical predictions based on 'confirmed' theory is not transferable to predictions stemming from simulation. Winsberg has explained this by arguing that, although simulation is a practice of applying theory, model output cannot be equated with deductive inferences since the inferences that take place in simulation modeling have neither the inevitability nor the epistemic certainty associated with deduction:

> [D]eductive inferences, by definition, confer certainty on their conclusions (provided that the premises are true!). The inferences that take place in simulation modeling confer no such thing. At their best, they confer reasonable warrant for believing the conclusions reached, and this only when painstaking steps are taken to ensure success. (Winsberg, 2001, pp. S448)

Without entering into a discussion about epistemology, Sarewitz and Pielke (1999) and Pielke (2003) make a similar point. In their view, it is sufficient to think of the difference between a closed and an open system to understand why more caution is required in relation to some forms of research. As Sarewitz and Pielke (1999) clarify, predictions made in traditional reductionist science in the fields of physics, chemistry and astronomy pertain to stationary systems. The behavior of these systems can be predicted with a high level of accuracy because it follows certain laws; the processes involved in producing a certain behavior or outcome are of an *invariable* character. In open systems, this is not the case; the processes involved are not stationary.[6] Even if one can, in principle, reduce epistemic uncertainty by learning more about the processes involved in an open system, the level of uncertainty can never be known with absolute certainty. Hence, there is an inherent limit to the predictability of an open system, which not even the application of simulation technology can change.

Even when a computer model recreates historical or present-time data with a high level of accuracy, this does not necessarily mean that it will be able to predict the future. The most intuitive reason for this is that in open systems, there is no guarantee against surprises; one debris clogged bridge can cause a flood to rise far above its predicted crest, and a huge volcano can negate a decades-long global warming trend (Sarewitz et al., 2000).[7] Besides, small errors in the input data, which do not impact the fit of the model to available data under the investigated time frame, can still result in deviations when extrapolated over a longer time horizon (Oreskes et al., 1994, pp. 643). Finally, Winsberg (1999, 2001) point out that simulation is often used precisely when data is scarce, meaning that even if a model recreates available empirical data, this does not necessarily mean anything.

The consequence of these aspects is that academics commonly portray it as a mistake to treat predictions generated by a computer model with the same kind of respect that the hypothetico-deductive research model accords to logical predictions in natural science disciplines (e.g. Oreskes, 2000; van der Sluijs, 2005).[8] The question is, if the normal rules for assessing whether or not to sanction belief in research-based predictions do not apply to simulations, what are we to apply instead?

In Petersen (2006)'s view, the difficulty of establishing the accuracy of simulation results means that we should focus on assessing a simulation's methodological

[6]Making a comparison with a deck of cards, Pielke (2003) compares the uncertainty associated with a closed system to the probability of drawing a particular card, and the uncertainty associated with an open system to the same exercise when the deck is handled by a less-than-honest dealer. The more open a system is, the harder it is to predict its behavior.

[7]Indeed, as long as we do not know whether future environmental conditions will be similar or different, we also do not know whether available historic and present-time data is suitable for evaluating model output extending into the future (PFP, 2008, pp. 3).

[8]Or, as Sarewitz and Pielke (1999) put it: to conflate the role of prediction in traditional reductionist science (where it serves the role of validating hypotheses about invariant natural phenomena) and the role of prediction as input to societal decision-making (where it is used to foretell the behavior of complex *non-stationary* environmental phenomena).

rigor, so that *methodological quality* rather than accuracy becomes the criterion of importance. 'Quality' in this sense does not only depend on how adequately the theoretical understanding of a phenomena is reflected in the model structure, but also on the quality of the initial and boundary conditions used as input data to the model, the numerical algorithms, the procedures used for implementing the model in software, the statistical analysis of the output data, etc. In effect, this means that a simulation's methodological quality can be assessed according to criteria such as (1) theoretical basis, (2) empirical basis, (3) comparison with other simulations and (4) acceptance/support within and outside the direct peer community (Petersen, 2006, pp. 57-62).

Representing a similar position, Winsberg (2001) writes that, even though modeling begins with theory, a simulation also includes techniques of mathematical transformation, choosing parameters, initial conditions and boundary conditions, application of ad hoc modeling, a computer and a computer algorithm, a graphics system and the final interpretation of the numerical and graphical output. Therefore, all of these elements and their influences need to be considered when justifying the results, including the facts we know about our computers and graphical techniques, our confidence in the various ad hoc models used, the ability of calibrating models against empirical results, and, finally, "the confidence we have in the tacit observing abilities [. . .] of simulationists to make judgments about the degrees of resemblance between different classes of images." (Winsberg, 2001, pp. 450).

Ultimately, this suggests that the means at our disposal for sanctioning belief in simulation results consist of assessing the various elements involved in producing those results, ranging from the quality of the input data to the skills and experience of the simulationist him- or herself. As expressed by Bruce Beck at the workshop *A new look at the interaction of scientific model and policymaking*, this essentially means that quality is in the eye of the beholder (PFP, 2008, pp. 2-3). Whereas one can argue that this is not a unique feature for simulation, since most research will ultimately be judged by recipients in the peer community and beyond, the problem with simulation is that, in comparison to other – more intuitive, well-known or less complex – methods of inquiry, very few non-peers are able to make an informed assessment. Instead, many users outside the science sphere must trust in someone else's assessment. As Ivanović and Freer (2009, pp. 2551) put it, "[t]he underlying science of models may be opaque to non-specialists, who then rely on honest communication of the implications of model predictions [...]". Likewise, Petersen (2006, pp. 67) note that policy makers become dependent on scientific policy advisers, since they are "usually not themselves able to judge the uncertainty of scientific simulation-model outcomes [...]".

From a philosophical point of view, this corresponds to a high level of *uncertainty of reliance* (see Hansson, 2002, pp. 45), as the less decision-makers know and understand about a topic, the more they must trust in and rely on what the experts tell them, although history clearly shows that experts are sometimes wrong. In theory, moreover, it is not impossible that difficulties in assessing research quality means that other aspects, such as a piece of research's strategic usefulness, become more important instead (see chapter 3).

2.1.2.2 Visualization of results: Seeing is believing?

A second characteristic that makes simulation special is that its output often comes in the format of digital images. Though other formats are also possible, graphical representation has significantly contributed to make simulation one of the formative research technologies of the 20th and 21st centuries (Spath, 2009, pp. 55). By constructing images, Küppers et al. (2006, pp. 8) note, simulation translate non-visual events into visual media:

> Whereas telescopes and microscopes render phenomena visible by affecting the *scale* of 'tangible' entities through optical processes of resolution, simulation renders 'visible' the effects of parameters and forces such as time, dynamic interactions, and so forth that are not dealt with by optics-related transformations. Thus, simulation, by constructing images, may translate absolutely nonvisual events into a visual media!

In literature, the visualization capacity of simulation is associated with two types of consequences. First, it means that the output is delivered in a format that makes it easily accessible, thereby increasing its chances of being used. Second, it is associated with the effect of 'hiding' uncertainties, allowing simulation results to appear more certain than they might actually be. Scheer (2010, pp. 7) has referred to this latter effect as the certainty-uncertainty paradox of simulation, noting that simulation may impart certainty due to the format of its results rather than due to quality criteria.

In relation to the first point, research shows that graphics attract and hold people's attention more effectively than numerical representations. By condensing and clarifying data and complex information, graphics can reveal data patterns that may otherwise go undetected. Furthermore, graphics allow the observers to process information more effectively than numbers alone, and they make messages more memorable (Nicholson-Cole, 2005; Lipkus and Hollands, 1999, pp. 149). In risk research, graphical representations were found to increase risk aversion to a greater extent than numerical representations (possibly because vision is our dominant sense), implying that visual representations are capable of eliciting a stronger affective response (Bostrom et al., 2008, pp. 31).[9] Moreover, interviews with policy makers and scientists have shown both groups to find visual representations of simulation results to be more attractive than traditional formats of scientific publication, as simple and colorful maps, graphs and tables make the content "understandable for anyone" (Kowalczewska and Turnhout, 2012, pp. 97).

Though generally thought to constitute an advantage, this 'immediateness' of graphical images can also represent a risk. Findings by Messaris (1993) show that people can recognize the content of images without being familiar with the applied representational conventions and that an image's lack of fidelity to visual reality will not impede interpretation even by an inexperienced viewer. Put differently, this means that graphical representations make it easy for people to recognize content and draw inferences as to what they see even if they actually lack the technical skill that it would require to make a 'correct' interpretation. Following the notion of the philosopher Sven Ove Hansson (2002, pp. 39) that data "must be cognitively assimil*able* in order to qualify as information, and cognitively assimil*ated* in order to qualify as knowledge", one might end up assimilating a mistaken understanding of what there is to know.

[9] According to Bostrom et al. (2008), these findings should, in principle, be transferable to cartographic representations.

In relation to the second point, academics in the field of *Science and Technology Studies* (STS) have traditionally criticized numerical representations for hiding the uncertain nature of certain types of research findings. Numbers, so the reasoning goes, convey an impression of objectivity and certainty by 'hiding' the value judgments and assumptions used to produce them. While language leaves room for discussion, mathematical methods leave little room for personal judgment, and, hence, also a minimum of opportunity for others to doubt the analysis, making numbers difficult to contradict (Porter, 1995; Heintz, 2007, pp. 72). This has, e.g. led to critique of quantitative risk assessments on the ground of numerical risk representation creating a false impression of certainty, in which case assessments may be used by regulators without them paying proper regard to the imperfections of the underlying science (see Jasanoff, 1986, pp. 27).

That the same kind of critique is applicable to graphical images is apparent, as these, too, fail to represent the true true complexity of the underlying research process. As commented by Yearley (1999, pp. 846), "simulation and sophisticated models commonly exert a compelling persuasiveness; they are designed to look 'real'– particularly to those beyond the model-constructing community [...]." Since it is rarely possible to compare simulated images with real-world originals, the result is that it becomes difficult to tell whether simulations are equipping "virtual worlds with visual and other qualities that do not mirror those of real-world processes." (Küppers et al., 2006, pp. 8). Though some techniques exist for illustrating certain sources of simulation uncertainty (see e.g. Pang, 2008), these are seldom applied in practice (Zerger, 2002). Thus, a graphical representation of simulation results will rarely *show* the model and data uncertainty involved. While such information is normally provided in a supplementary document, there is no guarantee that this type of fine print will be read in time to affect the audience's interpretation of the more easily accessible visual image.

Together, the lack of visual cues as to the uncertain nature of simulation results and the fact that the immediateness of graphical representations means that one might *think* that one understands what is being conveyed, although this might not actually be the case, implies a high risk of misinterpretation. Specifically, it implies a risk of anything beyond what is included in the graphical representation being overlooked, including information about limitations, assumptions and sources of uncertainty necessary for understanding the sensitivity and range of imprecision of simulation results. Essentially, this means that the visualization capacity of simulation represent both a strength in terms of enabling easy communication of complex scientific messages to non-experts and, at the same time, something of a risk in terms of increasing the likeliness of too intuitive and, hence, incomplete interpretations. As a result, end-users may not appreciate the uncertain nature of the predictive information presented to them as input to decision-making.

2.2 The simulation-policy/practice interface

To begin with a clarification, the fact that predictions based on simulation technology will always be associated with some form of uncertainty is not in itself a problem. Inherently uncertain research results are used to guide societal decision-making on a daily basis, including in economic, financial, social and educational issues. What concerns academic writers is not the presence of uncertainty, but the observation that there is insufficient awareness and consideration of this on behalf of audiences beyond the science sphere.

> As individuals, most of us intuitively understand uncertainty in minor matters. We don't expect weather forecasts to be perfect, and we know that friends are often late. But, ironically, we may fail to extend our intuitive skepticism to truly important matters. As a society, we seem to have an increasing expectation of accurate predictions about major social and environmental issues, like global warming and the time and place of the next major hurricane. (Oreskes, 2000, pp. 36)

Even if people understand, intellectually, that a certain research result or piece of information is associated with uncertainty, it is quite another to be able to understand the implications of this or to account for it in decision-making:

> Every prediction contains an element of irreducible uncertainty. This fundamental fact is not disputed by scientists or by those who use their predictions to inform decisions. However, important *implications*

> of irreducible uncertainty are rarely discussed and generally not appreciated. (Stewart, 2000, pp. 41).

The question is, what might the consequences be of not appreciating the uncertain nature of simulation or of failing to account for this in decision-making?

2.2.1 Perceived risks

In principle, one can distinguish between (1) the risk of negative implications for the science community and (2) the risk of negative consequences for decision-making when simulation output enters the policy and practice sphere. In regard to the first aspect, promising too much or failing to meet the – perhaps too high – expectations of the intended audience can lead to disappointment and, in the worst case, a lasting loss of trust in simulation technology as a whole. In this respect, it is highly problematic when model and simulation uncertainties are insufficiently documented and communicated, as this may lead end-users to understand the output as more certain than it actually is. According to Ivanović and Freer (2009, pp. 2551), end-users' confidence in model predictions has inter alia been undermined by "misrepresentation (or miscommunication) of model performance (where model limitations may have been understated and inadequately explained) leading to a false representation of results, which may later become evident." Providing a concrete example, van der Sluijs (2002) recounts how, in 1999, the Netherlands National Institute for Public Health and the Environment was accused of 'lies and deceit', e.g. for not clarifying the uncertainties associated with the results of what some perceived as "poorly validated computer models" (pp. 133). Ultimately, it was not only singular findings which were questioned but the monopoly position of the institute itself as main provider of environmental statistics and forecasts. As illustrated by this and other examples (see e.g. Pielke and Conant, 2003, pp. 1356), it may not be enough that the methodological quality is sufficient in view of its function. The documentation, management and communication of uncertainties must also live up to a high standard, as it can be serious enough to pretend a non-existent precision of estimation to trigger a credibility crisis.

When it comes to the second aspect, two forms of potential problems are commonly identified in academic literature concerned with simulation as decision input. Both of these are linked to end-users' misconception of simulation models as answer machines or truth generators (see Wagner et al., 2010). First, mistaken expectations or an unclear understanding of simulations' ability to deliver 'certain' answers can lead users in the policy and practice community to confuse the presence of uncertainty with an obstacle to decision-making, so that potentially useful evidence go unheeded, in the worst case meaning that the chance at acting in foresight is lost. Second, the same type of misconception can lead non-experts to uncritically accept research results of low quality or without paying attention to limitations, assumptions and uncertainties, treating the output as more certain than warranted. As a consequence, decisions and policies may be based on mistaken assessments or on an incomplete understanding of available evidence, in the worst case leading to suboptimal or unintended outcomes.

Borrowing from terminology used by Collingridge and Reeve (1986) to describe experts' role in politics, the first of these problems can be described as resulting from an 'over-critical' approach to simulation uncertainty, whereas the later is rather a result of an 'under-critical' attitude. Below, these two problems and examples of their potential consequences will be reviewed in more detail.

2.2.1.1 The 'over-critical' approach

Beginning with the risk that potentially valuable insights will go unheeded, a commonly referred to problem is that misconception about simulation's ability to deliver 'certain' answers will reduce leaders' willingness to act on available data in the present. Under the assumption that science will sooner or later be able to deliver more precise guidance, uncertainty becomes an obstacle towards decision-making. Instead of focusing on what can be done here and now, necessary and feasible action is deferred in anticipation of more certain evidence although this may not be forthcoming within a realistic time frame. Instead of considering hedging strategies and going for measures which would increase overall resilience, a mistaken expectation in science's predictive capacity deflects a focus on decision-making in favor of a focus on more research (Wagner et al., 2010; Sarewitz and

Pielke, 1999). According to Dessai et al. (2009), this is inter alia to observe in regard to how global leaders responded to climate change in many cases.

Alternatively, uncertainty as to the reliability of simulation results can make decision-makers and managers prefer to keep to familiar procedures and established sources of information rather than to rely on unfamiliar computer models. In the European water management sector, significant investments have been made in the development of models to support policy implementation. Yet, research by Brugnach et al. (e.g. 2007, pp. 1088) show that simulation models did *not* play a dominant role in the investigated practices. On the contrary, a number of the management organizations' cupboards had turned into "graveyards for unused, unmaintained academic models" (Borowski and Hare, 2007, pp. 1062). According to Brugnach et al. (2007, pp. 1076),

> part of the difficulties of incorporating computer models as a tool for policy formulation is rooted in the lack of confidence policy makers have in model information. Generally speaking, policy makers consider computer models as potentially unreliable tools. Being the ultimate responsible parties for the decisions, they fear that the incorporation of model information could mislead or bias the decision making process.

Rather than recognizing uncertainty as a natural and to some extent irreducible part of simulation research, 'over-critical' audiences view lack of certainty as an obstacle towards use, requiring predictive information of a more accurate and precise character than the science community is able or willing to supply. Although the water managers included in Brugnach et al.'s study stressed that they knew and accepted that models are only *representations* of real-world target systems, they still wanted models to represent reality in exact terms when the effects of different measures were considered. Similarly, policy makers tended to see the presence of uncertainty as a critical constraint to decision making, leading them to avoid solutions which would require them to deal with uncertain information (Brugnach et al., 2007, pp. 1080, 1086).[10]

In terms of empirical examples of what consequences it can have when available evidence is disregarded as a consequence of low uncertainty tolerance, Pielke and Conant (2003, pp. 1352) recounts how regulatory decision-makers in the USA, e.g. due to inexperience and lack of trust in ecological forecasts, failed to act on simulation results regarding the spread of zebra mussels into the Great Lakes – a problem which, 20 years later, cost 20-100 million USD annually in clean-up and environmental mitigation.

2.2.1.2 The 'under-critical' approach

Regarding the risk that non-experts will use simulation-results without sufficient recognition for the limitations, assumptions and uncertainties involved, the account of the 1997 Red River flooding (see above) is probably the most illustrative example of why this may be problematic. Whereas the Red River catastrophe was partially a consequence of too little uncertainty information, part of the problem was also decision-makers' lack of interest, leading them to treat forecasting models as truth-machines.

According to Brugnach et al.'s (2007) study of the European water management sector, national-level policy makers, especially, show little interest in understanding the uncertainties associated with modeling and simulation, preferring to rely on experts to translate model output into readily usable policy conclusions:

> Generally speaking, policy makers were not familiar with the modelling process; commonly they did not know what models do and what type

[10] At the same time, low levels of application can be linked to other factors, too. Apart from intended users' lack confidence in computer models, including in some of the own in-house models, Borowski and Hare (2007) showed non-use of simulation models in the European water management sector to be linked to structural differences and mutual misunderstandings between the science and policy communities. For one thing, academics' main focus was not the generation of 'directly applicable' products but the deeper exploration of their own field of interests, and they were rarely able to deliver the kind of documentation and maintenance support that public management authorities require. On the other hand, intended users in water management offices were subject to a number of constraints, having little time to invest in models in terms of being guided on their use or involved in their development. Moreover, some authorities lacked resources to provide for wider access to available models or were limited by copyright regulation.

> of questions models could answer. Many policy makers used models as if they were a black box, i.e., a device that, operating in a way that is completely ignored, provides the desired output result. Under these circumstances the participation of policy makers in the modelling process was not encouraged and misinterpretations of modelling results were likely. (Brugnach et al., 2007, pp. 1077)

Policy makers ignored model uncertainty and predictive limitations, and used model results "without taking into account modelling assumptions, and without examining how robust model conclusions were with respect to variations in these assumptions" (Brugnach et al., 2007, pp. 1080).

Apart from increasing the risk of misinformed decision-making as users in policy and practice act on the basis of what they *think* is the meaning of simulation output without having this interpretation confirmed, 'under-critical' acceptance also increases the risk of people relying on predictive information of questionable quality. An empirical example in this regard concerns the use of simulation results by public authorities in the United Kingdom, in 2001, to bring the spread of foot and mouth disease in livestock under control. Although several, e.g., veterinarian experts publicly questioned the assumptions underlying models of contagion constructed by epidemiologists, it was the results of one of these controversial models that responsible decision-makers chose to rely on; ignoring available criticism. As a results, a stricter cull policy than necessary was adopted, resulting in the slaughtering of over 6 million animals at a cost to the public and private sector of 8 billion GBP – an outcome that some referred to as 'carnage by computer' (Bickerstaff and Simmons, 2004). Due to the novelty of model-based analysis to the responsible decision-makers and the nature of the model outputs "to appear more certain than perhaps they are" (pp. 407), simulation was used as a substitute for poor information and it was overlooked that poor information will also affect the quality and reliability of modeling output. Moreover, pressure to secure the livestock export market and for public authorities to show that they had learned from the criticized BSE crisis a few years prior, led to a preference for a model which would deliver rapid and seemingly unambiguous results, and allow for quick and decisive action. Hence, there was little interest in looking at other models or in examining the sensitivity of the output to changes in the criticized assumptions (Bickerstaff and Simmons, 2004).

All in all, this matches well with the assessment by Sarewitz and Pielke (1999, pp. 130) that predictive information is sensitive to misuse "because the limitations and uncertainties associated with predictive models are often not readily apparent to non-experts, and because the models are often applied in a climate of political controversy and/or high economic stakes [...]". Apart from the risk of doing too little as a consequence of not having understood the uncertain nature of predictive information, the example above shows that under-critical acceptance can also lead to the opposite outcome: doing too much and waisting scarce resources. The methodological dilemma, of course, is that it is only if the misinterpretation of good or reliance on bad predictive evidence have negative implications that misuse following under-critical acceptance will be discovered or framed as problematic. To understand this statements, one can imagine what would have happened if the forecast issued for the Red River in 1997 had been too high instead of too low; most likely no one would ever have bothered looking into how this information was interpreted and used. Even if under-critical acceptance is problematic *in principle*, then, it will not always be of consequence in practice.

2.2.2 Solution suggestions

It is worth considering what lies behind the problems noted above. According to Scheer (2013, pp. 86), two strains of explanations can be identified in the research literature as to the 'deficient' (i.e. too low or erroneous) effect of simulation in decision-making processes: those that refer to characteristics of the simulations themselves and those that refer to contextual factors.

> In simulationsbezogenen Defizitanalysen werden vornehmlich Aspekte der Modelle selbst als Erklärungsfaktoren für eine geringe und/oder falsche Wirkung herangezogen. Diese Studien beschäftigen sich mit der Thematik von Unsicherheiten und Limitierungen von Modellen und der daraus resultierenden ungenügenden Reliabilität ihrer Ergebnisse.

> Als einen weiteren Erklärungsfaktor wird die Komplexität und Undurchsichtigkeit von Modellen angeführt, so dass Entscheidungsträger das Zustandekommen der Ergebnisse nicht verstehen und entsprechend fehlinterpretieren. Bei kontextbezogenen Defizitanalysen werden dagegen Modelle in den gesellschaftlich-politischen Raum gestellt. Der Blick liegt dann weniger auf den Limitierungen der Simulationsinstrumente als auf Akteuren und Institutionen, die sie erstellen (lassen), kommunizieren oder nutzen. (Scheer, 2013, pp. 86)

Often, though, empirical analyses draw on reasons pertaining to both of these categories when explaining non-use and black-box use. In relation to the European water management sector, for example, workshops and interviews with both modelers, policy-makers and practitioners have helped Brugnach et al. (2007) and Borowski and Hare (2007) identify a number of perceived or observed problems leading to difficulties in relation to non-experts' dealings with models and simulation results. Though the overriding issue found in Brugnach et. al.'s study was "the need for a more explicit and comprehensive statement of a model's assumptions and limitations and better information provided on the sensitivity and uncertainty inherent in the model outputs." (2007, pp. 1080), users' confidence in and use of simulations was also thought to be affected by lack of understanding of models; lack of certainty or validation of models; restrictions in models; modelers' behavior; lack of integration of policy-makers and modelers; and lack of stakeholder involvement in the modeling process. Here, then, we see that both characteristics of the model (i.e. restrictions, lack of certainty, complexity) and factors pertaining to the actors and the research and communication processes (i.e. modelers' behavior, users' lack of understanding and the insufficient exchange between the two groups) are pointed out as responsible.

In contrast, Borowski and Hare (2007) choose to focus more on structural and attitudinal differences between the science and policy communities, arguing that there is "a mutual misunderstanding about the resources (time and funding) available to each community to develop and use model-based tools [...]" (pp. 1070). The result of this is that it may not be sufficient to invest in more and better uncertainty analyses; what water managers want is not for uncertainty to be better represented, but for it to be significantly reduced. In other words, the problem does not lie in the representation of uncertainty but in the user community's attitude towards simulation uncertainty: "water managers are requiring a level of model validity and of a lack of ambiguity in results that modelers are increasingly disinclined to provide." (Borowski and Hare, 2007, pp. 1066).

So what can be done? Apart from calls for more explicit information on models' assumptions and limitations, and on the uncertainty and sensitivity of output data and predictions, a common recommendation is for more communication, interaction and exchange between users and producers of models and simulation results. First of all, this is thought to be able to affect attitudinal changes, i.e., so that researchers become better at articulating and understanding the policy-relevancy of uncertainty, while decision-makers become better at recognizing and dealing with it. Second, closer cooperation is thought to be able to lead to models that are better suited to the user's needs. According to Wagner et al. (2010), for example, it is a problem that policy makers and regulators see themselves as detached consumers of simulation output. Continuous interaction could not only help address misconceptions about the capabilities of computer models but also ensure model constructs that answer the right types of questions and rely on appropriate assumptions.

The implications of Borowski and Hare's analysis, however, is that structural and attitudinal differences can make interaction and model co-production difficult. In practice, managers often lack both time for and interest in such activities (Borowski and Hare, 2007), whereas policy makers feel that decision-making is complex enough in its own right, failing to see a need to complicate it further (Brugnach et al., 2007).

In a similar way, some see problems with the idea of offering more and better uncertainty information, arguing that there is a trade-off between offering complete information and keeping it comprehensible:

> Although tempting to provide more complete information in order to assist decision makers, in two experimental studies, we demonstrate that more complete information can lead to decreased comprehension and quality of choices, particularly for individuals with lower skills [...]" (Peters, 2008, pp. 297).

In practice, a different appraoch is noticeable. As noted by Borowski and Hare (2007), researchers are increasingly preferring to produce predictive information on a range of possible outcomes rather than a single future trajectory, referring to computer models as ‘ideas generators’, ‘epistemological devices’, or tools for awareness raising and exploration. At the same time, the authors note, this does not change that users of model-based tools still need concrete reason to trust that the simulated scenarios are ‘good enough’ to consider as serious possible futures, meaning that the problem of too high expectations on the predictive capacity of computer models largely remains.

For their part, Pielke et al. (2000) and Dessai et al. (2009) specify a number of factors supporting beneficial use of simulation in the policy sphere, including, e.g., that the predictive skill is known, that the user has experience with understanding and using predictions, and that the time frame of the predicted event is short (to allow for evaluation). Furthermore, recommendations for how to counteract problems stemming from over- and under-critical use of simulation concern for policy makers to hedge their bets, consider alternatives to prediction, and to focus on good (i.e. resilient) decisions rather than on good (i.e. certain) prediction (Pielke et al., 2000).

In principle, then, there are different recommendations and strategies for how to come to terms with problems related to a misconception of simulation technology. Central in this regard are those focusing on (a) more and better uncertainty information, (b) more interaction, (c) strategies for making simulation output less vulnerable to misuse, and (d) strategies for how to make decisions in spite of predictive limitations.

Having seen that non-use and misuse are two problems associated with the introduction of simulation results into the policy and practice sphere, but also that there can be different reasons for such outcomes, the next chapter will focus on research use in more general terms. After all, what constitutes sound and legitimate use of research and how this can be achieved or encouraged are issues that have preoccupied academics in the field of *Knowledge Utilization* (KU) for many years.

Chapter 3

The science-policy nexus and research utilization

3.1 Science in the policy sphere

Although the relation between science and politics has been subject to discussion much longer,[1] the idea that it is "critical that governmental decision-makers benefit from the best possible information they can get, relevant to the actions they contemplate", dates back more than 200 years (Chelimsky, 1991, pp. 226), to the time of the industrial and political revolutions (cf. Elzinga and Jamison, 1995, pp. 580). To mention but a few of the benefits that science can bring to policy and practice, research can be used to:

- offer evidence, ideas and concepts;
- clarify respectively reduce areas of uncertainty or lack of knowledge;
- confirm knowledge of tacit, local and indigenous character;
- identify issues requiring public policy or management attention;

[1] According to Weiss (2002, pp. 376), the discussion of the proper role of expert advice can be traced back to the era of classical Greece, during which Plato wished to install a form of technocrat-rule while Aristotle argued that the role of the technocrat was to advise but not to decide.

- identify and assess options for policy and practice;
- help exclude alternatives for action that contradict basic scientific principles;
- guide and legitimize decision-making;
- evaluate policy and account for the reasons for success or failure;
- constitute a language for communication (Weiss and Bucuvalas, 1980; Ascher, 2004; Weingart, 1983).

Yet, it is not always that research evidence is heeded or scientists' warnings taken seriously. An oft cited example in this regard concerns the 2005 flooding of New Orleans by Hurricane Katrina. Not only was it known that the levee system had been inadequately maintained, but researchers had continuously warned against draining the surrounding wetlands on the basis of this aggravating the risk of inundation. Hence, the disaster that followed was not so much a consequence of insufficient knowledge or research as of the policy community's unwillingness or incapacity to respond to available evidence (Egner, 2008, pp. 422).

Indeed, the relationship between science and policy can be tricky. According to Hoppe (2005, pp. 206) it often takes the form of an 'argumentative pin-ball machine':

> Scientists keep accusing politicians of asking the wrong questions and under-using their precious insights. Vice versa, politicians and policy-makers keep telling scientists that they produce usable knowledge too little and too late.

Likewise, Vogel et al. (2007, pp. 350) write that...

> policy-makers and managers often indicate that they do not receive the information they need, scientists are frustrated when their information is not being used, and ultimately, communities remain vulnerable in the face of extreme events and environmental changes.

While scientists tend to see themselves as 'speaking truth to power', policy-makers tend to prefer the metaphor of politics 'on top' and science 'on tap', signaling that it is for them to decide when scientific advice is called for (Knaggård, 2009, pp. 67-69). Hence, research use is all but straightforward although one would rationally expect it to be otherwise.

This chapter will first review what is meant by research use, and how it differs from misuse and non-use. Thereafter, it will be reviewed what is hitherto known about the factors affecting whether research is used or not used in the policy and practice sphere.

3.2 What is research use?

3.2.1 Typologies of research utilization

The issue of how to define and measure research use has traditionally been dealt with in studies of *Knowledge Utilization* (KU), and normally focused on the application and influence of social science findings (e.g., in the fields of health care, education and other forms of social service provision). In KU literature, it has long been subject to debate what should suffice for someone to say that research has indeed been *used*. Should it be equated with information being received, read, understood, appreciated, made the basis of a decision, leading to action, or having an effect (see Machlup, 1993, pp. 449-450)? Empirically, academics in the field of KU studies often look at whether or not research is read, referred to or having any kind of direct effect, focusing either on objective criteria and observable indicators (such as number of citations or actual policy change) or on decision-makers' and practitioners' own subjective assessments of whether and how research is used (Nutley et al., 2007, pp. 67).

In more theoretical terms, research is thought to be usable in different ways. Hence, there is no *one* exact definition, but rather typologies and categorizations of different forms of research use. An early and oft cited example in this regard is the typology developed by Carol Weiss (1979). In Weiss's view, one can distinguish between seven different forms of research use, pertaining to both natural and social science products:

- The knowledge-driven model, implying that research leads policy; once knowledge (or technology) exists, it will eventually become used.
- The problem-solving model, suggesting that research follows policy, being sought out or commissioned when there is a particular problem in need of a solution.
- The interactive model, in which research findings are used in a non-linear process of decision-making along with experience, political insight, social pressure, etc.
- The enlightenment model, implying that research knowledge will percolate through (or diffuse in) society, shaping decision-makers' general thinking about issues, although they might not actively pursue scientific information.
- The political model, implying that research is used selectively to support, defend and/or legitimize a previously adopted position.
- The tactical model, in which the fact that research is being undertaken or commissioned is used, e.g. to enhance decision-makers' credibility or to defend non-action.
- A seventh model casts research as part of the intellectual enterprise of society. That is, as a dependent variable rather than an independent.

While indeed covering many of the roles played by science in policy and practice, the many different categories – all of which are not mutually excluding – also makes this framework somewhat cumbersome as a basis for empirical analysis. A simpler but still related typology is a framework that differentiates between instrumental, conceptual and strategic (sometimes referred to as symbolic or legitimative) research use. From now on, this will be referred to as the ICS-framework.[2]

Instrumental use is the type of usage that has traditionally been aimed for under the assumption that research today means decision-help tomorrow (Hoppe, 2005, pp. 203). It involves direct application of research to decision-making in politics and practice, and can largely be said to correspond to Weiss's knowledge-driven and problem-solving models (Ginsburg and Gorostiaga, 2001). According to Nutley et al. (2007, pp. 34-5), instrumental use can mean somewhat different things in different settings. At macro policy level, it can mean that research is used to develop and choose between policy options. For practitioners, it can mean that research is used to define the most appropriate course of action, leading to new processes and activities on the ground. And for local policy makers, it can mean that research is applied in deciding on local priorities or for defining a strategic direction. In either case, use is explicit and direct, meaning that it is possible to tell whether research has been instrumentally used or not by looking at whether or not a specific piece of research has influenced decision-making or been instrumental in defining a solution to a problem (Nutley et al., 2007, pp. 36).

Conceptual use refers to more indirect and subtle ways of using research. Rather than direct application to a situation needing a solution, conceptual use means that research findings are assimilated into the user's belief system (potentially together with other forms of information), giving rise to new knowledge or confirming or revising existing one. Research can serve to raise consciousness, shape people's understanding, attitudes and ways of thinking, alert people to new issues, provoke societal debate, etc. Policy makers often state that research 'informs' rather than 'determines' policy, whereas practitioners emphasize how research enhances their understanding of key issues, provides new ideas and perspective, promote discussion, etc. (Nutley et al., 2007, pp. 36-7). According to Ginsburg and Gorostiaga

[2]Sometimes, process use is presented as a fourth category of the ICS-framework (see Nutley et al., 2007, pp. 38). Process use refers to changes in thinking or behavior stemming from learning arising during involvement in the research process, e.g. as a result of enhanced communication or interaction between the science and policy spheres or between different organizational departments. A different way to see this would be that both the results and the process of research can give rise to new knowledge or influence practical decision or routines. In this way, focus is kept on whether and how research is used, rather than mixing in what causes these effects.

(2001), conceptual research use largely corresponds to Weiss's enlightenment and interaction models. Compared to instrumental use, this means that conceptual research use is more difficult to identify since their influence is more abstract and less direct. At the same time, Nutley et al. (2007, pp. 36) write that "research is much more likely to be used in conceptual than instrumental ways".

Strategic use, finally, refers to when research is commissioned as an alternative to having to take action or when it is selectively deployed to advocate for, push through, or legitimize a predetermined position. In this sense, it corresponds to Weiss's political and tactical models of research use, but is also described to cover the somewhat different category of promotional use, in which research is applied to promote the implementation of a policy to individuals who were not involved in the decision-making process (Ginsburg and Gorostiaga, 2001, pp. 175-6). Representing a more critical perspective, the 'research as ammunition'-tradition argues that strategic usage involves the manipulation of knowledge to attain specific power or profit goals (Huberman, 1987, pp. 590).[3] Taking a different view, Nutley et al. (2007, pp. 37) describe strategic use as being when policy makers find that research provides credibility and weight to their agencies and policies, or when practitioners mention that research helps them validate what they do personally and publicly. Compared to conceptual and instrumental uses, strategic research use does not imply an effect on the user's knowledge level, decisions or behavior, but on his or her confidence and/or capacity to pursue a certain agenda. Indeed, strategic research use is often about affecting how *others* think and feel, thereby paving the way for a favorable context for policy and practice change. In this sense, strategic research use is partially related to the concept of 'framing' and activities in the field of public relations and political communication.

An alternative framework, which some feel reflects the complexity of the field better, is the conceptualization of research use as a linear and cumulative process of stages. In the model proposed by Landry et al. (2001), for example, research use is described as a ladder with six steps ranging from transmission to application via cognition, reference, effort and influence. While there are many different 'stages models' (see Blake and Ottoson, 2009), the critique against them is generally the

[3] Whereas some would refer to this as misuse of research, Weiss (1979) argues that research-as-ammunition is valid as long as all participants in the policy process have access to all evidence. Invalid use is instead when research is willfully distorted or deliberately misinterpreted.

same, pertaining to (a) the fact that they ignore strategic forms of research use, and (b) the way they depict instrumental use as the ultimate goal for all research evidence (Nutley et al., 2007, pp. 47-51). As Young et al. (2002) put it: considering that the policy processes is not rational enough to live up to the ideals associated with 'evidence-based' policy making, conceptual research use is often preferable.

In principle, this means that there is no general definition of what research use is, only more or less complex categorization systems and typologies. A common point of critique against these is that it can be misleading to think of research use as a one-off event to be classified according to a pre-defined schemata. For instance, Nutley et al. (2007, pp. 43-5, 58) argue that research use is better portrayed as a dynamic process that moves through different models and changes character over time, thus allowing for different types of usage to occur simultaneously respectively to interact in multiple and overlapping ways. So far, though, no model has been developed that captures this dynamic element. The closest try is to depict conceptual and instrumental research use as located in either end of a continuum; ranging from awareness of research findings to direct changes in policy and practice (Nutley et al., 2007, pp. 51). While such a conceptualization has the advantage of not requiring a sharp line to be drawn between conceptual and instrumental forms of influences, it has the drawback of not covering any strategic kinds of application.

3.2.2 Use, misuse and non-use of research

Regardless of which typology or way of thinking about research utilization one prefers, the fact is that not all research is 'used'. J. Bradley Cousins (2004) is one of the few authors who offers a conceptual framework covering both use, non-use and misuse of research.[4] In his view, research is either used or not used, respectively either handled in an appropriate and justified manner or not. Furthermore, he distinguishes between the use of 'good' and 'bad' research (the latter being a result, e.g., of unforeseen circumstances leading to design degradation, or of incompetence

[4]Though Cousins taxonomy concerns legitimate and illegitimate (non-)use of social science evaluation, nothing speaks against applying it to other forms of research as well.

or mischief on behalf of the researcher). Following these assumptions, Cousins arrives at a four-part taxonomy of research use (see Figure 3.1).

The first of these categories concerns cases of appropriate use of 'good' research. Cousins view instrumental, conceptual and strategic use as three different forms of legitimate research use, meaning that these become sub-categories of what he refers to as *ideal* use.

The second category contains two different types of misuse. First, there is the case of *mischievous* use of 'good' research, meaning that the recipient acts to "distort, fudge or otherwise misrepresent the findings" (Cousins, 2004, pp. 393). Second, there is the case of *mistaken* use of 'bad' research. If a user is too uncritical, for example, and fails to reflect on the quality of research, he or she might end up accepting and using results for which there is little real support.

The third category refers to illegitimate non-use. This is when 'good' research (i.e. valid findings) are intentionally swept under the rug for self-serving purposes. In Cousin's framework, such inappropriate suppression of findings is referred to as *abuse* of research.

Finally, the fourth category refers to legitimate non-use, of which there is two kinds. *Rational* non-use is something that can emerge as a consequence of a conscious decision not to transmit or use 'bad' research, or as a consequence of untimely reporting, poor communication, findings being irrelevant, etc. *Political* non-use, on the other hand, is when defensible findings go unused "in light of competing information, changes in the decision or policy context, and a host of other factors" (Cousins, 2004, pp. 393).

While Cousins's framework is comprehensive in terms of differentiating between both use and misuse, and use and non-use, the question remains how to operationalize and separate these categories from each other in practice. As already hinted to at the beginning of this chapter, what is seen as legitimate or illegitimate when it comes to research use will often be a matter of perspective. To give an example, Hoppe (2005, pp. 203) write that social scientists often discover that influence in the policy sphere comes at the cost of hard-worked findings being "severed from their nuances and qualifications and re-shaped as un-scientific,

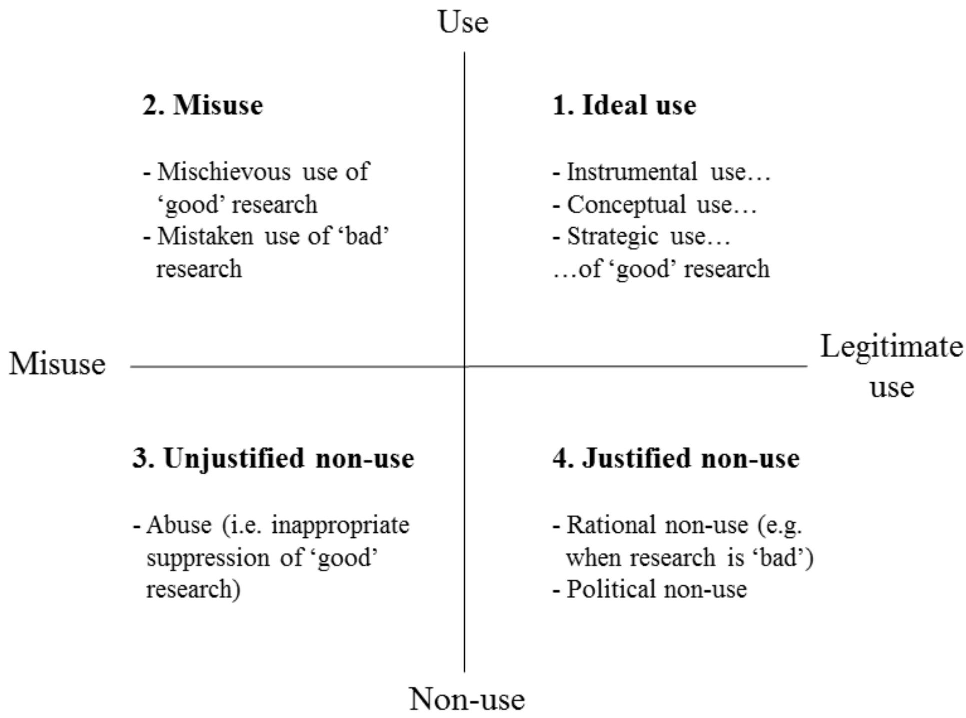

FIGURE 3.1: Use, misuse and non-use of research. Adapted from Cousins (2004, pp. 392).

over-generalized, and popularized stories." But is this 'misuse' or still within the boundaries of what is legitimate? Likewise, Ascher (2004) find that government officials in natural resource politics will, inter alia, interpret the implications of scientific information in ways that ignore the complexity of the situation; dismiss scientific input as biased; reach self-serving conclusions regarding the reasons for past successes or failures; over-simplify models to make the own agency's policies seem less prone to uncertainty; and exaggerate and exploit scientific uncertainty in order to justify inaction. But is this willful manipulation and abuse of unwelcome findings or simply what strategic research use looks like in practice? To provide a contrast, Knaggård (2009, pp. 280) does not portray it as problematic that scientific uncertainty associated with climate change research 'disappears' more and more as the policy process progresses, but describes this as a consequence of how knowledge brokers translate and reformulate evidence to match end-users' knowledge background and to make 'science' understandable to non-experts.

According to modern learning theory, it is *natural* for audiences of different backgrounds and interests to focus on somewhat different things and understand findings in somewhat different ways. People are not a *tabula rasa* onto which new knowledge can be inscribed and the human brain is not a sponge that will simply 'soak up' new findings. Instead, people will interpret new information in light of their pre-existing knowledge, values and experiences (cf. NCDDR, 1996). While this does not make all interpretations equally valid, it does suggest a difficulty in terms of separating willful manipulation from 'innocent' instances of selective perception.

Ultimately, this implies a possibility of the science and policy community having different views as to what constitutes legitimate or illegitimate use and non-use. Moreover, there is some support for the notion raised in chapter 2 that what some perceive as 'misuse' will not necessarily be the act of *intentional* manipulation or distortion of findings, but can also be the unfortunate result of insufficient understanding or erroneous reading of the same. As long as there are no obvious negative consequences giving raise to questions, though, decision-makers may never even learn of their interpretation and application of research being 'misinformed'.

3.3 Explaining research use

Traditionally, the role of science in policy and practice is often portrayed as making these more rational and evidence based, reflecting a view of decision-making as a linear and logic process of defining goals, analyzing options, and acting on the basis of what research and analysis suggest is best (Becker and Bryman, 2004; Nutley et al., 2007, pp. 92-4). Descriptive theories of later date, however, tend to distance themselves from such a rational understanding of policy making and the science-policy nexus.[5] If societal decision-making is understood as something that

[5]In the incremental model by Charles Lindblom (1959), for example, political administration is not a question of doing what research suggests is 'best', but about what is possible; goals and the means to achieve the same will be selected simultaneously and policy will be made and re-made in a process of successive approximation towards aims which may themselves be changing. Likewise, the policy streams model by John Kingdon (2003) depicts policy change as something that happens when three streams of recognizing problems, generating policy proposals

involves ambiguous goals, inconclusive information, public opinion, struggle over legitimacy, framing and agenda setting (cf. Becker and Bryman, 2004), it becomes understandable why influence over policy and practice is not simply a question of producing valid findings. Indeed, "information may be complicating and inconvenient, obscuring the clarity of choices most easily made under conditions of relative ignorance." (Young et al., 2002, pp. 218). To this comes the 'two communities theory', indicating that research use is prevented by a cultural gap between the science and policy communities, taking the expression of different incentives, interests and internal rules (Caplan, 1979, pp. 459).

While helpful for enlightening why research use is not straightforward, descriptive theory of this kind is not very helpful when it comes to understanding specific instances of (non-)use. Though the academic field of KU studies has focused on the issue of research use for quite some time, the fact of the matter is that there has been little theory building within this discipline, implying an general absence of explanatory models of what determines research influence (cf. Landry et al., 2001; NCDDR, 1996, pp. 7). What there is, instead, is an extensive amount of empirical work, sometimes referred to as the 'factors affecting'-literature.[6] Traditionally, this work has focused on knowledge utilization of social science research, but, recently, studies of the use of hazard and environmental assessments and vulnerability, resilience and risk reduction research have become more common, too (see e.g. Morss et al., 2005; Weichselgartner and Kasperson, 2010; Mitchell et al., 2006b; Kolkman et al., 2005). Whereas studies of social science usage have tended to rely primarily on quantitative methods, often ending up pointing towards the importance of factors related to *personal characteristics* of researchers and users, the *nature of research*, *linkages* between research(ers) and users, and the overall *context* of research use (Nutley et al., 2007, pp. 67-8),[7] studies focusing on the use of environmental assessments have often relied on qualitative case studies to

and engaging in political activities come together, e.g. as an external event opens up a 'window of opportunity' for action. Even if research identifies a serious problem or a rationally superior solution, it is unlikely to be of much influence unless someone lobbies for it or turns to the science community for input.

[6]In all of this literature, focus is placed on what affects research use, not on whether or not these reasons are legitimate or illegitimate or on whether the outcome should really be characterized as misuse.

[7]Though a research review by the NCDDR (1996) instead highlights the importance of factors related to the *source*, *user*, *content* and *medium*, these are largely different labels for the same relationships.

identify relevant 'factors affecting'. What these have been shown to indicate is that research use is largely dependent on the intended audience's perception of research (e.g. Mitchell et al., 2006a; Cash et al., 2003). As Cash et al. (2003, pp. 8086) put it, "scientific information is likely to be effective in influencing the evolution of social responses to public issues to the extent that the information is perceived by relevant stakeholders to be not only credible, but also salient and legitimate." In terms of what affects how research is perceived, this appears to depend both on the characteristics of research, users' needs and user-producer interaction, hence indicating clear similarities with more traditional KU findings.

Because simulation research on natural hazards has more in common with environmental assessments than with social policy analysis, the next section will begin with a review of the concepts of *credibility*, *saliency* and *legitimacy*, drawing both on the findings reported in Mitchell et al. (2006a) and Cash et al. (2003), and on insights stemming from KU studies. Thereafter, the categories of personal characteristics, research characteristics, science-policy linkage and context will be briefly enlightened to provide a complementary image to this picture. Finally, as neither of these strains of literature deal explicitly with the role of scientific uncertainty for research use, a short review of what *Science and Technology Studies* (STS) has to say on this topic will be provided at the end of the chapter.

3.3.1 Credibility, saliency and legitimacy

Credibility

Beginning with credibility, this involves the user's assessment of the scientific adequacy of the technical evidence and arguments provided by a piece of research (Cash et al., 2003, pp. 8086). As Mitchell et al. (2006a, pp. 317) puts it, the influence of research will partly depend on whether actors can be convinced "that the facts, theories, ideas, models, causal beliefs, and options contained in an assessment are 'true', or at least a better guide to how the world works than competing information." In this respect, it does not go unnoticed that non-experts may be hampered in their ability to independently judge the information claims made in research. According to Mitchell et al. (2006a, pp. 318-9), this means that credibility will sometimes be assessed through some form of proxy related to the source's credentials, or alternative sources of information will be sought out for comparison. Furthermore, close contacts between researchers and intended users before, during and after a scientific inquiry or project can help build trust and confidence both in the source and in end-results (e.g. by providing insight into how the latter were achieved).

Supporting these findings, KU studies tend to point to research quality as one of the factors likely to affect uptake of new findings, as doubts about research quality is found to be a key reason for non-use (Nutley et al., 2007, pp. 68). At the same time, audiences in policy and practice are noted to judge research quality differently from academic peers. For example, decision-makers will sometimes place more emphasis on a piece of research's ability to withstand political critique than on formal criteria of validity. In other instances, the trustworthiness of the source has been found to be more important than the credibility of the research itself (NCDDR, 1996, pp. 15). According to a quantitative study by Weiss and Bucuvalas (1980), furthermore, decision-makers judged the 'truthfulness' of incoming social science research on the basis of (a) its technical merit and the degree to which it adhered to basic scientific rules, and (b) "the extent to which research outcomes agree with their firsthand experience and professional judgment" (pp. 308), drawing on everything from direct observation to routine statistics (i.e. there are two components of what they refer to as the 'truth test'). Indeed, the better the fit with previous knowledge, the less important became the criteria of research quality. If, on the other hand, research diverged from the known, research quality suddenly became crucial for whether people would accept the findings or not (pp. 309).

Hence, it is not only the methodological quality of research that matters for whether or not an audience will perceive findings as credible but also whether there is other evidence supporting them; whether there is a fit between formal research results and professional knowledge and practice wisdom; whether the source is trusted; etc.

Saliency

Regarding relevancy, Cash et al. (2003, pp. 8086) write that saliency refers to the fit of assessments to decision-makers' needs. For information to be perceived as relevant, it helps if it is produced with an eye towards the decisions that are likely to be affected; if it is responsive to local needs and concerns; if it is timely, coming before – but not too long before – relevant decisions; if it links to issues on which decision-makers focus (and over which they have control); and if it identifies actions that can be taken to mitigate or adapt to a problem (Mitchell et al., 2006a, pp. 314). Hence, close ties between researchers and intended audiences can increase the chances of research being perceived as relevant. First, this is because this will allow the researcher to learn about decision-makers' constraints and the issues currently on the agenda, thereby allowing him or her to better respond to users' needs and concerns. Second, Mitchell et al. (2006a, pp. 327) note that it can take considerable effort to help decision makers understand the relevance of scientific findings to their decisions. In this respect, involving users in the research process can fill the function of strengthening the audience's interest in and capacity to make use of scientific evidence.

KU studies largely support these findings. According to Nutley et al. (2007, pp. 68-71), relevancy is largely a question of matching decision-makers' day-to-day needs, and of being timely and action-orientated. In terms of *which* research is likely to be seen as salient, both commissioned research and research which has been conducted locally, within the context of its future use, are more likely to be seen as relevant. Moreover, user-influence is something that is thought to increasing the chances of application by making sure that the 'right' questions are posed and that local needs and concerns are accounted for. Focusing on the saliency of research over which users have *not* had any influence, on the other hand, Weiss and Bucuvalas (1980) find that decision-makers will first of all assess whether the content of a study is relevant to their sphere of responsibility. Thereafter, a 'utility test' will be applied (together with the above-described 'truth test'). One part of this test consists of assessing "the extent to which a study provides explicit and practical direction on matters that they can do something about", suggesting that research will be influential if it is sensitive to established constraints and proposes solutions that fit with current practices (pp. 308). Alternatively, a study can pass the utility test if it challenges the status quo, drawing attention to problems associated with current practices, and suggesting new perspectives and orientations. In effect, then, saliency is only partially about producing results that fit with current practices. It can also be about questioning those practices or in some other way sound the alarm as to emerging problems.

Ultimately, this means that a number of different factors and circumstances may affect whether a piece of research is found to be relevant or not. In terms of the research itself, its content should preferably correspond to the intended audience's needs, concerns and current agenda. Furthermore, the results should either provide practical direction by identifying concrete options for action or they should bring hitherto unknown problems to light, thereby challenging the status quo. At the same time, saliency will also be a question of what is currently going on at a contextual level and of an institution's organizational constraints. Though user-producer interaction may help achieve a match between an audience's needs and research content and contribute to build interest in findings, there will also be cases in which no interaction is possible or in which this must be limited to selected representatives.

Legitimacy

According to Cash et al. (2003, pp. 8086), "[l]egitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests." Likewise, Mitchell et al. (2006a, pp. 320) speak of legitimacy as involving the perception of an audience of the assessment process as 'fair'; having considered the audience's values, concerns and perspectives: "Audiences judge legitimacy based on who participated and who did not, the processes for making choices, and how information was produced, vetted, and disseminated." (pp. 321). In this respect, pre-existing mistrust on behalf of the target group, e.g. for historical reasons, is something that can affect the chances of research being perceived as legitimate. For example, audiences in the southern hemisphere have been found to be skeptical of global environmental assessments produced by researchers in the north, whereas people in the former eastern block will sometimes reject findings stemming from the west (Mitchell et al., 2006a, pp. 322). As before, this means that close ties between users and producers are important since this can help bridge historical gaps and serve to build a common understanding of why and how a study should be made:

> The effectiveness of assessment processes depends on a process of co-production of knowledge between assessment producers and potential assessment user groups in which the boundaries among these groups are bridged so that they can develop reciprocal understandings of what salient, credible, and legitimate mean to the others involved. (Mitchell et al., 2006a, pp. 324)

In KU studies, there is no particular focus on legitimacy. Moreover, in a quantitative study by Weichselgartner and Kasperson (2010) to test the importance of users' perception of credibility, saliency and legitimacy for their use of vulnerability and resilience research, what the authors found was that, if a decision-maker did not consider an assessment to be legitimate, he or she would – in most cases – also not regard it as credible. Hence, it was between the variables of legitimacy and credibility perception that there was a significant relationship, rather than between legitimacy and research use. Essentially, then, the concept of legitimacy may be valuable for highlighting the possibility of research being rejected due to historical schisms, respectively for underlining the importance of user-producer cooperation to overcome pre-existing skepticism and hostility, but not necessarily for explaining research (non-)use.

3.3.2 Further affecting factors

This section reviews factors that KU studies emphasize as important in terms of affecting research utilization, and which have not yet been exhaustively discussed above.

Personal characteristics

Though attempts have been made to identify individual characteristics that shape the use of research, Nutley et al. (2007, pp. 73) conclude that this search has generally born limited fruit. In principle, there are some evidence that people with higher levels of education or qualification are more likely to use research, reflecting, e.g., differences in values and/or skills. Likewise, some researchers are more talented than others when it comes to interacting with users and/or marketing their results. In the end, though, what the findings come down to is often that some people are more willing than others to make changes to current practices or to experiment with new ideas (both in the policy/practice sphere and in the science community), without it being possible to identify any common characteristics to explain these differences.

Research characteristics

In relation to research characteristics, many of the findings discussed in KU studies, e.g. concerning quality and relevancy, have already been discussed above. Apart from the factors contributing to whether or not research is perceived as credible and salient, though, there are also factors that are observed to affect whether or not research reports are read in the first place. Specifically, these factors concern the results' format and comprehensibility in the sense that reports that are difficult to understand or which it takes too much effort to decode are less likely to be influential. In effect, this means that, for research to be used, it should preferably come in the shape of concise, simple, clear and repeated messages, well-packaged in an attractive, user-friendly and visually appealing format that makes them easily accessible (NCDDR, 1996; Nutley et al., 2007, pp. 68-72).

Linkages

When it comes to user-producer contacts (including the medium of research dissemination), studies show that utilization is enhanced when contact is sustained throughout the course of a study, when it takes the form of a two-way dialog and when it involves face-to-face interaction. Such exchange does not only increase the likeliness of research addressing relevant issues but is also pointed out to help establish relationships of trust, increase the audience's sense of ownership of the findings and address user-incapacity problems. Alternatively, a knowledge broker (i.e., an actor playing an intermediary role between potential users and evidence producers) can fill a similar function. Effectively, this suggests that some form of supportive institution or actors helping intended users understand research results and how these may be used is something that can facilitate research uptake

(NCDDR, 1996; Nutley et al., 2007, pp. 73-5). In contrast to the literature focusing on environmental assessments and natural hazards and disaster prevention (e.g. Mitchell et al., 2006a; Weichselgartner and Kasperson, 2010), though, KU studies seldom call for outright 'co-production'. On the contrary, a certain distance between users and producers is sometimes depicted as necessary for the sake of integrety.

Context

Context, finally, refers to the climate and incentive structures characterizing the current policy and practice environment. For example, research use is facilitated when an organization is characterized by 'readiness to change' (NCDDR, 1996, pp. 23-4), senior-level openness towards science usage or the presence of someone actively championing research use or lobbying for specific findings (Nutley et al., 2007, pp. 70, 74).

When it comes to policy processes, the concept of 'context' involves the interests of those involved in policy making, the ideology and institutions within which they act (characterized by certain belief systems, histories, cultures and constraints), and the extent to which alternative sources of information crowd for attention. Studies show that research is more likely to be used when findings are aligned and compatible with the current ideological environment, with personal values, and with individual and agency interests, but also in times of political crisis (Nutley et al., 2007, pp. 75-8). For practitioners, context has more to do with organizational characteristics; whether there is time, autonomy or authority to instigate change. Among heavy workloads, competing pressures and continual demand for change, research use sometimes takes a low priority and the requirement to engage with research can even be seen as a burden (Nutley et al., 2007, pp. 79-80).

In relation to risk managers, this assessment is supported by a study by (Morss et al., 2005), in which the intended audience's low interest in more precise flood risk information was explained with reference to their pressured work situation leaving little space for them to consider new research findings (including more precise uncertainty information):

> [P]ractitioners are constrained by time, money, and other resources, particularly given their multiple responsibilities. They also use many types of information that evolve and thus compete with scientific information to be updated. Under such constraints, familiarity with existing processes often reduces practitioners' motivation to invest in learning to use new scientific methods and information. (Morss et al., 2005, pp. 1595)

In effect, this means that there are similarities between the aspects that KU literature refers to as the 'context' of research use and some of the descriptions of what affects whether research will be perceived as relevant or not, specifically in the emphasis of an organization's interests and the importance of research matching eventual constraints and current needs. Ultimately, though, as with the category of personal characteristics, it appears difficult to pinpoint what determines whether or not an organization is characterized by readiness to change or openness to science use.

To conclude, what the 'factors-affecting'-literature shows is that there is no simple one-way relationship between any one factor and research use. According to Nutley et al. (2007, pp. 84-5), this realization has altogether curbed the enthusiasm amongst KU scholars for quantitative efforts to isolate main determinants of influence. Instead, more case study analyses are increasingly being called for to map out the complex relationship of interacting factors involved in knowledge utilization.

3.3.3 The role of uncertainty

Since the presence of uncertainty was identified in chapter 2 as something that can affect whether and how simulation results are used, this section will take a closer look at what STS literature says about the role of scientific uncertainty.

According to Knaggård (2009), scientific uncertainty is what we know that we do not know, rather than what we are unaware of not knowing. For empirical investigations, it can be identified either as the absence of certainty or as the lack of accord within the scientific community. For their part, Walker et al. (2003, pp. 8) have defined uncertainty in broad terms as "any departure from the unachievable ideal of complete determinism", noting that one can distinguish between the location of uncertainty, its level, and its nature, where 'nature' refers to the distinction between aleatory (i.e. stemming from variability in populations) and epistemic uncertainty (i.e. arising from a basic lack of knowledge). Since aleatory and epistemic uncertainty can – to some extent – be reduced by increasing the sample size or by doing more research, though, Renn (2008, pp. 70-1, 76) also refers to a category of 'genuine' uncertainty pertaining, e.g., to variation of effects due to random events or indeterminacy, and which cannot be completely resolved.

Regarding the role of uncertainty, high levels of uncertainty will not necessarily prevent a study from being perceived as credible. It may, however, affect a user's assessment of the results as relevant in the sense that, the higher the level of uncertainty, the less guidance the findings are perceived to offer. According to Shackley and Wynne (1996), this means that scientists must succeed with a dual interpretation of uncertainty. On the one hand, it is there and should not be ignored, and, at the same time, it should not be taken to undermine the authority of science or be seen as a threat to its usefulness for policy-making. Put differently, it should neither be seen as a scientific failure nor become an alibi for decision-makers to ignore available evidence.

To succeed with this dual interpretation, scientists are found to adopt different strategies, including to place the responsibility for uncertainty on someone else, to frame it as under control, to consciously or unconsciously condense it to one category, to reduce it, or to say *when* it will be reduced. Moreover, scientists in advisory functions will often represent uncertainty in conformity with policy makers' assumptions about its implication for decision-making and management (Shackley and Wynne, 1996).

When it comes to the policy process, (Knaggård, 2009, pp. 281) argues that there are three logical ways of responding to scientific uncertainty: (a) to ignore it, implying that decisions will be made as if available information was actually certain, (b) to perceive and/or to frame it as too large, in which case decision-making becomes difficult, or (c) to perceive and/or to frame it as manageable, in which case the focus will shift towards what is known and what can be done on the basis of this (including hedging strategies or efforts to increase overall resilience). In practice, this means that the role of uncertainty does not only depend on its size but also on how a user chooses to frame it (such as when uncertainty is exploited to avoid having to act).

In Knaggård's (2009, pp. 2071) view, uncertainty reinforces the incremental character of the policy process. Based on an empirical study of the role of uncertainty in Swedish climate change politics, scientific uncertainty was found to be handled in four different ways depending on (a) whether the uncertainty was seen as manageable or not, and (b) whether it was framed as the responsibility of the science or the policy community. The only case in which policy making was prevented was when uncertainty was seen as too large and as falling under the responsibility of the science community, in which case more research would be called for. In the other cases, large uncertainty would lead decision-makers to focus on what might be done from a *political* perspective rather than on scientific evidence, whereas manageable uncertainty would either lead them to trust in scientists' assessment or to focus on tactics such as the 'precautionary principle' (pp. 283-289). More specifically, uncertainty was *not* found to affect the political agenda setting, but rather to exercise an influence over the selection and design of policy alternatives, respectively over the timing of decision-making.

An additional thing that Knaggård notes is that the whole issue of scientific uncertainty became more and more invisible the closer it drew to policy making (pp. 268-9). This point is in accordance with Shackley and Wynne (1996)'s observation that research users are known to account for uncertainties to a lesser degree than research producers. Yet, actors in the policy sphere *can* come to appreciate the fragility of scientific knowledge. According to the authors, "[s]uch appreciation of uncertainty increases when the users are motivated to explore critically the basis of the knowledge claims that have an important bearing on their or their opponents' policy actions." (pp. 278).

All in all, this means that STS literature confirms (a) that scientific uncertainty is something that can be perceived or framed as an obstacle towards decision-making, (b) that this can present scientists with something of a dilemma (or at least a challenge) in terms of safeguarding political relevancy while ensuring a truthful representation of uncertainty, and (c) that research users tend to account for uncertainty to a lesser degree than producers. In contrast to the non-technical simulation literature, though, there is little focus on the risks associated with this. Moreover, there are few clues as to what affects whether uncertainty will be ignored, perceived/framed as too large, or perceived/framed as manageable.

3.4 Implications for the empirical study

What this chapter has shown can be summarized as follows:

(1) There is no accepted definition of research 'use', only more or less criticized typologies and models differentiating between different ways of using research. A common point of critique is that it is rarely recognized that research use can mean different things or take different shapes over time, respectively interact in dynamic ways. Empirically, some academics rely on objective criteria and observable indicators for investigating research use. Such methods are limited in their ability to capture more conceptual and strategic forms of research use, however. Often, it can be preferable to depart from the target audience's own subjective accounts of how research is applied and profited from.

(2) Though one can distinguish between legitimate and illegitimate forms of use and non-use in theory, it remains unclear how to recognize and separate these categories from each other empirically, as it will often be situational or a matter of perspective what constitutes misuse, ideal use, abuse or legitimate non-use.

(3) Though misuse is commonly defined as *intentional* manipulation or distortion of findings, there are also at least two ways in which research can be *unintentionally* misused. First, users may unknowingly be drawing on the results of low-quality research, and, second, there is a risk of them misinterpreting the findings of high-quality research so that they end up relying on a misguided understanding of this. In either case, misuse is often difficult to detect other than ex-post undesirable events revealing mistaken or mischievous interpretations, or, for that matter, scientific errors.

(4) In the 'factors affecting' literature, focus is exclusively placed on identifying factors increasing the chances of research use, including options of interaction, attractive presentation, etc. That there can be rational reasons for non-use is not explicitly recognized. Instead, research is implicitly assumed to be 'good', so that cases of non-use become something to 'fix'. In this respect, a number of factors supporting or obstructing research uptake have been identified. Key amongst these is the notion that users must find research results credible and salient. At the same time, what makes people see research as trustworthy or relevant is not limited to its quality or content but will partially depend on other factors as well; some people or organizations may simply be keener on consulting science, certain issues will or will not be on the political agenda, some audiences trust in a source that others distrust, etc. Moreover, though scientific uncertainty *can* be perceived to constitute an obstacle towards use, whether or not this will be the case is not necessarily tied to the size of uncertainty. Sometimes, it may simply be convenient to frame things in one or the other way.

(5) Having shown research use to be dependent on a broad range of factors rather than a single variable, KU studies have partially begun to turn away from quantitative searches for significance, calling instead for qualitative case study designs to allow for in-depth studies of complex relationships and interaction effects.

For the study at hand, this implies a number of challenges in terms of how to explore research (non-)use. For example, it seems impractical to use fixed criteria for identifying and distinguishing between legitimate and illegitimate forms of use and non-use. If one relies on the target audience's own subjective assessment, though, will not all cases of non-use appear rational? And how would that account for the possibility of users being unaware of conducting 'misuse'?

In response to these challenges, four conclusions have been drawn from the theory and literature reviewed above. First, the study should draw on intended users' subjective accounts to be able to capture the full variety of different forms of applications, but not *only* on these. It should also seek to include material from actors in the science community and/or with a more aggregate perspective. Moreover, the study should not focus on identifying cases of legitimate and illegitimate research (non-)use in absolute terms, but instead explore whether there are instances of application that are *perceived* to constitute examples of these different categories.

Second, though not escaping criticism, 'use' of research will be understood along the lines of the ICS-framework. This is because this is the simplest of the reviewed models, providing a relatively straightforward point of orientation. Hence, research use will be understood as something that can involve, e.g., direct influence over decisions and behavior (instrumental use), knowledge effects and changes in the audience's way of thinking (conceptual use), and efforts to influence the policy context, e.g. by silencing calls for action, legitimizing pre-defined proposals or increasing one's own credibility (strategic use).

Third, decision-making will be understood as a non-linear, non-rational process, meaning that there is no guarantee for research to be used even if it is of high quality and corresponding to a user's area of responsibility. To gain as full of a picture as possible of reasons for use and non-use, this question, too, should be investigated by exploring *different* actors' experiences and observations, rather than relying solely on the accounts of the user group. In light of the lack of explanatory theory in this regard, the analysis of this material should proceed in an inductive way while keeping the above reviewed factors in mind as potentially relevant aspects affecting application outcomes.

Finally, in light of the effects of research use being an under-studied topic (cf. James and Jorgensen, 2009), the benefits of introducing a new information product should also be explored inductively. The same applies to eventual problems as it cannot be excluded that other problems than non-use and misuse are possible as well (unintended effects, insufficiency of available information, etc.).

Chapter 4

Flood hazard maps in Baden-Württemberg

4.1 Simulating flood hazard

To reduce the negative impacts of flooding, people have long sought to predict the time and place of the next flood through forecasting. More recently, interest has also grown in predicting the outcome of various flood scenarios to allow for a better overview of what consequences inundation would be associated with and what might be done to prevent it or to reduce the risk of damage. For this type of hazard assessment research,[1] hydrological and hydraulic modeling are central elements. In comparison to efforts to map flood lines by hand, ex-post inundation, scenario simulation has the advantage of being able to account for changes in boundary conditions (streambed, land cover, etc.) having occurred since the last larger flood event, thus providing a more up-to-date hazard assessment. The outcome is mostly a graphical image of the predicted extent and depth of inundation, though other parameters such as flow velocity, flood duration, the rate at which the water rises, etc., can also be simulated (de Moel et al., 2009, pp. 291).

[1] Departing from an understanding of 'research' as not being limited to activities of academic researchers in academic settings, but as a form of evidence that pertains to any investigation towards increasing the sum of knowledge based on planned and systematic inquiry (see e.g. Nutley et al., 2007, pp. 21-23), commissioned flood scenario simulation falls under what counts as research.

Offering predictive information on more than one flood scenario, corresponding either to different statistical return periods or to assumed gauge level values, modern flood hazard maps are examples of the trend to simulate a range of likely outcomes to break with the understanding of computer models as answer machines. (In relation to other natural hazards, though, it still happens that only one pre-defined scenario is simulated.)

This chapter will first take a closer look at how flood simulation is done and what sources of uncertainty it is associated with. Thereafter, the case of Baden-Württemberg will be looked at, both in terms of what flood risk management looks like and what role flood hazard maps are hoped to play in this regard.

4.1.1 The *how* of flood scenario simulation

The calculations needed for producing flood hazard maps can be performed using methods of varying complexity depending, e.g., on the amount of data and time available. Independently of which method is chosen, the different steps involved tend to concern (1) estimation of the discharge associated with a specific scenario such as a return period, (2) a translation of this discharge into a water level, and (3) the combination of this water level with some sort of digital elevation model to obtain output data on the expected extent and depth of inundation (de Moel et al., 2009). Hence, one needs both hydrological input data and data required for hydraulic calculations.

Hydrological data refers to water discharge (i.e. the volume rate of water flow, e.g. m^3/s) at certain locations along the water body associated with a flood that – statistically speaking – occurs once in X years. In German and sometimes also English language publications (see e.g. Prinos et al., 2008), such scenarios are commonly denoted by the letters HQ followed by the number of years of the statistical return period (i.e. HQ100 for a flood with a recurrence period of once in 100 years). Gauge level data and corresponding discharges are published at state level in Germany. If a statistical method is used to produce the hydrological input data, these records can be used to calculate the estimated discharge at ungauged locations by applying a regionalisation approach. Alternatively, a rainfall run-off model can be used to generate hydrological input data.[2] Such models require spatially explicit meteorological data (e.g. temperature, precipitation and evaporation) and data on soil and land cover, and solves the water balance for each geographical unit (e.g. grid-cell) for each time step and route of the runoff downstream, yielding discharges throughout the entire catchment.

Hydraulic calculations are based on topological data. This is commonly provided by building a Digital Terrain Model (DTM) based on laser scan and geographical survey data. Laser scan data is collected by having a plane fitted with a rotating laser fly over an area, scanning the land at right angles to the direction of flight. This is normally done in winter when vegetation is sparse. This data is then processed to eliminate vegetation and man-made objects (using interpolation to fill in any resulting gaps), arriving at a dot grid, commonly with a grid spacing of something between one and five meters. Since laser scan data only reveals terrain characteristics above the water level, though, other survey methods are necessary for obtaining a sub-surface terrain model. Furthermore, manual on-site survey is used to increase the accuracy of the laser scan data with respect to buildings and terrain structures near water bodies. Based on laser scanning and geographical surveying, cross section data along the water bodies is produced. This can be imagined as a profile of what the ground looks like if cut vertically in two halves, with a line showing where the ground meets sky or water (see Prinos et al., 2008, pp. 5 for illustrations).

Based on hydrological data and the cross sections derived from the digital terrain model, hydraulic calculations are made. There are a number of flood inundation models available for these calculations. According to Prinos et al. (2008), many models have a similar primary function, making it somewhat difficult, sometime, to determine the most appropriate modeling solution. Basically, one can differentiate between empirical (or statistical) models which do not attempt to simulate physical processes but which relate observations or measurements of inputs (e.g. wave conditions and water levels) directly to outcomes (e.g. overtopping rates), and models which explicitly simulate the physical processes involved. This latter

[2]In Germany, conceptual rainfall run-off models are most common. These models seek to describe the hydrology of a drainage basin from rainfall to stream discharge as a sequence of interlinked processes and storages, but without solving the underlying physical equations explicitly (Prinos et al., 2008).

kind are referred to as first, second or third generation mechanistic models depending on how advanced they are and the amount of simplifying assumptions involved. Additionally, one can distinguish between the spatial aspect of the field characteristics and equations used. One-dimensional (1D) models can be applied to assess water levels along the axis of a water body. Some water bodies, however, do not satisfy the boundary conditions of a 1D model, e.g. due to irregular flow or flow in more than one direction. For flat or estuary areas or areas affected by tide, for example, two-dimensional (2D) models are often preferable (LAWA, 2010, pp. 13). A 2D model can be used to assess extensive hydraulic dimensions such as flow depth and speed of current in both directions along the axis of a water body. Three dimensional (3D) models are more accurate but also more complicated and demanding, and either not commonly used or confined to the study of smaller areas. Examples of first generation models (essentially 1D models) used to calculate the water level in each flood cell at given steps are Infoworks RS, Infoworks CS and ISIS, which use a DTM, time series and overflow discharges as input and produce data on flood depth, flood extent and flood duration as output. Second generation models (1D/2D hybrids or pure 2D models) use similar or somewhat different input data and produce similar or somewhat more detailed sets of output data. Examples of software include HYDROF, LOSFLOOD-FP, Mike 21 and TELEMAC 2D, to mention but a few (see Prinos et al., 2008, pp. 34 for a more extensive discussion of different models).

The result of a hydraulic calculation shows the different water levels along the length of a water body. Based on this, the flood outline can be calculated and maps created which show the extent and water depths associated with different flood scenarios (HQ10, HQ50, etc.). Many software packages include a graphical user interface (or a post-process directly linked to a GIS environment), allowing the user to visualize the results against a graphical background.

4.1.2 Sources of simulation uncertainty

When it comes to simulation results to be used for practical decision-making and management, it is normally the uncertainty associated with the output data that is of interest. This refers to the uncertainty that has been accumulated throughout the simulation process, stemming from the identification of the boundaries of the system to be modeled, the model design, the input, and the parameters (Walker et al., 2003). In relation to flood hazard maps, each element of the chain involved in creating flooding (hydrological load, flood routing, potential failure of flood protection structures, etc.) gives raise to uncertainty of one sort or another. According to Prinos et al. (2008), one can distinguish between three main categories of uncertainty affecting simulation output: (1) data uncertainty, (2) model uncertainty, and (3) parameter uncertainty. When it comes to calculations of annual discharge and water stages, data uncertainty arises from short or unavailable flood records, measurements error, sediment transport and bed forms, debris accumulation, and ice effects. In respect to model uncertainty, the authors mention, e.g., uncertainties related to rainfall run-off modeling, wave modeling, the selection of a distributing function with respect to annual discharge, model selection, and the use of frictional resistance equations with respect to the water stage variable. Parameter uncertainty, finally, involves such aspects as channel roughness and the geometry of calculating the water stage. If a dike breach is to be simulated, furthermore, this will also involve elements of data, model and parameter uncertainty (Prinos et al., 2008, pp. 42).

In de Moel et al. (2009)'s view, some of the main difficulties involved in flood hazard mapping concern the statistical determination of extreme events from relatively short time series of empirical data, the spatial extrapolation of data, and the presence and/or possible failure of structural protection works. Moreover, Büchele et al. (2006) note that the quality of output data is stongly dependent on the quality and spatial resolution of the DTM. This will namely assume the same elevation value throughout each grid cell, ignoring eventual differences in elevation within. Plus, there is the risk of confusing viaducts or other line structures in a DTM with flood barriers, although these will not actually be holding any water back (de Moel et al., 2009; Pine, 2009, pp. 71).

A further form of challenge in relation to hydrological data is the fact that protection works, channelization and other forms of anthropogenic interferences in river systems have contributed to increase the frequency by which unusual flooding occurs (Berlamont, 1995). This system instability is projected to continue, as global warming is likely to result in shifts in frequency, intensity and duration of extreme precipitation events, resulting in higher peak river discharges for Europe (see IPCC, 2014). Hence, time series of past flood events may no longer constitute a perfect basis for the statistical calculation of future scenarios. In general, the estimate of what constitutes a HQ100 scenario will often be somewhat uncertain, as the statistical basis on which this scenario is calculated changes every time a new flood episode arrives.

Together, these factors make flood scenario simulation a challenging task. According to Büchele et al. (2006, pp. 501),

> flood hazard and risk assessment is still associated with large uncertainties, even in areas where a rather good data and model base is available (as for example given at the Neckar river by means of the flood information system with relatively well-known hydraulic conditions and substantial spatial data).

Though a model can sometimes be evaluated against empirical data, such data is rarely available when it comes to flood hazard maps, for which uncertainty assessments must often be based on Monte Carlo or error propagation methods, instead. According to Prinos et al. (2008, pp. 47), this means that flood hazard maps should always be provided with a disclaimer with remarks as to the confidence, accuracy and estimated uncertainty of the displayed predictions. Preferably, this should involve a visualization representation to make the presence of uncertainty unmistakable. Failure in this regard can not only lead to unnecessary fear but also to a false sense of security (cf. Pine, 2009).

4.2 The case of Baden-Württemberg

4.2.1 Flood risk management and its challenges

Risk management of natural hazards is sometimes divided into four phases: (1) prevention/mitigation in periods of calm, (2) preparedness when a threat seems likely, (3) response during an event, and (4) recovery, including lesson drawing and analysis of how to improve as a new cycle of phases follows (McLoughlin, 1985). Flood hazard maps may be useful in relation to the first two of these phases. In terms of concrete strategies and options for action, one can differentiate between four different pillars of flood risk management measures:

- Technical flood protection, including structural defenses like dams, dikes, retention basins, flood gates, etc., constructed to keep the water away from areas with high damage potential.

- Non-structural flood alleviation, including land-use management, development planning, the use of risk sensitive building techniques, retro-fitting, and measures to conserve and reclaim natural flood retention space. These measures either aim at adaptation to the risk of flooding (e.g. by increasing resilience or practicing avoidance) or at decreasing the risk of rivers overflowing in the first place.

- Emergency management, including preparations in the form of installation of flood warning systems, preparedness and evacuation planning, drill exercises, investment in mobile flood defenses, etc., to be able to respond to an oncoming threat.

- Risk communication to seek to lower a community's vulnerability to flooding, e.g. by encouraging private flood insurance, private retro-fitting and building precaution, ensuring sensible conduct in case of a flood emergency, etc.

In principle, all strategies of flood risk management are associated with some form of difficulty. Due to the (false) sense of security that they convey, technical protection and structural defenses have been shown to be associated with *growth* in development in protected areas, thereby contributing to increase the damage potential in case of overtopping or failure (Parker, 1995). Moreover, such installations can aggravate the risk of unusual flooding for downstream communities by increasing a river's flood stage and velocity (Berlamont, 1995, pp. 343).

When it comes to emergency management, on the other hand, the idea of investing in crisis preparedness is often met with lack of interest or even outright opposition (McEntire and Myers, 2004, pp. 142). Whereas investments in day-to-day activities are certain to pay off, investments in preparedness planning, emergency equipment and drill exercises risk appearing like sunk costs as long as nothing happens. To this comes that no amount of planning or training can guarantee that a hazardous event does not result in disaster, and that there is generally little praise to be harvested if a crisis is handled well, only criticism if it is not. Together, these aspects make it into something of a 'mission impossible' to uphold the motivation for emergency preparedness (McConnell and Drennan, 2006). As a result, preparedness will often exist in the form of a paper plan but not in terms of actual readiness and response capacity (McEntire and Myers, 2004, pp. 142).

Traditionally, non-structural alleviation measures like hazard zoning and land-use regulations have often been avoided due a preference for structural protection and technical fixes, respectively for reactionary end-of-the-pipeline responses of emergency management and ex-post disaster assistance (Weichselgartner and Obersteiner, 2002; Thomalla et al., 2006, pp. 45). In light of growing economic losses, though, the perception of floods – and natural hazards in general – is increasingly changing from that of that of an engineering challenge to something that requires human adjustment and healthy ecosystems (Pielke, 1999; Jaeger et al., 2001, pp. 96-101). 'Safety' through flood control, it is recognized, may not be attainable to an affordable price. Hence, rather than aiming for a certain safety level irrespectively of the costs, 'risk-based' management approaches and strategies of avoidance are growing in importance. Part of this is the identification of cost-effective mitigation measures to "reduce the maximum magnitude of an effective risk at a lowest possible price to an individually and socially acceptable level." (Plattner et al., 2006, pp. 471). To help determine what is acceptable, public participation and stakeholder consultation is being advocated (e.g. Gamper and Turcanu, 2009).[3] In general, residents at risk are increasingly expected to take a larger share of responsibility for their own safety and damage potential through self-protection and private preparatory measures. Findings cited by Grothmann and Reusswig (2006), for example, suggest that precautionary adaptation by households and firms could reduce monetary damage from flooding by as much as 80 percent. At the same time, this process of *individualization of risk* is not only regarded as something

[3]This is not least apparent in the concept of 'risk governance' (as oppose to risk management), in which risk is seen as something that concerns representatives of civil society and economic actors as well as science and politics (Walker et al., 2010; Renn, 2008).

positive, but also with a shift in responsibility from the public to the private that weaker members of society may have difficulties coping with (Steinführer et al., 2009; Taylor-Gooby and Zinn, 2006, pp. 15-16).

Moreover, non-structural alleviation and risk communication to encourage behavioral change are associated with challenges, too. With regard to land-use and development planning, interest groups of land owners, developers and builders are known to resist regulation and legislation (McEntire, 2009, pp. 76), while local populations desiring safety will sometimes prefer a solution based on technical protection (e.g. Walker et al., 2010, pp. 42). Furthermore, cities in economical decline will often welcome development almost anywhere, making voluntary schemes difficult (cf. Parker, 1995, pp. 343).

In regard to risk communication, the idea of this is generally to counteract the fact that lay-people are known to underestimate the risk of natural hazards and therefore do less than necessary to lessen the risk of death and damage.[4] Commonly it aims to affect people's risk perception to increase their motivation to act, and, yet, this may not suffice. For one thing, lack of trust in experts and public authorities can make people doubt the content of information aimed at awareness raising, at the same time as too much trust is linked to lower levels of risk perception (see e.g. Wachinger et al., 2012). For another thing, the fact that risk perception tends to decrease over time, means that behavioral change will often require continuous transmission of the same information also after awareness has been reached (Renn, 2008, pp. 239). Moreover, it may not suffice for people to learn of the presence of a risk, as non-protective responses such as denial, wishful thinking and fatalism constitute viable options as well (Grothmann and Reusswig, 2006; Harries, 2008). Hence, protective motivation is unlikely to depend only on the assessment of a threat but will also require a positive coping appraisal (including the belief that protective actions will be effective; that one is capable of performing them; and that the cost are manageable). Hence, risk communication should not focus solely on awareness raising and information dissemination to 'correct' mistaken

[4]Known findings in this regard concern that certain risk characteristics (e.g. catastrophic potential or naturalness) and contextual variables (e.g. personal control or familiarity) can bias people's risk judgments (see 'the psychometric model' in Slovic, 1992), whereas the heuristics (i.e. judgmental rules) that people use to reduce difficult mental tasks to simpler ones will often lead them to over- or underestimate the prospect of gains and losses (Tversky and Kahneman, 1979).

risk perceptions, but must also address barriers to self-protection by underlining the limits of public flood protection and by providing information on the possibilities, effectiveness and costs of private precautionary measures (Grothmann and Reusswig, 2006). According to Höppner et al. (2012), this should preferably involve integrated longer term communication campaigns, multiple tools, and both one-way and two-way communication strategies.

The case of Baden-Württemberg

In Baden-Württemberg, the municipal administrations play a central role in the implementation of each of the four defined management pillars. In regard to technical flood protection, municipalities are responsible for measures pertinent to all water bodies of the second order (though they can apply to the state level for financial support). In this respect, it is becoming increasingly common for municipalities to join forces to obtain catchment-wide protection, delegating the task of planning, building and maintaining large protection works to so called 'flood associations' ('Zweckverband' in German) with their own legal status. For waterways of the first order (e.g. parts of the Neckar, Rhine, Elsenz, Leimbach), the State is responsible for technical protection issues, though coordination with local authorities is required.

In terms of non-structural alleviation, the municipal level is responsible for local development planning and for administrating private building permit applications. In this respect, two types of plans are prepared, both of which are to contain floodplain information:

- Preparatory land-use plans ('Flächennutzungsplan'in German) cover the whole municipality but do not contain any legally binding provisions. These plans have to show areas that are to be kept free in the interest of flood protection and regulation of water discharge, and areas where special building requirements have to be fulfilled.

- Legally binding development plans ('Bebauungspläne' in German) are developed from the preparatory land-use plans and are limited to specific parts of the municipality. They govern whether and in what way a plot of land may be developed. These plans have to assign areas for flood protection and regulation of discharge.

Local development planning is partially informed and/or restricted by regional-level plans.[5] Since these plans are not subject to frequent updates, however, it may be a few years before regional plans introduce new restrictions even if new evidence emerges in the meantime.

In regard to emergency management, municipalities are obliged to draw up alarm and response plans to prepare for their involvement in a disaster management operation. Each municipality must evaluate and plan which measures will be required under different potential scenarios. The mayor or the mayor's representatives carry the overall responsibility for making sure that the municipality's plan covers all measures within the own area of responsibility, and that it is coordinated with the next higher administrative level. On the ground, it is mostly the nearest fire brigade that carries out the practical measures and activities required, as fire brigades are required to offer assistance in case of imminent emergency. Therefore, they often play an active role in the preparedness planning even if they do not carry any formal responsibility in this regard. Depending on the type of waterway affected and how serious the flood is, furthermore, responsibility for coordinating the response work can sometimes shift to a higher administrative level.

Turning to the topic of risk communication, finally, §76 of the federal Water Resource Act (WHG, 2009) states that there is a legal obligation to inform the public of the location of floodplains and of measures for avoiding detrimental flood consequences. Though this act does not specify who is formally responsible for this task, the expert opinion is that, due to their closeness to the potentially affected,

[5]These define so called *priority areas* and *reserve areas* for flood protection. Priority areas refer to areas where flooding poses a threat to life and limb, or where flood control structures would be unduly costly (LAWA, 2006, pp. 8-9). These areas are to be kept free of further development for residential and commercial purposes to prevent increases in damage potential and to safeguard retention, and are not open to further consideration by subordinate planning authorities (Safer, 2008, pp. 30). In contrast, reserve areas are not subject to legal restrictions but refer to areas where the risk of flooding should be taken into consideration in planning and construction activities and/or where it would be desirable for flood control measures to be defined (LAWA, 2006, pp. 8-9). However, existing settlement areas and areas already covered by legally binding development plans – even if construction has not yet begin – are normally exempt from the definition of priority and reserve areas (Moser and Zeisler, 2003, pp. 9).

decision-makers at the local level are best suited to handle flood risk communication (see Greiving et al., 2006, pp. 748). According to Renn (2008, pp. 203), one can distinguish between four main functions of risk communication: (1) education and enlightenment, (2) risk training and inducement of behavioral change, (3) creation of confidence in institutions responsible for risk assessment and management, and (4) involvement in risk-related decisions and conflict resolution. How these functions or aims are to be reached in respect to flood risk is not formally specified in Baden-Württemberg.

4.2.2 Flood hazard mapping in Baden-Württemberg

Already towards the end of the 1990s, different flood mapping projects were initiated to cover the large rivers running through Baden-Württemberg. For the Neckar, the State government commissioned a hydrodynamic-numerical flow model to be developed by the Karlsruhe Institute of Technology, resulting in hazard maps depicting areas at risk of inundation at different water levels at the closest gauge station. For the Danube valley, laser-scanning enabled hazard analysis within the framework of the Integrated Danube Program, managed by the Regional Administrative Authority Tübingen in cooperation with the Regional Administrative Authority Freiburg ('Regierungspräsidium' in German). These hazard maps specify both gauge levels and return periods associated with different inundation scenarios. Additionally, special 'fact sheets' ('Steckbriefe' in German) showed the water depths to be expected from a 100-year flood. For the Rhine, finally, a project commissioned by the International Commission for the Protection of the Rhine (IKSR) and the German Federal Institute of Hydrology (BfG) resulted in the publication of the Rhine Atlas 2001, which depicts both the expected extent of inundation and the values at risk associated with floods of different return periods (HQ10, HQ100 and HQextreme) (see IKSR, 2001).

In March 2003 (i.e. shortly after the 2002 flood catastrophe along the Elbe), the need for state-wide flood hazard maps was recognized in a publication published by three of the state ministries (Moser and Zeisler, 2003). The same year, the EU-funded project "Safer" was initiated with the Regional Administrative Authority Stuttgart as lead partner. Between 2003 and 2008, this project served to map flood extent and water depths associated with different return periods both along the Neckar and in areas of Scotland and Ireland (Safer, 2008). The method and design currently used for mapping around 11000 km of waterways in Baden-Wüttemberg was developed within this project. Since early 2005, the production of flood hazard maps is required by law, as formulated by the state's Water Act (WG, 2005). Though each Regional Administrative Authority is responsible for the mapping within its area, the Regional Administrative Authority Stuttgart has retained a leading role in the project (Moser et al., 2011, pp. 9).

The hazard maps currently produced consist of two types of documents at a scale of 1:2.500.[6] Both types are produced for all water bodies with a catchment area larger than 10 km^2. The first type of map offers information on the inundation depth, in 50 cm increments, for the HQ10, HQ100 and HQextreme scenarios (see example in Figure 4.1). The second type provides information about the expected extent of inundation for the HQ10, HQ50, HQ100 and HQextreme scenarios (see Figure 4.2). All map types show a topographical basemap for orientation, and depict mobile and static flood defenses. Areas protected by an installation designed to withstand a 100-year flood or more (after subtraction of freeboard) are shown as hatched, but are still colored blue to indicate the risk of flooding in case of a larger flood event or dam break. A further item included in the maps is color-coded markings at bridges to indicate whether these are likely to be free or under water in case of a 100-year flood (Reich et al., 2014; Moser et al., 2011, pp. 14). To make flood hazard maps publicly available, a state-wide online map service has been set up (see 'InteraktiveGefahrenkarte' under `http://www.um.baden-wuerttemberg.de/servlet/is/71525/`).

The hydrological data and the DTM are both centrally produced. The hydrological data is mostly calculated through a rationalization approach, except for cases where retention basins play a significant role, for which the runoff model *Larsim* is applied instead. The DTM comes in a format of a 1x1m grid, and is based on laser-scanning (carried out between 2000 and 2004) supplemented with empirical terrain surveys (see Moser et al., 2011, for more detail). The hydraulic simulation is outsourced to private engineering bureaus. However, in contrast to the hazard

[6]The recommended map scale for local planning purposes, defined by LAWA (2006, pp. 10) is 1:1,000 to 1:25,000.

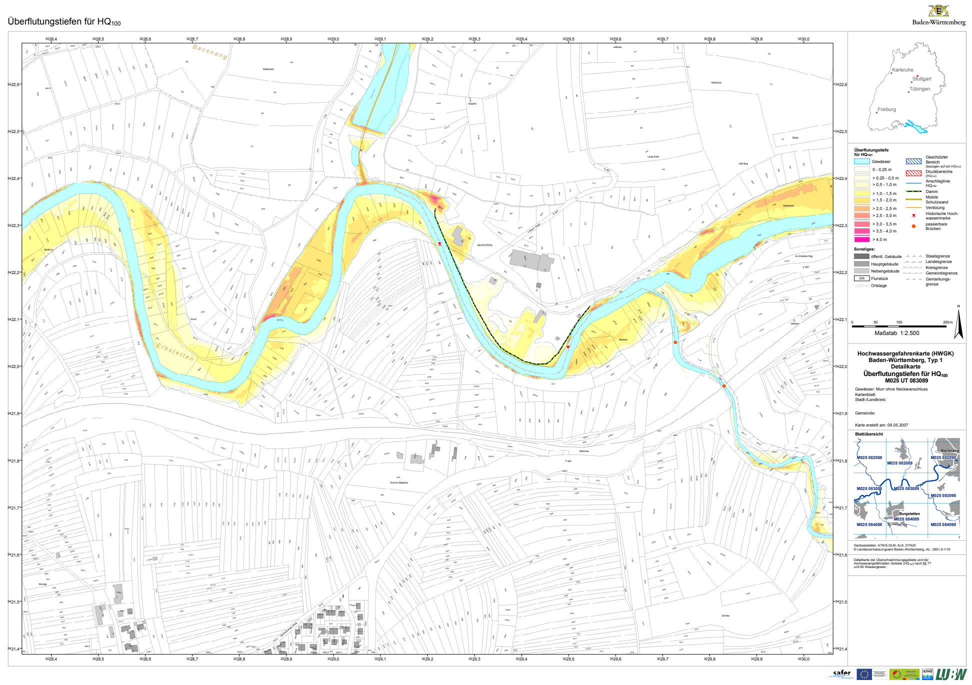

FIGURE 4.1: Example flood hazard map depicting inundation depth for the HQ100-scenario: “Überflutungstiefen für HQ100” (LUBW, 007a)

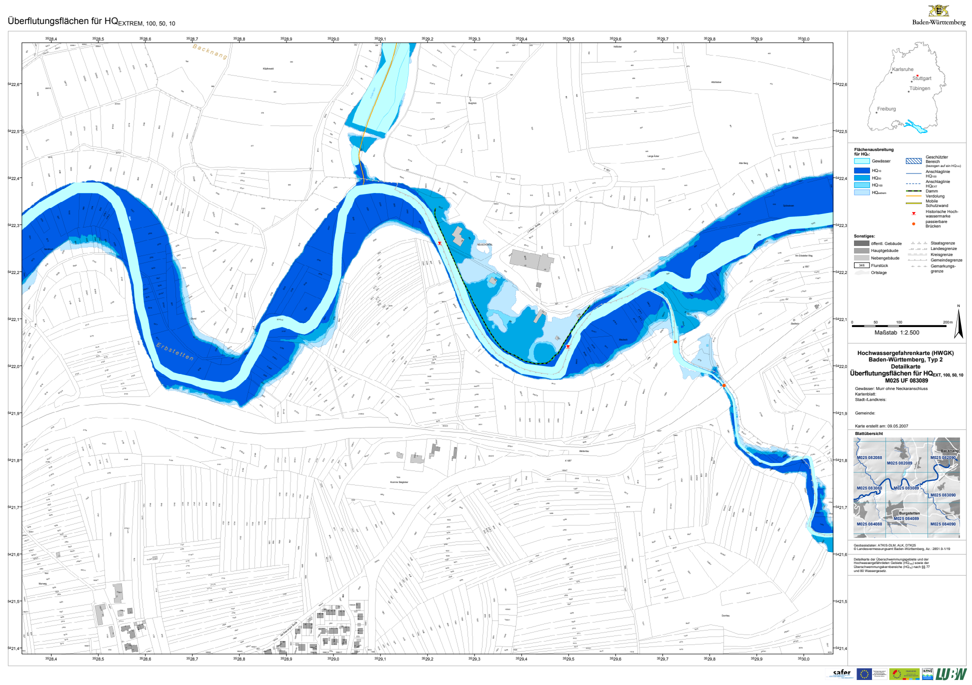

FIGURE 4.2: Example flood hazard map depicting inundation extent for different HQ-scenarios: “Überflutungsflächen für HQEXTREM, 100, 50, 10” (LUBW, 007b)

mapping reviewed in Landström et al. (2011) and Lane et al. (2011), where the responsible environment agency specified which simulation software should be used, the state of Baden-Württemberg leaves it to the respective engineering bureau to choose which model and software program they prefer to work with. To still ensure a standardized, uniform end-product, detailed instructions are provided, specifying which tasks and obligations the responsible bureau has to fulfill. Mostly, 1D models are sufficient for the hydraulic calculations, though 2D models are required in areas with complex flow patterns. On the basis of the simulation results, hazard maps are finally centrally produced by the Regional Office for Environment, Measurements and Nature Protection (LUBW) in Baden-Württemberg (Moser et al., 2011).

When it comes to simulation uncertainty, the flood hazard maps and map legends in Baden-Württemberg do not provide any information in respect to limitations or uncertainties associated with scenario simulation. Such information is instead found in other documents. In a handbook published in 2005, for example, one can read that only flooding due to overflowing water bodies is simulated. Flooding resulting from flash floods (i.e. sudden extreme precipitation over a limited area), slope water, rising groundwater, sewer backwater, and flooding due to ice or other objects obstructing the normal discharge profile are not depicted in the hazard maps (Zeisler, 2005, pp. 2). Furthermore, the final report on the Safer project offers a qualitative disclaimer: "The reliability of the maps is limited by the input data. The information provided is indicative only and is subject to the normal uncertainties associated with ground level and modelling accuracies as well as to the causes of flooding." (Safer, 2008, pp. 14). To learn more, one must consult a special method paper published in 2011, offering technical information on the data, models and procedures involved in hazard mapping.

In relation to the DTM, this paper tells us that:

- The accuracy of the DTM is estimated to lie within a range of ±0,3m.[7]
- Changes to the landscape undertaken since 2004 will not be reflected in the DTM.

[7] In Zeisler (2005: 27) it is specified that "[t]he position accuracy of the aerial laser scanning-derived DTM is around +/- 50 cm and the elevation accuracy is +/- 20–30 cm."

- Small-scale structures like walls, dikes and embankments are difficult to model in a way that reflects their actual extent and height in spite of the use of a 1x1 m grid.

- Steeply inclining terrain is only approximately modeled, while values related to flat areas without vegetation are highly reliable.

- The manual processing of the terrain data included in the DTM shows a low error rate.

- In areas with dense vegetation or a high concentration of buildings, the DTM is partially inexact. (Moser et al., 2011, pp. 17).

Furthermore, we can read that the hydrological data is one of the most sensitive aspects of the mapping project, representing an important input source but also one where the values can diverge greatly depending on the calculation method (Moser et al., 2011, pp. 21). Particularly for small catchments, it is difficult to produce reliable hydrological input data:

> Je kleiner die Einzugsgebiete sind, desto schwieriger ist die Bereitstellung der hydrologischen Grundlagendaten. In einzelnen Fällen kann die Neuerstellung der Hydrologie für kleine Einzugsgebiete erforderlich werden. Allerdings gibt es in der Regel jedoch insbesondere in kleinen Einzugsgebieten keine Aufzeichnungen über abgelaufene Hochwasserereignisse, sodass sich die hydrologische Datenlage auch durch die Erstellung von Niederschlags-Abfluss-Modellen (N-A-Modell) – mangels Kalibrierungsdaten – nicht signifikant verbessern lässt. (Moser et al., 2011, pp. 23)

The calibrations are normally done on the basis of high water marks or documented flood lines associated with known discharge levels. Parameter values following from such calibrations are assumed to be applicable to other river stretches of similar size and structure, too. For areas to which these values cannot be transferred, parameter values are assumed based on the water and terrain structure. To ensure transparency, such assumptions are part of what engineering bureaus must provide information on (Moser et al., 2011, pp. 20). Other forms of difficulties concern the simulation of areas where rivers merge, the effect of retention basins and other forms of defense structures, the possibility of failure of such structures, etc. (Moser et al., 2011).

Though it is clear from the method paper that several steps of quality control of the input data and calculation steps are built into the mapping process, it is also clear that such precaution can never completely eliminate the presence of uncertainty. Considering that the maps are intended to guide both public and private risk management, explicitly targeting audiences without experience of modeling and simulation, this is something that should be unmistakably conveyed directly in the maps. Presently, this is not the case. In principle, this implies a risk in the sense of missing that areas displayed as ‘safe’ may still be inundated from other sources of flooding, due to the occurrence of unexpected events, or as a result of model and data imprecision. Though this type of information is included in the handbook and method papers, respectively documented and supplied together with the hazard maps, the separation of uncertainty information from the mapped flood lines makes it questionable to what extent it will be recognized.

4.2.3 Special features: legal status and linkage

Two things make the flood hazard maps produced in Baden-Wüttemberg special in relation to many other mapping efforts in Germany and beyond.

The first is that, following a period of mandatory public display at city hall and at the Administrative District Office (‘Landratsamt’ in German), the area shown in the flood hazard maps to be at risk of inundation from a HQ100 scenario will *automatically* gain legal status as floodplain; no further designation process or legal ordinance is necessary. Originally, the state Water Act of 2005 (WG, §77) specified that this automatism only applied to so called external zones or outlying areas, meaning that it was only in non-built-up areas that raising or lowering the earth’s surface, or constructing, demolishing or significantly modifying buildings or other facilities required official consent. Since the introduction of the federal Water Resource Act in 2009, however, a discrepancy emerged, since the federal law did not make a distinction between outlying and built-up areas (WHG, 2009, Ch. 6). Thus, a new state Water Act was introduced, entering into force on January 1, 2015 (WG, 2013). Since then, areas shown in the maps as likely to become inundated in case of HQ100 scenario automatically count as floodplain independently of whether they are located in outlying or built-up areas (Reich et al., 2014, pp. 7). In these areas, firm land-use restrictions apply, making it prohibited to designate new construction zones, to erect or modify buildings, to turn meadows into farm-land, to store substances hazardous to water, etc., with exceptions being permissible only under particular circumstances (see WHG, 2009, §78 for a complete list of both bans and exceptions). Furthermore, in so called *core flooding areas*, corresponding to the areas predicted to be inundated in case of a HQ10 scenario, such consent is also required for planting or removing trees or bushes (see Zeisler, 2005, pp. 34-35). This makes Baden-Württemberg special, since most other German states still designate floodplains in separate processes.

The second aspect setting the mapping project in Baden-Württemberg apart, is that it has accounted for and followed many of the recommendations specified in KU studies for how to increase the chances of research use. Such recommendations include the involvement of intended users throughout the research process, and the setting up of institutions or support structures to motivate and enable target audiences to use available evidence (Nutley et al., 2007, Ch. 5).

In Baden-Württemberg, the hazard maps' design reflect a conscious effort to inquire about different target groups' needs and requirements, realized by involving stakeholder representatives in the Safer project (Safer, 2008, pp. 16). Furthermore, the latest mapping project has offered the municipalities several chances at direct involvement. First, prior to the mapping, local authorities were able to specify additional catchments (i.e. smaller than 10 km^2) that they wanted to have mapped (Zeisler, 2005, pp. 3). Second, once the mapping of a municipality started, the administration would be requested to help the responsible engineering bureau with information. Third, all municipalities are asked to review and give feedback on the first map drafts produced (a so called 'plausibilization' process). In this way, local knowledge and experience is safeguarded and the risk of errors is reduced (Reich et al., 2014, pp. 6). In literature, both stakeholder involvement and repeated contact with intended users are described as tactics for increasing the chances of research being perceived as credible, relevant and legitimate (e.g. Mitchell et al., 2006a).

Moreover, in terms of institutional arrangements to support research use, a training association (the 'WBW Fortbildungsgemeinschaft') has been set up to support the formation of voluntary catchment-based flood partnerships, where municipal decision-makers and administrators can meet and discuss different aspects of risk management (Zeisler, 2005, pp. 7). Apart from increasing awareness, enabling exchange of information and know how, and inspiring more non-structural protection measures, one of the main aims of these partnerships is to support the municipalities in making use of flood hazard maps. To encourage attendance, active efforts are made, e.g. by choosing well-respected actors to chair the meetings (Safer, 2008, pp. 38). Furthermore, the municipal level is suggested to have explicit ownership of the mapping process through the fact that they co-finance the production of the maps together with the State through the committee in which all the municipalities in Baden-Württemberg are represented (Reich et al., 2014, pp. 1).

4.2.4 Intended areas of application

In official publications concerning flood risk management, mostly published by the Ministry of the Environment and Transport, the Ministry of Commerce and the Ministry of the Interior, one finds descriptions of the flood hazard maps' intended effects. Similar descriptions can be found in reports of the Safer project. One such report states that the introduction of flood hazard maps particularly aims to support *local-level risk management*.[8] By allowing local administrations to make better informed judgments and decisions, foresight should enable them to take a more proactive approach to flood risk management (Safer, 2008). In general, hazard maps are thought to be useful tools for each of the four pillars of flood risk management:

> [F]lood hazard maps are an ideal instrument to create awareness of the diverse stakeholders. With the help of flood hazard maps owners of

[8] Other actors that flood hazard maps may be used by include regional administrations, insurers, businesses and households (Zeisler, 2005).

> properties as well as stakeholders in responsible authorities and politicians are able to see if they are in danger and if precaution activities are necessary. Detailed hazard maps are essential to implement efficient technical flood protection and a sustainable land use management. In addition they are necessary to initiate self help activities and to prepare an emergency management. Not least hazard maps clearly highlight areas where further development should be avoided to protect natural floodplains and safeguard original retention capabilities. (Safer, 2008, pp. 70)

More specifically, flood hazard maps are expected to be useful in the following ways:

Technical protection: In relation to the planning, construction and maintenance of technical and infrastructural measures aimed at flood control, hazard maps can help authorities identify (a) hot-spot areas, where hazard or vulnerability are particularly large, and (b) gaps in the existing flood defenses. They may also help local administrations determine the expected damage potential associated with different flood scenarios, thus supporting cost benefit analyses of possible defense options (Safer, 2008, pp. 31). Furthermore, hazard maps can help determine the need for targeted physical protection, e.g. of sites likely to contain materials hazardous to water, such as fuel or heating oil (Moser and Zeisler, 2003, pp. 11).

Non-structural alleviation: In relation to local land-use management, some use is more or less unavoidable as a result of the legal status awarded the HQ100 and HQ10 scenarios. In other areas, flood hazard maps constitute an important tool for enabling risk-sensitive development planning, helping "local authorities and others to understand flood risk when considering where new homes, businesses and other developments should be built." (Safer, 2008, pp. 29). Other ways in which the flood hazard maps are expected to enable risk reduction is by allowing municipalities to specify particular building requirements (e.g. a minimum floor height), pursue re-naturalization, and taking measures to ensure free discharge of flood water.

Emergency management: In the field of emergency management, flood hazard maps offer input for creating and revising the alarm and response plans that each municipality is required to develop according to §2 of the Civil Protection Act (LKatSG, 1999). The maps can help emergency managers plan what equipment and assignments will be necessary, which roads to take, where to evacuate people to, what to focus on and prioritize. Moreover, information about flood depth can help them analyze beforehand what types of vehicles will be functional for reaching different areas and districts (Safer, 2008, pp. 32-34). In general, predictive information as to the extent and depth of inundation is expected to make emergency management planning more purposeful and precise (see Moser and Zeisler, 2003, pp. 10).

Risk communication: Official accounts show that flood hazard maps are seen as suitable tools for fighting the unawareness and complacency that is known to set in when enough time has passed without a hazardous event. Flood hazard maps are "an ideal instrument to create awareness", helping stakeholders "see if they are in danger and if precaution activities are necessary" (Safer, 2008, pp. 70). Flood hazard maps, so the reasoning goes, "will help people to be aware of the hazard and prepare for it." (Safer, 2008, pp. 31). By consulting the information in the maps, members of the general public can identify whether or not they live in an area at risk of flooding, and use this insight to assess whether and what form of precautionary action is required:

> The publication of the FHM allows everyone to be informed about the level of threat of flooding to one's home. Flood prevention measures such as installing door guards, putting up demountable flood defence, moving valuable goods upstairs if taken in sufficient time can significantly reduce the loss and damage caused by floods. (Safer, 2008, pp. 33-34)

Also businesses and enterprises are expected to benefit from the publication of hazard maps. Predictive information as to inundation risk is, e.g., relevant in relation to water-hazardous substances, for analyzing the need for retrofitting or re-location, and for developing emergency and business contingency plans (Safer, 2008, pp. 33-34). Hence, one of the purposes of flood hazard maps is to encourage people to take more own protection measures; becoming more responsible for their own risk situation.

What is *not* mentioned anywhere is *how* citizens and businesses are to learn of flood hazard maps being available or of options and costs for protective measures. There are no guidelines or recommendations in place for what flood risk communication should look like. On the contrary, official documents appear to assume that it will suffice to make hazard information publicly available for people's awareness and behavior to change. Even at EU-level, this is sometimes the view as illustrated by the notion that "[p]roducing flood risk maps will mean the public is better informed about flood risks" (Commission of the European Communities, 2006, pp. 23). Though, the Safer report (2008) recognizes that supplementary information about how to prepare one's house or business facility for flooding should be provided along with the hazard maps, it remains up to each local administration to decide upon whether and how flood hazard maps should be used for risk communication purposes.

Ultimately, this implies official expectations of flood hazard maps being both conceptually and instrumentally used, whereas there is no mentioning of strategic application. In terms of obstacles and challenges, only the Safer report touches upon this topic, noting that low levels of risk awareness, the presence of competing interests, and lack of manpower in small communities constitute challenges for local-level map use (Safer, 2008, pp. 47-48). Regarding benefits and problems, available reports do not allow for any conclusions to be drawn about what local administrations or other actors associate with any of the hazard maps hitherto published.

Chapter 5

Method and material

5.1 The study interest and research questions

As previously noted, this study takes an interest in computer simulation as a technology for identifying and visualizing areas predicted to become affected under different natural hazard scenarios. More specifically, it takes an interest in what happens when public decision-makers and practitioners are presented with the results of such simulation runs, considering (a) that these are the actors that are the most directly responsible for a community's level of vulnerability, preparedness and protection, and (b) that they are often non-experts when it comes to simulation technology. Academic literature on non-experts' use of simulation results warns that insufficient understanding of the inherent uncertainty associated with computer modeling can jeopardize the benefit of 'foresight', leading to non-use or misuse of what could have been valuable insight for decision-making and regulatory activities. So far, though, this literature has not focused specifically on natural hazards or hazard maps.

Hazard maps constitutes an interesting type of product because it is a common format for displaying scenario simulation results and an increasingly emphasized kind of policy tool, expected to allow risk managers to plan and act in foresight rather than hindsight. In this respect, actors in policy and practice are not provided with simulation output in its original form but with a processed product, showing lines or colored fields in a cartographic representation of the area in question. This type of product will rarely give any hint as to the uncertain nature of the mapped assessment results although technical literature often emphasizes the importance of this.

What underlies this study is primarily curiosity about whether the problems and risks identified in relation to non-experts' dealings with simulation technology and simulation output in other areas are also afflicting simulation-based scenario maps introduced to support risk management of natural hazards. So far, there is nothing that allows us to expect that they should *not* be. Yet, we cannot know since the question has not been made the focus of empirical study. For the same reason, it remains unknown what benefits are actually experienced in practice compared to what is suggested in theory.

To allow for an open and unprejudiced exploration of risk managers' use of visualized scenario simulation results and what benefits and problems this entails, the following three research questions were formulated:

- *How are risk managers in the public sphere using simulation-based scenario information about the predicted outcome of a natural hazard – if they use it at all?*
- *What affects whether or not predictive information is used?*
- *What benefits and/or problems are associated with the introduction of predictive information to an audience that lacks expertise in the field of modeling and simulation?*

The selected product and context in regard to which these research questions are approached are simulation-based flood hazard maps and the German state of Baden-Württemberg.

5.2 Research design: Exploratory case study

A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context (Yin, 2009, pp. 18). Though a case study must not be limited to a single case or draw on any particular form of data, the design is often associated with the practice of in-depth study of one or a few examples of the phenomenon of interest with the help of qualitative methods. According to Yin (2009, pp. 47-49), a case study, even of a single case, is motivated when a researcher is provided with the opportunity to observe and analyze a phenomenon that has not yet been explored or that was previously inaccessible to social science inquiry. At the same time, one should also be aware that a case study comes with a trade off between depth and generalizability. That is, even if the possibility to dig deep is a plus in terms of allowing for detailed descriptions and the construction of plausible within-case explanations, there is also a minus in the form of afterwards not knowing whether these are useful for or applicable to other cases as well. Without reviewing a larger number of cases, we cannot know whether we are dealing with a 'typical' example or an 'outlier' (King et al., 1994, pp. 56). In principle, though, it is not always that this type of critique is significant. For example, some cases are important in themselves or even 'unique'. Furthermore, when available knowledge about a phenomenon and its different components and causes and effects is scarce, theory development may be well-served by an approach that seeks to identify systematic components of a phenomenon in one context, before these are tested and/or developed for a more diverse range of cases (Stebbins, 2001; Esaiasson et al., 2005, pp. 186).

Nevertheless, a few criteria are often set up for a single-case or small-n study to be of scientific relevancy. For example, Esaiasson et al. (2005, pp. 172-173) note that it must (a) relate to or draw on previous research and/or existing theoretical thinking (i.e. to fulfill the requirements of cumulative research instead of inventing the wheel anew), and (b) that it is clear and explicit what the investigated case is a case *of*; what type of general, recurrent phenomenon the empirical study is concerned with. In this respect, it may be pointed out that the overarching phenomenon of interest is the introduction of simulation output in graphical format to non-experts in policy and practice, while the *category* of cases focused on is simulation-based hazard maps as public risk management tools. In this respect, the single case selected for empirical investigation is flood hazard maps in Baden-Württemberg, introduced to support local-level risk management (see Chapter 1 for details as to the background of this choice).

For his part, Yin (2009) is careful to point out the value of studying more than one case, of including more than one unit of analysis per case, of drawing on more than one source or form of data, and of seeking to repeat initial findings (either for further cases or in a new context)[1] – everything to get as full of a picture as possible of the phenomenon of interest. In this respect, the study has drawn on more than one source of data and more than one unit of analysis per data source. Furthermore, as will be explained in chapter 10, a small excursion was eventually made into the field of scenario simulation of alpine hazards in Austria to see whether or not the material collected there would corroborate what the case of flood hazard maps in Baden-Württemberg showed. As this was not part of the original study design, however, the rest of this chapter will continue to focus on how the first, and main, part of the study was carried out.

Departing from a view of social science as something that is not only preoccupied with discovering regularities and correlations but also with understanding people's reasons and motives for how they act and behave, it becomes interesting to access and interpret relevant actors' own experiences and ways of thinking. At the same time, it can also make sense to collect data from *different* perspectives, to get a fuller and more complete understanding of the phenomenon of interest. To handle the possibility of human memory being biased and keen on finding ex-post rationalizations and idealizations (sometimes without the research subject even being aware of it), for example, Boyatzis (1998, pp. 56-59) recommends the technique of 'bracketing'; to interview people on the outside of the target group to generate comparative information, thereby generating a conceptual context or 'bracket' for the event or phenomenon under study.

For the study at hand, this means that qualitative interviews were conducted to gain access to local risk managers' subjective descriptions of whether, how and why they use flood hazard maps or not. Additionally, a number of interviews were held with other actors, located outside the world of municipal administrations. Drawing on the writing of Meuser and Nagel (1991), one can refer to this second

[1] This last point can be compared with the logic of repetition adhered to in grounded theory. For example, Glaser and Strauss (1967, pp. 23-26) argue that the collection of comparative data, whether collected from a different unit of analysis or a different case, is advantageous for allowing the analyst to discover what the core aspects of a phenomenon of interest are by seeing which emerging generalizations are replicated and which not.

group as a form of 'external' experts, possessing knowledge about the contexts and conditions under which the target group acts:

> [D]ie ExpertInnen [repräsentieren] eine zur Zielgruppe komplementäre Handlungseinheit, und die Interviews haben die Aufgabe, Informationen über die Kontextbedingungen des Handelns der Zielgruppe zu liefern. [. . .] Die ExpertInneninterviews bilden eine Datenquelle neben anderen, sie stehen z.B. neben Interviews mit der Zielgruppe, teilnehmender Beobachtung, Dokumenten- und Aktenanalyse. (Meuser and Nagel, 1991, pp. 445-446)

Apart from gaining access to contextual knowledge, method literature often emphasizes the advantage of drawing on a second source of data as a way of corroborating what is being told by the first data source, thereby strengthening a study's internal validity (e.g. Yin, 2009). Hence, interviews with external experts can be useful in more than one way.

Regarding the issue of who to interview, the fact that it was not known beforehand who uses or refrains from using flood hazard maps made it impossible to make this into a sampling criteria. Instead, it was decided to go for a sampling logic aiming at maximum variation. The aim of such a strategy is to achieve a sample that reflects the extent of variation and difference that is naturally present in the field. By selecting few but as different cases as possible, one is able to cover the same phenomenon from many different angles, elucidating many different perspectives and experiences (Witt, 2001; Flick, 1995, pp. 87-88). According to Esaiasson et al. (2005, pp. 286-287), the fact that qualitative studies seldom make more discoveries when based on 30 interviews than when based on 15 shows that a limited number of interviews can suffice for discovering and describing the main aspects of relevancy in relation to a social phenomenon.

5.2.1 Sampling

When it came to the risk managers, information from the state's statistical authority shows that there are around 1100 municipalities in Baden-Württemberg, and that the number of inhabitants in these communities range from less than a hundred to over half a million. Through the state's official hazard map website, it was possible to identify municipalities for which hazard maps could already be accessed online.[2] In the beginning of 2011, these amounted to about 30 communities of somewhat varying size. Six months later, this number had already doubled. In the meantime, internet searches and preparatory interviews (e.g. conducted to achieve a better understanding of local flood risk management and flood hazard maps) provided information about specific cases with recent flood experience respectively one or two communities thought to represent (or to have represented) a more or less active stance towards flood risk. Other forms of information generated during this time concerned in which parts of the state that other forms of flood hazard maps had been produced, some catchments for which flood associations had been formed to implementing a joint technical protection concept, respectively a not-too-detailed overview over where flood partnerships had so far been formed.

Based on these different pieces of information, it was decided to include interview partners working in different positions in different local administrations to try to catch as broad of a sample of experiences and perspectives regarding the role of foresight information for different forms of risk management tasks as possible. In this respect, it was decided to focus both on mayors, for carrying the overall responsibility for a community's safety, and administrators and practitioners responsible for management, planning or the carrying out of practical activities in the fields of technical protection, non-structural alleviation and emergency management. Based on the experiences made during a test interview with an actor responsible for a local administration's public relations and communication work, it was decided *not* to include this type of actor, as the discovered lack of autonomy in terms of deciding whether, what or in which format to communicate suggested it to be questionable whether a person in this position can really be described as a risk manager. Instead, it was decided that usage of hazard maps for communication purposes would be covered through the sampling of mayors and by

[2]Special progress maps showing where the mapping process was only just being initialized, where first versions of the maps were currently subject to local review, and where this had already been finished were also available and consulted.

raising the issue of hazard maps as a communication tool as a sub-topic in the other interviews.

In terms of municipal characteristics, it was decided to interview actors in both small and large communities along both small and large waterways, covering both more recent and more distant histories of being flooded respectively both members and non-members of flood associations and partnerships. Furthermore, the information gained through test interviews about areas being (or having been) more or less active in regard to flood risk management was used to include one case each or these ‘extremes’. To corroborate that a municipality selected on the basis of being thought to fulfill certain criteria did indeed fit the profile, a one-page questionnaire was supplied at the end of each interview. In this way, it was, e.g., possible to learn whether an interviewee had personal experience of flood partnership meetings or whether the municipality’s membership in this was of little personal importance. Rather than filling in a strict pre-defined schedule of which mixes of characteristics were sought, though, these aspects worked as general guidelines to help decide where to look for the next interview partner and whom to contact with a formal request.

The very first interview was the result of a contact established during the test-interview phase. After that, communities and actors were sought which would complement the characteristics and experiences already covered. This would normally begin with a look into the state’s online map service to see along which waterways that had not already been covered there were finished simulation results. Once one or more municipalities of suitable optical size had been identified, an effort would be made to research the population size, local flood history and eventual membership details. Once a municipality with complementary characteristics to those already covered had been identified, the local organigram would be studied and a candidate judged as likely to work with risk management in a field not yet covered in this particular constellation would be sought. That many requests for interviews (first sent with e-mail and then followed up on with a telephone call) were rejected meant that these steps were sometimes repeated a few times before an interview was actually scheduled. It also happened that the person originally contacted would reject but refer to a colleague thought to be better suited or have more time. In these cases, the suggestion was always accepted even

Denotation of risk manager	Position or main area of responsibility	Flood experience (at the time of the interview)	Municipality size (1000 inhabitants)	Member of a flood association	Participating in a flood partnership
I01RM	Mayor	HQ100 within past decade	10-20	No	Yes
I02RMa/I02RMb	Technical protection	HQ100 within past decade	40 or more	Yes	Yes
I03RM	Mayor	HQ20-50 within past decade	0-10	Yes	Yes
I04RM	Technical protection	HQ20-50 more than 10 years ago	40 or more	Yes	Yes
I05RM	Non-structural alleviation	History of minor flooding	10-20	No	No
I06RM*	Technical protection	HQ100 within past decade	0-10	Yes	Yes
I07RM	Fire brigade/Emergency management	History of minor flooding	20-40	Yes	No
I08RM	Emergency management and Non-structural alleviation	History of minor flooding	0-10	Yes	No
I09RM	Non-structural alleviation	HQ100 more than 10 years ago	20-40	No	Yes
I10RM	Emergency management	HQ100 more than 10 years ago	10-20	Yes	Yes

*Work covers a number of municipality of varying sizes

FIGURE 5.1: Overview of interviewed risk managers

if it led to slight changes in terms of whom was approached where. The table in Figure 5.1 shows the variation achieved in the sample of risk managers interviewed.

Though the numbering does not necessarily represent the chronological order in which the interviews were held, the following particularities may be noted: interview numbers 01 covers a municipality not thought to have paid much attention to risk management in the past (though since then hit by a severe flood episode); the municipality in interview 02 was contacted for having been described as very active since a few years back and was then discovered to have – on its own initiative, inspired by large flood events in the 1990s – made an active effort to engage with simulation-based hazard assessment prior to the state's general mapping initiative; interview 05 covers an area for which the final map was not yet available but where the interviewee had been directly involved in the plausibilization process; interview 06 covers a risk manager responsible for coordinating the technical protection across a larger number of settlements; and interview 10 covers a different form of hazard map (depicting gauge level scenarios instead of statistical return periods). Sometimes, the inclusion of these particularities in the sample was the result of having planned it that way, but it also happened that it was only during an interview that this type of information came to light. In other instances, what had been planned did not really pan out as imagined. For example, the sample does not really cover a community openly giving risk management low priority (in the community covered by interview 01, for example, flooding had *become* a priority since the last inundation episode, and in other areas requests for interviews were turned down). In light of the exploratory research purpose and of enough material having been collected to indicate that it might be more relevant to extent the study with an excursion than to dig any deeper into the case at hand, interviews which should perhaps have been replaced to ensure better methodological stringency were eventually kept and no replacements were sought.

In terms of how potential interview partners were contacted, an effort was made not to reveal too much about the specific research interest in order not to repel actors not appreciating or using flood hazard maps. Instead, the study was always described in broad terms as concerning the preconditions, practices and challenges associated with local-level flood risk management. Nevertheless, there were some instances were telephone calls to follow up on unanswered requests for interviews would be met with the statement that no interview could be given since flood risk management was not a prioritized question locally. In principle, this implies a risk for slight bias in the sample of risk managers in the sense of actors feeling that they could defend the local risk management work possibly being more keen on accepting an interview request. Ultimately, though, the data covers a wide range of experiences in terms of whether and why hazard maps are used or not. And through the effort to tap into aggregate-level observations as well, there is at least indirect access to voices of a more critical nature.

In regard to the experts, it was decided to cover interview partners working in engineering bureaus having produced simulation results for hazard mapping and actors working in public offices and institutions responsible for coordinating, implementing or advising others in relation to the most recent forms of hazard maps. Additionally, some interview partners were approached for the purpose of providing particular contextual knowledge, e.g. in relation to hydrological and hydraulic modeling and the state's legal framework pertinent to the hazard maps. In this sense, the experts were partially contacted for different purposes (i.e. insight as

Denotation of expert	Institution	Area of responsibility or expertise
I11Ea/I11Eb	Public authority or organization	Supporting risk management, offering guidance on map usage
I12E	Private engineering office	Flood simulation for mapping purposes
I13E	Public authority or organization	Implementation of mapping policy
I14E	Private engineering office	Flood simulation for mapping purposes
I15E	University	Hydrological and hydraulic modeling
I16E	Private engineering office	Flood risk management consultancy
I17E	Public authority or organization	Legal framework of flood hazard maps
I18E	University	Hydrological and hydraulic modeling

FIGURE 5.2: Overview of interviewed experts

to the municipal-level response to and use of flood hazard maps respectively contextual knowledge pertinent to simulation and its use). The table in Figure 5.2 offers an overview of the experts interviewed.

Two interviews came about through previously established contacts. The rest of the interview partners were recruited per e-mail after considering who represents key players in relation to the state's hazard mapping project.[3] In contrast to the risk managers, the experts were either told that the research interest concerned simulation technology in the field of hydrology/hydraulics or that it concerned flood hazard maps explicitly. This was done in order to make sure that only interview partners would accept who would also have something relevant to say in relation to these topics. All of the interview requests resulted in a meeting, albeit sometimes with a colleague or subordinate to the actor originally contacted.

For the sake of anonymity, when a risk manager or expert is referred to in the results chapters, the personal pronom 'he' is used independently of whether the

[3]Some 'key' players had already been interviewed during the study's very early phase. Hence, there are one or two cases of central institutions whose experience is *not* covered by the expert interviews but whose insights instead contributed to help focus the study and identify relevant interview topics. The impression from these interviews is largely similar to that which was left by the 'official' talks.

person in question is male or female.

5.2.2 Interviews

All interviews were done at the interview partner's office. Most of them took around an hour, but in the case of two of the experts the interview lasted for more than two hours. In both these instances, the interview partner was explicitly asked whether it was ok to continue the interview.

The interviews were semi-structured, in the sense that an interview guide had been prepared ahead of each meeting to provide general structure while still allowing for flexibility in terms of order, follow-up questions, and whether or not to pursue additional topics or side-tracks. The purpose of the interview guide was primarily to ensure that all topics identified as relevant would be covered. Though it is often desirable to aim for comparability between the content of the different interviews (e.g. Schnell et al., 1999, pp. 355), some variability in terms of the content and focus of each interview was unavoidable in this case, considering the large number of different experiences, institutions and types of actors covered. Additionally, it may be raised as a point of critique that the interview guide still underwent optimization and adjustments after the test-interview phase was over and the 'real' interviewing had begun. This was partially related to language difficulties associated with carrying out interviews in a non-native language[4] as all interviews were held in German.

The topics pursued in the interviews with the risk managers included an initial focus on the challenges involved in flood risk management, how these are countered, and the role of research information. This question block was intended as warm-up, as well as a way of exploring whether the problems and challenges experienced in this field could be related to lack of (reliable) knowledge. The topic of flood hazard maps was introduced through a general question about whether or

[4]Around 15 research-/test-interviews were conducted. Some of these were as brief as 15 minutes on the phone whereas others took a whole hour of face-to-face time. These talks were used to (a) corroborate and complement the understanding of simulation technology provided in academic sources, and (b) to identify flood hazard maps as a potential topic for a case study and learn of the main actors to target for data collection. Though some interviews were held with local-level risk managers respectively external experts during this phase, these were not enough to arrive at a final version of the interview guide.

not the interviewee was familiar with this type of tool and what he or she thought about it. This was followed by questions about how the maps were used, and what advantages or problems the interviewees associated with the introduction of flood hazard maps. Often, this question block also included inquiries about other forms of uses made of the hazard maps within a municipality, e.g. in order to cover the topic of dissemination and communication, but also to use each risk manager as an informant as well as a respondent. To allow for an exploration of the role of simulation uncertainty for whether and how hazard maps are used, each risk manager was asked about how trustworthy he or she felt the maps to be, respectively about the basis for this assessment. Sometimes, this would result in further questions on simulation technology and uncertainty more generally. Before the interview ended, the topic of the hazard maps' usefulness or problems for risk management was raised again in the form of an indirect control question about whether the interviewee would recommend the hazard maps as a risk management tool to a third party. The aim of this question was to allow the risk manager to reflect on this new tool in a more general and abstract way, without having to be concerned about how this might reflect on their own municipality or job performance. In this sense, this question was partially a strategy to facilitate for people to voice potential criticism.

When it came to the external experts, it was difficult to define an interview guide that would work for engineers and modeler as well as for civil servants in higher offices. Emphasis was mostly placed on eliciting the experts' viewpoints of the maps as a risk management tool, their knowledge about how this tool is received and/or used at the local level, and the benefits and problems that this is perceived to bring with it. Beyond that, specific questions were asked to the area of expertise of each interview partner. This could concern details regarding the mapping process, the pros and cons associated with simulation technology, etc.

In terms of data quality, some difficulties were experienced as a consequence of lacking experience in the 'art' of interviewing, as well as of having to work in a non-native language. Some interview mistakes are therefore present. Most of these are of a less serious nature, such as posing a yes/no-question when a more open formulation would have been more suitable. But there are also some instances in which a question was misunderstood or in which an 'easily formulated' follow-up question was posed instead of a more relevant one. In some cases, this led to less material than desirable being collected on a certain topic or perspective. While this was occasionally a source of frustration during the analysis phase, the fact that different aspects were affected means that the error is not of a systematic nature.

5.2.3 Data analysis

The data analysis followed along two paths. The first and initial path was inspired by a method developed by Meuser and Nagel (1991) for analyzing expert interviews. The aim of this approach is to compare the texts with the aim of discovering what is representative in relation to different topics, as well as the areas of difference. The 'topics' can have theoretical origins, stem from the interview guide, or concern areas for which detailed description is desired.

In its original form, the analysis strategy consists of different steps Meuser and Nagel (1991, pp. 455-464). First, the interviews are transcribed. In this respect, little weight is placed on tone of voice and/or non-verbal elements. Thereafter, the transcripts are paraphrased, whereby the chronology of each interview is still respected. Following this, the paraphrased passages in an interview are given one or more headlines (here it is recommended to stay true to the interviewee's own terminology). The original sequence of the interview is broken, so that passages referring to the same or similar topic are grouped together. These headlines should then be reviewed and revised, and overarching categories formulated to reflect the topics raised across the interviews. Eventually, the different transcripts are brought together and compared, and theoretical concepts and terminology are used to formulate categories of a more analytical character.

While this description of how to analyze interview data served as a guide, the process had to be adjusted to accommodate the limitations associated with working in a non-native language. This means that the interviews were recorded and subsequently transcribed by a German native speaker hired for this purpose. In the following step, the transcripts were read-through and made anonymous, and, in some of the longer interviews, monologues not directly referring to the research topic were paraphrased to save space. In the following steps, rather than paraphrasing (and thereby taking the risk of introducing language errors), the interview texts were condensed by deleting repetitions and (half-)sentences disrupting the main narrative. (All places where text was deleted were marked with three dots in square brackets.) The resulting – shorter and clearer – transcripts still reflected both the full range of topics and the interviewees' own terminology.

In the subsequent phase, each reduced transcript was dissected so that passages dealing with flood hazard maps were grouped together, whereas material dealing with other topics were put under other headlines (such as 'risk management', 'simulation technology generally', etc.).[5] This provided a first rough sorting of the material. Eventually, further sorting, revision and harmonization of categories between interviews resulted in a set of categories and sub-categories under which passages from different interviews could be brought together. Generally, though, these steps only served the purpose of bringing overview in terms of what the interviews covered and in which direction this pointed. It was useful for providing a concrete strategy for sorting through the material and thereby developing a preliminary category system. This category system was then transformed into a 'code schedule' in MaxQDA, with which the anonymous transcripts were then coded. The advantage with this was that the original text remained intact, facilitating going back to check the context of a statement, while text segments tagged with the same code could also be retrieved together to allow for direct comparison in regard to what different interviewees have to say about the same topic. This facilitated both the analysis and the writing process.

In the results chapters, shorter citations, included directly in the text, have been translated into English to make for easy reading. Longer and freestanding quotes have been kept in German to stay true to the original. A translation of these can be found in Appendix A. Parenthesis are used to mark passages where the transcription is uncertain. Square brackets are used when a word has been added to make for grammatically correct sentences or when a editor's note has been introduced (marked '- Ed.').

[5]In contrast to Meuser and Nagel (1991)'s recommendations, the headlines were rarely formulated in line with the interviewees' own terminology, as the material covered too many different categories of topics to make this practical.

Chapter 6

Utilization of flood hazard maps

6.1 (Non-)Usage per management field

This chapter will present the results pertaining to whether and how flood hazard maps are used by local-level risk managers in Baden-Württemberg. It will also present what external experts have observed in respect to map usage. To structure the presentation, each management field will be reviewed separately, followed by observations of a more general character. At the beginning of each section, it will be noted whether this particular management field is central or more peripheral in terms of what the interviewees see scenario prediction as relevant for. In this way, one does not only get an idea of how hazard maps are used but also of the how important such usage is regarded as.

6.1.1 Technical protection

When risk managers and experts are asked whether they know and what they think of flood hazard maps, technical flood protection is rarely amongst the first or even second target areas mentioned. Indeed, some of the experts are of the viewpoint that the purpose of foresight simulation is to *reduce* the municipalities' focus on infrastructural protection and control measures by supporting other areas of application. *When* technical protection is mentioned, on the other hand, what is emphasized is primarily the possibility to discover and/or analyze weaknesses in existing defense structures. Indeed, in I02RMb's view, this is the very point of hazard mapping. Raising the topic spontaneously, he notes that the benefit of scenario simulation is that it allows you to *see* where there is a risk of flooding and thereby also whether or not more technical protection is required:

> Früher hat man es nicht gewusst. Da hat man die Möglichkeiten nicht gehabt solche hydrodynamischen, numerischen Modelle zu erstellen. Da hat irgendeiner erzählt: "Ja ganz früher, da stand da mal Wasser oder da." Es war nicht aufgezeichnet richtig. Und heute weiß man es einfach. Durch die Hochwassergefahrenkarten sieht man es und dann weiß man auch, dass man einen technischen Hochwasserschutz herstellen muss, wenn es nicht ausreichend ist, was da ist. (I02RMb, 00:32:59-3)

Similarly, I04RM see flood hazard maps as additional helpful information for reconsidering the current state of a community's structural protection concept, whereas I14E claims that one of the effects of hazard mapping will be that municipalities take action to repair and extend their existing flood defenses. Nevertheless, it is clear that technical protection is relatively peripheral in terms of what most of the interviewees see flood hazard maps as relevant for.

Moving on to the issue of actual use, only the mayors and the risk managers working explicitly with technical protection had anything to say about flood hazard maps' role for this type of management work. In the other cases, technical protection was not part of the interviewee's area of responsibility or altogether low on the municipal agenda.

Beginning with interview 02, one of the first things that happened in this area was that the result of flood scenario simulation[1] gave rise to a new understanding of the local hazard situation, as several of the town's defense structures were found to be

[1]It should be noted that the interviewees partially discussed scenario simulation findings resulting from their involvement in a pilot mapping project interchangeably with the latest flood hazard maps produced by the state. Since all comments pertain to the role and use of visualized simulation results depicting the predicted outcome of scenarios based on statistical return periods, it has not been judged to be of great consequence for the study's purpose or validity that it cannot always be clearly marked when which set of scenario simulation results are meant.

too low or too run down to offer effective protection, resulting in larger areas than expected to depicted as being at risk of inundation. Having looked up photos of past flood events in the city archive and thereby confirmed that inundation of this magnitude could indeed be realistic, what happened then was that the responsible department decided to carry out a detailed survey of the state of the existing defenses to assess their stability and protective capacity:

> Nachdem wir jetzt quasi wussten durch die Hochwassergefahrenkarten, wo kann sich oder wo breitet sich das Wasser aus oder... wo sind die geschützten Bereiche, haben wir jetzt die Hochwasserschutzanlagen, die vorhandenen, untersucht und haben eine Überprüfung der Standsicherheit der Hochwasserschutzanlagen durchgeführt. Und da hat sich ergeben, dass nicht alle Anlagen standsicher sind, sondern dass sie ertüchtig werden müssen beziehungsweise vielleicht sogar erneuert. Und in manchen Bereichen hat sich herausgestellt, dass die Anlagen nicht hoch genug sind. Und das war der zweite Schritt dann. Zuerst gucken wo ist die Gefahr und dann das, was da ist, ist das ausreichend? Ist das standsicher? Und natürlich ergänzend, wo fehlt noch was. (I02RMb, 01:31:07-4)

Hence, the first step was to see where there is a hazard, and the second step to analyze what defenses there are and whether these are sufficient and stable or need to be complemented. Together, these assessments gave the responsible department an overview both of the state of the existing flood protection and of the areas, objects and activities at risk if something would happen. Together, the dug-up photos, flood hazard maps and the new defense assessment were presented to the municipal council, which responded by ordering a plan for how to improve the current situation:

> [W]ie gesagt zum Einen wurde der Gemeinderat informiert und dann wurde der Beschluss gefasst, dass die Verwaltung, also wir, beauftragt worden sind... auf der Grundlage dieses Berichts, einen Maßnahmenplan und ein Finanzierungskonzept zu erarbeiten. (I02RMa, 00:42:23-9)

In the end, it was not only decided to repair existing defenses but also to reinforce and extend these to achieve a higher and *even* level of protection along the main river.[2] As I02RMa explains, this was done because the areas likely to become inundated were industrial zones, implying a very high damage potential:

> I02RMa: [. . .] Das war dann auch noch ein weiteres Thema. Also wir hatten bisher eine Sicherheit, die je nach Einrichtung unterschiedlich war. Also es war nicht ein einheitliches Schutzziel gegeben. Und die Stadt hat sich dann entschlossen durch einen Gemeinderatsbeschluss entlang des Hauptflusses einen Hochwasserschutz für ein größeres Hochwasser herzustellen. Also nicht wie an den kleinen Gewässern für ein 100 jährliches Hochwasser, sondern aufgrund des wesentlich höheren Schadenspotenzials... Sie müssen sich vorstellen, diese Bereiche, die hier so schön blau sind, das ist alles, das ist das Industriegebiet. Wenn das unter Wasser steht... entstehen riesige Schäden. Und deswegen hat man sich entschieden einfach einen höheren Schutzgrad zu realisieren. 00:28:55-4

In terms of the maps' role, I02RMb notes that a simulation (or rather the visual representation that is the result of simulation) is something that can be well presented to the municipal council since it is more impressive than an oral account and therefore also more convincing:

> I02RMb: Und dann konnten wir das natürlich auch gut im Gemeinderat präsentieren, weil so eine Simulation ist viel beeindruckender, wie wenn man irgendjemand erzählt: "Hier wird alles blau sein" und die sagen... -Ist halt schwierig. Aber ich denke durch diese Visualisierung... ist die Akzeptanz einfach anders. 00:36:25-9

Ultimately, then, predictive flood scenario information was used in several different ways. First, simulation results filled an alarm function by alerting the responsible

[2]Currently, the trend in risk management is otherwise to move away from uniform protection standards, in order to adjust the level of protection according to the vulnerability and/or value of the area at risk.

department to the possibility of the municipality not being as well protected as hitherto assumed, corresponding to conceptual use in the sense of affecting the audience's knowledge and understanding of the local risk situation. This, in turn, pushed the issue of flood risk onto the administration's agenda, motivating the interviewees to undertake a more detailed review of the current flood defenses. Hence, predictive information was instrumentally used to define the most appropriate course of action, leading to the initiation of a new activity. Eventually, available evidence, including hazard maps, photos of past flood events and the current defense assessment were presented to the municipal council, which proceeded by ordering an action plan and make a formal decision to realize a higher and more even level of protection. Even if flood hazard maps were not the only evidence relied upon in this regard, constituting a case of direct application of specific findings to decision-making, this is best described as a form of (knowledge-driven) instrumental research use.

In contrast, the situation in interview 04 is that the the final version of the state's flood hazard maps has only just become available. Hence, usage has so far been limited to involving the engineering bureau conducting the simulation work for the hazard maps whenever new defense structures were being planned to ensure that these would be made high enough to count against the maps' provisions (i.e. a form of 'control use' most similar to what is described as personal validation under strategic research use). Now that the maps are finally finished, what they will be used for, according to I04RM, is to reassess the local technical protection concept. In contrast to interview 02, though, it was not the maps themselves that triggered the realization that this kind of reassessment task is needed, but a survey sent out by higher authorities to prepare for the development of risk management plans in accordance with the EU Floods Directive:

> Wir selber müssen natürlich von Verwaltungsseite auch ein paar Hausaufgaben noch erledigen, was jetzt dieser Fragebogen gezeigt hat. Zum Beispiel schauen, aufgrund der neuen Erkenntnisse, die man jetzt durch die Hochwassergefahrenkarten hat, halt unser Konzept für den technischen Hochwasserschutz zu überarbeiten. [...] Die Schwachstellen

> genau zu analysieren und welche Maßnahmen man, also technische Maßnahmen man in die Wege leiten kann. (I04RM, 00:07:35-3)

Hence, this cannot be classified as knowledge-driven research use, but may – once use has actually followed – come to amount to a form of problem-solving application if some form of practical activity or formal decision follows on the basis of the new insights brought along by the hazard maps.

In comparison, the communities covered by interviews 03, 06 and 01 did not have any full-fledged flood control systems in place that scenario simulation could question the effectiveness of. Instead, plans for catchment-wide defenses were either subject to negotiation or currently under implementation, at the time of the interviews. Consequently, both the realization of being at risk and the phase of analyzing and settling on a solution were already finished at the time of the hazard maps' arrival, leaving little space for any kind of conceptual knowledge effect or need for input to decision-making:

> SK: Verstehe ich es richtig, dass die Karten vielleicht nicht so eine große Bedeutung für Ihre Arbeit gehabt haben? 00:39:59-1
>
> I03RM: Das verstehen Sie richtig, ja. Weil der Wasserverband eigentlich zum dem Zeitpunkt, da die Karten veröffentlicht wurden, schon seine Konzeption entwickelt hatte. [. . .] 00:40:32-9

> Also das hat bei uns nicht ausgelöst, dass man sagt: "Oh schau mal, wir müssen hier was tun." Sondern es war vorher schon klar, wir müssen hier was tun. [. . .] Das ist möglicherweise an anderer Stelle, dann ist [die] Hochwassergefahrenkarte Auslöser dafür, dass man überhaupt diesen Denkprozess beginnt. Das war bei uns nicht der Fall. (I03RM, 00:55:09-9)

Likewise, I06RM states:

> Also wir habe schon vor der Hochwassergefahrenkarte diese ganzen Berechnungen gemacht gehabt. Wo Hochwasserschutzanlagen gebaut

> werden müssen und wie groß die werden müssen, das stand schon vorher alles fest. Und das hat sich auch nicht mehr verändert mit den Berechnungen für die Hochwassergefahrenkarte. (I06RM, 00:17:53-2)

Yet, it is not completely true that there is no use at all. First, both the mayor in interview 01 and the mayor in interview 03 have compared the predictions displayed in the hazard maps to the input of the planned protection measures to confirm that these "go in the right direction", as I03RM puts it (00:29:01-1). Second, the visual representation of the predicted extent and depth of inundation is something that I03RM has been able to use to convince local skeptics of the need to accept a structural solution to flood risk. Even if everyone cannot be convinced, this is altogether a central part of what I03RM finds good about predictive information:

> I03RM: [...] Wenn man dann plötzlich bei jemand im Garten steht, der nur in der HQ100-Linie ist, der noch nie Hochwasser hatte [...] wenn sie dann kommen und sagen, sie möchten da jetzt Hochwasserschutz machen und deswegen muss er möglicherweise sein Gewächshaus abbauen, [...] dann hat er zunächst mal kein Verständnis. Wenn sie ihm aber zeigen, letztes Mal war HQ50. Jetzt unterstellen wir, irgendwann kommt HQ100 und dann steht das Wasser hier 20 cm hoch. Und dann gehen wir einfach mal in sein Gebäude rein, was ist in den 20 cm dann betroffen. Dann wird er plötzlich sehr aufgeschlossen für Hochwasserschutzmaßnahmen. [...] 00:34:36-6
>
> SK: Und hatten Sie schon solche Beispiele, wo Sie die Karten mitgenommen hatten und (...)? 00:34:42-8
>
> I03RM: Wir hatten dann eher hier, das Gespräch. Und hatten dann, konnten es dann visualisieren mit dem PC, dass man dann einfach die Überschwemmungshöhe dann darstellt. Da hatten wir zwei Fälle, ja, die bis heute, glaube ich, noch nicht 100% einsehen, dass sie das brauchen. [...] 00:35:15-0

Hence, a certain strategic use can still be identified, as hazard maps are used to legitimize a predetermined management strategy and help risk managers validate what they do personally and publicly.

Turning, to the experts, none of the interviewees in this group has anything concrete to say on the topic of map usage in practice. Judging from I14E's comments, this can possibly be related to the fact that technical protection is quite an enormous task, meaning that a certain delay between learning of a risk and acting upon it can be natural. For his part, he is 'curious' to see how the municipalities will react to the publication of hazard information, noting that some will suddenly be depicted as being very much in risk, as existing defense structures lack the necessary freeboard to count against the HQ100 scenario. Indeed, this is something that he is somewhat critical of, noting that other states have chosen to let such defenses installation count, using color coding to indicate the urgency of addressing the freeboard issue.

To conclude, this suggests that there are cases of both use and non-use in the field of technical protection, depending on what kind of use is looked at. Regarding non-use, this is something that risk managers themselves portray as rational so far, e.g. with reference to timing. Amongst the experts, usage is expected to occur in areas where simulation results reveal weaknesses in current defense concepts, but whether this is actually the case remains to be seen.

6.1.2 Emergency management

When it comes to hazard maps' relevancy for emergency management, this is primarily something that the experts emphasize. For example, I18E (00:25:39-1) describe them as "quite centrally important", both for alarm and emergency operation planning and for evacuation planning, whereas I11Ea (00:17:48-6) see them as a "quite essential basis".

> Wenn Sie sich jetzt so eine Karte anschauen, Sie sehen: Welche Gebiete in meiner Kommune sind überschwemmt? Wo muss ich eventuell evakuieren? Wie muss ich evakuieren? Und dann gibt es verschiedene Gefahrenpunkte: Krankenhäuser, Kläranlage, wie auch immer. Was sind Punkte, wo ich mir im Vorfeld überlegen muss, wo ich agieren muss, wie ich agieren muss, und dann auch die entsprechenden Alarmstellen festmachen. Das ist einfach mit den Hochwassergefahrenkarten

> sehr gut möglich. Also Thema Rettungswege zum Beispiel. Und Straßen: Welche Straßen sind überschwemmt, welche Gebiete sind nicht mehr erreichbar. Das kann man einfach anhand der Karten sehr gut lesen. (I11Ea, 00:23:04-6)

Representing a somewhat more skeptical view, I16E notes that not all hazard maps are equally useful. In his view, some maps are produced at a too coarse scale to be directly applicable to preparedness planning. Furthermore, he finds it questionable whether most municipalities do not already know what to expect from a HQ25 or HQ100 scenario, other than if they completely lack own flood experience. In his experience, there are other – more advanced – tools available that provide more detail and are more useful for emergency management purposes. Though a helpful basic tool where there is no information or experience present, in most areas flood hazard maps are already a bit obsolete in I16E's view:

> I16E: Sie sind sinnvoll in den Bereichen, wo vorher keine Informationen vorgelegen haben. [...] [D]ass dann auch die Kommunen sich überlegen: Was muss ich tun? Oder ich muss was tun. [...] [Aber] aus einer einen Hochwassergefahrenkarte in dem Sinn von einem HQ100, ob da so viele Erkenntnisse herauskommen, das möchte ich bezweifeln. Weil im Prinzip vielleicht die meisten damit schon Erfahrungen gehabt haben. [...] Also ich meine, wenn ich jetzt, wenn ich jetzt hier eine Fluss habe und ich habe hier ein 25 jährliches Hochwasser, dann wird die Feuerwehr sagen: "Das habt ihr toll ausgerechnet. Das wissen wir auch." [...] Also Hochwasserrisikokarten, also Gefahrenkarten sind ja auch mittlerweile, sozusagen das ist schon so ein bisschen obsolet. Man spricht auch heutzutage nur noch von Hochwasserrisikokarten. [. . .] Und... das ist, meiner Meinung nach, das A und O, dass man halt weiß, welche Objekte in dem Bereich vorhanden sind irgendwie. (I16E, 01:00:10-8)

While the experts can nevertheless be said to generally display a positive attitude towards the relevancy of predictive information for emergency management purposes, the picture amongst the risk managers is more neutral. Hardly any of the interviewed managers refer to preparedness planning when discussing hazard maps, or some other area of application will be mentioned first. And there are more mixed feelings, too, particularly on behalf of the chief fire fighter in interview 07. Even if he recognizes the principal advantages of being able to explore the hazard of rare flood events and generate a more precise estimate of expected consequences, this is nothing that he thinks that his community has a need for:

> Hier, wir können jetzt halt nach dem Gefühl hier urteilen, aber mit so einer Computersimulation kann ich halt durch das, dass ich heute halt diese Hilfsmittel habe mit den Höhenpunkten, dass ich das einspielen kann, da habe ich eigentlich einen genauen Wert nachher. Also ich finde das nicht schlecht! Wie gesagt, für uns vor Ort zu groß. Zu weit. (00:38:52-4)

Turning to the issue of how the results of such simulation exercises are used, we see that, in spite of not having mentioned emergency management as one of the primary areas of relevancy, several risk managers still proceed to refer to some kind of use. Simultaneously, the interview material also contains a number of cases of more or less confirmed non-use.

Beginning with the cases of use, it is, again, in respect to the community described in interview 02 that the most influential role can be noted. According to the two administrators responsible for flood risk management in this community, it was not only in respect to the state of technical protection that scenario prediction led to unwelcome discoveries but also in respect to the sufficiency of crisis preparedness. Hence, in this management field, too, the arrival of flood hazard maps has filled something of an alarm function, giving rise to a new reading of the sufficiency of the current response capacity. The result was an intensification of preparedness planning as the administration begun to work out detailed analyses of needs and response options:

> I02RMb: Genau. Wir sind etwas intensiver in die Einsatzplanung eingestiegen. Haben festgestellt, dass wir viele Bereiche vorher gar nicht beachtet haben. [. . .] das ist viel intensiver geworden. Man

> hat das richtig ausgearbeitet, wo kommen jetzt zum Beispiel an einem Straßenzug entlang des Bachs, wo ist mit Überflutungen zu rechnen? Wo muss gesperrt werden? Das hat man ganz genau im Detail alles angeguckt und hat das mit den Karten verglichen. Und das ist jetzt richtig ausgearbeitet auch. Und das war vorher ein bisschen grob. Oder gar nicht. 01:04:03-3

According to I02RMb, furthermore, it was only after the arrival of flood hazard maps that a a special catastrophe plan was developed for how to respond to a catastrophic flood scenario (e.g. in case of failure of the city's technical protection works). Having had a direct effect on the level of activity in this management field, predictive scenario information has not only been conceptually but also instrumentally used. Yet, it is one thing to develop a new exemplary form of alarm and response plan for a single district to be presented at a conference, and quite another to maintain interest and engagement over a longer period of time. Due to scarce resources in terms of time and personnel, it appears that the rest of the city has been put on hold:

> I02RMa: [. . .] wenn hier entweder ein Versagen eintritt oder eben ein Hochwasser eintritt, das größer ist als das Bemessungshochwasser [. . .] haben wir mal beispielhaft für einen Ortsteil mal einen Alarm- und Einsatzplan entwickelt. Was denn zu tun ist, wenn es versagt. Weil die Menschen, die leben ja zunächst mal im Bewusstsein: Wir sind geschützt. Und jetzt ist der Schutz in Frage gestellt. [. . .] Da ist noch sehr viel zu tun. Eben auch jetzt in, für den Hauptfluss. Das erfordert Zeit und... also personelle Ressourcen. [. . .] Da muss einer hinsitzen und einen Plan machen. Und da sind wir noch ganz am Anfang. Wie gesagt, wir haben es mal für den Ortsteil mal für eine Tagung aufbereitet. [. . .] Und... Aber für das Stadtgebiet haben wir das noch nicht... weil wir personell noch nicht in der Lage sind das alles... zu... aufzuarbeiten. 01:23:25-8

Even if flood hazard maps have been used, then, there is something of a question mark when it comes to their long-term effect.

If interview 02 can be said to constitute a case of knowledge-driven research use, the situation described in interview 08 is rather one of problem-solving. Here, there was no emergency management plan in place since beforehand. Yet, it was not the arrival of scenario simulation results that motivated I08RM to change this fact, but the fact that this is something that state law requires:

> [I]n der Zeit, wo ich jetzt hier bin hat es sich dann ergeben, dass dann das Gesetz dementsprechend vorgab, dass man einen [Plan – Ed.] erstellen muss als Gemeinde. Es gab eine gesetzliche Vorgabe. Und es hat dann aber doch noch eine gewisse Zeit gedauert bei uns, weil einfach die Zeit nicht da ist. Wir sind für so viele Dinge verantwortlich in so einem kleinen Rathaus [. . .] Und ich habe sie mir jetzt genommen, weil ich gesagt habe: "Wir müssen jetzt etwas tun." Und habe mich dann mal eine Woche aus allem anderen ausgeklinkt und habe dann den Plan mal gemacht. (I08RM, 00:32:29-0)

Only after this decision had been taken for another reason than it being regarded as necessary from a risk management perspective were the flood hazard maps sought out and made use of. Though I08RM has fairly little to say about this, responding to efforts to probe for details with saying that they were 'helpful', the fact that the hazard maps have been included in the emergency plan in the form of an appendix still qualifies it as a case of direct application and, hence, as instrumental research use.

Proceeding with a case in which emergency management was already a priority *before* the arrival of predictive information, this is how the administrator responsible for crisis management in interview 10 describes how flood hazard maps based on gauge level scenarios have been used to update the emergency plans in his community:

> Zur Erstellung dieses Plans braucht man ja die Karten dazu, weil man einfach sagen muss, man muss wissen, wenn ein Wasserstand, nehmen wir ein Beispiel, von 5 m erreicht ist, was ist davon betroffen? [. . .] Und dann muss man ja sagen können, wenn der Bereich betroffen ist, welche

> Schutzmaßnahmen werden getroffen, um weitere Bereiche oder um andere Bereiche abzusichern. Dafür ist so eine Karte enorm wichtig. Das ist ganz klar. Zusammen mit unserem Bauamt, mit unserem Bauhof legen wir anhand dieser Karten und dieser Wasserstände dann schon fest, welche Maßnahmen wir veranlassen. [...] Sie haben einen Parkplatz direkt am Fluss unten und da stehen 150 Fahrzeuge. Sie wissen ganz genau, wenn der Fluss 4,50 m kommt, müssen die Fahrzeuge dort weg sein. Das sehen sie aber nur, wenn sie so eine Gefahrenkarte erstellt haben vorher, um zu sehen bei 4,50 m, welche Bereiche sind denn betroffen. (00:33:43-4)

In spite of seeing flood hazard maps as an important tool for preparedness planning, though, other sources of information are required too, including professional knowledge, experience, and lesson-drawing following each new flood episode. This is how it has always been, according to I10RM, and this has not changed. After all, the city keeps changing – and flood risk with it – while hazard maps remain static between each new update:

> Dieser Plan wurde von meinen Vorgängern erstellt, ursprünglich. Ohne Hochwassergefahrenkarten. [...] Die haben einen Plan erstellt, nachdem sie mehrere Hochwasser mitgemacht haben [...] Und anhand dieser Erkenntnisse hat man dann festgelegt welche Maßnahmen man ergreift. Das ist natürlich ein ständiges fortschreiben, das geht heute noch genauso. Wenn Sie heute ein neues Baugebiet erschließen, zum Beispiel, dann hat das natürlich Auswirkungen beim nächsten Hochwasser. [. . .] Wir kriegen das schon oft von Leuten mit, die dann bei uns anrufen und sagen: "Wir haben jetzt auf einmal Wasser im Keller." [...] Und das wird von uns alles schriftlich festgehalten und dann können wir beim nächsten Hochwasser sagen: "Stopp! 20 cm vorher müssen wir die Leute anrufen. Trefft Maßnahmen, da kommt etwas." (I10RM, 00:35:30-1)

Though consulted for planning purposes, then, flood hazard maps are not what made I10RM engage with preparedness planning in the first place; not the sole form of input relied on; and not associated with any direct kind of effect. On the contrary, scenario simulation results appear to be *one* of the sources of information which have been drawn upon and which can be said to have helped *inform* the content of the emergency plan. In this sense, the most appropriate description is conceptual use, i.e. in the form of a management version of the *interactive model*, meaning that what ends up in internal planning documents for guiding practical activities reflect *inter alia* the findings of predictive research, but also what experience shows works, what local priorities dictate, what was already in the plan since before, etc.

Turning to examples of less enthusiastic responses to predictive information for emergency management planning, I03RM's answer to the question of how flood hazard maps have so far been used is: “Honestly, hardly at all.” (00:31:13-9). And although flood hazard maps have been available for I07RM's community for well over a year already, he is still unaware of their existence, living under the impression that this is something that will be produced for the larger waterways first, not really seeing a need for his own community:

> I07RM: [. . .] Die sind aber, es hieß vor fünf Jahren, dass auch wir so was bekommen, aber ich glaube, dass diese Karten zunächst mal für die Anrainer von Neckar, Rheintal, zunächst mal für die größeren Flüsse, dass sie die vorziehen und die zunächst machen, dass wir es dann auch vielleicht mal bekommen. Wie gesagt, die brauchen wir, wenn wir ein hundertjähriges Hochwasser haben brauchen wir die, normal alle 100 Jahre (lacht). [. . .] 00:28:35-8

Moreover, though not really up to him, I05RM says that he cannot imagine that flood hazard maps will play a role for emergency management in the administration where he works. In his view, there is no need for foresight information to support local preparedness planning, as the risk of flooding is already well-known and altogether quite low:

> I05RM: Also wir wissen, wir hatten hier schon ein paar große Hochwässer. Insbesondere in dem Bereich, wo die Bäche zusammenstößt. [. . .]

> Also das ist eigentlich der Bereich bei uns, wo [. . .] Schäden entstehen können. Und das ist bekannt. [...] Man hat auch in der Vergangenheit dort das Gelände angehoben, damit [...] die Gefahr der Überschwemmung nicht mehr so hoch ist. Also die Bereiche sind bekannt. Man weiß, wenn Hochwasser ist, ist das das Gebiet wo es Probleme gibt. Aber die Probleme sind jetzt nicht so, dass man Alarmpläne machen würde. Das sind jetzt keine, was weiß ich, Heizöllager oder irgendwas, wo man jetzt die Feuerwehr vorwarnen müsste oder irgendwelche Ölsperren oder so was machen müsste... 00:28:08-7
>
> SK: Für das Emergency-Management wird die Karte also nicht so eine große Rolle spielen, denken Sie? Dadurch dass sich- 00:28:17-9
>
> I05RM: Also ich kann es mir nicht vorstellen. 00:28:21-1

Likewise, I09RM recounts how the colleagues responsible for coordinating respectively carrying out crisis operations in his municipality cannot see what they should need flood hazard maps for, as they already have everything they need to manage the risk of flooding:

> Ich habe mal hier im Haus eine Runde gemacht, als diese Hochwassergefahrenkarten für die eine Bach dann verbindlich wurden, mit allen, wo ich dachte die könnten damit zu tun haben. Also angefangen vom Bauhof, der dann raus muss im Hochwasserfall und Bereiche absperren, Sandsäcke auffüllen, was weiß ich, bis hin zu unserem Ordnungsamt, das da organisatorisch die Federführung hat in solchen Katastrophenfällen. [. . .] Und da war die erste Reaktion: “Hm? Wozu brauchen wir diese Karten? Wir wissen ja genau was passiert, wenn das Hochwasser kommt.” Wir haben ein Warnsystem. Es gibt ein Pegel [. . .]. Und [. . .] einen entsprechenden Einsatzplan [. . .]. (I09RM, 00:12:47-6)

Though neither of these reactions exclude the possibility of use by someone else or at a later stage, they all point in the direction of non-use *for now.* According to I06RM, even if a colleague of his has applied scenario simulation results to preparedness planning in a very direct way and made good experiences with this,

his general impression is that flood hazard maps are “too little” used in this way, as local fire brigades lack the knowledge that it requires to appreciate them (00:35:20-0). Hence, there are not only cases of use but also on non-use in this management field.

Turning to the experts, it is only in interview 13 that any concrete experience is present. Apart from the brief mentioning of an effort to show municipalities how flood hazard maps can be used to assess the risk of flooding to critical infrastructure, what I13E’s account concerns is a pilot project initiated to help a community develop an emergency management plan following the revelation that a newly developed housing area was at high risk of inundation.

> Das war auch durch die Gefahrenkarte ausgelöst. Die Gemeinde hat gesehen, ihr Neubaugebiet von vor 20 Jahren steht unter Wasser schon beim HQ10. [. . .] Dann hat der [Bürgermeister – Ed.] auf die Schiene gesetzt, einen gescheiten Gefahrenabwehrplan zu machen. [. . .] Dann haben sie mal einfach anhand der Gefahrenkarten und anhand des Ablaufes, mit externer Unterstützung, [. . .] haben sie geschaut, was passiert denn eigentlich tatsächlich in der Ortschaft, wenn das Wasser ankommt und wenn es anfängt zu steigen. (I13E, 00:27:08-3)

In spite of this analysis provenly having helped the community improve its protective capacity by showing the fire brigade’s suggested response strategy to be inadequate for avoiding the undesirable scenario of parts of the city being cut off, it was eventually discontinued at a premature stage. As in the case described in interview 02, it appears to have been difficult to maintain interest over time, suggesting predictive information to be something which may trigger a spike in activity rather than provoking a lasting change in trend:

> Ist dann aber auch irgendwo stecken geblieben, weil es halt doch viel Aufwand ist und die Kommune knapp bei Kasse, wenig Personal. Und dann hat man es geschoben. Oft ist es ja auch so, dass der Bürgermeister, der das angestoßen hat, vielleicht abgewählt wird. Und, wenn dann eine neue da ist, geht es... Ach, da passiert nichts mehr... (I13E, 00:27:08-3)

If an area of application is characterized by continuous activity rather than one-off decision situations, instrumental research use may not even be the most desirable thing (unless it comes in the format of lasting behavioral change). At least in the cases reviewed here, the conceptual use described by I10RM may, all things considered, be a preferable form of application compared to the kind of discontinued activity bursts described in interview 02 and 13 as it indicates a sustained interest in local preparedness planning and in drawing on all forms of available evidence for optimizing this.

In summary, the material contains cases of both use and non-use. While none of the risk managers portray this non-use as problematic, it is too early to tell whether there may also be other opinions in this regard.

6.1.3 Non-structural alleviation

In contrast to technical protection and emergency management, non-structural alleviation occupies a central position in terms of what both interview groups see flood hazard maps as relevant for. Amongst the experts, it is especially as input to land-use and development planning that hazard maps are described as important. In light of scenario simulation results, local planning documents should be changed so that areas at risk from flooding are withdrawn from current building plans to prevent further increases in damage potential. Moreover, flood-proof construction techniques and risk sensitive building designs should follow, as well as a stronger focus on 're-naturalization' to preserve and increase the local landscape's natural retention capacity. Though I16E appears to regard risk zone maps accounting for an area's vulnerability as well as its hazard as a superior form of tool for development planning, hazard maps are still acknowledged as a useful starting point.

Amongst the risk managers, similar uses are mentioned. In contrast to the experts, though, the risk managers' accounts are much more concrete, defining specific tasks and areas of application for which hazard maps are salient. Looking at the nature conservationist in interview 05, for example, we see that, even if he did not have access to a finished version of the hazard maps at the time of the interview, being familiar with this tool from the plausibilization process, he can already pinpoint a number of management tasks for which this type of foresight tool will be useful, including water body maintenance, land leasing, storage decisions, etc.:

> I05RM: Im Bereich der Liegenschaften, der Landwirtschaft, also wenn wir unsere Grundstücke verpachten. Im Baurecht, ob man da das und das bauen oder lagern darf. Sicher auch in der Gewässerunterhaltung, wie pflege ich den Bach (...). [...] 00:25:51-5

And not only for the sake of human lives and property, but for the sake of local nature, too:

> I05RM: [...] Wenn ich einen Auffüllungsantrag von einem Landwirt kriege und ich sehe, dort ist Überschwemmungsgebiet, dann [...] werde ich in meiner Stellungnahme zu dieser Auffüllung sagen: "Nein, Moment. Das ist ein Bereich, der immer wieder überschwemmt wird. Also machen wir es nicht." Wenn ich ein Grundstück verpachte, das der Stadt gehört dort, dann werde ich [...] der Liegenschaftsverwaltung sagen: "Hört mal her. Da ist jetzt zwar Acker, aber versucht doch das als Wiese zu verpachten, weil: wenn es als Acker verpachtet wird habe ich den Dreck nachher im Bach." In unserem Bach kommen seltene Fischarten vor, wie Strömer und Groppe. Wenn da dann noch Hochwasser, der Dreck eingespült wird, gehen die Lebensräume oder die Hohlräume verloren, wo der Fisch seine Eier ablegt. [...] 00:22:15-7

Hence, hazard maps' relevancy is not something that risk managers 'imagine' but something that they are convinced of. Indeed, when I09RM is asked what he thinks of flood hazard maps, his response is not a theoretical but concrete description of how this new tool has already proven itself useful in terms of helping the administration limit the damage potential associated with new building projects:

> I09RM: Also für uns ist das auf jeden Fall sehr hilfreich, definitiv, diesen Überblick zu haben. [...] Und wir haben Informationen zur

> Überflutungstiefe. Also das ist ganz wichtig, wenn jetzt, was hier noch möglich ist, Bauvorhaben beabsichtigt sind [. . .] dann können wir dem Architekten sagen: "Der Pegel bei dem 100 jährigen Hochwasser wäre jetzt an dieser Stelle deines Grundstücks 50 cm, an der Stelle 70 cm. Richte da deine Planung darauf aus, damit eben das Schadenspotenzial minimiert wird." [. . .] Also ist für uns sehr, sehr hilfreich. [...] 00:41:42-1

Compared to the other management fields reviewed, then, the relevancy of flood hazard maps for non-structural alleviation is not only mentioned more often but also with more emphasis.

Regarding the actual issue of use, the field of non-structural alleviation is somewhat different from the other management fields as some of the predicted hazard lines introduce binding land-use restrictions. In effect, this makes it close to impossible for local administrations to completely ignore available flood hazard information. As a result, the data material does not contain any first-hand examples of admitted or evident non-use, only of usage being perceived to be insufficient or more or less 'forced'.

Beginning with the risk managers' accounts, it is, again, in interview 02 that the most direct influence of hazard maps is noted. For one thing, I02RMb feels that access to flood hazard maps has increased the local administration's ability to account for the risk of flooding in relation to building permit applications and the issue of whether or not to define particular construction requirements:

> [D]ass wenn Menschen einen Bauantrag stellen, dass wir reinschreiben: "Achtung Hochwasser! Hochwasserangepasst bauen." Oder "hier ist es nicht zulässig." Also solche Dinge. Die sind früher auch nicht so streng mit einem roten Faden verfolgt worden, weil man einfach diese Karten nicht hatte und nicht wusste, wie weit geht jetzt die blaue Fläche. Heute können wir mit den Karten uns genau angucken und sagen: "Ok, da ist blau. [...]" (I02RMb, 00:55:02-8)

For another thing, the local administration has proceeded to withdraw certain areas from the local development plan, in spite of such measures not being popular with the citizens owning land in these areas:

> Und [. . .] wir haben in Teilbereichen dann schon die Bebauungspläne ändern müssen, überarbeiten müssen, was dann eben oft bei betroffenen Grundstückseigentümern, die nach altem Planungsrecht einen Bauplatz hatten und jetzt dann nur noch ein überflutetes Grundstück, planungsrechtlich, das ist kommunalpolitisch ein Problem. (I02RMa, 00:56:56-8)

Providing that it was indeed the hazard maps that inspired this decision, this represents a case of instrumental research use. In contrast, the former kind of application mentioned is more difficult to pinpoint, defying the view of research use as a one-off event as hazard maps are consulted on a regular basis in relation to routine administrative errands. Though likely to be instrumental in terms of determining the outcome of these errands in some cases, there may be other instances in which predictive information does not play any role at all. Indeed, rather than using flood hazard maps on their own, these will often be integration into a municipality's Geographical Information System (GIS), where they can be retrieved and overlayered with other pieces of relevant information, just like previous forms of hazard estimates and floodplains before them:

> Das ist im Alltag eine Riesenhilfe. Also dieses geographische Informationssystem überhaupt. [...] Also ich sage immer, ich habe in der einen Hand einen Telefonhörer, in der anderen Hand die Maus am PC und kann, wenn mich jemand was fragt, eigentlich zu allen relevanten Themen, die wir hier zu bearbeiten haben, eigentlich direkt Auskunft geben. Ich kann diese Hochwasserthematik abrufen. Ich sehe, wo Leitungen liegen. Ich sehe, welches Baurecht darauf ist, was der Flächennutzungsplan sagt, wo Schutzgebiete sind und so weiter. Und da sind diese Informationen eben auch ein ganz wichtiger Baustein... (I09RM, 00:41:42-1)

Judging from these descriptions, simulation-based hazard information is *one* of the pieces of information that risk managers will consult in relation to routine management task. Actual areas of application concern where to designate building or commercial zones, the location and design of public construction, and where to survey the river banks for debris. What is eventually decided, though, will not only depend on the predicted risk of flooding but on other factors, too. In this sense, the influence of hazard maps is not given, but something that is likely to change from case to case, not only depending on what level of hazard is indicated but also on the cost-benefit balance of tolerating respectively *not* tolerating the risk that this implies:

> Sprich im Fall von dem Acker, der verpachtet wird [...]. Bevor jetzt die Stadt das dann pflegen muss, also Wiese, wird das dann eben als Acker verpachtet. Wie gesagt, es ist nicht so, dass das was dann nachher drin steht die Bibel für alle ist. Aber es ist die Information, die eben mit in die Entscheidung vor Ort einfließen muss. Wie die nachher ausfällt, das steht auf einem ganz anderen Blatt. (I05RM, 00:24:29-5)

Hence, predictive information is not described to have changed either *what* is done or *how* this is done. Often, it is consulted in relation to issues and errands which would have had to be decided upon anyhow and for which the risk of flooding is only one aspect amongst others. In terms of their effect, risk sensitive land-use planning was already a priority in I09RM's administration, meaning that they did not really need the arrival of scenario simulation results to begin to pay attention to non-structural alleviation strategies (00:12:47-6). For his part, I05RM hopes, but does not know, whether the arrival of flood hazard maps will make the responsible decision-makers give more weight to the risk of flooding in local development planning (00:22:15-7). And I08RM notes that, even if his administration uses flood hazard maps to exclude the possibility of new building zones being located in risk areas, the situation in other municipalities is different:

> Man sieht, dass andere Gemeinden im Bereich von HQ100-Flächen durchaus Bauten, öffentliche Bauten erstellt haben in der jüngsten

> Vergangenheit. [...] Letztendlich entscheidet die Politik ja nicht immer rational, sondern man verfolgt Interessen. Und da muss man den Hochwasserschutz gegen andere Interessen abwägen. (I08RM, 00:20:37-3)

Indeed, one of the problems identified with flood hazard maps in chapter 8 is their lack of effect as local administrations continue to designate building zones in areas known to be at risk of flooding:

> I06RM: Ja ich finde sie sehr gut. Hochwassergefahrenkarten geben schon Auskunft darüber das theoretisch sich ergebende Überschwemmungsgebiet. Aber man sieht schon, dass Gemeinden trotzdem noch in diesen Flächen, also gerade was den HQ extrem-Bereich betrifft, dass sie dort versuchen immer noch Baugebiete auszuweisen. Und da sollte es noch eine Handhabe geben das zu verhindern. [...] 00:13:47-3

Turning to the experts, finally, these have little concrete insight as to the use of flood hazard maps, but some as to the municipalities' general reactions. In this regard, the fact that flood hazard maps basically 'force' municipal administrations to practice a management strategy of risk avoidance is noted to make them somewhat unpopular amongst local political leaders:

> Es gibt insofern Akzeptanzprobleme, dass natürlich viele Kommunen wollen diese Karten nicht. Weil sie dann Auflagen bekommen. Zum Beispiel ein Industriegebiet, was sie neu ausweisen wollten, dürfen sie nicht ausweisen. Oder ein Baugebiet. Sie wollen expandieren, jede Kommune will expandieren [...] Und die Gefahrenkarten, die stoppen das in den Flusstälern. (I18E, 00:34:16-3).

> [D]ie Gemeinden sind zwar in diesen... wie heißt das? In diesen kommunalen Verbänden an der Finanzierung mitbeteiligt. Und machen das Spiel halt mit, notgedrungen. Weil es ist ja eine EU-Richtlinie, die dann über Landesgesetze umgesetzt wird. Aber die Gemeinden

> sind nicht darüber begeistert, weil ja dann Karten herauskommen, wo bestimmte Flächen überflutet sind. Wo dann möglicherweise ursprünglich geplante Baugebiete gar nicht mehr realisiert werden können oder nur viel schwieriger, weil man dann, wenn man das Baugebiet dort baut, muss man auffüllen, verbraucht dann ein Volumen, ein Reduktionsvolumen, muss dieses Volumen an einem anderen Ort wiederherstellen. Das ist ja der tägliche Kampf der Gemeinde, nicht nur gegen das Hochwasser, sondern auch gegen die... diese Hochwassergefahrenkarten. (I14E, 00:29:38-8)

Even if this does not say anything, per se, about how flood hazard maps are used, it does show a lack of enthusiasm on behalf of some communities as to *having* to prioritize local flood risk over other interests. Apparently, the chance at acting in foresight is something that some actors could do without. Even if there are no cases of admitted or evident non-use, then, there are some hints in the direction of hazard maps being perceived to be under-used at the local level, not living up to their full potential as useful for guiding local planning and decision-making.

6.1.4 Risk communication

Both amongst risk managers and experts, risk communication is the management field mentioned the most often as an important field of application for flood hazard maps. Particularly, the capacity to visualize the likely outcome of flooding is perceived to make them practical for communication purposes. As I02RMb and I18E explain, *seeing* the predicted consequences of a flood scenario makes the risk of inundation 'real', and thereby harder to ignore:

> Und das Land hat ja jetzt oder ist dabei die Hochwassergefahrenkarten zu erstellen und dann sieht man es Blau auf Weiß: So sieht es aus. Und das ist einfach dann real. Dann weiß man: Ok, das kommt irgendwann. (I02RMb, 00:32:59-3)

> Also Simulation und Animation sind Möglichkeiten, diese Hochwassergefahr real werden zu lassen und damit die Menschen zu sensibilisieren. (I18E, 00:25:39-1)

Amongst the experts, what exactly this is seen as useful *for* varies. To I15E, it concerns the possibility to explain the options for public risk management and how they would affect the local hazard situation. To I17E, it is about awareness raising to increase people's consciousness of the consequences of their actions. I18E and I11Ea and -b do not specify why it is important to bring hazard information to public knowledge, but to I13E and I12E it is about building societal acceptance for a management strategy based on adaptation rather than technical flood control and encouraging private precaution in addition to public protection:

> [I]n diesen [geschützten – Ed.] Bereichen Vorsorge in irgendeiner Form zu erwirken. Dass die Leute was tun, dass sie sagen: "Ja hoppla! Wir können ja doch betroffen sein." Und da sind halt gerade diese Karten wichtig. Dass man da eben aufzeigen kann: da ist was! [...] Genau das sind die Punkte, wo wir heute was tun können in der Vorsorge. Wo wir also Möglichkeiten haben beim Bürger was zu erreichen, dass er selber was tut. Was ja häufig wichtig ist. Also ich meine, wir können nicht sagen immer nur: "Baut Hochwasserschutz!" Der Bürger kann sehr viel selber tun in punkto Vorsorge. Dass er wenig Schaden erleidet und damit ist es vielleicht wertvoller als das, das hundertste Rückhaltebecken irgendwo an einem Gewässersystem zu bauen. Also, dass kann durchaus sinnvoller sein, dass man da mit den Karten einfach Vorsorge erzeugen kann. (I12E, 00:27:45-2)

In the case of I12E, there is outspoken hope that foresight information will make private citizens take more own responsibility and rely less on the public authorities:

> Dass die Bürger selber anfangen Vorsorge zu betreiben, ganz wichtiger Punkt. Dass sie also nicht sagen, wie eben schon gesagt, "der Staat muss sich darum kümmern" oder "die Gemeinde muss was tun". Sondern jeder selber kann was tun indem man einfach nur sagt: "Gut, wie

> nutze ich meinen Keller? [. . .] Was kann ich tun, wenn ich neu baue? [. . .]" (I12E, 00:28:45-5)

When it comes to what the experts see flood hazard maps as relevant for, hence, it is awareness raising for encouraging self-protection and a shift in focus from technical protection to adaptation and a shared responsibility for risk management that is mentioned the most often (as oppose to processes of public consultation or stakeholder involvement, for example).

Amongst the risk managers, there is no mentioning of any expectation of citizens becoming less inclined to rely on public authorities. What flood hazard maps are appreciated for is simply the prospect of being able to enlighten the local hazard situation, thereby enabling people to account for this when making decisions of a private nature. In I06RM's view, foresight information is a 'blessing' for risk managers wanting to explain where there is a hazard and what can be done about it (00:32:51-9), whereas I05RM explains how this is relevant for informing people:

> Man kann dann der Bevölkerung eben sagen oder zeigen: "Bis hierher wird es gefährlich. Du kannst dich oberhalb auf der sicheren Seite wähnen." Oder wenn er innerhalb von diesem HQ100-Hochwasser ist eben sagen: "Bau entsprechend." Oder wenn, was weiß ich, wenn die Heizung umgebaut wird oder was auch immer, dass man sich entsprechend darauf einrichten kann. (I05RM, 00:29:56-6)

In a couple of cases, this form of usefulness is not simply imagined but something that has been experienced first hand. When I10RM, for instance, is asked whether he knows and what he thinks about flood hazard maps, his answer is:

> I10RM: Die sind natürlich sehr wichtig, wenn es um irgendwelche Bebauungsdinge geht. Das heißt, wenn es um Bebauungspläne geht oder aufstellen von Bebauungsplänen. Oder wenn es darum geht, es kommen öfters mal Personen zu uns her, die wollen irgendwo in einem gewissen Gebiet eine Wohnung anmieten, die Fragen dann nach: "Ab wann haben wir denn dort das Hochwasser?" Dafür sind die Karten

> natürlich sehr wichtig, muss man ganz klar sagen. Oder es ist sehr hilfreich, dass es sie gibt. [...] 00:25:16-2

Only in the case of the mayor in interview 03 is a different form of relevancy to be found. Though acknowledging hazard maps as valuable tools for awareness raising, what he sees this as important for is helping the local administration explain and justify the need for structural protection measures (i.e. a form of strategic use):

> Ich denke [die Gefahrenkarte – Ed.] ist nachher zum verdeutlichen für die Anwohner ein wichtiges Instrument, um auch aufzuzeigen: "Passt auf, auch wenn ihr bisher noch nie Hochwasser hattet oder nur ganz selten, ihr wohnt in einem Hochwassergefährdeten Bereich." Das ist gerade für das, was wir eben angesprochen haben, die Vermittlung der Maßnahmen, ganz wichtig. Weil wenn sie zu jemanden kommen und sagen: "Wir bauen Ihnen jetzt eine Mauer in den Garten." Und wenn die nur 50 cm hoch ist, dann ist er zunächst mal nicht begeistert. Wenn man ihm aber sagt, man tut es, weil man diesen Anwohner direkt schützen möchte und man kann das auch belegen, weil es eine Hochwassergefahrenkarte gibt, dann ist die Offenheit auch plötzlich für so eine Mauer da. Weil man sagt: "Ja bevor ich Wasser im Keller habe, lieber so eine Mauer." (I03RM, 00:29:01-1)

Turning to the issue of actual use beyond the hazard maps' online presence and mandatory period of public display, the fact that the concepts of instrumental and conceptual research use as somewhat difficult to apply in this respect means that this section will discuss the use of flood hazard maps in terms of the kind of communication activity that they are applied to (e.g. two-way, face-to-face, large- or small-scale). In this regard, it can be noted that the majority of the risk managers' comments pertain to face-to-face information provision to a single individual or household. In the case of interview 02, this is partially something that is described to occur when it comes to the administration's attention that someone wants to build in a high-risk area and persuasion is the only means available for seeking to prevent an increase in local damage potential:

> Also es ist so, dass die, die bauen wollen und dort einen Bauplatz haben – geschenkt bekommen, vererbt oder sonst was – die sind sehr uneinsichtig. Weil sie sagen dann "da hat es noch nie Hochwasser gegeben", weil sie unbedingt auf dieser Fläche bauen wollen. Und dann überzeugen wir sie oft, wenn wir Fotos haben mit Fotos. Oder eben mit diesen blauen Karten. [...] Und da ist schwierig oft, die zu überzeugen. (I02RMb, 00:55:58-5

In the rest of the cases, though, what is described are not active efforts at information provision, but a form of 'passive' use in response to being approached with a request for information from someone wanting to move, invest in construction or buy new property:

> Wenn Bürger herkommen und fragen, [. . .] sie möchten Wohnungen anmieten irgendwo oder ein Haus kaufen oder ja. Gibt vielleicht irgendwo ein Grundstück, dass sie bebauen möchten, da gibt es schon mal den einen oder anderen, der nachfragt: "Liegt das im Hochwassergebiet?" [. . .] Da es schon mal ab und zu die Nachfrage da und dann greifen wir auf diese Karte zurück. (I10RM, 00:40:53-5)

> Ich meine der einzelne Bauherr oder Architekt, der dann zu uns kommt und sagt: "Wie ist denn das da?" Und ich kann ihm relativ schnell sagen: "Beim 100 jährigen Ereignis, wo die Gebäudeversicherung sich darum kümmert und wo es auch für das Baurecht gewisse Konsequenzen hat, ist der Pegel auf deinem Grundstück so und so." Dann sind die natürlich auch sehr dankbar, wenn sie da schnell eine zuverlässige Information kriegen können. (I09RM, 01:02:12-4)

According to the risk managers in interview 02, it is a rather new development that people are aware of the risk of flooding and choose to inquire about it. Rather than linking this to the arrival of flood hazard maps, though, intense media coverage of past flood catastrophes is what is thought to have sensitized people to this risk:

> I02RMa: Das stimmt, wenn, bei Grundstücksgeschäften wird zwischenzeitlich nachgefragt. 01:40:18-8
>
> I02RMb: Genau. [...] [S]eit Oder und Elbe so durch die Fernseher getingelt sind [. . .] Und dann natürlich auch Hochwasserereignisse in Ländern, die sonst nie Hochwasserprobleme haben. [. . .] [D]ie Menschen, die am Bach wohnen oder leben oder ein Haus kaufen wollen, [sind] schon sensibilisierter. Sie kommen dann und fragen auch wie sieht es da aus? [. . .] Das war früher nicht. Früher hat keiner sich interessiert. Weil das war einfach nicht in den Köpfen drin, Hochwasser... 01:41:23-0

Judging from the experiences of I06RM and I08RM, furthermore, even if this development is positive, it remains limited. Most people simply begin building without making any form of inquiry (I06RM, 00:15:56-3), and it is only sporadically that people come by city hall to view the displayed hazard maps (I08RM; 00:10:27-0).

When usage of hazard maps is not passive in the sense of provoked by someone else's active request or small-scale in the sense of targeting a single household, what is described instead is some form of public meeting or information evening to reach a larger audience. In theory, this type of meeting format can allow for two-way communication, i.e. that the audience has a chance to ask questions and voice concerns, instead of just being fed with information. In terms of practical examples, I03RM describes having co-organized a series of information evenings together with the other municipalities in the catchment area. Particularly after the river last overflowed, he says, there was much interest in learning about local flood risk:

> I03RM: Also wir haben auch da Informationsveranstaltungen gemacht und noch mal erklärt wie funktionieren die Hochwassergefahrenkarten, welche Informationen kann ich daraus ziehen. Und insbesondere nach dem Hochwasser hat es natürlich dann immer wieder die Anfrage gegeben: "Ja wie ist das bei mir? [. . .] Bin ich überhaupt noch im gefährdeten Bereich oder bin ich schon außerhalb?" [. . .] [W]enn jetzt das Wasser kommt, ist dann nur mein Kohlekeller nass oder ist dann auch mein Wohnzimmer nass. [. . .] 00:34:36-6

Before the town was flooded, in contrast, interest was low, implying that risk communication represents a difficult challenge in periods of calm. Apart from offering information, I03RM notices, there is little you can do if people do not want to listen.

In the case of the mayor in interview 01, what was organized in his community was a public presentation and explanation of the flood hazard maps as these became publicly available. As I01RM puts it, though, the whole affair was 'rather short' and 'somewhat politically motivated':

> Und die Information, es war ja so, dass man sie auch öffentlich präsentiert hat. Das war eine ziemlich kurze Angelegenheit. Das war ein bisschen politisch motiviert. Man wollte eben nach außen zeigen, jetzt sind sie da die Karten. Es wurde auch ein bisschen was erklärt dazu. (I01RM, 00:43:59-5)

Even if what occurred at this event was information provision, then, the usage itself appears somewhat tactical; an effort to enhance the public authorities' standing in an area recently hit by severe flooding by showing that something has been done in response to this disaster. In terms of the audience, I01RM thinks that, truly, some people came because they see the necessity of contributing to risk reduction. Others, though, were rather there to look after their own interests; fearing the imposition of restrictions that will limit what they can do: "they don't want to be restricted. This is their real estate, their plot of land, and they want to be able to continue to act just as they have so far." (I01RM, 00:58:49-1)

Representing a final example, I04RM tells that the local administration where he works is planning to arrange an information evening during the time that the state's flood hazard maps are displayed at city hall, to proactively respond to the questions that the arrival of this new tool is expected to trigger:

> I04RM: Ja, haben wir jetzt besprochen. Die Verwaltungsspitze möchte auf jeden Fall einen Informationsabend machen. Hier in der Stadthalle, also mit großem Publikum, mit Einladung vom Regierungspräsidium, über die ja die Karten kommen und vom Landratsamt natürlich. Und

> wir als Beteiligte wollen da also einen Informationsabend machen während der öffentlichen Auslegung. Weil da ist das Thema aktuell und da tauchen auch die meisten Fragen auf. [...] 00:06:14-1

All in all, then, there are some cases in which flood hazard maps are used for active, large-scale communication efforts. Nevertheless, the main form of use is one-to-one meetings of a 'passive' kind. As it turns out, not all administrations are willing to make more active use of flood hazard maps for communication purposes. I08RM states that his administration does *not* intend to use flood hazard maps for any kind of active public relations work (00:10:57-3); I05RM admits that he does not quite see the necessity of something like that (00:34:51-1); and I02RMb says that, for the moment, they are doing less than they should (01:42:32-1). According to I06RM, one of the problems with the hazard maps is that they there is no strategy for how to convey these to the public: "There is no structure for bringing this to people in a positive spirit... It [communication – Ed.] is left to depend on itself." (00:28:22-8).

Turning to the experts, concrete attempts to reach a larger audience were referred to in interviews 11 and 13. The first of these concerns a best-practice example of a joint municipal effort to arrange three information evenings targeting different public and private groups of audiences. The second concerns how a mayor responded to the discovery of a newly developed housing area being at high risk of flooding by arranging a public meeting to explain this to the residents and offer concrete guidance for self-protection:

> Die Stadt [Name] hat das gemacht. Die hat die ganze Bevölkerung dieses Baugebietes eingeladen zu einer Informationsveranstaltung. Hat gesagt: "So sieht es aus Leute. Da sind damals Fehler gemacht worden, Okay. Jetzt ist es so, wenn wir ein Hochwasser bekommen, dann steht das Wasser euch 1 Meter. Schaut, dass ihr genügend im Material habt, um euch zu schützen. Wir können das euch auch geben." Haben gezeigt, wie man so was macht, wie man auch mal ein Kellerfenster dichtmacht, also die ganzen Objektschutzmaßnahmen macht. (I13E, 00:35:07-7)

In the rest of the interviews, there are no references to concrete cases of map use. In some instances, notably in interviews 12 and 18, it is specified how risk communication and awareness raising *could* be pursued, including by displaying flood hazard maps in prominent public locations, issuing press-releases about them, linking to them on the municipality's homepage or erecting pillars around town to indicate predicted and historic flood depths. What is actually done, though, is not familiar. In I12E's (00:40:57-1) view, there will be little active map use for enlightenment purposes amongst communities having escaped flooding for the past 10-30 years. Even in 2002, at the time of the Elbe flood catastrophe as local newspapers had parts of the Rhine Atlas reprinted in color, the municipalities made no attempt to use this momentum to use available flood hazard maps to talk about flood risk:

> Also, Karten sind so in Farbe abgedruckt worden, in den Tageszeitungen. Und es gab keinen Aufschrei. "Ach so sieht das aus, wenn das bei uns kommt, das Hochwasser." [...] Es ist jetzt auch nicht irgendwo politisch dann dazu genutzt worden, zu sagen: "So, ihr habt das jetzt gesehen auf den Karten, auf dem Rhein-Atlas. Jetzt müssen wir was tun! [...]" (I12E, 00:34:59-3)

To summarize, this means that some map use follows more or less involuntarily, as risk managers are faced with direct inquiries as to local flood hazard, whereas, in other cases, individual households or a larger audience of citizens are actively targeted. Though in a way constituting direct application, what the hazard maps are applied *to* is neither decision-making nor definition of best-practice, but a form of external enlightenment and/or persuasion attempt, making it difficult to classify these as instrumental forms of research use. Possibly, it could qualify as a form of knowledge-driven use if the *decision* to seek to raise widespread awareness about flood risk would have been taken with direct reference to the predicted outcome of the scenarios displayed in the flood hazard maps. Though the case described by I13E might constitute such an application, the lack of access to a first-hand account makes it difficult to know. In some of the other cases, usage appears to be of a more strategic character, with hazard maps being applied to raise or safeguard people's confidence in the local authorities and to uphold good public relations. What can be said for sure is that there are *ways* in which some risk managers avoid using flood hazard maps, and that there are at least some indications of flood hazard maps being perceived to be under-used as tools for risk communication.

6.2 Complementary observations

One of the things that the above overview has shown is that, often, the experts have little to say concretely about how flood hazard maps are used in practice for local level risk management. Though it cannot be completely excluded that this is a result of poor sampling, the fact is that some of the interviewees occupy central positions in public offices; if they do not have more to say, it is hard to imagine who would. The experts' *own* explanations are that it is too early to tell. When I11Eb is asked about the extent to which his expectations concerning flood hazard maps have been realized or fallen short, his answer is that many of these are still "dreams of the future", suggesting that there is still hope (00:28:10-0). Likewise, I13E states that, since it is in the flood risk management plans that new and additional measures will be defined and committed to, it is not until the next step of the EU Floods Directive has been completed that the influence of simulation-based foresight will be recognizable.

Rather than concrete insights about use, what many of the experts have to offer, instead, is a general impression of how flood hazard maps have so far been received and responded to. For example, the experts in interview 11 suggest that there have been fewer attempts to influence or manipulate the simulation process than expected. I17E says that, from what he has heard, flood hazard maps have so far been well received, adding that this may change when built-up areas in the HQ100-zone are no longer exempt from land-use restrictions. Indicating a widespread conceptual effect, furthermore, I13E suggests that flood hazard maps make a light bulb go on in almost every administration even if this will not always result in a full response program:

> Also... da wird sich schon damit beschäftigt. Und da geht auch, in, ich würde mal sagen 90 Prozent der Fälle, geht ein Aha-Effekt durch

> die Kommune, durch die Stadt, wo, wo man sich dann schon am Kopf kratzt und sagt: "Da müssen wir aber mal etwas machen." Also das war bisher unsere Erfahrung. Also es ist wirklich so, dass die wenigsten gar nicht reagieren, wenn sie das sehen. [...] Natürlich nach reiflichem überlegen [dass sie] möglicherweise zum Schluss kommen, sie machen A, B, statt A bis F. Das schon. (I13E, 01:14:40-2)

There are also reports of less positive reactions, though. Although I13E thinks that the introduction has generally gone well, some areas have responded negatively; doing everything they can to prevent the arrival of flood hazard maps:

> Wobei wir hier auch zwei verschiedene Reaktionen von draußen haben. [...] Und wir haben Regionen, zum Beispiel die hier... Die sind ja fertig schon, die dunkelgrünen. Das war problemlos. Die Kommunen, ja, man hat ein bisschen diskutiert und aber in Ordnung. Hier in dem Gebiet, da unten, da, da werden sie gerade fertig gestellt. Da gab es also massive Widerstände: "Die Karte stimmt nicht. Es kann nicht sein, dass wir Millionen ausgeben für Hochwasserrückhaltebecken und unsere Siedlungs-, künftige Siedlungsfläche ist trotzdem überschwemmt." [...] "Es kann nicht sein. Die Karten sind falsch. Das Präsidium hat falsch gerechnet." Und versuchten politisch mobil zu machen, dass die Karte nicht hergestellt wird. Also so etwas gibt es auch... [...] [E]s gibt die ganze Bandbreite. [...] Also ich habe ja schon gehört, ihr bringt uns das Hochwasser mit euren Karten zu uns. (I13E, 00:14:47-0)

Offering similar observations, I18E notes that some people will actively look for mistakes and discrepancies to use as ammunition against hazard maps, whereas I14E describes cases in which the relationship between the higher and lower authorities is so infected that there is very little acceptance at all for things that are introduced top-down. At the same time, I14E also knows of an enterprise where the first reaction towards simulation results indicating a flood risk was denial and protest, but where the end-result was that an own hazard assessment was undertaken, indicating that a negative reaction can nevertheless lead to a constructive response in some instances.

Thus, even if the expert interviews contain relatively few concrete insights about local map use, the data material still provides a general assessment of the local level response to this new foresight tool. Judging from these descriptions, the local reaction is mostly welcoming, though instances of opposition are encountered, too. The next chapter will not only explore what leads to use or non-use but also review what is thought to underlie these different forms of reactions. Before proceeding, however, a general comment as to what these findings show is in place. In short, this could be summarized as cases both of use and of non-use having been identified. In terms of how the maps have been applied, instances of instrumental, conceptual and strategic research use have identified, but also some forms of use which are difficult to fit into this framework (notably in the field of risk communication). Moreover, some of the critique voiced against typologies of research use for not capturing the 'effect' of knowledge utilization respectively for not allowing for a view of research use as a long-term process rather than a one-off event has been recognizable throughout the data material. In regard to the issue of whether this use is legitimate or not, none of the stated or observed cases of application are described to be questionable or to have had regrettable consequences. Hence, there does not appear to be any concrete cases of misuse so far (at least not any which have been discovered). For the instances or observations of non-use reviewed, some are rationalized as legitimate whereas others are described as – if not illegitimate then at least – unfortunate.

Chapter 7

Factors affecting application

7.1 Reasons for (non-)use per management field

The following chapter will explore the reasons for use and non-use of simulation-based flood hazard maps. It will draw on both risk managers' subjective explanations and on the observations of experts representing a more aggregate form of insight. It will begin with an overview of reasons for use and non-use within each management field before observations of a more general character are presented.

7.1.1 Technical protection

When it comes to map usage in the field of technical and infrastructural risk management, the previous chapter provided us with a few descriptions of both conceptual-instrumental use (interview 02 and 04) and admitted non-use for anything but internal confirmation and external legitimization of pre-formulated plans (interview 03, 06 and 01). Beginning with interviews 02 and 04, these cover instances in which the arrival of predictive scenario information revealed weakness or confirmed a recent suspicion of deficiencies in the existing defenses. Hence, both cases are characterized by flood hazard maps indicating a problem rather than by confirming status quo. In comparison, the situation in interview 03, 06 and 01 is that the arrival of flood hazard maps is not described to have affected either the local understanding of risk or the administration's plans or activities in relation to technical protection. On the contrary, the risk of inundation was already known and already part of the local political-administrative agenda. In the case of interview 03, for example, a survey of the local hazard situation had already been undertaken by an engineering bureau to inform the development of a inter-municipal technical protection concept to guarantee catchment-wide flood control. Hence, the reason why scenario simulation results could not bring much new information to light is that comparable information was already available:

> [U]nsere Flussgebietsuntersuchung lag ja zu diesem Zeitpunkt schon vor. Das heißt, vieles was in der Hochwassergefahrenkarte jetzt als Gefährdungsgebiet ausgewiesen ist war vorher bereits bekannt. Weil man ja wusste, wie ist das Einzugsgebiet und wie wirkt sich das dann auch von der Wasserspiegellage in den betroffenen Gemeinden aus. (I03RM, 00:29:01-1)

Considering that the local flood hazard maps have largely been based on the data from this survey, it becomes understandable why I03RM thinks that "they have brought us few new insights" (00:29:01-1). Representing a similar situation, I06RM's work is focused on the realization of planned defense installations. In his view, it is not for the work associated with the implementation of technical protection that scenario simulation results are useful, but for other types of management tasks:

> I06RM: Also für die tägliche Arbeit nutzen wir sie nicht. Sie müssen dann mehr von den Gemeinden selbst genutzt werden, wenn irgendwelche Baugebiete zur Diskussion stehen und neue sich weiterentwickeln für künftige Bebauungen oder so. Weil unsere Aufgabe ist es ja festgelegte Hochwasserschutzanlagen, also Standorte für festgelegte Hochwasserschutzanlagen zu realisieren. [...] 00:16:58-2

Finally, the situation in interview 01 is that, even if flood hazard maps are not seen as completely irrelevant from an information perspective, the surrounding circumstances appear to have made them so. A large part of this interview is namely spent explaining why there may not be any flood association or catchment-wide protection concept after all. Not only is there no viable solution for how to share the costs in sight (i.e. between municipalities of different size with different means, facing different levels of risk and being expected to profit to different degrees) but the political motivation is partially dwindling as the last catastrophic flood is no longer fresh in memory. Whereas one might imagine flood hazard maps to be just the right thing to make a change in this regard, reminding people of the risk faced if nothing is done, no such application is described. Generally, the interview material suggests joint technical protection to require relatively quick action in the 'window of opportunity' that opens in the wake of a flood episode. In any case, it is easier to get people to agree to investments after they have *experienced* hazard than on the basis of a graphical representation of the same:

> Es ist aber trotzdem, trotz allem immer leichter direkt nach einem Hochwasserschaden Maßnahmen zu ergreifen und Unterstützung zu bekommen, wie wenn man das aus jetzt, auf Grund der Hochwassergefahrenkarte zum Beispiel (...). Da ist keine Gemeinde bereit, ohne jetzt in großer Not zu stehen, Geld dafür bereit, locker zu machen. (I06RM, 01:01:58-2)

Comparing these empirical insights to what was written about research use in chapter 3, the situation in interview 02 and 04 is indeed one of flood hazard maps being perceived as salient. To some extent, this appears to be connected to the unexpected character of the displayed assessment indicating larger areas than presumed to be at risk of inundation, ringing a bell of Weiss and Bucuvalas's (1980) finding that one of the things that can make research relevant is if it challenges the status quo. At the same time, the community in interview 02 is also characterized by having had its eyes towards the seriousness of flooding opened at an earlier stage, meaning that some of the mapped scenario simulation results that they have used have emerged as a result of the administration itself having taken an interest in these issues. In this sense, there was also a pre-existing interest in finding out about the local hazard situation in this case.

For their part, both interview 03 and 06 appear to be characterized by a low perception of saliency due to the timing of the hazard maps in terms of coming *after* the hazard of flooding has already been assessed and a defense concept defined. At the same time, this circumstance was beyond the control of those commissioning or producing hazard maps, making it into something that has to be attributed to the local context rather than indicating a failure to produce suitable content. To the contextual situation can also be counted the existence of relatively up-to-date information since before, which has also alleviated the need for further, marginally different, assessment results. Besides, though I06RM admittedly think of flood hazard maps as something of relevance to *other* management fields, I01RM describe them as a "very important foundation" for risk management, including protection planning, on account of changing hydrological patterns:

> Weil [...] es sich über die Jahrzehnte hinweg verändert hat wie die Hochwasserereignisse stattfinden. Heute kommt das Hochwasser anders daher, als vielleicht noch vor 20, 30 Jahren. [...] Und wenn man jetzt die Hochwassergefahrenkarten nimmt und vergleicht mit alten Karten, früheren Karten, dann allein schon dieses zeigt, wie notwendig es war das ganz neu aufzulegen als Grundlage für Planungen im Gewässerbereich und im Bereich des Hochwasserschutzes. (I01RM, 00:39:55-7)

Whereas it is difficult to imagine that there would have been much space for applying flood hazard maps to technical protection planning considering that concrete options for measures had already been defined, what I01RM focuses on is not that the timing was bad or the content wrong, but that the current political situation has put all plans in jeopardy. Lacking access to comparable information since before, this decision-maker is not characterized by a view of flood hazard maps as being of low relevancy. Instead, non-use of available hazard knowledge (independently of origin or format) is attributed to general risk management challenges related to resources, costs, cooperation difficulties, risk slipping into oblivion, etc. Hence, (non-)use will not only depend on hazard maps being perceived as salient but also on whether or not external circumstances presently create a need for or interest in hazard information and risk management.

7.1.2 Emergency management

The previous chapter showed there to be both cases of simulation-based flood hazard maps being appreciated and used for preparedness planning and of this not being the case. While one might have expected hazard maps to be of particular relevancy to areas hitherto lacking alarm and response plans, what we see, instead, is that usage is occurring both in areas with and without some form of pre-existing emergency plan, respectively that usage is seen as unnecessary both in areas with and without a tradition of preparedness planning. Hence, there is no obvious common denominator to point to for understanding these different outcomes, instead this must be explored through the intended users' subjective reasoning.

Beginning with the cases of use, these seem fairly straightforward. The municipality in interview 02 is characterized by flood hazard maps having revealed an unexpected level of risk; I08RM needed information to fulfill the legal obligation of developing an alarm and response plan (previously having postponed this due to lack of time and relevant know-how); and, in I10RM's area, preparedness optimization was already part of the local agenda since before, implying a pre-existing interest in new hazard information. Particularly, I10RM holds hazard maps based on gauge level scenarios for a relevant form of input for enabling direct translation of flood warnings into a visual idea of which areas might be affected:[1]

> [D]ann sieht man genau zu welchem Zeitpunkt welches, welcher Bereich, welches Gebiet überschwemmt wird. Also das hilft schon weiter. Weil man dann ja auch genau weiß durch die Vorhersage, den und den Wasserstand kriegen wir, also können wir vorher schon Schutzmaßnahmen dort treffen. (I10RM, 00:25:16-2)

Hence, there is one case of flood hazard maps themselves having triggered a need for planning input, one case of external circumstances (i.e. state law) having filled

[1]Though the state's forecasting center does not only publish gauge level information but also runoff data (m3/s) for most gauging stations, the comparison of runoff values with scenarios based on statistical return periods is still less direct, requiring knowledge as to what runoff value each return period is assumed to corresponds to. Hence, it cannot be excluded that this reason for seeing simulation results as relevant is less applicable to hazard maps based on scenarios of statistical return periods.

this role, and one case characterized by general organizational openness towards incorporating new evidence into existing planning. Moreover, even if they would not have defined flood hazard maps as particularly salient for crisis management beforehand, they all claim to have found them useful in retrospect.

Moving on to the instances in which no use was established or perceived as necessary, the risk manager giving us the most detail as to the reasons for this is the chief fire fighter in interview 07. All in all, four things are found to affect his attitude towards predictive information. First, a low risk perception is something that reduces I07RM's need for information. As he puts it: "Yes, we have [...] the flood too rarely. And then it's like... If we have 10 basements, then that's a lot, which has been flooded here in the area." (00:32:46-7). Not only in terms of hazard frequency, then, but also in terms of damage potential, the risk associated with flooding is thought to be low. Besides, it is a less serious form of risk compared to fire: "No, a flood is not as problematic as a fire operation. [...] [T]he water doesn't come so quickly. [...] [E]everyone would have time to go to a higher story or out of the house and perhaps to an acquaintance or so." (I07RM, 00:02:07-6).

Second, what is already in place in terms of information resources is thought to suffice. As I07RM sees it, the emergency services in his community have no urgent need for an instrument like the state's flood hazard maps since they already know through experience and auxiliary means of documentation where which basements will be standing under water:

> Also (...) das ist nicht das Dringlichste bei uns. Weil wir wissen in so einer Stadt, wir wissen schon. Wir wissen es kommt das Gebiet bei dem und dem. Wir haben hier unten auch an der Brücke so einfache Hilfsmittel. Da haben wir, beim jedem großen Hochwasser machen wir da mit Farbe nachher einen Strich hin und schreiben die Jahreszahl hin und da wissen wir genau, wenn jetzt der Bach hier unten über die Böschung so und so hochkommt, dann wissen wir es läuft hier unten, in der und der Bereich laufen der Keller voll. Also das ist so der Vorteil von einer kleineren Stadt, dass wir uns da noch auskennen. (I07RM, 00:30:24-1)

As I07RM explains, there is no expectation of any added value from hazard maps as the response workers already have routines in place for assessing the anticipated extent of inundation, respectively sufficient experience for knowing what to do about it:

> I07RM: Die bringen uns nicht viel, das ist-. Weil wir können dann vielleicht die Schlauchsperre an eine Straße hinmachen, aber das wissen wir auch von uns von alleine. [...] [W]enn jetzt ein größerer Regen ist, dann fahre ich einfach, fahre ich mal raus an die erste Brücke und schaue mal wie hoch steht da das Wasser. Und dann weiß ich in zwei Stunden habe ich in der Stadt die und die Höhe. Das sind einfach Erfahrungen, die wir haben [...] wo wir dann tätig werden müssen oder können. Wenn wir dann warnen müssen [...]. 00:34:24-8

While recognizing the principal relevancy of scenario simulation in terms of being able to explore the consequences of an unprecedented flood, this is nothing that his community is thought to have a need for, but possibly something that other towns and cities may profit from.

Third, there is the fact that there is anyhow little that I07RM can do to prevent flood damage. Essentially, his job is to wait until the water recedes enough for the fire brigade to start pumping out basements and garages. While other municipalities may be equipped to prevent the flood water from causing damage, this is not the case in his area: "*we* can prevent very little damage. [...] When we come, the damage is already there, really." (I07RM, 00:21:56-6). Though more or different emergency response equipment could potentially change this, this is not something that the local administration is seriously expected to invest in: "It wont, the city [...] will not build a dam here down the road and keep beams ready. [...] They will never hold that ready for the case of, every 15 years, there being a flood." (I07RM, 00:32:46-7).

Fourth and finally, the source of inundation that is *really* causing I07RM concern is not riverine flooding, but the risk of heavy precipitation over a limited geographical area leading to slope water. Since this source of flooding is *not* subject to simulation, the state's flood hazard maps are also of low relevancy:

> Aber das größte Problem sind so kleine Flüsse, kleine Bäche, die im Normalfall bloß so breit sind und vielleicht so tief [zeigt mit den Händen]. Und wenn sie gerade so ein punktuelles Hochwasser haben, dann kann sein, das ist ein Fluss mit drei Meter Breite oder ja, und tief. Das sind so, die Hauptprobleme. Aber das bekommen sie auch mit solchen Karten nicht in den Griff. Weil das, da müssten sie ja jeden kleinen Fluss, der irgendwo aus dem Wald her rauskommt, müssten sie berechnen. Und der kommt vielleicht alle 200 Jahre mal. [...] In 15 Jahren ist es dort drüben und in 20 Jahren ist es in der Richtung. Da ist der Aufwand viel zu groß. Da finden sie die Pläne schon gar nicht mehr (lacht). (I07RM, 00:32:46-7)

Looking at the rest of the cases of non-use or not perceiving a need for hazard maps, a low risk perception is also what characterizes I05RM's interview response when he says that the risk of flooding to his community is not of a nature that requires an official preparedness plan (see quote in chapter 6). Additionally, it would appear that he is unaware of the fact that state law requires municipalities to possess this kind of document. In case of I09RM's colleagues, in comparison, it is not that the risk of flooding is thought to be low, but that the available knowledge resources are thought to suffice. They already have an emergency management plan, a gauging station and a warning system; they already know what to expect in case of flooding, and have no expectation of hazard maps telling them anything new. In contrast to I10RM, the fact that an alarm and response plan already exists is, here, taken to speak against there being a need for flood hazard maps. Finally, while not excluding that predictive information may become interesting *at some point of time*, the situation as I03RM sees it for now is that the administration already possesses an emergency plan that "more or less reflects what the flood hazard map says" (I03RM, 00:31:13-9). Only once the planned defense installations have been finished, and the flood hazard maps updated to reflect this, might it become interesting to use these for preparedness planning.

Turning, finally, to the observations of the experts, I13E's account of the discontinued pilot project referred to in the previous chapter point to lack of resources as an obstacle to a lasting effort of hazard information, while also pointing to the personal interest and agenda of whomever is mayor as a factor of importance. Besides, not all municipalities are thought to be aware of the legal requirement for preparedness planning, and it is overall perceived as something of a challenge to get local administrations to understand why this is necessary:

> I13E: Also was, wo wir natürlich nach wie vor immer wieder auf Schwierigkeiten stoßen ist die Einsicht vor Ort, dass das notwendig ist. Dieses oder jenes zu tun. Zum Beispiel einen Gefahrenabwehrplan aufzustellen durch die Kommune. Dass das auch notwendig ist, wenn wir einen technischen Schutz haben durch einen Deich oder ein Hochwasserrückhaltebecken. Dass es trotzdem notwendig ist, weil es ein Ereignis kommen kann, das größer ist als das, für das diese Becken oder dieser Deich bemessen sind. Dann muss die Kommune trotzdem vorbereitet sein. Und das ist nach wie vor sehr schwierig an die Kommunen herüberzubringen. [. . .] 00:14:47-0

In summary, this suggests that the cases of use are all characterizes by some form of circumstance creating a need for and/or interest in hazard information in combination with these being found to offer helpful overview and guidance. In contrast, the cases of non-use are characterized by one or more circumstance being felt to alleviate the need for predictive hazard information. Only in one case are hazard maps, as such, not thought to target the most relevant origin of flood risk. From an observer's perspective, finally, lack of resources, personal engagement of local leaders and a general lack of interest in preparedness planning respectively awareness of this being mandatory are factors perceived to affect application.

7.1.3 Non-structural alleviation

As noted in the previous chapter, *complete* non-use of flood hazard maps is basically impossible in the field of non-structural alleviation, as two of the displayed scenarios introduce binding land-use restrictions. Nevertheless, we can explore what supports application and what is thought to explain that not *more* use is made of available foresight information.

Beginning with the cases of used discussed in more detail before, the ones described in interview 02 suggests two factors to affect map usage. First, even if not explicitly stated, the explanation closest at hand for the decision to withdraw certain areas from the local development plan would be that these had been revealed to be associated with a previously unknown level of flood risk, in which case use would again be related to findings having challenged the current status quo. Second, there are reasons to believe that the application of flood hazard maps to the administration of local building permit processes is something that has followed more or less automatically. At least in the cases of interview 05 and 09, electronic maps have been integrated into an established GIS-environment, just as other forms of flood estimates before them. Yet, it is also clear that this is something that scenario simulation is perceived as highly salient for, as a more precise hazard estimate facilitates the process of assessing where which type of construction may be permissible.

In the cases of I05RM and I09RM, available evidence as to the risk of flooding was considered before, too, indicating a pre-existing interest in accounting for available hazard information. Additionally, both cases are characterized by a perception of flood hazard maps as offering salient information for non-structural alleviation work and of GIS as a relevant program for retrieving and considering this together with other relevant pieces of information. As I05RM explains, this provides for better decision-making compared to when this kind of information was only available in paper format:

> Das [GIS – Ed.] ist im Prinzip wie eine Zwiebel, die verschiedene Schalen hat, durch die ich nachher durchgucken kann. Dann sehe ich eben an diesem Punkt, [...] es ist Naturdenkmal, es ist Überschwemmungsgebiet, es ist Pipapo. [...] Wenn ich da dann eben diese Hochwassergefahrenkarte auch habe und weiß an der Stelle, ich sehe es am Luftbild, geht das soweit raus und kann dann prüfen, ist mein Vorhaben, dass ich da jetzt habe mit betroffen? Oder ist es nicht betroffen? Dann kann ich es halt viel besser entscheiden als früher als man das als Kartenmaterial hatte. (I05RM, 00:15:36-1)

Ultimately, then, it is not only that flood hazard maps are perceived to be salient in relation to routine administrative errands but also that their compatibility with an established information system makes them easy to use to this end. Indeed, one of the main benefits of the state's flood hazard maps, as I09RM sees it, is that...

> ...man auch auf elektronischem Weg jetzt sehr schnell alles eruieren kann, wie die Situation ist. Früher mussten wir entweder, wie gesagt, in Akten wühlen oder wir hatten gar keine Daten. [. . .] Und das ist für uns schon wirklich wichtig die Informationen zur Verfügung zu haben. (I09RM, 00:43:46-1)

In the other interviews mentioning some form of use, either no particular reason for application is mentioned or this is noted to be something that is more or less coerced. For example, the mayor in interview 01 notes that his municipality has not had much choice, as binding land-use restrictions *had to* be accounted for in the last update of the preparatory land-use plan:[2]

> Es gibt örtlich die Flächennutzungspläne, die über die ganzen Gemarkungen gehen. Und in einer aktuellen Fortschreibung, jedenfalls hier bei uns vor Ort, musste das natürlich berücksichtigt werden. [...] Sie können an mancher Stelle dann vielleicht keine Nutzung ausweisen. Ob jetzt wohnen oder Gewerbe oder sonst etwas. Da war das schon eine ganz konkrete Anwendungsmöglichkeit oder auch ein Zwang letztendlich, das zu berücksichtigen. (I01RM, 00:49:58-9)

Turning to the reasons for less positive reactions towards hazard maps, the only risk manager openly indicating any kind of displeasure in this regard is the mayor in interview 03. In his view, the land-use restrictions introduced for some of the depicted hazard zones are overly strict and rigid. As he sees it, it is 'unrealistic' to

[2]That jurisdiction can be an effective way of guaranteeing knowledge utilization is also indicated by I14E, who gives an example of how knowing that information of legal implication is being produced can make private actors adjust to this even before it becomes mandatory to do so.

want to prohibit all forms of expansion in areas at risk since it is often indispensable for already established businesses to have space to grow. If the municipality cannot make floodplains safe for development by investing in technical protection, enterprises may choose to move and leave the municipality without one of their main sources of income:

> [O]ft ist es eben so, dass gerade gewerbliche Flächen in den Bereichen liegen. Und wenn die auf Dauer nicht mehr nutzbar sind und nicht mehr veränderbar sind, dann stellt das für das Gewerbe am Ort und damit auch für die Gemeinde ein Problem dar. Denn wenn sich ein Unternehmen nicht entwickeln kann, dann wird es sich [...] nicht unbedingt auf einen anderen Standort im Ort vertrösten lassen, sondern es wird irgendwann die gesamte Standort [in]frage stellen und möglicherweise abwandern. Und das ist für eine Gemeinde sehr gefährlich und auch teuer. Weil eine Gemeinde sich zu großen Teilen aus der Gewerbesteuer finanziert. [...] Wenn wir gute Schutzmaßnahmen haben, die verlässlich funktionieren, dann muss sich das dann auch [...] auswirken. Momentan ist es sehr strikt gehandhabt, dass auch diese geschützten Flächen eigentlich nicht überbaut werden dürfen. (I03RM, 00:39:11-4)

In general, avoidance and re-naturalization are management strategies that I03RM thinks are nice in theory, but nothing that it makes sense to prioritize where flood risk is high. In his community, the management strategies to be pursued in the short- to mid-term are structural protection and emergency management planning. While not telling us anything about what this means for the chances of use at the subordinate administrative level, this confirms that there can be political resistance towards having to forsake other interests on account of hazard evidence. Providing a further observation in this regard, I06RM claims under-usage to be related to local leaders' preference for not knowing about flood risk in order to be able to pursue other interests:

> im Prinzip gibt es da Berührungsängste oder Widerstände. Man will das nicht wirklich wissen. Weil eine Gemeinde, wenn sie Firmen hat im überschwemmungsgefährdeten Gebieten oder so, dann will man die

> eher arbeiten lassen und Steuern bezahlen und so weiter und nicht belasten und irgendwie-. Es wird so betrachtet, wie wenn man den Leuten Schwierigkeiten machen würde, wenn man sagt: “Ihr lebt aber im überschwemmungsgefährdeten Gebiet.” Also es gibt viele Gemeinden, die weiterhin bauen wollen in solchen Gebieten. (I06RM, 00:27:39-3)

Supporting this view, I14E argues that scenario simulation results will be welcome where they represent a solution to a problem, and less welcome where they constitute a potential obstacle to the municipality’s plans of expansion and growth:

> I14E: Ja, es ist immer die Frage, wenn eine Gemeinde vor allem ein Problem hat und möchte informiert werden und möchte Ideen haben, wie kann ich mich schützen, was kann ich tun, dann ist es ein Riesenvorteil. Wenn aber in der Gemeinde, sage ich mal, einen sehr engagierte Bürgermeister da sitzt, der seine Aufgabe vor allem sieht Gewerbe anzusiedeln, Baugebiete auszuweisen, also quasi die Gemeinde zu entwickeln, und dann eben das Problem hat, dass er in einem engen Tal sitzt und nur die Entwicklungsmöglichkeiten am Bach hat, für die ist es ein Problem und die sehen es auch nicht immer ein. [. . .] 01:35:16-3

Likewise, I17E notes that the reason why flood hazard maps are associated with a high conflict potential is that many political actors still regard floodplains as desirable land:

> Und da muss man schon damit rechnen, dass die Kommunen, die natürlich – das sind ja interessante Grundstücke entlang der Gewässer, solange die kein Hochwasser führen – dass die Kommune natürlich schon ein großes Interesse daran haben, auch diese Grundstücksflächen zu sichern und zu nutzen für Bebauung, für städtische Entwicklung. Und das wird, da steckt viel Konfliktpotenzial darin [. . .] (I17E, 00:23:22-4)

At least where hazard information is met with a lack of enthusiasm, then, this is thought to be associated with non-structural alleviation generally being low on the local political agenda (or at least lower than growth, expansion and trade taxes). Apart from when knowledge use is linked to regulatory requirements, things that are found to support map use are: if these indicate a hitherto unknown risk of inundation; that their content is perceived as salient; and that their format facilitates application by being compatible with current systems and routines.

7.1.4 Risk communication

While risk communication is central to what the interviewees see flood hazard maps as relevant for, the type of use that is made of them is often small-scale and passive in the sense of happening upon request. The question to explore in this section, thus, is what separates administrations willing to use hazard maps as communication tools at a larger scale (e.g. by organizing public meetings) from those not wanting to do so.

In this respect, most – though not all – instances of large-scale use described in the previous chapter appear to be characterized by the perception of communication as something that is necessary to avoid problems and reduce the risk of protest. Looking at I03RM, for example, his viewpoint is that it belongs to 21st century policy making to take citizens' concerns and viewpoints seriously. Independently of whether those opinions are irrational, misinformed or well-founded, the best way of responding to them is through open communication and dialog:

> Also man kann nicht sagen: "Wir wissen es als einzige am besten und so machen wir. Und Bürger, du musst es so hinnehmen." Sondern man sollte den Bürger sehr frühzeitig miteinbeziehen [...]. (I03RM, 00:15:50-8)

In I03RM's view, communication is both a way of sounding out and responding to people's concerns and a chance at information provision to get them to see the administration's point of view. Even though there is no explicit statement as to why a series of information meetings on local flood hazard has been arranged in this catchment area, the fact that a common structural protection concept is to be pursued makes it appear at least somewhat likely that it has something to do with the need to make people understand why such a solution is regarded as necessary. In this sense, it is not only I03RM's general openness towards communication with the public that is a favorable circumstance but also timing in the sense of there presently being a political message for which flood hazard maps lend support.

Turning to I04RM, he tells of a local administration wondering whether it will have to face a storm of protest once flood hazard maps become public. There is a clear concern that something will be triggered that local administrators do not know where it will end, respectively that they will be overwhelmed with inquiries in response to a mapping project that they have not themselves initiated:

> [W]enn die Hochwassergefahrenkarten jetzt in nächster Zeit veröffentlicht werden, dann auch die Reaktion aus der Bevölkerung, von den direkt Betroffenen. Weil das ist noch ein großes Fragezeichen. Geht hier ein Sturm der Entrüstung, kommt da? Weil viele sehen: "Oh, ich liege ja im Überschwemmungsbereich", was denen vielleicht vorher nicht so bewusst war. Und ob da was über uns herein bricht. Die Befürchtung hat jetzt mein Chef zum Beispiel. (I04RM, 00:02:47-9)

> Aber wie gesagt, es wird jetzt gerade eher die Gefahr gesehen, dass hier irgendwas losgetreten wird, wo man noch nicht weiß, was dabei unter dem Strich herauskommt und viele Fragen auf die Kommunen dann zukommen werden. (Dass) wir da überhäuft werden mit Anfragen und wir als Kommune ja gar nicht der Veranlasser sind von dieser ganzen Geschichte. Also das wird ein bisschen zwiespältig gesehen. (I04RM, 00:17:55-2)

Seeing the publication of flood hazard information as a source of potential public unrest, it lies in the administration's own interest to proactively reach out with information to respond to people's questions and concerns before these have a chance to develop into protest. Similarly, the case described by I13E concerns a mayor deciding to inform the residents of a newly build housing area about facing frequent flood risk. As noted in chapter 6, this can either be interpreted as a response to the discovery of a hitherto unknown level of risk or as an effort to forestall a negative public reaction to the publication of hazard maps. (Which reading comes closest to the truth cannot be told without access to a first-hand account.)

In comparison, the mayor in interview 01 is somewhat skeptical of the trend of moderators, mediation and involving citizens in decision-making. As he sees it, public protest is sometimes what puts a stop to projects designed to serve the general good, meaning that it can actually be preferable for decisions of this kind to be pushed through with a strong hand without too much regard for local skeptics. Judging from the use of the third person pronoun when describing the wish to organize a public presentation of scenario simulation results (see citation in chapter 6, 00:43:59-5), it was not I01RM himself who desired this but the higher authority responsible for the mapping project.

Turning to the statements rejecting a more wide-reaching use of flood hazard maps, many of these suggest that it would not bring much – or at least nothing positive – to apply scenario simulation results to awareness raising purposes. This is particularly clear in the case of I08RM. Not having the funds to invest in flood control or technical management solutions, risk communication is something that his administration prefers to avoid; it would be like revealing to people that they are not perfectly protected and, generally, you only communicate positive news:

> I08RM: Ja, es ist so, wenn wir jetzt unsere Becken erweitert haben denke ich, dass wir das natürlich bewerben. Weil positives kann man natürlich gut vermarkten. Aber aktuell fehlt uns das Geld, um jetzt ganz konkret im Moment etwas auszubauen oder etwas Neues zu machen. Und etwas Negatives vermarktet man natürlich nicht... Man würde ja die Leute auf die Idee bringen, dass sie vielleicht nicht perfekt geschützt sind. Deshalb werden eigentlich nur – das hat politische Gründe – nur positive Nachrichten in dem Bereich auf unserer kleinen Ebene kommuniziert. (Pause) 00:11:41-6

While some would argue that the very point of making flood hazard maps publicly available is to enable people to learn about being at risk to allow them to take appropriate precaution, the position in I08RM's administration is instead that potentially upsetting information is best kept under wraps so that people are not unsettled. Similarly, the reasons given by I02RMb for why flood hazard maps have not yet been used to the extent that the administration itself would like to see do not just concern lack of personnel and a need to prioritize but also that it might actually be preferable to wait with risk communication until planned improvement of technical protection are underway. Then, one can inform people in parallel about the existence of a flood risk and about what the administration is doing about it. Only telling people about a risk, without being able to point to concrete measures, would just scare them and lead to unwelcome political pressure:

> Also für uns ist es momentan wichtiger den technischen Hochwasserschutz herzustellen, als die Zeit zu investieren Sachen aufzubereiten, um die Bevölkerung zu informieren und dann sagen zu müssen: "Wir müssen jetzt das und das noch machen." Es ist vielleicht sinnvoller erst mal anzufangen und zu sagen: "Wir sind im Bau. Wir machen das." Und dann parallel zu informieren. Weil sonst hat das wieder so ein bisschen die Wirkung, dass die Bürger Angst haben, dass sie wieder extrem Druck aufbauen. Und so können wir aber gleichzeitig sagen: "Wir wissen es nicht nur, sondern wir arbeiten auch daran." (I02RMb, 01:42:32-1)

Hence, while the current academic paradigm and official European policy see flood risk as a shared responsibility that not only public authorities but also citizens and local businesses must prepare for, the reality is that local administrations sometimes hesitate to provide people with the information that such a joint approach requires. Still regarding the citizens' safety as something that falls under the responsibility of the public authorities, the presence of a flood risk becomes synonymous with a risk of being perceived to have failed. Hence, scenario simulation results are not necessarily welcomed as a tool for awareness raising and local capacity building, but may instead be interpreted as a political risk factor. Variations on this theme concern that the risk of flooding is both too low and too well-known for there to be any need to cause panic, or that people are already so aware of the risk of flooding that there is nothing to be had from presenting them with hazard maps. In I05RM's view, for example, there is no need to disseminate scenario predictions since the affected parties have already experienced flooding first hand:

> I05RM: Also die Notwendigkeit sehe ich eigentlich nicht. Zumal bei uns das im Prinzip auf ein paar wenige Wohnhäuser bezogen ist und auf zwei Geschäftsgebäude oder eins vermutlich nur. Die wissen was Sache ist, weil sie es schon erlebt haben. [...] [D]as ist bei uns jetzt nicht ein riesiges Gebiet, was überschwemmt wird. Insofern gibt es auch keine Veranlassung, da Panik zu machen. Die betroffen sind jetzt direkt vom Hochwasser [...], die wissen das... [...] 00:34:51-1

Likewise, I09RM argues that the residents at risk in his community lack interest in flood hazard maps since they already know what to expect. The only thing to be had from information dissemination, in his view, is unwelcome discussion:[3]

> SK: Und die Leute, die schon ein Haus haben nahe an dem Fluss? 01:02:55-3
>
> I09RM: Für die ändert sich nichts... 01:02:59-1
>
> SK: Gibt es da kein Interesse hierherzukommen, die Karten anzuschauen und zu gucken, wie hoch die- 01:03:04-1
>
> I09RM: Die Höhe. Die wissen genau, wie hoch das in ihrem Keller war zu jenem Zeitpunkt und diesem. Die fangen dann höchstens noch an zu diskutieren und sagen: "Das stimmt nicht."

Low risk perception and/or not thinking there to be anything to gain from pursuing risk communication means that there is no perceived need for or interest in applying flood hazard maps to this end.

[3]Essentially, both of these positions can be criticized for assuming that well-aware is synonymous with well-prepared, thus disregarding the possibility of people lacking belief in their own protective capacity (see Grothmann and Reusswig, 2006). Furthermore, it disregards research showing that behavioral change can require continuous transmission of a message also after reaching awareness (Renn, 2008, pp. 239), as well as the possibility of residential fluctuation.

At a more aggregate level, furthermore, local-level risk managers are noted to lack the skills required for effective communication whereas higher-level authorities are thought to provide insufficient support and guidance. As I06RM notes, there is no formal implementation strategy for how to bring people at risk to pursue more private precaution. Instead, this is, unfortunately, left to the municipalities to figure out on their own:

> Also man braucht ja Spezialkenntnisse zum Hochwasserschutz, um das auch den Bürgern schmackhaft zu machen. Wo der positive Zweck, der Zweck und der Sinn von der Hochwassergefahrenkarte liegt. Und das wird dann auch von der Gemeinde, von der Kommune aus nicht kommuniziert. Und das Personal ja auch nicht da ist und das Fachwissen nicht vorhanden ist. Und da ist es dann schade, dass man so ein gutes Instrument sich zulegt, wie die Hochwassergefahrenkarte, aber dass dann nicht mit mehreren Schritten die positiven Sinne an die Bevölkerung heranträgt... (I06RM, 00:30:31-4)

Although there is a long-term attempt to correct this situation by offering a forum for best-practice exchange within the flood partnerships, I06RM notes that these are voluntary, and the resonance at the local level low (though it may be noted that this is contradicted elsewhere). A better solution, in his view, would be if a designated group would take charge of presenting the published flood hazard maps to local populations everywhere:

> Das Land Baden-Württemberg hat die Hochwassergefahrenkarte herausgegeben, aber dann müsste eigentlich eine Gruppe von Leuten sagen: "wir stellen das jetzt in jeder Gemeinde vor und machen Beratungsgespräche und führen auch Gespräche mit einzelnen Betrieben, die von Hochwasser bedroht sind." Es gibt da keine Struktur, um das in positiven Sinne auch an die Leute heranzubringen... Das lässt man auf sich selbst beruhen. (I06RM, 00:28:22-8)

Such an approach would cost money, however, and what costs money is difficult. Hence the solution with the flood partnerships, as I06RM sees it.

Moving on to the experts, several of these note it to be important to integrate flood hazard maps in some kind of public relations strategy. Rather than defining clear targets in this respect together with local-level representatives, though, I12E thinks that the state has avoided discussion, settling for a program of the bare minimum (00:36:55-3). Though some of the other interviews contain references to plans for templates for information meetings and information materials, there is (a) doubt about the extent to which local administrations would make use of such materials, and (b) indications of higher-level authorities, too, struggling with how best to explain flood hazard maps to lay-people. Considering that there is no tradition at the local level of sharing hazard information with members of the public, the absence of guidance and support in this direction is problematic. Before it became mandatory to display flood hazard maps online and at city hall, the results of the flood scenario simulations would rarely be published or made officially available. Even now, I16E notes, decision-makers often prefer not to talk about the risk of flooding (even when this is limited to the unlikely scenario of over-topping or dam break), as this goes against the message of everything being under control (00:23:34-1).

In general, municipalities with recent (within the last decade) flood experience are thought to be more willing to present flood hazard maps to the public. In contrast, mayors in areas with less recent flood experience are known to downplay risk, preferring not to scare people respectively to invest in popular public services rather than management measures:

> Weil man ja eine Daseinsvorsorge hat als Bürgermeister für seine Bürger und man möchte denen ja keine Angst machen mit diesen Gefahrenkarten und mit diesen Themen. Und da wird man unter Umständen auch mal sagen: "Gut, ist ja bei uns kein Thema, Hochwasser. Von daher kümmern wir uns da nicht weiter darum. Wir haben das [die Hochwassergefahrenkarten – Ed.] da und wer das sehen möchte kann das sehen, aber wir machen uns nicht aktiv. Wir haben ja noch da und da die Baustelle, und der Kindergarten soll ja noch gebaut werden und das und das." Und dann werden einfach die Ressourcen anders gebunden. [...] (I12E, 00:40:57-1)

In contrast, I18E does not refer to flood experience but to the personal risk perception of mayors and technical leaders. In his view, it is difficult to find any other explanation for how different municipalities react towards scenario simulation results:

> I18E: [. . .] [E]s gibt Kommunen, die, aus meiner Sicht, sehr verantwortungsvoll damit umgehen und die Hochwassergefahr auch nie klein reden, sondern immer sagen: "Es gibt die Gefährdung." Die auch kein Problem damit haben, dass wir überfluteten Flächen darstellen von irgendwelchen Industriegebieten [. . .] Die gehen sehr offensiv mit diesem Thema um. Und es gibt andere Städte, die sagen: "Oh, was? Hochwassergefahr? Nein das dürfen wir niemand sagen." Weil dann haben sie Angst, dass die Industrie wo anders hingeht, und sie zahlen ja viele steuern. Und dass sie Angst davor haben, dass die Leute Panik bekommen und vielleicht aus diesem Gebiet herausziehen. [. . .] Also da sieht man, es gibt viele, die wollen die Hochwassergefahr lieber gar nicht groß erwähnen und hoffen, dass während ihrer Amtszeit, als Bürgermeister zum Beispiel, hoffentlich nichts passiert. Und wenn, dann war es ein ganz schlimmes Naturereignis. [...] 00:19:08-3
>
> SK: Woran liegt das denken Sie, dass einige gut damit umgehen und andere eher schlecht? 00:19:15-7
>
> I18E: Also ich denke das ist zum einen wirklich eine reine persönliche Frage, welche Personen da sitzen. [. . .] Also eigentlich muss es daran liegen. Weil die beiden Städte, die ich gerade im Kopf habe, die [...] sind wirtschaftlich sehr stabil, haben beide große Industrieanlieger in ihren eingedeichten Gebieten, sind beide bei einer ähnlichen Hochwassergefahr ausgesetzt, beide mit riesigen Schadenpotenzialen. [. . .] Aber sie gehen völlig unterschiedlich damit um. [. . .] [D]ie kriegen Schäden erst ab Ereignissen Größe HQ100 oder HQ200. Das ist ja sehr selten. Der eine sagt: "Ja trotzdem wichtig. Das kann passieren, die Leute muss ich informieren." Und der andere sagt: "HQ200. Einmal in 200 Jahren. Ob mich das je trifft? Dann lieber jetzt gute Politik, viele Gewerbesteuern einnehmen." [...] 00:22:36-0

Offering some support for this view, I11Eb notes that "When you have a committed mayor, everything runs much easier than when you have one who does not engage in it at all." (00:45:08-9).

In effect, this means that experts observe flood experience, personal risk perception, political interests, low local competence, and lack of pressure and support from higher levels to affect map use, whereas the reasons which can be derived from the risk managers' responses largely concern whether or not decision-makers perceive there to be anything to gain or lose from communicating flood risk.

7.2 Complementary observations

As the expert interviews contain a number of observations that are not related to any specific management field, a brief overview of comments of a complementary character is necessary. In this respect, a main factor emphasized is the role of local political interests and whether or not flood hazard information is perceived to be associated with negative implications. As I14E puts it, municipalities "must have an interest in knowing about their risk" for flood hazard maps to be used (00:29:38-8). Often, it is suggested, other interests dominate, leading to a preference for not giving too much weight to the risk of natural hazards. Instead of taking it seriously, the municipalities "close down", questioning when they will ever be confronted with earthquakes or flooding (I13E, 00:51:49-2). As soon as scenario results run counter to local planning and interests, I14E adds, there will be conflict (00:29:38-8). This does not only pertain to public authorities, but to all actors, public and private; as soon as a risk for negative implications is perceived, they will question predictive results and/or not want to accept them:[4]

> Ein Problem ist es immer, wenn es Konsequenzen gibt. Und wenn dann plötzlich eine Auflage kommt [. . .] Dann sage ich: "Hm, vielleicht stimmt das nicht. [...]" Dann gibt es immer Akzeptanzprobleme. Wenn Menschen dadurch Nachteile sehen. (I18E, 00:38:02-0)

[4]In line with this argument, I17E associates what he perceives as a relatively high level of acceptance of hazard maps with the fact that built-up areas were long exempt from the land-use restrictions applying to outlying areas in the HQ100 zone, meaning that the interference with local building and development planning was originally of a more limited character.

That competing interests are perceived to make local administrations regard predictive flood information as a hassle rather than a help is also thought to have implications for its ability to motivate more risk management activity. Though the idea of flood hazard maps is that they should enable action in foresight rather than hindsight, it still often takes the effect of experiencing flood hazard to get local decision-makers to prioritize risk management in I11Ea's experience:

> Wenn wir unterwegs sind in den Hochwasserpartnerschaften, es wird ja auch von vielen Maßnahmen, die durchgeführt wurden, berichtet. Aber diese Maßnahmen werden meistens ergriffen auf Grund von Negativ-Erfahrungen. Also weil Hochwasser-Ereignisse passiert sind. Und im Vorfeld passiert sehr wenig. Ich muss zugeben ich habe keine sehr großen Hoffnungen, dass wir viele Kommunen dazu bewegen, dass sie im Vorfeld sich darum kümmern. (I11Ea, 00:30:36-3)

Ultimately, this suggests that map usage will partially depend on local leaders' willingness to carry out management measures and/or to advocate flood risk as a political issue (I11Eb, 00:44:07-9). Additionally, a mayor's authority, standing, and capacity to push through his own priorities matter. As I13E notes, some mayors are driven by the municipal council's agenda rather than their own (00:51:49-2).

Finally, there are a number of indications pointing towards the importance of user-producer linkages and a supportive institutional framework. Specifically, close contacts between those coordinating the mapping project and intended users are perceived to have been key for defining a foresight product that answers to different target audiences' needs and requirements. In general, having involved the municipal level from the beginning, having the municipalities pay part of the costs,[5] and approaching them both before and during each individual mapping process is believed to have helped generate both interest in and acceptance of scenario simulation results:

> In Baden-Württemberg waren die Kommunen von Anfang an mit am Tisch, die kommunalen Spitzenverbände. [...] Und damit... gibt es

[5]In this regard, it may be noted that it is not always that local-level risk mangers are aware of the municipalities contributing financially to the hazard mapping project (e.g. I08RM, 00:16:50-4).

> [. . .] einen großen Wunsch, ich möchte das Ergebnis auch haben. Ich habe mitbezahlt, also kann ich auch sagen was ich haben will. Und es gibt von vorneherein eine größere Akzeptanz. Das heißt die Kommunen fragen nach: "Wann kommt denn endlich unsere Karte?" Und möchte auch wissen, was ist auf der Karte dargestellt. Und plausibilisiert auch mit auf den Karten. Guckt damit darauf und sagt: "Das gefällt mir jetzt nicht. [. . .] Oder da ist die Brücke, die ist jetzt neu gebaut. Das müssen wir ändern." Also die Kommunen sind da sehr stark mit dabei. [. . .] Und das ist halt an anderen Stellen, anderen Bundesländern einfach nicht der Fall. Und das ist halt einfach vorbildlich, dass da halt so viel passiert ist. Und man sieht es ja auch an der Summe, die umgesetzt wird. Also [. . .] es wird richtig geklotzt und nicht gekleckert, ja. (I12E, 00:21:07-5)

Additionally, flood partnerships, in spite of admittedly constituting something of an emergency solution to the gap created by recent reforms having dissolved the administrative body previously functioning as the municipalities' point of contact in water management issues, are thought to motivate local administrations to pursue flood risk management and thereby support map usage. This is not only noted by I16E in the quote below but also by I13E (00:27:08-3), who claims that there would not have been a reasonable level of risk awareness in the region had it not been for the flood partnerships.

> Und das [Hochwasserpartnerschaften – Ed.] ist zum Beispiel ein ganz tolles Werkzeug oder eine tolle Methodik, das Thema Hochwasserschutz bei den Kommunen kontinuierlich aktuell zu halten. Dort gibt es viele Veranstaltungen, Hochwasserpartnerschaften, wo sich die Kommunen gegenseitig austauschen, wo es viele Unterlagen gibt. [...] Wo sich also die Kommunen auch gegenseitig helfen, unterstützen und, sage ich mal, antreiben. (I16E, 00:17:12-8)

One a future note, furthermore, attention to flood risk is expected to grow as flood risk management plans are developed in line with the EU Floods Directive, providing a set structure for defining current weaknesses and concrete response measures. Besides, not having much choice about the introduction of hazard maps and management plans also makes is somewhat futile to try to oppose them.

Comparing the hitherto reviewed findings with the theoretical analysis in chapter 3, one sees that many of the factors pointed to in academic literature as affecting research use can also be recognized in relation to flood hazard maps in Baden-Württemberg. Primarily, many cases of use are characterized by predictive information being perceived as relevant whereas several cases of non-use are rationalized by not sharing this view (at least not under the present circumstances). At the same time, it is not always that these statements and comments refer only to the content of flood scenario simulation. Often, what affects whether or not there is a need for and interest in hazard information is related to some other aspect (e.g. timing, risk size, response capacity, etc.). Moreover, several of the factors pointed to in KU studies have been mentioned too, including aspects related to the format of findings, stakeholder involvement in the research process, individual actors' attitudes, organizational culture and political interests. What has not been mentioned yet are aspects related to research quality, credibility perception and the presence of simulation uncertainty. But is this because credibility is unimportant or because the hazard maps are credible enough to be accepted? And are they accepted in spite of being recognized as somewhat uncertainty or because local-level risk managers are unaware of the presence and implication of simulation uncertainty? These are the issues to be reviewed next.

7.2.1 Credibility and the presence of uncertainty

A first thing to note with regard to the issue of credibility is that there are indeed indications of research quality being an important factor even if it is rarely stated as an explicit reason for use. As the mayor in interview 01 explains,

> es muss fundiert sein. Da hatte ich dann gesagt: "Gründlichkeit geht vor Schnelligkeit." Weil es hat keinen Sinn, wenn ich – egal bei was – eine falsche Datengrundlage habe. Dann setzt sich ja das, was an Fehler drin steckt, nachher fort. Auch selbst wenn das, was man entwickelt hat, was man geplant hat, auf der Grundlage, auf der es basiert, richtig

> war, aber die Grundlage eben falsch ist, dann ist auch das, was man im Nachgang macht, eben auch falsch. Oder jedenfalls nicht wirkungsvoll. Nicht so wie man es sich wünscht. (I01RM, 00:39:55-7)

Moreover, all interviewees make a positive assessment of available flood hazard maps in this regard. In terms of spontaneous comments, I01RM notes them to be "well made" (00:39:55-7), whereas I03RM thinks the displayed assertions are "good" although he questions the sense of referring to statistical return periods (i.e. technical terminology) when the audience consists of lay-people (00:42:44-9). Mostly, though, quality appraisals are not offered spontaneously, but something that must be inquired about. Faced with a direct question about the perceived trustworthiness of flood hazard maps, I07RM says that they made a good impression (00:34:59-6), whereas I08RM says that he thinks the depicted predictions come close to reality in terms of what a real flood could look like (00:13:46-5). For his part, I10RM has never contemplated whether or not to trust flood lines based on gauge level simulation. Thinking about it, he says that, provided that they are based on year-long experience and not just a single data point, they *should* be trusted since it is important that the risk of flooding is considered before new building projects are initiated.

What underlies these assessments differs. In around half of the interviews, one component of how risk managers judge whether or not to sanction belief in displayed flood lines is to compare these with other sources of information, including local experience and photos of past inundation episodes:

> Wir haben ja vom Hochwasser damals auch Fotos aus ein Hubschrauber machen lassen, und da sieht man eigentlich, die Karte, die Fläche, die Blau auf der Hochwassergefahrenkarte dargestellt ist, das deckt sich schon mit der Fläche, die man vom Hubschrauber aus auf dem Gelände, auf dem Boden dann tatsächlich sieht. Also das passt schon sehr gut [...]. (I06RM, 00:43:25-2)

To a lesser extent, the credibility of hazard maps is judged through the proxy of trust in the source or in the competence of the involved engineers. Not being engineers themselves or feeling literate when it comes to simulation issues, the mayor in interview 01 (01:04:46-5) prefers to stay out of the technical discussion, noting that this is what experts are for, while I07RM (00:38:52-4) says that he 'relies' on the specialists. In other cases, local administrations and municipal councils embrace flood hazard maps because these are produced by the state and what the state vouches for is accepted:

> Und das Land ist ja eine übergeordnete Behörde zu den Kommunen. Und was von oben kommt, wird eigentlich akzeptiert. Das ist verwaltungsspezifisch eigentlich immer so, dass man Ergebnisse, die von einer übergeordneten Behörde kommen, dass man die eigentlich gar nicht anzweifelt. (I08RM, 00:14:19-6)

Indicating that a lack of confidence in higher authorities can render acceptance of hazard maps more difficult, furthermore, I14E notes that when the relationship between the higher- and lower-level authorities is tarnished since previously there will not always be any willingness to engage constructively with questions as to the hazard maps' plausibility.[6] Instead, the smallest suspicion that something is off will suffice for old trenchlines to reopen:

> [E]s kommt immer natürlich auf die Gemeinden darauf an, wie gut die Leute da sind oder wie das Verhältnis zur Landesregierung oder zum Regierungspräsidium ist. Manchmal, wenn es nur einen Verdacht gibt, dass etwas, was die Büros, die für das Regierungspräsidium arbeiten hier, kartiert haben, das an irgend einer Stelle nicht stimmt, dann wird es sehr schnell explosionsartig in den Gemeinderäten dann hochgekocht, geht an die Presse und so weiter. (I14E, 00:29:38-8)

Making a similar observation, I13E notes that local acceptance of hazard maps will partially depend on the communication between the regional administrative authority and the municipalities, and the animosities between the respective civil servants (I13E, 00:51:49-2).

[6] In I14E's view, such animosity can sometimes be traced back to experiences during the time of the Third Empire leading to an erosion in some communities' faith in higher authorities.

The most commonly mentioned reason for assessing hazard maps as credible, though, is neither correspondence with other information nor trust, but respect for the quality of the research method and input data, respectively the 'effort' going into flood scenario simulation. I06RM states that he trusts the displayed predictions because the mapping process is solid and the maps professionally investigated and produced (00:43:25-2); I04RM mentions precipitation-runoff modeling, laser scanning and empirical surveying before concluding that he has "a good feeling" about the effort that the state invests in the production of hazard maps (00:22:35-2); I05RM says that he knows from other assessment processes how exact the local terrain can be determined (00:42:57-7); and, offering somewhat more detail, I01RM is convinced by the multitude of data sources relied upon:

> Also ich denke die sind gut erarbeitet, diese Karten. Da hat man sich methodisch auch nicht nur darauf gestützt, was jetzt so allein die Verwaltungen wissen. Die Verwaltungen können auch nicht alles wissen. Sondern man hat wirklich draußen die Leute befragt und hat auch noch mal alles quasi angeschafft. Ich glaube die Experten sprechen, also wie hier beispielsweise, sprechen dann von einer Geschwemmsellinie oder wie das Ding heißt. [. . .] Und das wurde dann alles aufgenommen. Und hat auch noch einmal die Leute gefragt wie es eben in ihren Gärten aussah oder was weiß ich, wo überall. Also ich denke die Karten, die sind sehr gut gemacht... (I01RM, 00:39:55-7)

In this regard, involvement in the mapping process and interaction with higher-authority civil servants represent important ways in which to build trust in the quality of hazard maps. Through these processes, the user community gets a chance to learn about scenario mapping, to ask questions, give feedback, raise doubts, etc. For example, I09RM says that direct talks of this kind helped strengthen the administration's confidence in the modeling output:

> Wir haben dann auch mit diesem Kollegen vom Landratsamt, der da direkt involviert war in die Erstellung der Karten, im Gespräch sehr direkt Dinge dann noch mal rückgekoppelt und gefragt: "Kann das sein?" Oder "wie kommt ihr darauf, dass das hier so und so aussieht?"

> Und da konnte viel geklärt werden. Insofern ist die Vertrauensbasis da schon gestärkt. (I09RM, 00:50:54-8)

Likewise, I04RM refers to the administration's involvement in the plausibilization process, commenting that he has no doubts as to the correctness of the local hazard maps, as these have been re-worked to account for everything that the municipality voiced concern about, meaning that they have basically "made sure [...] that they are exact." (00:18:44-2).[7] In this sense, the state's efforts to consciously involve the target audience in the review process as a strategy to ensure acceptance appears to have paned out:

> Und wir haben das gesagt: [...] bevor die dann tatsächlich durch das Landratsamt ausgerichtet wird und fertig ist und auch als Überschwemmungsgebiet gilt, muss die Kommune noch einmal eine Gelegenheit haben dazu Stellung zu nehmen, das noch einmal zu überprüfen und ihre Anregungen und Bedenken noch mal zu melden. Sonst kriegen wir keine Akzeptanz in der Fläche. (I13E, 00:27:08-3)

That none of the interviewees question the maps' quality or trustworthiness does not mean that there is no recognition of uncertainty, however. On the contrary, several of the risk managers can point to at least one source of uncertainty affecting science's ability to make exact predictions, including:

- the exactness, quality and actuality of input data, e.g. associated with laser scanning and the Digital Terrain Model (DTM) but also with local flood history;
- the variability of hydrological statistics, meteorological conditions and the local landscape and terrain;

[7] Also for risk managers who were not directly involved in the plausibilization process, knowing that the maps' flood lines have been checked against local experience can help, giving them the feeling that whatever mistakes or errors there might have been, the worst of these have surely been caught (e.g. I06RM, 00:44:38-9). On the other hand, it also happens that one person checks the preliminary results and that the rest of the administration is thought to be unaware of this work having been carried out (i.e. I05RM, 00:57:18-4).

- the fact that computer models cannot “know” everything and that the model’s predictive capacity is limited for highly complex forms of problems;
- the possibility that, during the next flood, something unpredictable happens that changes how the water flows.

While less complete and exact than the technical experts’ knowledge, this still indicates a basic understanding of the difficulties associated with prediction in open systems. More specifically, one might say that the simulation uncertainty is one of the forms of uncertainty that risk managers are aware of. Rather than undermining their confidence in flood hazard maps, though, this is appears to be something that they accept:

> Natürlich können da kleine Fehler drin sein, aber das ist ja nicht ausschlaggebend. Nur das Ergebnis, das große Ergebnis unterm Strich zählt. Und das stimmt auch, denke ich. (I04RM, 00:22:35-2)

> Natürlich kann man über 10 Meter mehr oder weniger vielleicht mal diskutieren, aber ich vertraue den Hochwasserkarten schon sehr. (I06RM, 00:43:25-2),

Though I09RM doubts the accuracy of the predictions made in relation to one part of the city, suspecting these to be exaggerated, this does not cause him to dismiss the hazard maps as unreliable or doubt their methodological quality. He simply notes that it remains to be seen when the next large flood episode comes weather this is really what the consequences will look like (00:50:54-8). Likewise, having experienced parts of the city to become inundated although they had been predicted to stay dry in the hazard maps (including a building of relevancy for the emergency response operation) has not caused the mayor in interview 03 to reject scenario simulation as unreliable. On the contrary, seeing that the predictions mostly paned out and having been explained that some imprecision is unavoidable, his confidence in the maps’ predictive capacity has increased (00:43:47-0).

All in all, three things help us understand why the presence of simulation uncertainty is not being taken to constitute an obstacle towards use. First, as can already be told from the reference above to the presence of 'genuine' uncertainty, e.g. due to the risk of random events, there is no real expectation of complete certainty as something that will even be possible – at least not to an affordable price. As I09RM puts it, one cannot expect everything to be calculated down to the very last detail since that would be much too cumbersome. To remain affordable, a *reasonable* level of precision must be picked (00:56:25-8). Likewise, I05RM comments that the cost-benefit balance must be kept in mind in research projects like this:

> Es muss auch immer in einem vertretbaren, oder der Kosten-Nutzen muss in einem Verhältnis stehen. Also ich kann nicht 100.000 verschiedene Rechnungen durchführen. [. . .] Datensicherheit oder Forschungssicherheit nur damit man sagen kann: "Ich weiß es 100 Prozent genau" [. . .] Sehe ich eigentlich nicht als notwendig. (I05RM, 00:46:27-4)

Hence, there is no expectation of flood hazard maps offering perfect certainty; neither I09RM nor I03RM think that it is the job of the hazard maps to be all-telling or 100 percent reliable. What they should do is to draw attention to flood hazard and sensitize people to this risk (I03RM, 00:43:47-0), and what they are understood to provide is mainly "a point of orientation" (I08RM, 00:13:46-5).

Second, the presence of uncertainty does not constitute an obstacle to use because it is not thought to be of great consequence for the types of tasks performed:

> Ob das nachher auf 5 oder 10 oder 20 Meter genau stimmt im Gelände, kommt es bei uns eigentlich gar nicht so exakt darauf an. Weil wie gesagt das meiste ja sowieso draußen in der freien Landschaft ist und da spielen die paar Meter kein... (I05RM, 00:39:16-0)

Would it be perceived to constitute a problem, moreover, a manual floodplain survey can always be undertaken to gain more clarity (I01RM, I09RM).

Finally, imperfect or not, predictions based on flood scenario simulation are often thought to be better than whatever estimate or information which was previously available. Ultimately, risk management is a question of preparing for the prospect of something undesirable happening; it is per definition about making decisions under uncertainty. Under these circumstances, an improvement in the local knowledge situation is welcome even if it does not deliver perfect information:

> Also ich bin mir bewusst, dass das nie 100 Prozentig genau ist, aber es wird in jedem Fall genauer sein, als die Überschwemmungsgebiete [...] [S]o 'en gros', im Ganzen, wird das mit Sicherheit verlässlicher sein. (I05RM, 00:39:16-0).

> So was hat man bisher ja in der Form noch gar nicht gehabt. Das waren höchstens irgendwelche Erfahrungswerte, die aber auch nie so richtig festgehalten worden sind. [. . .]. Aber diese Abgrenzungen, diese ganz genaue Abgrenzung, die auch sehr, sehr genau ist – so wie ich jetzt auch aus meinen Erfahrungen heraus habe es sehen können und vergleichen können – das ist einfach mal etwas gänzlich Neues. (I04RM, 00:16:39-4)

As long as there is no superior assessment method, the best local risk managers can do is to heed what it generates and prepare as best they can.

In summery, it is not that credibility is unimportant that explains why this factor is not found to constitute an obstacle towards hazard map use, but that none of the interviewees doubt this product's credibility. In spite of understanding flood hazard as something which cannot be predicted with complete certainty or accuracy, flood scenario simulation is confined in to deliver credible guidance. In other words, there is no indication of non-use being related to low confidence in simulation output or of risk managers' commonly taking an over-critical approach to predictive research. Though it happens that the credibility of the state's hazard maps is questioned, this is mainly due to political resistance in I13E's experience:

> [A]lso ich sage mal ganz überspitzt, wenn man die Überflutungsfläche, so wie sie dargestellt ist, nicht haben möchte, aus politischen Gründen... Das ist meistens der Beweggrund, in dem dann das dann das Modell angezweifelt wird. (I13E, 00:59:35-0)

To conclude, this suggests low confidence to be what is used as an argument by those opposing the introduction of hazard maps rather than constituting a genuine concern.

Chapter 8

Benefits and problems

8.1 Flood hazard maps as input to risk management

As stated in the introduction, this thesis is not only interested in whether, how and why flood hazard maps are used but also in the potential benefits and problems associated with presenting non-experts with a graphical representation of simulation results. In theory, access to foresight information should allow local risk managers to adjust and improve the local protection, preparedness and vulnerability situation. But, in practice, we lack insight as to how risk management is perceived to benefit from predictive information. Moreover, it is yet unknown whether the problems identified with non-experts' use of simulation products elsewhere are also present for flood hazard maps or not.

8.2 Benefits

To explore, e.g. the benefits of flood hazard maps to risk management, the interviewees were asked openly about their thoughts and feelings towards this new tool before more direct questions as to specific experiences of pros and cons were posed. This was followed by a form of indirect control question towards the end of the interviews, in which the interviewees were asked whether they would recommend flood hazard maps as a management tool to someone else. What the outcome of this inquiry showed was not only a predominately positive view of hazard maps as management tools but also that one of the central reasons for this (next to relevancy) was the experience or observation of some form of benefit.

In principle, two categories of benefits can be detected. First, there are expected benefits linked to being provided with more and better information than what was previously available and profiting from this in different ways. In principle, one can refer to these as conceptual, instrumental and strategic forms of benefits, corresponding to information and knowledge benefits, management and decision-making benefits, and persuasion and awareness-raising benefits. In essence, they concern that local-level risk managers (including both elected leaders and civil servants) somehow *profit* from access to foresight information. Second, there are benefits of a more unexpected nature, concerning the role of hazard information (sometimes, but not always, in combination with formal regulations) in pressuring local-level risk managers to give flood risk more weight respectively in restricting their possibilities to ignore it.

8.2.1 Benefits of knowledge, guidance and persuasion

Beginning with what it brings to be presented with and draw on flood hazard maps, both risk managers and experts emphasize the value of scenario simulation for offering new and better overview and understanding of local flood risk than what was previously available, making flood risk more real and less abstract; providing for a novel kind of certainty. Before, flood hazard was not properly recorded, and available assessments were based on old or incomplete data. In comparison, the projection offered by flood hazard maps is both clearer and more palpable:

> [E]s wird einem doch jetzt deutlich vor Augen gehalten, wo genau die Überschwemmungsgrenzen sind bei welchem Hochwasserereignis. [...] Und das hat man eben vorher so nicht gehabt, wo das so deutlich oder so offensichtlich war [wie es] in der Karte dargestellt [ist]. (I04RM, 00:16:39-4)

Alternatively, electronic hazard maps make available evidence more easily accessible, thereby facilitating use. In either case, what is emphasized is a conceptual form of effect as local knowledge – or the ability to draw on this – improves; it is information access that is emphasized, not what it is done with this or what effect it has. Other forms of benefits can be read-out inbetween the lines in descriptions of how hazard maps are perceived and used, including that they make the risk of flooding less abstract, fill in previous knowledge gaps and help confirm what some already knew tacitly.

In terms of more instrumental forms of effects, it is mentioned how access to hazard maps is affecting local preparedness, management capacity and damage potential. For example, I09RM mentions how information as to the expected depth of inundation allows the administration to require adjusted building designs, noting that this is good for both property owners and their insurance conditions, and for the municipality, too (I09RM, 00:41:42-1). Similarly, application to preparedness planning has helped at least one municipality avoid embarking on an ineffective emergency response operation by revealing holes in the strategy that the emergency services would have gone for intuitively (I13E, 00:27:08-3). In the case of the community in interview 02, furthermore, access to a formal hazard assessment has resulted in an (at least partial) update and extension of preparedness planning and allowed the administration to give more weight to flood risk in its handling of local building permit applications (00:55:02-8). Moreover, it let the municipal council do something about unmaintained and deficient flood defenses in foresight rather than hindsight. Other examples include that they have allowed the mayor in interview 01 to approach the problem of unsolicited building projects more effectively (00:58:49-1), and that at-risk residents have been offered information as to the local hazard situation and options for self-protection (e.g. I13E, 00:35:07-7 and I03RM, 00:22:46-0).

Where the more strategic forms of benefits come in is when the graphical representation of flood hazard is used to convince others of the existence of a flood risk. As I04RM points out: now that flood hazard can be illustrated in black and white, one can also convince people more effectively by showing them the maps and pointing to the latency of flooding (00:31:30-8). Likewise, speaking specifically about local citizens, I01RM notes that the new flood hazard maps constitutes a more persuasive argument than manually drawn lines of older date, as these are often not accepted as significant anymore:

> [D]ie neuen Karten konnte man nicht so einfach ignorieren. Und wenn sie alte Karten, die 20, 30, 50 Jahre alt sind heranziehen, dann interessiert das natürlich insbesondere den Bürger, der etwas vorhat zu bauen oder zu verändern, nicht. Der wird sagen es ist keine aktuellen Datengrundlagen. (I01RM, 00:52:19-5)

Though it is throughout theoretically possible that the persuasiveness of a graphical hazard representation makes it easier to get municipal councils to prioritize flood risk, the benefit focused on in the data material is instead how this helps local administrations explain and legitimize public management measures and/or positions to external audiences. For example, this is how I02RMa explains what he experiences as a benefit of scenario simulation:

> I02RMa: Wenn wir in der Vergangenheit am einem oder anderem Ort Hochwasserschutzmaßnahmen geplant haben, ist uns vorgehalten worden: "Es hat noch nie ein Hochwasser gegeben..." Und das ist eben das Hauptproblem. Heute, auf Grund der technischen Möglichkeiten kann ich eben simulieren oder berechnen, wo ich eine Hochwassergefahr habe. Auch wenn es die letzten 50 oder 100 Jahre kein Hochwasser gegeben hat. Und davor, davor wollen wir die Menschen schützen, dass das Ereignis möglicherweise gar nie eintritt. 00:33:40-7

Likewise, they *sometimes* help I02RMb convince people not to exercise a building right in an area at risk of flooding:

> I02RMb: Also [...] was wirklich beeindruckend ist, [ist] wenn wir Fotos zeigen von abgeflossenen Hochwasserereignissen. Dann kann keiner mehr sagen: "Ich sehe das nicht. Ich will das nicht sehen." Sondern dann fängt es bei den Leuten auch an, dass sie nachdenken. Und manche sagen dann trotzdem: "Ach das kommt nie wieder und das

> war nur einmalig." Ich sagen dann oft: "Ja gut, aber wenn das jetzt sie nicht mehr erleben, aber ihre Kinder irgendwann so einen Schaden im Haus, das macht auch keinen Spaß." Aber am eindrucksvollsten ist es natürlich, wenn man Fotos zeigt oder diese blauen Karten. Und das hat man bis neulich – hat man diese Karten nicht gehabt. 00:57:40-4

As I03RM explains, flood hazard maps provide an instrument with which one can relatively easy present the local hazard situation and point to it politically, as one does not have to talk about it in abstract terms anymore, but can concertize it (00:57:45-1).

In a nutshell, then, a couple of cases exist in which flood hazard maps have brought a benefit along the lines of motivating activity in foresight rather than hindsight. Additionally, they sometimes help local administrations act more effectively or do better what they would have done anyway. Examples in this regard cannot only be found in the review above but can sometimes also be derived from descriptions of use of a more general character, as when I08RM says:

> [U]nser Gemeinderat entscheidet zusammen mit der Verwaltung, ob wir neue Baugebiete ausweisen oder neue Gewerbegebiete ausweisen. Und bei uns ist es jetzt so, die Bereiche, die wir andenken, wo wir möglicherweise einmal etwas ausweisen, die liegen bei uns alle außerhalb der Bereiche, die von Hochwasser gefährdet sein könnten. Also diese Konsequenz hat es bei uns bereits. Wir schließen da von vorneherein jedes Risiko aus. (I08RM, 00:18:36-3)

Here, there has been no change in the municipality's planning. They have simply used the hazard maps to confirm that the plans as they stand are acceptable also from the perspective of not wanting to increase local damage potential. In other cases, hazard maps are described as useful input without any concrete effect or advantage being identified, and in at least one case (interview 01) one does not get a proper sense for whether or how they have been used at all. In many cases, the benefits associated with hazard maps are of a different character than the official vision of them giving local-level risk managers more clarity as to where there is a risk and thereby facilitating informed risk management.

8.2.2 Benefits of pressure and restriction

The second category of benefits concern that production and publication of hazard information makes it more difficult for public and private actors to ignore or willfully close their eyes to the risk of flooding. In some instances, this is something that risk managers themselves mention benefiting from as when I09RM says that access to flood hazard maps help keep the space for non-risk related interests in local politics in check:

> [E]s ist definitiv eine Erleichterung. [...] Jetzt ist ganz klar, wir brauchen im Gemeinderat nicht darüber diskutieren. Wenn da einer die Idee hat "ach da ist doch noch viel Platz, da könnte man doch noch ein schönes Gewerbegebiet machen und mein Bruder hat da ein Grundstück" oder so irgendwie, da gibt es eine klare Entscheidungsgrundlage. Das geht nicht! Und man braucht da überhaupt keine Zeit, Mühe und Nerven auf solche Diskussionen verwenden. Und das ist bestimmt auch positiv zu sehen. (I09RM, 01:01:08-3)

Noting a similar effect, I01RM suggest that, when it comes to the topic of risk, elected representatives of the municipal council are generally careful. Even if it means forgoing a desired project, disclosed information will not be openly contradicted (01:01:51-0). As I02RMb points out, a municipal council may still decide to live with the risk of flooding instead of doing something about it. Thanks to the arrival of flood hazard maps, though, such a decision has to be made explicit. By making it easier to hold decision-makers accountable, information obligates once it is on the table:

> I02RMb: (. . .) Aber es ist natürlich auch so, wenn man so was mal hat und der Gemeinderat hat davon Kenntnis, dann ist er natürlich auch in der Pflicht. Dann kann man nicht mehr so tun: "Ich weiß nichts über Hochwasser. Ich weiß nichts über die Gefahren." Sondern wenn so was mal da ist und bekannt ist, dann muss man Entscheidungen treffen. Akzeptiere ich das, nehme ich das billigend in Kauf oder versuchen ich eben entsprechend des Schadenspotentials auch Schutzmaßnahmen

> herzustellen und dazu irgendwelche Maßnahmen zu ergreifen. 00:47:17-3

In I04RM's view, it is really only to be seen as an advantage that flood hazard maps makes naivety more difficult by ensuring that flood damage cannot come as a surprise anymore (00:29:20-2). Representing a more unique view, the benefit that I05RM focuses on is not that local decision-makers are reigned in, but that hazard maps makes it easier to dismiss residents' and private actors' arguments against the official interpretation of flood hazard. While such processes have been associated with massive protest and conflict in the past, the introduction of a solid scientific method and automatic legal implications effectively put a stop to this by making local opposition inconsequential:

> Bei dieser [vorige – Ed.] Ausweisung [. . .] gab es massiv Probleme. Also die Landwirte oder auch Betroffene Anlieger am Bach haben sich da vehement daran gestört. Auch diese Abgrenzungen, die anhand von Geschwemmsellinien oder von früheren Hochwässern teilweise auch durch Querschnittsberechnungen vor Ort festgelegt worden sind, in Zweifel gezogen. Weil es halt seit Menschengedenken dort kein Hochwasser gab [. . .]. Also das ist sehr stark in Zweifel gezogen worden. [. . .] Wenn jetzt aber das anhand von so einem topographischen Geländemodell errechnet werden kann, weil man genau weiß so und so viel Einzugsgebiet, so und so viel Niederschläge führen nachher dazu, dass sich das im Talraum so und so verbreitet, ist das eigentlich nicht mehr so leicht anzweifelbar. Und es ist dann einfach de facto (...) Überschwemmungsgebiet. Ob jetzt der Anlieger meint, es ist rechtlich haltbar oder nicht beziehungsweise fachlich haltbar oder nicht tut da nix zur Sache. (I05RM, 00:09:13-0)

In other words, it is not that members of the public should be convinced of the presence of a flood risk as in the quotes above pertaining to strategic forms of benefits. Instead, the benefit that I05RM perceives is that it no longer needs to matter what the local population thinks.

Mostly, though, it is amongst the experts that benefits of pressure and restriction are emphasized. According to I12E, the mere availability of information means that no mayor will be willing to designate a building zone in an area at risk of flooding anymore and risk being held accountable in case something happens:

> Wenn ein Bürgermeister die Hochwassergefahr kennt und trotzdem ein Baugebiet ausweist, dann macht er sich strafbar und haftbar dafür. Und es wird kein Bürgermeister mehr irgendwo hingehen und sagen: "Das mache ich jetzt zum Bauland", wohl wissend, dass da Hochwasser ist. Weil er selber versucht Geld damit zu machen. Dass... die Gefahr wird er nicht eingehen. Dann kommt doch das Hochwasser, und die Häuser stehen unter Wasser. Das kommt sehr schnell raus, wie das zusammenhängt. Und es ist also nicht so, dass es dann wie vor 20, 30 Jahren: "Oh, das habe ich nicht gewusst. Und hätte ich das gewusst hätte ich ja nie das Grundstück verkauft." Also das ist, mittlerweile die Haftungsfrage ist relativ eindeutig geklärt. (I12E, 00:24:35-2)

Likewise, I16E notes:

> Das kann nicht in die Schublade gelegt werden, weil: das sind Fakten, wenn die auf dem Tisch liegen. Und wenn dann etwas passiert, dann weiß auch jeder Bürgermeister oder jeder, jeder zuständige Hochwasserschutzbeauftragte, dass er dann Probleme kriegt. (I16E, 01:02:38-9)

Even more unmistakable are the effects of introducing a formal regulatory framework giving some of the simulated flood lines legal status. As I18E explains, this alleviates the need to rely on people to voluntarily prioritize risk reduction over other interests:

> Vorteil ist aber, [...] dass es einen Zwang gibt wirklich Veränderungen durchzuführen. [...] [F]reiwillig ist es manchmal schwierig, weil Hochwasser, wenn es um ein 100, 200 jährliches Ereignis geht, also seltene Ereignisse sind für viele, die dann jetzt Geld in die Hand nehmen müssen, um sich vor einem Schaden in 50 Jahren oder 100 Jahren

> vielleicht erst zu schützen. Natürlich kann das auch morgen kommen. Aber viele denken: "100 jährlich? Ach das trifft mich schon nicht. Das ist unsicher." (I18E, 00:56:12-1)

That merely making information available can be of limited effect is something that I13E has experienced first hand; as the mapping attempts first began, there were no legal implications and also not much effect:

> Wir hatten ja ursprünglich vor, wir zeigen die Gefahr auf durch die Karten. Und der Rest erledigt sich von selbst. Nach dem Motto: Die Kommunen wissen dann, was zu tun ist. Die sehen die Gefahr und dann... ist klar. Da steht ja eigentlich alles drin. Aber dem ist nicht so. Also wir hatten 2005 die ersten Gefahrenkarten am Neckar ausliegen... [. . .] Und die Ansprechpartner (...) vom Landratsamt hat mir dann mal, eine Weile später habe ich gefragt: "Ja und? Wie war denn jetzt so die Reaktion von den Gemeinden und so? Was ist denn passiert?" "Ja, zwei Wochen nachher kam der nächste Bebauungsplan und das nächste Einzelbauvorhaben mit der Bitte um Genehmigung genau in den so und so dunkelblauen Flächen." Wie wenn nichts gewesen wäre... (I13E, 01:14:40-2)

Judging from the rest of the interview material, a legal framework that automatically attaches restrictions to areas predicted to be at risk of flooding has two further benefits compared to when floodplains are designated by way of legal ordinance in separate assessment processes. First, it circumcises the negotiation space for the local administrations; reducing their chances of influencing the assessment of which areas are at risk to make it reflect local interests as well as formal hazard evidence. Whereas flood lines used to be open for discussion, the introduction of a formal assessment method based on scientific principles has done away with this possibility:

> I14E: Die alten Überschwemmungsgebiete wurden meistens oder vorwiegend nach abgelaufenen Ereignissen kartiert. Also man hat ein Hochwasserereignis gehabt, das wurde kartiert und dann wurden die

> Überschwemmungsgebiete gemacht. Und diese Überschwemmungsgebiete wurden intensiv mit den Gemeinden diskutiert. Deshalb hat es manchmal jahrelang gedauert [...] Aber diese Hochwassergefahrenkarte wird nicht mit den Gemeinden diskutiert. Also nicht abgestimmt, dass man sagt, man lässt ein Gebiet weg, weil die Gemeinde da ein Baugebiet vorhat. 01:56:29-7
>
> SK: War es so früher? 01:56:31-3
>
> I14E: Ja, war so früher. Da ist gehandelt worden. Und jetzt ist es ja so, dass diese Hochwassergefahrenkarte einfach nach diesem methodischen technischen Vorgehen gemacht wird [...] Das ist der riesige unterschied. Es hat keine Gemeinde, niemand hat die Chance sich gegen diese Rechtsverbindlichkeit von dieser HQ100-Fläche zu wehren. [...] 01:57:20-5

Reducing the municipalities' chances at influencing the floodplain designation process and manipulating the assessment of which areas are at risk, flood hazard maps can also be said to ensure that these represent a truer picture of the sum of available evidence than what was perhaps the case before. Moreover, the mapping process introduces a kind of control function that makes it more difficult for clients to influence calculations for other types of errands, too:

> [S]ie kommen ja auch oft und sagen: "Ja könnt ihr uns da nicht irgendwie rechnerisch ein bisschen was machen" und so weiter. [...] [D]as ist der Zwiespalt, der Auftraggeber möchte ein positives Ergebnis. Und dann haben, dann ist diese Gefahrenkarte für uns auch noch mal ein viel besseres Argument, um zu sagen: "Nein, machen wir grundsätzlich nicht und sowieso nicht, weil wir müssen immer damit rechnen, das andere nachher quasi eine Art Kontrollrechnung machen..." (I14E, 01:30:38-6)

Hence, it is not only in risk management and local politics that simulation-based hazard maps help limit the influence of non-risk related interests but also in the hazard assessments produced to provide input to these.

Second, in an equivalent to I05RM's assessment that it is a benefit that the municipality no longer needs to bother with local critics, the experts note that the automatic floodplain designation facilitates the process of placing areas at risk under formal protection considerably for the higher-level authorities. Not having to undertake a separate assessment process and not having to discuss every proposed flood line with each municipality mean that things move much faster, taking up less resources, with the result that large areas have been placed under formal protection much sooner than what would otherwise have been possible:

> Weil bis 2004 hatten wir ja das ganz normale Verfahren über Rechtsverordnungen. Und wir hatten über Jahre das Problem, dass die Landratsämter dieser Rechtsverordnungen nicht angegangen sind, [. . .] [dass] diese Verfahren nicht voran kamen und nie zum Ende geführt wurden. Weil... es gab Einsprüche, es wurde verzögert, es wurde wieder infrage gestellt, es wurde wieder, ja? [. . .] Wir haben zwar einige Überschwemmungsgebiete festgesetzt, aber so, so wie jetzt, wo ich also jetzt an 12, also in Kürze an 12.300 Kilometer Gewässer Überschwemmungsgebiete fix und fertig festgesetzt habe, die gelten. Also das hätte ich damit nicht erreicht. (I13E, 01:18:26-3)

In effect, then, one of the benefits of the simulation-based flood hazard maps in Baden-Württemberg is that they helped the state place large areas of land under legal protection without this first having to be demanded at federal level. As I17E sees it, this would hardly have been possible without the hazard maps:

> Wenn ich mir vorstelle, was wir für die Ausweisung eines Wasserschutzgebietes [. . .] was wir da an Aufwand brauchen, um eine räumlich begrenzte, so eine Verordnung in Kraft zu setzen, auszuarbeiten, mit allen Beteiligten abzustimmen. Das ist, das bindet sehr viel Arbeitskraft und dauert sehr, sehr lange. Wenn ich mir vorstelle, dass wir das entlang aller Gewässer in Baden-Württemberg machen müssten, das wäre, das wäre nicht zu leisten. Personell nicht zu machen. (I17E, 00:39:21-3)

Ultimately, then, the type of benefit that many of the experts emphasize (and some risk managers note, too) concerns the ability of simulation results to 'force' people to consider and account for flood risk in their decisions and behavior, either by making it more difficult to escape accountability or, more directly, by way of formal restrictions. Furthermore, it is noted that, while floodplains could be placed under official protection before too, the advantage of standardizing this process and tying it to the results of a traceable assessment method is that the area shown to be at risk become more difficult to question and manipulate. This improves state's ability to quickly place large areas under protection, thereby having a direct effect on the growth in damage potential.

8.3 Problems: under-usage and risk of negative implications

Regarding problems, two things cause concern in both interview groups. First, there is the perception that, in spite of constituting a relevant tool, foresight information is so far underused and insufficiently promoted. Second, there is the experience or fear of some form of negative effect following the introduction of flood hazard maps.

Beginning with the first point, this concerns that the chance of acting in foresight is lost both at the municipal level and at the level of private citizens and businesses, e.g. due to the local level's disinterest and lack of know-how, respectively due to the higher authorities' passivity and lack of support. Essentially, local administrations have access to a wonderful instrument for risk communication and non-structural alleviation work, as I06RM sees it, and yet neither local leaders nor their direct superiors realize what a blessing they have been provided with, whereas higher-level authorities fail to recognize the presence of reservations:

> Es müsste hier noch einiges an Überzeugungsarbeit geleistet werden, um das ganze Personal, das im Rathaus arbeitet zum Beispiel oder an verschiedenen Stellen im Landratsamt, dass die auch davon überzeugt sind, dass die Hochwassergefahrenkarten einen Segen bringen für die

> Leute. Es schwingt immer so mit: "Ach, die bringen ja nur Problem, die Hochwassergefahrenkarten." [. . .] Also wir sehen das natürlich als Segen und sagen: "Ja die Leute bekommen jetzt Informationen und können Vorsorge betreiben." Aber auf der anderen Seite sehen es auch viele so: "Ja da entstehen ja uns jetzt Kosten für die Hochwasservorsorge und wir können auch in bestimmten Gebieten gar nicht mehr hineinbauen, wo wir eigentlich bauen wollten." Und man kann das schon von zwei Seiten [aus] sehen. [. . .] Aber das wird offiziell so nicht gesehen. Diese Vorbehalte, die man gegen die Hochwassergefahrenkarte hat. (I06RM, 00:27:39-3)

In his view, more could be done to provide guidance for how to read the flood hazard maps and what to conclude from them (I06RM, 00:34:38-4). As it is now, they are too little appreciated and in consequence too little used:

> I06RM: [...] [A]uf die Hochwassergefahrenkarten greifen nur die zurück, die sich konkret selbst von sich aus dafür interessieren... Natürlich Raumplanung und Raumordnung, für die größeren Behörden, die wissen dann schon mitunter damit umzugehen. Aber konkret auf den einzelnen (...) einer Gemeinde, da findet wenig statt... 00:30:31-4

> I06RM: Also ich bin ja ein Fachmann im Hochwasserschutz und ich sage, die Karten selbst die sind super. Mit denen kann man ganz toll erklären[. . .]: "Hier ist die Überflutungstiefe so und so groß, dann in dieser Fläche darf nicht gebaut werden. Und wenn man Vorsorge betreiben will muss man die Türen, Tore, Sandsäcke und was auch immer so und so hoch schichten, um sich vor dem Hochwasser zu schützen." Also für jemand, der sich mit Hochwasser, mit der Hochwasserproblematik auskennt ist das ein Segen, die Hochwassergefahrenkarte. Aber es müsste eben besser an die Bevölkerung herangetragen werden. Und ich finde sie ist sehr-. Es ist jetzt die Frage was man damit macht. Sie steht im Moment so für sich im Internet und wartet darauf genutzt zu werden. 00:32:51-9

Pointing in a similar direction even if he does not explicitly state flood hazard maps to be under-used, I13E appears to find it problematic that it is so difficult to get municipalities to comprehend the hazard maps and the possibilities that they offer. In his experience, the situation is often that only part of the message hits home, meaning that only part of it can be responded to:

> Weil wir oftmals schon die Erfahrung gemacht haben, dass einmal der Informationsgehalt der Karte sehr hoch ist und die Schwierigkeiten haben zunächst einmal die ganzen Informationen rüberzubringen... bzw. das rüberbringen an sich, da wir Fachleute sind und wissen, was da drin ist, ist einfach. Aber beim Gegenüber kommt nicht alles an... und nur Teile davon. Und dann werden nur Teile davon umgesetzt. Oder auch nicht. (I13E, 00:02:29-2)

In line with the assessments in interview 11 that reported management measures are still mostly taken in hindsight, this shows that actors which regard flood hazard maps as a vital tool for risk management and which are in a position to assess their aggregate level effect are partially somewhat troubled by what they see.[1]

Turning to the second point, a small number of interviewees refer to a experienced or observed negative effect of flood hazard maps or the mapping project. These include that it has become more difficult to find colleagues prepared to help out in case of a flood emergency since it became clear what responsibility this implies (I02RMb), that the announcement of the hazard maps' arrival has triggered an increase in local damage potential, as people hurry up with building projects out of fear of having these prohibited (I06RM), and that local administrations have gotten an alibi for postponing emergency management planning, as they can claim that it is not worth pursuing until the maps are ready (I11Ea).

Mostly, though, it is the *risk* of negative effects that is described, such as the risk of land-use restrictions leading to a loss of local business life and a lower trade

[1]That others are more unconcerned in this respect does not per se contradict that hazard maps should be under-used. Amongst several of the experts, there is still a strong belief in this management tool as something that *will* lead to improvements even if this cannot yet be observed or they themselves cannot offer any concrete examples of this. And amongst the risk managers, the expectations expressed with regard to the role of flood hazard maps for risk management are often more low-key than in the example of I06RM.

income (I03RM) or the risk of people pressing legal charges that can delay or undermine the whole mapping project (I18E). Most central, though, is the risk of 'innocent' citizens having to suffer an disproportional negative consequence as a result of hazard mapping, e.g. as a result of higher insurance premiums, loss of coverage, falling property value, etc. For instance, I14E states that...

> ...der einzige Konflikt mit diese Hochwassergefahrenkarten, ist eben das Problem, man weiß, man hat jetzt flächenhaft dargestellte Risiken über die man sich manchmal vorher nicht bewusst war [...]. Und das Problem ist, dass der einzelne, also das Hauptproblem sehe ich, dass der einzelne private oder die Firma oder die Gemeinde jetzt plötzlich in so einem Gebiet drin sitzt, eventuell ein Problem mit Versicherungen oder Immobilien und so weiter hat. Also es kann Fälle geben, wo einfach das Vorhandensein eines neuen Wissens dazu führt, dass ein einzelner... im Prinzip, obwohl es gar nicht so beabsichtigt war, einen wirtschaftlichen Schaden hat oder eine Versicherung ihn nicht mehr versichert... [...] wollen [ein Haus – Ed.] verkaufen und haben dann ein Riesenproblem, dass sie einfach das nicht verkauft bekommen, weil dieses Wissen um dieses Risiko jetzt veröffentlicht ist [...]. (I14E, 01:50:22-5)

Whereas several interviewees mention the plan to subject flood hazard maps to regular updates as something positive and even as a precondition for their continued significance, I14E also notes an "unsolved problem" with the situation of making a technical non-stationary assessment the basis of juridical regulation, as it implies that who is defined as being at risk and subject to legal restraints can suddenly change at a later stage (00:17:42-2).

In general, the introduction of legal restrictions is sometimes perceived to be harsh on people owning land in risk areas. While I09RM thinks that it is the right approach, in principle, to place all floodplains under protection even if it implies reverting an existing building plan, it cannot be disregarded that this is something that can affect private citizens disproportionately hard. To explain, he gives a concrete example of a young man for which such an outcome would have meant disinheritance:

> Und zwar kam da mal ein junger Mann [. . .] Der hat angefragt bei unserer Bauordnung, er würde gerne ein Haus bauen, was er da beachten muss. Und dann gingen natürlich zunächst die Alarmglocken hoch, das ist kein 100 jährliches Hochwasser, ist ein 50 jährliches. [. . .] Allerdings gibt es eben älterer Gebäude, die da vorhanden sind. Und insofern gibt es ein Baurecht [. . .] Und in dem Fall hat der Grundstückseigentümer uns da zahlreiche Argumente geliefert, wo wir sagen mussten, da können wir uns nicht verschließen. [. . .] Er hat gesagt: "Ich habe noch drei Brüder. Jeder von uns hat vom Opa einen Bauplatz geerbt. Das ist mein Erbe. Wenn ich da nicht drauf bauen darf oder das als Bauplatz verkaufen kann, sondern das ist jetzt mehr oder weniger nur noch ein Garten, dann bin ich enterbt. [...] Nächster Punkt: Ich zahle für dieses Grundstück seit zig Jahren Grundsteuer B für bebaubares Gelände. Kriege ich das Geld dann wieder, wenn ich da nicht bauen darf?" [. . .] Und da kann man jetzt auch nicht sagen, das ist alles Schnee von gestern und das Grundstück ist jetzt nur noch einen Euro wert. (I09RM, 00:29:29-3)

Even if it would be the right thing to do from a risk management perspective to recall the right to build in areas now known to be at risk of flooding, it is not always that a municipal administration finds the consequences of such a measure acceptable:

> Das hat definitiv Effekte auf den Wert von Grundstücken und kann- . Also die Eigentümer sprechen ja dann von kalter Enteignung und solchen Dingen, und fühlen sich ihrer Werte beraubt, was zum Teil, denke ich, nicht von der Hand zu weisen ist. (I09RM, 00:32:38-7)

In I09RM's view, there has been no guidance or support from higher levels regarding how to handle these forms of effects; they have not foreseen and do not comprehend what kind of challenges this puts the local administrations before.

Hence, while economists and risk researchers tend to see information as a policy tool for regulating market prices and thereby to curb the growth in damage potential, the perspective taken here is a focus on the implications of such measures for those potentially affected. Though, in principle, a problem of private nature, public dissatisfaction is not without political risk. In sum, this nevertheless means that, apart from not always being perceived to live up to their full potential of motivating more precaution in foresight, there is no widespread *confirmed* form of problem associated with the introduction of flood hazard maps.

8.3.1 What about non-experts' handling of uncertainty?

Judging from the descriptions of map use and reasons for non-use reviewed in chapter 6 and 7 and from the above presented analysis of problems, there is no indication so far of problems related to over- or under-critical approaches being taken towards flood hazard maps. Yet it has also been recognized in previous passages that an absence of observations of, for example, misuse does not mean that this does not exists; often it is only if some kind of negative implication materializes that misuse is discovered. Hence, this section will take a look at whether or not the interviewed experts recognize a theoretical *risk* of such problems.

Regarding the possibility of an over-critical approach resulting in a lack of confidence that could lead to non-use, there is indeed some recognition of this in the interview material. For example, I15E (00:38:41-5) notes that people are often skeptical towards computer-generated images on the basis of not knowing whether they are film tricks or reality. Often, he says, it will depend on the credibility of those responsible whether simulation results are trusted or distrusted. In his view, simulationists must be honest about there not being any 100 percent exact solution for complex natural processes and open about the parameters where they are uncertain and/or have made assumptions. Otherwise, people will lose confidence in modeling: "It is very important for the credibility, because otherwise there will be some detail where model and some empirical observation do not quite fit and then the whole trust goes down the drain." (I15E, 00:46:02-8). In this regard, it is a problem that not everyone adheres to the same standards:

> Und daran kranken eben viele Modelle, die man im Ingenieurwesen anwendet. Dass man sagt: "Schnell, schnell wir müssen jetzt mal wissen, ja wir wissen ja wie die physikalischen Zusammenhänge sind

> und dann rechnen wir mal." Und wenn ein Modell nicht ganz sauber über Messdaten geprüft und validiert worden ist, so lange muss man da große Vorbehalte haben. So und daher kommt auch, [dass] viel Unfug gemacht wird heutzutage mit Computermodellen. (I15E, 00:07:29-8)

Sharing this view, I12E notes that the problem with more and more data and increasingly user-friendly simulation programs is that this increases the risk of computer models being acquired and run without the necessary understanding or competence. In his view, this is something that can lead to people losing confidence in modeling and to good models being subject to bad use getting an undeserved bad reputation in the policy sphere:

> Dass was ich als negativ oder als problematisch ansehe ist, dass viele versuchen und sagen: "Wir können das. Wir machen das. Wir kaufen uns so ein Modell." Aber schauen nicht nach den Randbedingungen, die dazu zu erfüllen sind. [. . .] Also dieses Simulieren ist das Eine... [...] Aber das Vorbereiten der Daten für die Simulation ist vielleicht genauso groß und genauso aufwendig. Und man kann nicht einfach sagen ich habe heute hochauflösende Daten, die kaufe ich mir einfach alle zusammen und dann kann ich das machen. Und da sehe ich einfach eine große Gefahr. Dass immer mehr versuchen, die Modelle werden immer anwenderfreundlicher, dass immer mehr getan wird, immer mehr gerechnet wird. Aber die Modelle... vielleicht sogar in Misskredit kommen, weil sie falsch eingesetzt wurden. Und dann unter Umständen Modelle mit falschen Attributen versehen werden, obwohl sie eigentlich gut sind. Nur weil sie jemand falsch angewendet hat [...]. (I12E, 00:07:56-8)

When it comes to flood hazard maps specifically, moreover, I12E notes that a failure to be open about various areas of uncertainty or limitations can quickly lead them to be dismissed as lacking credibility (01:03:02-3). Likewise, I14E notes that a failure to document what data one has used can quickly lead to problems as technical administrators not recognizing the numbers will then become suspicious and wonder what is going on (2h+00:12:27-3). In I13E's impression, though, it is rarely that doubts as to the accuracy of flood scenario predictions result in a lack of confidence in the hazard maps as such. In his experience, most doubts can be constructively handled through dialog and discussion (i.e. personal contact), and it is only when there are political reasons for not wanting hazard maps that simulation modeling is dismissed as unreliable:

> Also ich will mal sagen: Entweder wird die Darstellung komplett verworfen, weil man es nicht haben möchte. Oder es wird konstruktiv an Details diskutiert. Nach dem Motto: Wir hatten da schon mal ein Hochwasser, aber die Fläche war noch nie nass. Wie kommt das? Wieso ist die bei euch nass und bei uns war die noch nie nass? Dann wird sich aber konstruktiv mit dem, mit dem Modell auseinandergesetzt. Dann geht der Ingenieur natürlich hin [. . .] Also dann läuft ein ganz normaler und auch guter Prozess ab, weil am Ende dieses Prozesses steht die Einsicht der Kommune: "Jetzt stimmt sie, die Karte." Obwohl die auch Unschärfe dann hat. Aber dieses jetzt... also dass quasi aus der Argumentation heraus: "[. . .] Und das ist ja so unscharf und so ungenau. Damit kann ich ohnehin nichts anfangen." Also das kommt selten glaube ich... Es kommt eher wie gesagt diese pauschale Ablehnung aus ganz anderen Gründen, politischen Gründen sage ich mal. (I13E, 01:03:18-0)

In other words, low confidence is a real risk, but one that extensive measures have been taken to handle (e.g. through several steps of involvement of the municipalities, including one of letting them review and comment on map drafts before these count as finished). Judging from the data, these measures are perceived to suffice for keeping this risk at bay.

Moving on to the risk of an under-critical approach, e.g., resulting in unintentional misuse, there is also a form of theoretical recognition of this as something that simulation results in general (but also other forms of data) can be vulnerable to. For example, I12E notes it to be extremely important to document and describe assumptions to avoid giving free reign to speculation as to what is being displayed, as well as for this information to be read and recognized (00:55:34-8). Providing a concrete example, I12E recounts how a figure contained in the 2001 Rhine-Atlas (assumed to represent the value of rural land areas) was re-used for other types of calculations without the user bothering to look up what it really represented. As a result, later estimates of the risk of flooding often over-estimated the value of rural land areas, something that I12E notes can lead decision-makers to consider flood protection measures for locations where this would not be rationally motivated (00:55:34-8). Noting that non-experts in local administrations have a tendency to simply adopt what they are presented with without critical scrutiny, furthermore, I16E sees it as important not to give out an exact figure, but to rather present simulation results in the form of a span:

> Das sind technische Instrumente, da stecken Randbedingungen dahinter. Wenn ich sage 3,42 m, dann weiß der Modellierer, der es gemacht hat, ganz genau: ich habe das Szenario angenommen, ich habe die Kurve angenommen, ich habe die Rauheit angenommen im Gelände. Ich weiß genau, was da drin steckt. Also wie viele Unsicherheiten und [wo] jede Stufe der Modellierungskette herkommen. Und der Sachbearbeiter klickt auf den Tisch, 3,42 m: “Ach 3,42 m, da mache ich bis hierhin. Da mache ich bis 3,42 m einen Objektschutz und dann bin ich auf der sicheren Seite.” Und da sieht man dann halt auch irgendwie, [...] dass man vielleicht auch... ja die Ergebnisse dann auch entsprechend einordnet in Klassen. Dass man eher sagt: “Ja das könnte bis zu so-und-so viel Meter kommen, das Wasser. Das kann natürlich auch schlimmer werden.” (I16E, 00:23:34-1)

In regard to flood hazard maps, specifically, I16E perceives a risk of people focusing too much on whether they are inside or outside the HQ100-line, not realizing or remembering that a less frequent flood poses a risk, too (00:31:25-2). For similar reasons, I18E sees it as suboptimal that it is not more clearly stated that it is only the hazard associated with riverine flooding that is displayed in hazard maps. Without a disclaimer about other forms of hydrological hazards also constituting a threat, people may be lulled into a false sense of security by flood hazard maps:

> I18E: Also das einzige Problem, das ich sehen könnte wäre das Thema, dass die Karten immer nur Flusshochwasser sind. Und dadurch ablenken

> könnten davon, dass Hochwasser überall stattfinden kann. [...] Und dass man dadurch, dass man immer nur an der Flusshochwasser denkt, und da gibt es Gefahrenkarten, dass man vergisst, dass es ja auch Sturzfluten, Flash Floods gibt vom direkten Niederschlag. Also deswegen sage ich mal, das wäre vielleicht ein Punkt, den man tatsächlich ein bisschen verbessern müsste, dass immer zumindest über jeder Karte darüber stehen müsste: "Flash Floods überall möglich" sozusagen. [...] Und also wenn Sie jetzt so fragen, wäre das ein Punkt, wo ich sage, das könnte ein Nachteil von so einer Karte sein. Dass man sich in Sicherheit wiegt in Gebieten, wo es gar keine Sicherheit gibt. [...] Weil es die Wahrnehmung auf ein Gebiet konzentriert und von anderen Gebieten ablenkt. 00:50:24-2

Moreover, it is suboptimal that there are no indications as to the elevation of the land areas depicted as lying outside the likely inundation zones, as this limits people's possibility of assessing the likeliness of *nevertheless* being flooded.[2]

Some experts would like to display more uncertainty information in flood hazard maps directly, only this is not thought to be politically desired or practically possible. For instance, even if I18E would have preferred if the uncertainty of scenario simulation could have been visualized in the form of a buffer zone around the mapped flood lines, this is not something that he thinks the political scene could handle. Instead, he must produce as precise of a hazard estimate as possible in spite of knowing the limitations involved:

> Und das ist natürlich auch einer Herausforderung eine Karte möglichst genau zu machen, aber zu wissen, sie kann auch nicht 100 Prozent genau sein. Auch jede Modellierung hat seine Unsicherheiten... Also ich wäre sowieso immer dafür gewesen, dass man nicht eine Kartenlinie zieht, sondern dass man, wo hier der Fluss ist und hier die Häuser,

[2]Where the terrain is steep, houses located close to the area depicted as being at risk of inundation can mostly count on remaining dry. But, where the terrain is flat, it is more difficult to tell where the water will halt, and even small deviations from the assumed status quo can mean that an area indicated to stay dry is nevertheless inundated. Hence, elevation data for the 'dry zone' would facilitate for map users to assess the eventual seriousness and/or implications of simulation uncertainty.

> dass es nicht eine Linie gibt, sondern dass es so eine Art Puffer gibt zum Beispiel. Wo man noch hier sagt: "Okay, das ist Ungenauigkeitsbereich." Aber damit kann die Politik nicht umgehen. Als Modellierer, ich bin ja Hydrauliker, wäre so was viel besser. Dann kann man noch ein bisschen mit Statistik arbeiten, Wahrscheinlichkeiten, die Unsicherheiten irgendwo mitreinnehmen, wenn es so einen Puffer gibt um eine Linie. Aber die Politik will genau den richtigen Wasserstand und genau eine Linie. (I18E, 00:25:39-1)

Likewise, I12E (01:02:02-9) says that, although not just he but probably all engineers would like to include more uncertainty information, this is not possible when the displayed flood lines are used as a legal instrument to decide where what is allowed respectively prohibited. That there are uncertainties involved in making an exact prediction is nothing that anyone wants to hear:

> Und da muss es eine klare Abgrenzung geben, eine klare Linie geben. Und diese Linie, wenn ich dann sage: "Gut, also sie könnte da liegen, sie könnte da liegen" und dazwischen mache ich so ein Vertrauensband rein, dann entspricht das nicht mehr einer gesetzlichen Vorgabe. Ich muss also klar abgrenzen, da liegt die Linie. Und das muss ich nach meinem besten Wissen und Gewissen machen, obwohl ich eigentlich weiß: "Naja, es könnte da, es könnte da sein." [...] [E]s wird aber erwartet, dass wir so eine Linie ganz klar abgrenzen. Und das machen wir natürlich auch. Aber halt wohl wissend, da ist noch irgendetwas da. Aber das lässt sich sehr schwierig dokumentieren solche Sachen. Das will keiner hören... [. . .] 00:58:20-3

In principle, this suggests recognition for under-critical adoption of simulation results as a real risk. And, yet, none of the interviewed experts appear to think that it would constitute a great problem or pose a serious risk if local-level users would fail to recognize and/or account for the presence of simulation uncertainty in flood hazard maps. As I18E explains, the maps are really quite reliable, meaning that, even if one can discuss the exact course of the flood lines, the scenario overview as such is still a useful form of guidance:

> I18E: Ich glaube für einen größten Teil hat das nicht so die Bedeutung, weil wenn dann geht es ja nur um die Grenze. Also der Großteil ist ja schon sehr belastbar, einer Karte. Also es ist nicht so, dass (in) eine Ortslage ganz viel überschwemmt ist und die Ortslage ist überhaupt nicht gefährdet. Also zumindest bei den Karten in Baden-Württemberg wird es das nicht geben. Es wird immer nur darum gehen, ist das Gebäude auch noch? Oder das Gebäude? Oder die Trafostation? Der ganze Rest, also der Großteil der Karten ist ziemlich eindeutig. [...] Und dann beginnt ja die ganze Diskussion. Und das ist ja das Wichtige. [...] 00:40:16-7

Furthermore, as both II18E and I12E point out, even an imperfect product can generate awareness and discussion. Hence, it would be unreasonable to abstain from mapping just because all flood sources cannot be accounted for or because the resulting picture will be somewhat uncertain (e.g. I12E, 01:06:48-9). Besides, there is not that much in the hazard maps that can be misunderstood as I16E sees it. In his experience, what is vulnerable to misuse is rather when some form of numerical digit is produced that people might misinterpret or re-use without understanding where it comes from:

> Aber jetzt das direkte missverstehen... Eigentlich nicht.. Deswegen, ich denke Missverständnisse gibt es immer dann, wenn klassifizierte Werte da sind. [. . .] [W]enn ich jetzt sage irgendwie, ich habe einen... Schadenswert von 0-200 Euro, von 200-4000 Euro und... von, weiß ich nicht, über 5000 Euro, über 4000 Euro. [. . .] Und da ist aber dann, [...] je nachdem, was man halt wählt, auch eine Gefahr darin... [. . .] Ich nehme jetzt die umweltrelevante Anlage als sozusagen Vulnerabilität hoch und stufe den ganzen Bereich auch als hoch ein. Also so, solche Sachen können dann irgendwie passieren. Aber bei dem, bei der Hochwassergefahrenkarte selber... ist vielleicht höchstens das Missverständnis da, was dem zu Grunde liegt. [. . .] 00:48:26-0

Furthermore, apart from the hypothetical risk of people being lulled into a not quite justified sense of security, there is no clear idea of why it would be problematic if people would fail to comprehend or account for the presence of uncertainty. At least in I13E's view, it is not too much but too little trust that poses a risk:

> Nein, wüsste ich jetzt nicht, was, was daraus entstehen könnte... Also eher das wenigere Vertrauen, das macht einem dann Probleme natürlich... (I13E, 01:08:59-9)

What concerns him, in other words, is not that scenario simulation results will be misused but that they will not be used at all.

In many cases, it is thought to suffice if people understand that *some* uncertainty is present respectively that what is displayed is a prognosis; a form of snapshot in time, rather than certain prophecy (i.e. I11Eb, I12E and I17E). As I13E sees it, it is only when local administrations question or make a fuss about the hazard maps that it is important to explain the technical details to avoid a loss in confidence (00:57:11-2). In a world of increasing specialization, I16E points out, it must be legitimate to work also with outputs that one does not oneself have the expertise to assess. As long as one understands the 'dimensions' of uncertainty involved, one can still make good use of them:

> Also dass man die Größenordnungen, in denen es sinnvoll ist zu denken, dass man sich die mal vor Augen führt. Das ist, denke ich mir, notwendig. Ansonsten, wenn man so etwas, solche Gedanken sozusagen berücksichtigt, ist es absolut legitim, denke ich, mit Modellergebnissen zu arbeiten, auch wenn man sie nicht komplett... durchschaut wissenschaftlich. Darauf ist man angewiesen auch, also... dass man nicht immer jede Information auch sozusagen bis ins kleinste Detail nachvollziehen kann irgendwie... (I16E, 00:51:30-8)

Indeed, the idea of getting end-users to account for simulation uncertainty is not thought to be quite realistic. According to several experts, end-users lack both interest and competence when it comes to engaging with uncertainty information. In municipalities where the same person is responsible for building planning and the local finances, I14E points out, the competence required for understanding the documentation provided together with the hazard maps is often not present (2h+00:16:26-9). Similarly, I13E's experience is that it is 'futile' to try to explain the basis of flood hazard maps, e.g. because it is only in municipalities of a certain size that the necessary know-how for a constructive discussion is present. While he and his colleagues always underline that the displayed flood lines represent various carefully calculated *scenarios*, anything beyond that is difficult:

> Das ist aussichtslos. [...] [W]ir versuchen klarzumachen, es ist ein Szenario und es ist so gut, wie es irgendwie geht. Wir haben einen Riesenaufwand in der Vermessung. Wir haben einen Riesenaufwand in der Modellierung. Wir sind also wirklich ganz genau unterwegs. [...] Aber... Mehr, mehr können wir nicht kommunizieren. Weil mehr ist einfach... fehlt der Hintergrund oder es ist dann, man merkt auch deutlich, wenn man da ein bisschen ins Detail geht im Gespräch, dann kreist das Auge des Gegenüber plötzlich irgendwo durch die Gegend und man hört angestrengt noch zu, aber es erreicht ihn nicht mehr. (I13E, 00:55:16-7)

Hence, even if simulation results in general are complex and easy to misuse, there is no perception of this as a risk that flood hazard maps are sensitive to: the uncertainties are fairly limited; there are few concrete values to re-use in unsuitable ways; and there is no clear idea of what a failure to consider uncertainty information could lead to. Ultimately, then, there is not only a lack of observed examples of misuse in the data material but also a lack of risk perception amongst technical experts when it comes to this as something to worry about.

Is there anything speaking against this view in the rest of the data material? Indeed, at least in a theoretical way, one could argue that there is. In the case of the mayor in interview 03, the situation is namely one of simulation uncertainty *not* having been accounted for when looking upon the predictions displayed in flood hazard maps:

> Wobei ich jetzt auch sagen muss, über die Messgenauigkeit hatte ich mich jetzt vorher so intensiv nicht informiert. Das kann durchaus sein,

> dass es vorher auch schon mitkommuniziert wurde, ich es dann aber einfach nicht als Information aufgenommen hatte. (I03RM, 00:47:19-7)

In I03RM's view, no one takes the time to read the fine print of the complementary documentation delivered together with the flood hazard maps. Only if something happens that indicates that what is displayed might not be quite accurate or reliable will an effort be made to learn of eventual uncertainties involved:

> Das ist denke ich auch immer das Wichtigste, dass man dann nicht 300 Seiten Information bekommt, die nachher sowieso keiner lesen kann. Sondern, dass man dann eher, wenn man eine konkrete Frage hat, Auskunft bekommt bei der entsprechenden Stelle. (I03RM, 00:53:26-0)

Though difficult to classify as an example of misuse since I03RM denies any use at all having been made of hazard maps for planning purposes, what happened in this case was that parts of the city (including a building of importance to the emergency response operation) ended up standing knee-deep in flood water although they had been predicted to stay dry according to the simulation results displayed in the flood hazard maps. While it would be wrong to portray this outcome as a consequence of not having accounted for simulation uncertainty in preparedness planning, then, it does show the potential for real nagative consequences if predictive information is treated as absolute 'truth' instead of being recognized as containing sources of uncertainty.

Considering that there is one example in the interview material speaking against it being completely free of risk to disregard simulation uncertainty, this gives raise to the interesting question of how come experts in practice do not seem to agree with experts in academia that it is vital for end-users to understand and account for the presence of simulation uncertainty? Which of the above stated reasons is the decisive one? And what does it depend on if a high level of uncertainty awareness is important or not?

Chapter 9

Discussion

9.1 Discussion per research question

In light of academic literature showing the potential benefits of simulation to not only depend on *whether* but also on *how* such evidence is used, three research questions were formulated to guide the study of simulation-based flood hazard maps as tools for local-level risk management in Baden-Württemberg. These concern how this type of information is used (including options of misuse and non-use); what affects whether it is used or not; and what benefits and problems are experienced or observed. In each of the sections below, it will be discussed what the findings in chapters 6 to 8 suggest are the answers to these questions, before a concluding remark is made in relation to the study's overall research interest.

9.1.1 How flood hazard maps are used

In chapter 3, a distinction was made between ideal use, misuse in the form of reliance on 'bad' research or illegitimate use of 'good' research, and more or less illegitimate forms of non-use. At the same time, it was also argued that different actors can have different views as to what is legitimate or illegitimate, respectively that it can be situational when a form of application should count as the one or the other. Hence, it was decided *not* to study the presence or absence of these categories in absolute terms, but to explore different actors' perceptions of the use or non-use made of flood hazard maps.

Beginning with the issue of use, it is worth reiterating that research use can mean different things. One of the simpler models (and the one relied on by J. Bradley Cousins for describing different forms of ideal use) is the ICS-framework differentiating between instrumental, conceptual and strategic research use. In chapter 4, it was shown that formal descriptions of how flood hazard maps should support local-level risk management commonly emphasize knowledge-driven instrumental research use, intending for foresight to *inspire* activities in relation to all four management fields.

Judging from the results presented in chapter 6, flood hazard maps are indeed used in line with what official sources prescribe (see chapter 4). Empirically, some kind of direct application has been identified in relation to all four management fields, including in the following forms:

- Technical protection: decisions to reinforce and extend existing structural defenses;
- Emergency management: main input to preparedness planning and/or inclusion as appendix;
- Non-structural alleviation: restriction of land-use, withdrawal of building rights from areas at risk, incorporation in GIS;
- Risk communication: presentation ceremonies and organization of public meetings and information evenings.

Not all of the use described by the interviewed risk managers was driven by the arrival of new knowledge about the local hazard situation, however. Apart from the case of interview 02, where several forms of direct application followed upon simulation results showing the municipality to be less well-protected and less well-prepared than hitherto assumed, it has often been something else that has motivated the decision to make use of hazard maps. For example, much use is linked to legal requirements and official regulation. In other cases, usage has been pushed for from above or helped along by external policy processes calling attention to a problem.

In effect, this suggests comprehensive management reform to be a rather peripheral form of effect. Rather than challenging the status quo, flood hazard maps are often associated with a new and/or better kind of overview of the local hazard situation without this necessarily implying any real surprises. Likewise, it is relatively rare for them to be linked to the initiation of new measures and activities or to a change in focus or attention. More common is that they are applied within the scope of already established activities. Often, this form of use is of a more long-term consultation character than a one-off decision situation. Or there is a knowledge effect without it being completely clear what consequences this will have in the long run. Examples of more conceptual forms of uses within each management field include:

- Technical protection: contributing to a reassessment of the sufficiency of current defenses; starting an indeterminate thought-process;
- Emergency management: serving as one input amongst others to preparedness planning which would have been carried out anyway;
- Non-structural alleviation: being consulted together with data on other relevant aspects in relation to routine administrative errands – just like other available hazard information before them; being consulted to help local administrations exclude that flood risk constitutes an obstacle to local development plans;
- Risk communication: facilitating information provision when local citizens inquire about flood risk.

Thinking of risk management as an *ongoing process* of dealing with recurrent errands, consulting relevant information, learning and optimization, it becomes clear that scenario simulation results will often constitute one source of input amongst others. Sometimes they will play a larger role, sometimes a smaller one (such as when the risk is low or other arguments weigh heavier). Mostly, though, this form of use is about foresight information helping local-level risk managers do better what they would be doing anyway.

Additionally, there is a number of instances in which flood hazard maps have played a more strategic role (without this necessarily implying *selective* use of the kind suggested by the original definition). Apart from the field of emergency management, this form of use has been identified in relation to all management fields:

- Technical protection: illustration of the seriousness of local flood risk to legitimize pre-formulated plans for structural defenses and/or reduce local opposition to the same, private validation of the soundness of made plans;
- Non-structural alleviation: illustration of the seriousness of local flood risk to get private individuals to follow the administration's preferred policy of keeping high-risk areas free of construction;
- Risk communication: external presentation of research to build confidence in public authorities, respectively forestall negative reactions and maintain good public relations.

Though such forms of use are not what official documents emphasize, they are nonetheless part of what risk managers appreciate about being provided with a graphical representation of flood hazard. Here, focus is not placed on what is learned from or decided on the basis of simulation results, but on their usefulness for confirming respectively conveying specific ideas or pre-defined plans to others.

To summarize, this means that the ICS-framework has been useful for distinguishing between different forms of use made of flood hazard maps. At the same time, it has also shown some of its limits and weaknesses. For example, not all policy and administrative processes have the character of one-off events. Though a phenomenon like recurring consultation can be included under the headline of conceptual research use, as has been done here, this leads to new difficulties in terms of keeping the meaning of the different categories stable and clear, as this – strictly speaking – falls beyond the original description. In this sense, there is a conflict between the complexity of the field and the rigidity that it implies to draw on pre-fabricated concept categories.

As pointed out in chapter 3, different forms of use will often interact and build on each other, so that the way a person or organization has used research resembles a fluid process of different forms of applications and effects rather than something that falls squarely into a single category. In the case of the flood hazard maps, direct application to decision-making was often the consequence of a conceptual knowledge effect about the necessity of taking action. In other instances, the objectively establishable application of integrating new findings into an existing database was what enabled these to influence other actors' understanding of the local hazard situation and allowed for regular consultation. Furthermore, strategic ulterior motives can accompany different forms of more direct application. In this sense, it is indeed questionable to regard instrumental, conceptual and strategic research use as distinct and separate categories. A better option could be to think of them as *ideal types* and to openly discuss forms of use falling inbetween or not fitting the picture. In this study, such an example concerns when research is used for communication purposes without this necessarily or only corresponding to a strategic form of application. In several cases, flood hazard maps have been used to enlighten people about local flood hazard to allow them to make informed choices without this corresponding to an attempt to advocate a clearly defined political position. Though this, too, is a way in which research can be used, it does not correspond to any of the existing categories of research use.

Another thing that this study has shown is that, as already noticed in KU-theory, it is not always suitable to think of instrumental research uses as the ultimate goal. At least when it comes to the field of risk management, there is often a difference between *knowledge* utilization and *research* use in the sense that where knowledge of the risk of flooding has already been accounted for there is not necessarily much need for direct application of new findings. Put differently, the absence of instrumental research use can be a positive signal if it reflects a high level of preparedness and no particular weak spots. Moreover, there is a difference between instrumental one-time application and lasting reform. In this sense, the aim of research use is not direct application of individual findings but policy and practice that is sensitive to and accounts for the current state of knowledge while being open to the idea of this being something that evolves and requires adjustment.

Regarding the option of misuse, this can pertain either to – willful or unintentional – use of research of inferior quality, or to – willful or unintentional – misinterpretation and/or distortion of research of high quality. In this regard, the fact that the hazard maps are generally thought to represent a case of 'good' research means that the first of these categories is of little relevance. Moreover, though the second category is, theoretically, something that could lead to concrete negative effects, this is nothing that any of the interviewees have experienced, observed or heard of. While recognizing that risk managers without technical skills will often accept flood simulation results uncritically (i.e. in trust), there is no perception of this as a significant problem and no concern about it leading to specific undesirable consequences. In this sense, there is a difference between the way the risks of simulation use by non-experts is framed in academic literature and how this is regarded by technical experts active in the field. (The nature and implication of this difference will be returned to in the discussion of the overall research interest.)

Turning to the issue of non-use, finally, chapter 3 distinguished between illegitimate and legitimate non-use. Illegitimate non-use is described as the willful act of sweeping evidence under the carpet for self-serving purposes, whereas legitimate non-use concerns both non-use of 'bad' research and non-use of 'good' research if this is, e.g., untimely or irrelevant (so called *rational* non-use) or if changes in the decision context respectively presence of competing information makes it obsolete (so called *political* non-use).

Looking at the results, we see that risk managers tend to frame their own acts of non-use as rational and justified. Only in the case of interview 02 is it recognized as 'unfortunate' that some forms of use have not been continued or not yet initiated. In the rest of the cases, aspects related to timing, knowledge saturation, lack of relevancy, resource scarcity and political context are described to alleviate the need for flood hazard maps or for there being anything to apply them *to*. Per management field (apart from non-structural alleviation, for which there were no instances of admitted non-use), this looks as follows:

- Technical protection: non-use due to plans for structural protection already having been made or currently being implemented (i.e. timing), or due to political cost-sharing challenges obstructing management altogether (i.e. decision context);

- Emergency management: non-use since current plans already cover what simulation results show (i.e. information saturation), because current practices and local experience suffice (i.e knowledge saturation), because risk is low or the means to preventing damage lacking (i.e. translating into low relevancy for there not being any need), or as a result of hazard maps not covering the risk of highest concern (i.e. low relevancy);

- Risk communication: non-use for large-scale communication efforts due to lack of human resources (i.e. political context), low risk (i.e. translating into low relevancy for there not being any need), or sufficient local awareness (i.e. knowledge saturation).

In contrast, when risk managers or experts refer to non-use elsewhere or at a more aggregate level, this is more commonly framed as problematic and undesirable. A 'regrettable' lack of application is referred to in relation to all management fields apart from technical protection (in relation to which usage is either thought of as less relevant or still expected to follow over the next few years):

- Emergency management: non-use due to lack of awareness of legal requirements, general failure to prioritize crisis preparedness, change in local leadership leading to new priorities (i.e. political context), lack of skill;

- Non-structural alleviation: under-use due to political priorities of growth, expansion, trade-taxes, etc.;

- Risk communication: non-use for large-scale communication efforts due to unwillingness to draw attention to bad news or not wanting people to doubt that everything is under control, because of lack of skill and/or external support, for the reason of not believing anybody to be interested in listening.

In effect, this means that, even if there is use in the direction of what official documents expect and prescribe in relation to all four management fields, there are also those who think that the level of use is too low and the impacts disappointing. Rather than being enthusiastic about being provided with foresight information and the ability of taking proactive action, political decision-makers and administrative risk managers are noted to sometimes regard simulation results as a nuisance respectively fail to see their benefit. In the field of risk communication, moreover, there is not only a gap between the desired and observed *level* of application but also between the desired and observed *form* of application. Though in theory regarded as a suitable tool for awareness-raising for the sake of motivating more risk acceptance, less reliance on public authorities and more self-responsibility for flood protection, the situation in the interview sample is one of many local administrations actively avoiding such use or drawing on flood hazard maps to advocate for a structural solution rather than for adaptation. Rather than regarding the risk of flood hazard as something that the public has a right to know about and act upon, it is treated as a political risk factor; something that can raise doubts as to whether or not the administration is doing a good job. This is noteworthy as it suggests a discrepancy between the official wish for risk management to be regarded as a shared concern rather than as the responsibility of the public authorities and the attitude and activities on the ground in the municipalities in Baden-Württemberg (cf. Kjellgren, 2013).

9.1.2 Factors affecting whether flood hazard maps are used

The second research question concerns what factors affect whether or not simulation results are used. In this regard, one thing that the results show is that it is not possible to specify a single main factor leading to use or non-use of flood hazard maps. Instead, different management fields are characterized by different mixes of factors. Somewhat simplified, one might say that in the field of technical protection flood hazard maps were used where an unexpectedly high risk was or had just been discovered, whereas non-use was the outcome when a plan for dealing with an undesirable risk level was already in place. In relation to emergency management, low risk perception or already having a plan or 'enough' knowledge and experience discouraged use, whereas a high risk perception and openness towards optimizing the local preparedness plan supported use. In the field of non-structural alleviation, complete non-use was not present, but negative attitudes towards hazard maps were thought to be linked to local political interests and a preference for growth and expansion, whereas positive attitudes were tied to such tasks already being performed and hazard maps thought to facilitate this. Regarding risk communication, finally, the idea of using hazard maps for large-scale awareness-raising was resisted where risk managers could not see what advantages this would bring or expected negative results, whereas it was welcomed where risk communication was associated with an opportunity rather than with a risk. At the same time, especially the experts were of the view that there were also background factors of a more general nature influencing map usage.

On a theoretical note, chapter 3 presented two different strains of 'factors affecting'-literature. On the one hand, it was suggested that research use depends on the audience's perception of findings as salient, credible and legitimate, whereby the relevancy of the legitimacy category was also suggested to be somewhat questionable. On the other hand, findings from the field of KU studies emphasize factors related to personal characteristics, research characteristics (including relevancy and research quality), user-producer linkage, and contextual factors. Thinking of the results presented in chapter 7, there is support for each of these categories in some kind of way:

> **Credibility**: Flood hazard maps are regarded to be of high quality or a better guide to flood risk than previous assessments, and this is noted to be important for risk managers to want to use them;
>
> **Saliency**: Cases of use are often associated with a perception of flood hazard maps as salient for the task at hand or for having questioned the status quo, whereas cases of non-use are sometimes linked to a perception of flood hazard maps not showing anything new or covering the right form of risk (i.e. suggesting that the content of the maps is of low relevancy) or there not being any need for them or any real sense in using them (i.e. suggesting that the external circumstances reduces their relevancy);
>
> **Legitimacy**: Whether there is a history of trust or distrust between a municipality and higher administrative levels (though this is not noticed to

affect the perception of the research process as fair as much as whether or not the end-product is accepted as credible);

Personal characteristics: Risk managers with low skills are less able to scrutinize flood hazard maps and make an informed assessment about whether or not to trust them and can also lack the know-how about how best to apply them;

Research characteristics: Apart from aspects related to quality and relevancy, the flood hazard maps' format is appreciated for making them user-friendly;

User-producer linkage: Stakeholder involvement in the development and design phase is noted to have helped create ownership and a product that answers towards the intended users' needs, while continuous contact throughout the research process and a chance to review the draft maps before these are finalized is something that facilitates acceptance of the end-product as credible;

Context: What political interests dominate, the personal engagement of local leaders, and whether or not local administrators champion flood simulation results to be considered by the municipal council.

While supporting the relevancy of categories identified in previous literature, the problem with such a list is that it fails to clarify the relationship between the different components. Hence, a different way of organizing or making sense of the empirical findings is required.

To this end, an inductive analysis was undertaken. The result of this is the proposition of three overarching factors as important for whether or not flood hazard maps will be used: (a) whether or not users perceive themselves to *need* hazard information, (b) whether or not flood hazard maps are accepted as an appropriate tool in this regard, and (c) whether or not contextual conditions and background factors support or obstruct a perception of needing respectively accepting hazard information. Hence, rather than being isolated from each other, these are aspects which partially influence and depend on each other.

a) Users' perceived need for information

Throughout the interview material, there is a number of indications of it mattering whether or not a risk manager perceives himself, or his community or management field to need the kind of information provided by flood scenario simulation. In this regard, not less than five different aspects were identified to play a role in the interview material, reflecting that an outcome of use or non-use will rarely depend on one factor but the consideration of many interlinked aspects.

First, *risk perception* mattered in the sense that risk managers who appraised the threat of flooding as low (normally in terms of frequency *and* damage potential) also perceived a low need for flood hazard maps in relation to a management activity. In contrast, being or recently having been alerted to weaknesses in current flood defenses (implying a change in risk perception from low to high) increased an administration's interest in hazard information. Hence, risk perception is not a static category, but one that can suddenly change.

Second, risk managers' *attitude* and/or *openness* towards a certain activity or measure affected whether or not they perceived a need for hazard information. A telling example of this is the effect of different attitudes towards large-scale risk communication. In some municipalities, there was no expectation of such a measure being effective or leading to anything positive, whereas, in other areas, dialog was seen as a basis for good public relations; as something helpful. Another example concerns the low interest in new evidence in areas where a management plan was already in place or currently being implemented, reflecting a limited openness to re-open already handled policy items. In this sense, attitude is both about whether or not a management activity is expected to be effective and about timing in the sense of whether or not it has already been crossed off the list.

Third, a risk manager's *assessment of viability* of carrying out a certain activity or of doing so successfully mattered. In the field of emergency management, for example, interest in learning where flood damage is likely to occur was limited by the fact that the fire brigade did not have the means to prevent it anyhow. In other instances, lack of time and (e.g. human) resources meant that, even if one would like to pursue a certain activity, it was not always regarded as possible. Additionally, lack of know-how and external support were things which reduced the need for flood hazard maps if it meant that the audience did not know how to use these in a good way and not end up making things worse.

Fourth, *perceived sufficiency of already available information and knowledge* played a role in the sense of the need for hazard maps being lower where relatively up-to-date hazard assessments were already available, respectively where experience and established routines were thought to suffice. At the same time, this is not necessarily a question of actual quantities; in some instances, much knowledge and information was already present without this being regarded as sufficient or as alleviating the relevancy of a new assessment.

Fifth and finally, *awareness of legal requirements* for a certain management activity would sometimes produce a need for hazard information, whereas unawareness of the same meant that both the target activity and the tool were regarded as somewhat obsolete.

Apart from the last two points, the rest of this category bears certain likeness to Protective Motivation Theory (e.g. Grothmann and Reusswig, 2006). According to this socio-psychological model, residents at risk will respond to a threat on the basis of two major perceptual processes: 'threat appraisal' and 'coping appraisal'. The first of these consists of perceived probability and severity of exposure, together with a subcomponent of fear. The second consists of a person's belief in the effectiveness of protective actions, in their own ability to perform these, respectively assumptions about what costs (money, time, effort) this would require.

b) Users' acceptance and assessment of flood hazard maps as appropriate information tools

Following the lead of previous literature, it does not suffice for there to be a need for information, but the information that is available must also be perceived to correspond to this need and to constitute a reliable source of information. In regard to the flood hazard maps, the latter of these two criteria was not found to constitute a problem to any of the interviewees whereas the former was something of an issue in some instances.

All of the risk managers described the hazard maps to be of high quality and/or to offer a credible representation of local flood hazard. In line with the description in chapter 3, these actors' arguments for sanctioning belief in the hazard maps' credibility followed over different tracks, including efforts to assess the underlying data, method and research effort, comparison with other sources of information, and proxies of trusting the state or responsible engineers. For this reason, a contaminated relationship with higher-level authorities was raised as something that can obstruct acceptance.[1]

With regard to relevancy, a perception of flood hazard maps as a suitable tool for a certain management activity was often – but not always – linked to use whereas a perception of them being of limited relevancy for the same was linked to non-use. Aspects that made the interviewed risk managers regard flood hazard maps as suitable tools included: when simulation results reveal an unexpected level or risk, thereby challenging the status quo; the provision of new or better (as in more exact, reliable or up-to-date) information about local flood hazard compared to previous assessments; and a format that makes the information easy to access without requiring any extra work or departure from established routines. In contrast, things that were perceived to reduce their relevancy included: that they contain technical terminology about statistical return periods instead of gauge level data that people are more familiar with; when they fail to cover sources of flooding of local concern; and when their content fails to offer any new information in comparison to what was already known.

c) Contextual conditions and background factors

Contextual conditions and background factors can affect risk managers' perception of needing hazard information respectively seeing flood hazard maps as a suitable tool in both positive and negative ways. In this regard, the interview material contained references to five different kinds of factors.

First, *personal and agency interests* are a form of contextual background factor that affects local leaders' priorities and interest in risk management. In some areas, openness towards certain forms of management measures is limited because these are perceived to stand in conflict with local political interests. Elsewhere,

[1]Though pre-existing mistrust is described by Mitchell et al. (2006a) as something that can jeopardize the perception of research as legitimate, here it was found to be related to whether or not hazard maps will be accepted as trustworthy rather than whether or not they should be regarded as fair (i.e. reflecting on their credibility rather than on their legitimacy).

risk management is part of the local agenda and political tradition, or part of what the mayor defines as important (in which case the relationship between the mayor and local council may also play a role in terms of affecting whose agenda wins out). In this regard, there is a link between what the local interest definition looks like and whether or not there is openness towards particular management activities.

Second, *flood experience* is noted to affect both risk perception and the definition of what lies in a community's best interest. Frequently affected municipalities have often learned to live with flood risk and, e.g., not be afraid of using hazard maps for communication purposes. In contrast, municipalities lacking such experience will not always regard it as necessary to invest time and effort into management measures. Hence, the occurrence of a flood episode is something that can quickly lead to a new kind of openness towards management reform.

Third, a community's *resources* play a role in the sense of affecting whether particular management measures are (perceived to be) viable or not. In this regard, a community's size is sometimes of importance, as large administrations are often able to employ more people with higher skill sets and as technical protection can be too expensive for small townships.

Fourth, *linkages and relations* are important both for developing a product that corresponds to the intended users' needs and requirements and for increasing the chances of it being accepted as methodologically sound. Considering that higher-level authorities will sometimes serve as knowledge brokers between municipalities and contracted engineering bureaus, furthermore, it matters whether the chances of a constructive dialog are high or low in the sense of there being a good or a strained relationship between different offices or levels. In the empirical material, the following things related to user-producer linkage were specifically mentioned: that the municipalities' financial involvement created ownership; that the municipalities' presence at the table from the start allowed them to express ideas and needs in terms of content and design; that the municipalities' involvement at several different stages throughout the mapping process was productive; that the Flood Partnerships offer institutional support in the form of information meetings and a chance at best-practice exchange; and that the municipalities' involvement in the plausibilization process reduces the risk of these containing errors while at the same time allowing intended users to learn about and gain confidence in the mapping method.

Fifth and finally, the *legal framework* can play an important role for research use in the sense of making activities for which hazard maps constitute a relevant source of input mandatory. In this sense, it has the capacity to overrule the necessity of users being open towards a certain management activity or considering it worthwhile to prioritize.

If the results of the empirical analysis are sorted in this way, it becomes clearer what different kinds of deliberations and factors affect whether or not foresight information is used while still recognizing the core importance of research being perceived as credible and salient. In line with Protection Motivation Theory, the implication of this is that instances of insufficient protection and preparedness often cannot be alleviated through information provision alone. Though a mistakenly low risk perception is sometimes part of the picture, lack of action and attention can also be related to local leaders not wanting to recognize risk as a priority problem or to risk managers lacking the means or know-how for addressing the same. In the interview material, this is indirectly recognized and reflected in statements emphasizing other measures and tools, too, as important for boosting local management reform (e.g. the EU requirement for flood risk management plans, the work pursued in the Flood Partnerships, and effects of different forms of legal requirements and regulations). Moreover, the similarities between the components of Protection Motivation Theory and the factors identified to affect risk managers' perception of needing information are interesting for indicating that not only private actors but also public officers can suffer from low risk perception and protective motivation.

9.1.3 Benefit and problems associated with flood hazard maps

The final research question concerns the benefits and problems associated with introducing flood hazard maps to be used by local-level risk managers. Even if there are no specific models or typologies of the positive effects of research use as this is a somewhat under-studied topic (cf. James and Jorgensen, 2009), chapter 3 noted that research can, e.g., offer evidence, ideas and concepts; reduce areas of uncertainty or lack of knowledge; confirm knowledge of tacit, local and indigenous character; identify issues requiring public policy or management attention; guide and legitimize decision-making, etc. In addition, chapter 2 described graphical formats to be associated with advantages in terms of being more immediate, awakening more interest, being more convincing, etc. At the same time, there is also the risk of non-use and of insensitive or misinformed use leading to negative effects.

Looking at what the results chapters tell us about what the interviewees think of the introduction of scenario simulation results as input to flood risk management, we see that both the risk managers and experts offer predominantly positive assessments of this. In the case of the risk managers, the reasoning in this regard is relatively concrete, referring both to first-hand experiences and specific tasks for which hazard maps are relevant. In contrast, the experts' arguments are often tied to hopes and expectations about what flood hazard maps *will* or *should* affect, not only in regard to specific tasks and activities (i.e. instrumental use) but also with regard to such conceptual and overarching effects as: higher risk awareness, attitude change, higher priority for flood risk, shift in focus from flood control to adaptation, more municipal cooperation, etc. This points to a difference between the two groups in the sense of risk managers mostly appreciating simulation-based flood hazard maps for supporting risk management as it *currently* works, whereas the experts often focus on what access to graphical foresight information might *change* about local-level flood risk management, framing it as a tool for implementing a new management paradigm.

Regarding what benefits are observed and experienced, more concretely, many of these do indeed correspond to the aspects noted in chapter 3. They concern flood scenario simulation's usefulness for providing some form of information advantage compared to previously available evidence, offering guidance and relevant input to decision-making and planning, and being helpful for legitimizing and promoting favored management solutions internally and externally. In short, this category can be referred to as *benefits of knowledge, guidance and persuasion*. An overview

Information and knowledge benefits:

- Providing a new or better 'overview' and understanding of the local hazard situation, thereby allowing for more clarity and certainty;
- Making flood risk more palpable and less abstract by *showing* which areas are at risk;
- Reducing lack of knowledge and uncertainty by providing a more up-to-date, detailed and scientifically solid hazard assessment than what was previously available;
- Confirming local and tacit knowledge, respectively provide solid evidence for the same;
- Facilitating access to and internal dissemination of hazard information.

Management and decision-making benefits:

- Helping risk managers identify issues requiring political and administrative attention, e.g. by revealing hazard hot spots and previously unknown weaknesses in defenses and preparedness;
- Offering guidance in terms of where to allow for construction, where to stipulate particular conditions, where to survey river banks, what emergency scenarios to prepare for, which residents to inform, etc.;
- Enabling the authorities to approach problems and tasks more effectively;
- Helping public officials confirm the soundness of planned measures.

Persuasion and awareness-raising benefits:

- Helping local administrations legitimize, build support for and reduce objections to planned management measures;
- Facilitating the communication of the existence of a flood risk respectively making such a risk more difficult for both internal and external audiences to deny.

Figure 9.1: Overview of main benefits identified

of the main forms of benefit within each of these categories is included in Figure 9.1.

These benefits largely correspond to the functions that scientific knowledge is traditionally expected to fulfill. At the same time, they do not represent the full picture. In addition to the more expected benefits, there were also several advantages mentioned which are best categorized as *benefits of pressure and restriction.* Amongst the risk managers, these mostly consisted of flood hazard maps limiting the capacity of local political actors to disregard the threat of flooding in favor of other interests, respectively that reliance on a scientific method which it is difficult to question limits the chances of local land-owners and business interests to argue against floodplain designation. Similarly, external observers emphasize that the threat of being held accountable for not having taken action in spite of knowing of the risk of flood hazard *pressures* local administrations to become more active, and that basing hazard assessments on simulation technology removes the floodplain designation process from the municipalities' sphere of influence, limiting their chances of manipulating it. Additionally, by alleviating the need to negotiate the floodplains with the municipalities, the introduction of automatic land-use restrictions for areas shown to be at risk from a certain flood scenario is observed to have helped the state place larger areas under protection more quickly than what would have otherwise been possible.

In effect, this means that one can differentiate between flood hazard maps' overt purpose of supporting local flood risk management and a more latent function of pressuring local administrations to acknowledge flood hazard and restricting their ability to ignore this and prioritize other interests.

In terms of the interviewees' overall assessments of the hazard maps, reservations and critical remarks commonly concerned that these are associated with high costs and efforts, suggesting that cost-benefit balance might not always add up (especially where flood risk is low or much information already available). Since these aspects were mentioned in both interview groups, both risk managers and experts can be said to find flood hazard maps good in principle, while at the same time recognizing that there are also places and circumstance under which they make less sense. For less affluent states, this implies an implicit recommendation to take the time to evaluate where hazard frequency, exposure and damage potential justify hazard mapping rather than to map all waterways per default.

With regard to actual problems, two things were mentioned: first, that flood hazard maps are under-used or not having as much impact as hoped for, and, second, that their arrival is also associated with a risk of unintended negative effects. Concerning the latter point, actual experiences of negative effects were rare. What dominated the interview material, instead, was concern about the *possibility* of hazard information producing negative effects (primarily in terms of private actors being disproportionately affected by impacts on real estate prices, insurance conditions or building rights). With regard to the former point, this shows that it is not *how* the hazard maps are used that is causing concern, but the issue of *whether* they are applied to help improve local risk management in the first place. For example, many local administrations are perceived to do little beyond what is formally required, to continue to prioritize other interests, and to still need to experience flooding first hand to become motivated to act.

To summarize, this means that, where they are used, the results of flood scenario simulation are appreciated for supporting and improving local flood risk management in Baden-Württemberg. Contrary to how the idea of acting in foresight rather than hindsight is sometimes framed in theory, though, the way they do this is not necessarily by triggering comprehensive reform or a novel interest in risk management where this was lacking. Instead, it is often by helping risk managers and administrations for whom and which risk management was already on the agenda to do better what they were basically interested in doing anyway that flood hazard maps are perceived to make a difference.

9.2 Implications for the overall research interest

Regarding problems reported in academic papers about non-experts' dealings with simulation results, this means two things.

The risk of over-criticalness leading to non-use: Although flood hazard maps are indeed found to be somewhat vulnerable to problems of under-usage, there is nothing in the interview material that ties this to risk managers taking an over-critical approach to scenario simulation or to a lack of confidence in flood modeling. Though there is recognition in the expert group for lack of confidence being something that *could* constitute a problem, e.g. if users are confronted with hazard assessments which do not correspond to local experience without this being explained, active efforts are perceived to keep this risk in check. For example, official directives specifying detailed requirements for the scenario simulation and mapping processes lower the risk of assessment results of questionable quality being issued. Moreover, the involvement of the municipalities in the plausibilization process contributes to lower the risk of errors being overseen, at the same time as it allows the target audience to learn of and confirm the quality of flood simulation output. Hence, local credibility doubts can normally be resolved in a process of constructive dialog, and it is only where the hazard maps are resisted for political reasons that the presence of disagreement and scientific uncertainty become ammunition in a battle against research use.

The risk of under-criticalness leading to misuse: Though there are a couple of comments about negative effects, none of these can be tied to flood hazard maps having been misused. Generally, there are no experiences or observations of flood simulation results being used in questionable or problematic ways. Yet, this is not the same as to say that there are no indications of under-critical acceptance. Although local officials are generally thought to be aware of the presence of *some* uncertainty, it is also noted that small communities rarely posses the competence to engage in constructive dialog as to what underlies the displayed predictions or how plausible these are. Among the risk managers, this was corroborated by the fact that some interviewees had never contemplated the credibility of flood hazard maps prior to being asked or actual flooding occurring. In theory, this implies a risk of inferring safety where this may not be justified with regard to the assumptions and uncertainties underlying the displayed flood lines, and a risk of black-box use in the sense of hazard maps being drawn on for planning and decision-making without consideration for simulation imprecision. Rather than regarding this as a potential problem, however, uncritical acceptance was largely 'sanctioned' by the expert group. Not only was it regarded as unrealistic to expect local-level actors to comprehend the details of scenario simulation but it was also portrayed as a lesser evil to over-trust simulation results than to under-trust and reject them. This, in turn, was rationalized both with reference to flood simulation results in Baden-Württemberg being generally reliable and with reference to it not being clear what negative effects could come out of black-box use.

In effect, this means that there is a discrepancy between what academic literature frames as problematic in relation to non-experts' use of simulation output, generally, and the views of experts in science, engineering and policy when it comes to risk managers' use of simulation-based flood hazard maps, specifically. Particularly, the latter group rejects the idea of misuse due to insufficient understanding of simulation uncertainty as a central form of risk. What they would possibly regard as problematic is the fact that the growing availability and increasing user-friendliness of simulation software means that anyone can produce output data – including people without the necessary training and knowledge or the right kind of understanding and respect for what it takes to produce a good simulation.

This gives rise to a new puzzle, namely: how can it be that what is pointed out as a problem in theory is regarded as a non-issue in practice? Is it only in the case of flood hazard maps that under-critical acceptance is unproblematic? Or only in the case of local-level flood risk management?

Chapter 10

Excursion: Alpine hazard simulation in Austria

10.1 Motivation, method and material

According to (Esaiasson et al., 2005, pp. 147), the value and interest of exploratory research can be raised if the author does not satisfy with presenting inductively generated ideas and hypotheses but makes an additional effort to check whether there is any kind of support for these in other material. This can, e.g., be done by having a look at what available data at the aggregate level suggests or by collecting a small amount of new data from another context. Inspired by this recommendation, a way of collecting more data on the use of computer simulation of natural hazards was sought. Following a telephone call resulting in an invitation to learn about alpine hazard simulation in Austria, the chance was taken to do a small excursion into scenario prediction of avalanches, debris flow and torrents. In the end, seven face-to-face interviews were conducted, covering both technical details in respect to computer modeling and the use of output data for public and private risk management.[1]

Most of the Austrian interviewees worked in research, developing and running computer models to answer basic or commissioned research questions, or doing

[1] An eight interview was made but never analyzed. The reason for this was that it concerned decision input based purely on statistical data, which is not what this dissertation focuses on.

hazard simulations for expert opinions ('Gutachten' in German) or hazard zone maps. Additionally, one actor working at a regional office of the Austrian Service for Avalanche and Torrent Control ('Wildbach- und Lawinenverbauung' in German) responsible for public risk management, including hazard zoning and technical protection, was interviewed. Through his work, he was familiar with simulation programs and simulation output, but also with other methods of hazard assessment. A conscious decision was taken *not* to interview any local-level users or private clients commissioning hazard simulations, but to focus on technical experts and the questions of *whether and when there is a risk of misuse or confidence-related non-use* and *who must know what about simulation uncertainty to ensure 'good' use of hazard simulation?*

Since the opportunity to collect data in Austria turned up before the analysis of the material from Baden-Württemberg was done, it was not possible to formulate interview questions to 'test' the findings made in Germany. Instead, all interviews were conducted in a relatively open manner, where the interview partners were asked about what they do, what experiences they have made of the simulation-management nexus, and what they can tell about the role of simulation uncertainty. As long as the informants stayed somewhat on topic, the interview guide was sparsely used. In this way, data was collected on a wide range of issues, allowing for a broad reflection on the topic of interest.[2]

When it comes to the analysis, this followed more than a year later, after the coding of the German data was done. It was relatively targeted in character in the sense of consciously looking for descriptions confirming, contradicting or helping us understand the findings made in relation to flood hazard maps. All relevant passages were summarized, first once and then again, allowing for a step-wise reduction of the data material until the core messages emerged. These would not always reflect the original language anymore but be freely formulated. To allow for traceability, an excel sheet was used where the original text was placed in the left-most column and each step of summary shown in its own column to

[2]All interviews were recorded and subsequently transcribed by a native speaker. The only exception concerns a half-hour or so talk held with one of the researchers upon the day of arrival – i.e. prior to the 'real' interview held the next day. This conversation was not recorded. Instead, the hand-written notes from this talk were proofread later the same day and written out on a computer after the journey's conclusion. When a reference is made to this material below, it will be marked 'notes from pre-interview talk'.

the right. Eventually, the core messages from the different interviews were placed in a separate sheet to allow for more direct comparison and overview. Before it is revealed what this overview showed, though, it should be explained in which ways the Austrian context diverges from the case of flood hazard maps in Baden-Württemberg and how this matters for the exploration.

10.1.1 Contrasts between alpine and riverine hazard simulation

A first thing to note about alpine hazard simulation is that it represents a greater scientific challenge compared to the simulation of riverine flooding. When it comes to avalanches and debris flow, for example, it still remains somewhat unknown how snow and debris behave physically. Hence, a model has to calculate what goes on in a cloud of snow or debris rushing down a slope without us completely understanding what the internal process actually looks like. Indeed, when it comes to avalanches, the science community is not even completely sure about what causes them. That the three-day-sum of snowfall in meters is a main input is mainly a result of practice, and the likely point of departure must still be manually assumed. Moreover, different countries focus on different output data. In Austria, run-out length is defined over pressure, but elsewhere a combination of pressure and deposition height is used. For debris flow, on the other hand, the variability in terms of the size of stones and amount of clay involved means that the same model may not be suitable for all scenarios. In contrast to avalanche simulation, moreover, there are no calibrated standard parameters to rely on. Torrents, finally, are difficult to simulate because the catchment areas are mostly very small (implying higher levels of uncertainty) and because data is scarce. According to one of the interviewees, there are gauging stations for less than one percent of Austria's over 10.000 mountain streams. Consequently, it is difficult to use measurement data to determine what value a statistically defined design event corresponds to, especially since there are only around 30 years of observations (compared to around 100 years for some of the waterways in Baden-Württemberg).

Lack of data is a problem, generally. Small events in uninhabited areas are rarely registered unless some form of damage emerges. That not all events are recorded makes it difficult to define a design event and also implies a limited number of well-documented hazard episodes to use for model calibration. For avalanches, hence, model parameters are often calibrated on the basis of particular types of events, although they will then be used to simulate all kinds of avalanches. When a simulation is run, furthermore, there will not always be much empirical data to use for comparison to get a sense of how well the model output fits with reality. In comparison with riverine flooding, then, alpine hazard simulation is generally associated with larger model uncertainty, parameter uncertainty *and* data uncertainty. Ultimately, it can difficult to assess even within which dimensions they lie. For the study at hand, this means that data is collected on the use of *less certain* simulation results, allowing us to reflect on whether or not the size of uncertainty matters for whether hazard simulation is thought to be vulnerability to problems of misuse and/or lack of user-confidence.

More differences compared to the material collected in Baden-Württemberg concern the output and information products generated and the different users of these. For one thing, only one scenario is simulated, namely that of an event with a statistical return period of once in 150 years. For another thing, we can distinguish between direct users of simulation output and users of simulation-based information products such as expert opinions and hazard zone maps.

To explain this, we can begin with a look at the hazard maps produced. These are published by the Austrian Service for Avalanche and Torrent Control and are normally based on a combination of simulation results and the professional knowledge of actors with long practical experience of hazard estimation. In the maps, red and yellow zones are defined, representing high and mid-level hazard, for which different types of binding land-use restrictions apply. Apart from plans in paper and electronic format, a mapping tool is by now available online, showing the hazard zones for all of Austria.[3] During a period of public display, anyone is free to study the map proposal and put in a formal objection if something is thought to be wrong. All complaints are reviewed by a commission and, if an objection is found to be scientifically valid, the maps must be worked over and the public review process repeated. Apart from introducing binding land-use

[3]For floods see `http://www.naturgefahren.at/karten/hochwasser/karte.html`, and for avalanches see `http://www.naturgefahren.at/karten/lawine/karte.html`.

restrictions, hazard maps are also supplied to local administrations for the purpose of supporting their risk management efforts. Hence, we can differentiate between two types of users. First, there are the practitioners (or civil servant risk managers) in the regional offices of the Service for Avalanche and Torrent Control, who use the direct output of a simulation inquiry as input to hazard zoning but also as a basis for decision-making about where to build and how to dimension structural defense installations. Indeed, such actors will sometimes themselves have access to simple software programs and be able to run their own simulations. Second, there are land-user planners responsible for regional development issues, local-level decision-makers and risk managers, and residents and business-owners, all of which constitute end-users or potential end-users of the information contained in simulation-based hazard zone maps.

Turning to expert opinions, these are often commissioned by private actors and publicly-owned service providers working in ways similar to that of private businesses. Expert opinions are used as input to building and construction decisions (e.g. for planning roads, railroads, power lines, structural protection measures, or deciding where to place a new ski lift system), and are sometimes even legally required for obtaining a building permit. Both research institutes and private engineering bureaus can produce expert opinions. Apart from some form of representation of the simulation results, expert opinions will also include a formal interpretation of the results. Consequently, what is eventually used will not only or necessarily be simulation results in a graphical format but can also be numerical output or the written account of what the simulation is interpreted to show.

For the study at hand, this implies a chance to explore whether different products, formats or user groups are particularly vulnerable to problems related to over-or under-critical approaches to simulation output and simulation-based information products.

10.2 Simulation as input to risk-management

Before reviewing the interviewees' experiences in regard to different actors' use of simulation-based hazard assessments, their views of alpine hazard simulation in general shall be explored. In this regard, it would appear that many interviewees perceive a form of dilemma in respect to modeling and simulation. On the one hand, predictive research is associated with clear and concrete benefits. On the other hand, simulation output is difficult to interpret and non-experts are often challenged in this regard, running the risk of sanctioning belief in findings of low quality just because these look convincing.

10.2.1 Benefits...

Unquestionably, computer models constitute a valuable complement to other methods of hazard assessment such as historical documentation, expert-based estimates or the results of non-numerical mathematical equations. Even if a simulation can be wrong and much interpretation of the results is necessary, the possibility of using simulation technology still represents a quantum leap in the eyes of the regional-level risk manager in interview A22:

> [E]s ist so, dass diese, diese Lawinenmodelle eben diese, diese Geländeabhängigkeit sehr stark zeigen. [. . .] [Und] was da dann links oder rechts außen passiert, das hat man nie gewusst. Also das war immer nur ein Längenschnitt. Und mit diesem 2D zum Teil 3D Modellen bekommt man jetzt also ein, ein flächig-räumliches Bild. Und da muss ich schon sagen, also das hat enorm viel gebracht, also da kriegt man eine gewisse Sicherheit. Wobei es auch nicht immer stimmen muss, also es ist immer die Interpretation notwendig. Aber das hat schon viel gebracht. [...] Es war, es war wirklich ein, ein Quantensprung in, in, in der, in der, in der Berechnung von diesen Phänomenen. (IA22E, 00:24:16-7)

As IA23E points out, a simulation run can help a simulationist or producer of hazard maps or expert opinions see things that he or she might otherwise have missed and remained unaware of:

> Wofür es gut geeignet ist, meiner Meinung nach, ist halt als Entscheidungsunterstützung für [...] Expertengutachten. Wenn man halt vielleicht in der Simulation Sachen sieht, die man halt eben im Gelände draußen aus, aus verschiedenen Gründen halt nicht unbedingt gesehen hat. (IA23E, 00:09:19-6)

Representing a way of drawing general conclusions on the basis of all available historical and empirical evidence, a simulation run will not only indicate the run-out length of, e.g., an assumed avalanche scenario but also the predicted width of the affected area. Furthermore, regional-level risk managers are helped by the way simulations shows how sensitive avalanches are to local terrain conditions. As IA22E puts it, simulation technology is something that allows practitioners to look with two pairs of eyes instead of one; that of experience and professional knowledge and that of a numerical calculation. Moreover, where no or very little documentation or local experience is present, such as in a previously uninhabited area for example, simulation technology offers a possibility to nevertheless get an idea of the hazard situation and whether or not development there might be tolerable:

> Und was auch, es ist natürlich, dass jetzt häufig in Gebieten gebaut wird oder etwas erschlossen wird, wo früher keine Lawinen, wo also keiner gesiedelt hat oder nichts gebaut wurde. Und das Gebiet ist dann sehr unbekannt. Also hat man auch keine historische Dokumentation, wo man belegen kann, hier ist eine Lawine herunter gegangen. Man weiß es einfach nicht. Und da spielen dann glaube ich die Simulation, werden in Zukunft auch eine größere Rolle spielen. Weil das dann schon irgendwie, man vielleicht das eventuell dann besser abschätzen kann... (IA21E, 00:29:18-0)

Where much experience and documentation are present, on the other hand, running a simulation will not necessarily reveal anything that an expert could not tell as well. (Possibly, it is associated with the advantage of model errors being systematic and therefore quantifiable, whereas an expert will not make the same misjudgment twice, but sometimes overestimate and sometimes underestimate (IA20E, 00:12:53-8).) Consequently, some regional-level risk managers are skeptical of using computer models and simulation results, arguing that they are easy to manipulate, associated with large uncertainties, and not bringing any added value anyway. And yet the popularity and use of simulation programs are growing. Not because the use of a computer model will necessarily result in a better hazard assessment, as IA24E explains it, but because of the traceability that they offer. Whereas what underlies a professional estimate based on long practical experience is difficult to make explicit and substantiate, everything that went into and came out of a simulation model can be documented:

> [A]lso der Unterschied zwischen Modellierung und den Erfahrungswerten der Wildbachverbauer, der Praktiker, ist nicht exorbitant groß. [...] [V]iele alte Wildbachverbauer sagen: 'Dazu hätten wir jetzt kein Modell gebraucht. Das hätten wir so auch gewusst.' Nur das Wissen alleine hat, reicht heute nicht aus. Weil dieses Wissen kann man behaupten, dass man es hat, aber sehr schwer nachweisen... (IA24E, 01:16:40-9)

According to IA24E, it is no longer sufficient to 'know' and to draw a line in a map based on knowledge that others cannot scrutinize. After all, expert knowledge is uncertain and vulnerable to the influence of external pressure, too, as IA20E points out (00:12:53-8). Thus, what drives the societal demand for simulation results is the growing need for public authorities to be able to substantiate and document assessments and decisions for the sake of accountability if something goes wrong; public officials must safeguard themselves much more today than just a few decades ago:

> [I]ch glaube, dass ein ganz maßgeblicher Faktor auch die rechtliche Absicherung des Praktikers ist. Wenn, früher [...] eine staatliche Behörde, die das dann entscheidet, die wurden ja nicht hinterfragt. [...] Aber mittlerweile, in allen Bereichen des Lebens, von Amerika kommend schlagen die Rechtssysteme immer mehr... zurück und sagen: 'Ja, Entschuldigung. Da hat doch jemand etwas entschieden und wie ist

> denn der der überhaupt auf das gekommen.' Und wenn jemand betroffen ist und einen Schaden hat und nachweisen kann rechtlich, dass die Behörde da nicht nach Stand der Wissenschaft entschieden hat, dann wird es für die Behörde schon enger. [...] [D]ie Praktiker wissen schon, man muss sich besser absichern. [...] Und dafür sind die Modelle als Instrumentarium. (IA24E, 00:42:50-8)

Supporting that a growing pressure for accountability is *one* of the drivers of simulation demand, IA21E says:

> Also es ist sicher so, dass also das häufiger, auch wenn es zu einem Unfall kommt oder so, das danach gefragt wird: "Ihre Entscheidung, worauf basiert sie? Hätte man, wenn man jetzt eine Simulation oder ein Prognosemodell gehabt hätte, was wäre dabei herauskommen?" Also das stimmt. Also das ist sicher so, dass es abgesichert werden muss heutzutage. Bei den Lawinensimulationsmodellen ist es aber auch, die werden glaube ich schon auch dazu verwendet, um seine eigene Entscheidung also noch einmal zu überdenken. [...] [W]enn jetzt bei einer Simulation, man sieht, dass jetzt bei der Lawine einen Lawinenarm auf einmal irgendwo in eine andere Richtung schwenkt, schaut man sich den Bereich dann vor Ort noch einmal genauer an und überlegt: Kann das sein? (IA21E, 00:27:47-0)

In summary, this means that the benefit of alpine hazard simulation lies partially in improving experts' capacity to estimate hazard, providing them with an extra pair of eyes and facilitating appraisal where data is scarce. The other part of it lies in helping those responsible for producing hazard assessments to document the basis of these and thereby making them more likely to hold up against eventual questioning. Ultimately, this supports the view that what fuels societal demand for computer modeling is not only their predictive capacity but also the need for a rational basis for decision-making.

Regarding the specific possibility of using hazard simulation for introducing legal land-use restrictions, furthermore, this is associated with the benefit of reducing the space for non-experts to influence the assessment of where construction should be permissible or not:

> In Österreich ist zum Beispiel, die oberste Baubehörde ist der Bürgermeister. [. . .] Und der Bürgermeister, wir haben sehr viele kleine Gemeinden, der ist sehr häufig befangen. Wir sprechen immer vom Bock und Gärtner Problem. Wenn man den Bock zum Gärtner macht, braucht man sich nicht wundern, wenn der Salat fehlt. Wenn der Bürgermeister seinem Sohn eine Baubewilligung erteilt... in einem Bereich, wo er es nicht hätte sollen... Wen wundert es? Bei der Gefahrenzonenplanung, die ist bewusst sehr weit weg angesiedelt. Und das ist sehr gut so... Weil eben diese persönlichen Befangenheit meist nicht greifen können. (IA24E, 01:11:44-6)

Even if this kind of benefit is not limited to hazard zone maps based on scenario simulation, it does show that it is partially the need to reduce local influence over hazard assessment that underlies the need to base this on a traceable scientific method – just like in regard to floodplains in Baden-Württemberg. The fact that zoning decisions will often have large effects on real estate values[4] means that civil servants must try to make these as incontestable as possible and make sure that they hold up to public scrutiny. As I22E points out, "it [the hazard zoning – Ed.] is quite, quite laboriously produced precisely for the reason that it is known that it is a huge intervention in private property." (00:34:04-7). The better an authority can under-build its zoning assessment with computer models, the better it can rebut eventual objections, IA24E points out, and "accordingly, the planner must also invest very much work to document and substantiate it as well as possible." (01:32:49-8).

Ultimately, then, simulation both supports higher-level practitioners' hazard assessments and helps them document and defend these outwardly, making *risk*

[4]Though loss of insurance coverage or higher premiums are a less commonly mentioned side-effect compared to the case in Baden-Württemberg (inter alia because people living in certain areas are already excluded from insurance), falling property values are nevertheless thought to be problematic, e.g. due to the prospect of not have enough banking collateral anymore to cover one's loans. Hence, private people often attempt to question the draft hazard zone maps during the public display period as a final attempt to prevent or at least delay their arrival.

managers less vulnerable to accountability claims and the *zoning* less vulnerable to manipulation.

10.2.2 ...and problems?

There are several reasons why computer models are perceived to be complex tools to handle with care. First of all, the quality of the output is completely dependent on the quality of the input: garbage in – garbage out. Furthermore, most models have a number of different wheels to turn, each of which will affect the end-result. In this regard, not only mischievous manipulation is a risk but also that this will happen accidentally or undeliberately. To this comes that, as soon as a model is somewhat complex, a non-expert running a simulation program will not always be able to fully comprehend or follow how a certain result was obtained. In IA24E's view, this means that some models should require a 'weapons license' to run since one cannot trust the output without knowing the process:

> Eigentlich braucht man für viele Modelle einen Waffenschein... weil es bei vielen Modellen von den Parametern, alleine schon von der Parametrisierung und dem ganzen Modellablauf dahinter für viele Anwender nicht mehr möglich ist zu sehen, was tut denn dieses Modell überhaupt. (IA24E, 00:16:38-7)

> Ein Modell ist häufig nur so gut, wie sein Anwender. Und das Gut ist jetzt meistens viel auf Erfahrung bezogen. Ein Modellanwender, der nicht weiß, was das Modell eigentlich tut und irgendwas herein schüttet und irgendetwas heraus kriegt, wenn der ein Vertrauen in das Ergebnis hat, dann würde ich sagen, hat er das Thema verfehlt. Dann ist er fehl am Platz. (IA24E, 01:26:50-0)

Even if the visual format of simulation results means that they *appear* easy to interpret, IA19E says that one cannot really know what a picture is supposed to tell unless one also understands what input data and model was used to produce it. Only when one comprehends the limitations and uncertainties of the building parts will one be able to also understand the end-product:

> [W]ie man zu diesem Bild gekommen ist, ist meiner Meinung nach einer der wichtigsten Punkte, um dieses Bild überhaupt interpretieren zu können. [...] Und da geht es dann wieder um das Modell, aber auch sogar um die Numerik. Da geht es eigentlich um alles. [...] Weil wenn ich nicht weiß, [...] wo die Grenzen davon sind oder wie das ganze überhaupt funktioniert, finde ich persönlich es schwierig, so etwas richtig interpretieren zu können. (IA19E, 01:13:16-2)

The problem is that through the visualization of simulation results in a graphical user interface, the output becomes so convincing that people risk believing what they see even without any confirmation as to its quality or credibility. The more convincing the format and the less experienced the user, the higher the risk of uncritical acceptance without the necessary scrutiny or control. A colorful visualization will thus make it difficult for non-experts to differentiate between simulation output of low quality, for which there may not actually be much support, and simulation output of high quality resulting from a careful research process. In IA20E's view, this makes computer simulation somewhat deceptive, as simulation results without empirical significance may still be adopted as confirmed 'knowledge':

> Also wir haben sehr oft das Thema, dass halt bunte, schöne Bilder [. . .] wo die Drucke oder irgendetwas dargestellt ist, vermitteln irgendwie dem Betrachter: Ja, das ist die Wirklichkeit. Oder das ist die Lawine, die geht (...). Das ist so. Wenn ich das selber einfach hinschreiben würde und würde sagen: 'An Punkt X ist Druck mit 15 Kilopascal und so weiter', das darf man halt in Frage stellen. [...] Aber halt, wenn du ein schönes, buntes Bild hast, gerade bei so Entscheidungsträgern oder so, die, das können sie herzeigen oder das kann er sagen seinem Bürger, wenn er kommt. Da sagt er: 'Da schau her, die Lawinen, das ist simuliert worden. Das schaut so aus.' Und das ist halt trügerisch, weil sozusagen ein buntes Bild teilweise halt nicht viel aussagen muss. Aber die Akzeptanz halt sehr, sehr hoch ist dann davon. (IA20E, 00:42:55-1)

Especially amongst lay-people, who lack expertise both when it comes to modeling and alpine hazards, this form of uncritical acceptance is thought to be common:

> Je laienhafter jemand ist, umso mehr glaubt er diesen Bildern. Vor allen Dingen, wenn sie sich bewegen. [. . .] Das überzeugt natürlich. Und je mehr man weiß, umso, und je intensiver man sich mit dem Phänomen beschäftigt, umso kritischer wird man natürlich. Und sieht nicht nur die schönen Farben und die tollen, eindrucksvollen Filme, sondern weiß natürlich, dass das Ganze sehr grob ist [...] [I]m Grunde ist, sind die Experten schon wesentlich kritischer. (IA22E, 01:45:21-4)

While on the one hand constituting a useful complement to other assessment methods, then, simulation is on the other hand also associated with a risk in the sense of its output seeming more convincing than the model and data warrant and this not being recognized by under-critical audiences. So far, the Austrian experts largely mirror the analysis presented in chapter 2. The question is whether this relationship between convincing output and a risk of misuse is also observed to give rise to problems in practice, or whether it is most of all a problem of theoretical nature.

10.3 Different audiences' responses to simulated hazard assessments

In the following three sections, it will reviewed how different target audiences are thought to respond to hazard assessments based on computer simulation, and how important it is thought to be for them to consider the uncertain nature of hazard simulation in their use of such information.

10.3.1 Regional development planners and local leaders

Because the product the most similar to riverine flood hazard maps in Baden-Württemberg are alpine hazard zone maps, this section will begin with a review of how these are received, though one or two comments will also touch upon simulation-results of a less binding character. Beginning with regional development planners, these are not thought to concern themselves with the issue of what underlies the derived hazard zones but to accept these in trust of the source, i.e. the Austrian Service for Avalanche and Torrent Control:

> [F]ür die Raumordnung sind die, die Simulationsergebnisse eigentlich uninteressant. [...] [W]ie wir zu unseren roten und gelben Zonen kommen, das ist relativ uninteressant. Die, die trauen uns da übern Weg und, und übernehmen dann die Zonenpläne eigentlich, naja, ich will nicht sagen in blindem Vertrauen, aber doch im Vertrauen. (IA22E, 01:27:57-6)

Rather than making some kind of concession to the uncertain nature of simulation-based hazard assessment such as adding some kind of buffer when designating development zones, construction is normally allowed right up to the yellow line (IA20E, 00:28:32-0). Hence, even if they know and are told about the presence of uncertainty, they are not observed to do anything particularly to account for this:

> SK: Ist es den Raumplanern bewusst, dass es eigentlich, dass es eigentlich schwierig ist, eine Linie zu ziehen? 01:31:35-5
>
> IA22E: Ich glaube schon, ja. Also wir kommunizieren das auch immer wieder. Also so diese Dinge, also ja, große Unsicherheiten (...). Also das wird kommuniziert. Das wissen sie schon, die mit uns zu tun haben. 01:31:53-7
>
> SK: Wird das auch berücksichtigt? 01:31:58-4
>
> IA22E: Wird nicht berücksichtigt. Nein, das wird, kann man nicht berücksichtigen. Das ist eben diese, diese Linie ist einfach notwendig, dass man sagt, o.k. mit sehr hoher Wahrscheinlichkeit bleibt sie dort dann auch wirklich stehen. [...] 01:33:24-6

Moving on to public decision-makers at the local level, the presence of simulation uncertainty is not observed to give rise to much discussion here either. Most of the time, mayors are not thought to comprehend where the depicted hazard lines come from but to simply accept these as given, in trust of the higher authorities' competence:

> Wenn es der Bürgermeister als Baubehörde ist, der weiß wahrscheinlich nicht, was jetzt genau hinter dieser Linie steckt. Was wurde da modelliert? Mit welchem Modell? Mit welcher Schärfe? Mit welchem Input? Der muss sich darauf verlassen, dass die vorgeschaltete Behörde, die, die das erarbeitet hat, dementsprechend nach besten Wissen und Gewissen das produziert hat. Ich glaube mittlerweile, dass das, die meisten auch so annehmen... (IA24E, 01:29:02-8)

According to IA22E, mayors are mostly glad about receiving a document that gives them information and arguments. A hazard zone map is something solid that a mayor can point to in order to resist pressure from actors wanting to build in hazard zones. Moreover, it can be used to support crisis management planning by showing where evacuated people may be brought to. But, of course, there are also those who resist them for how they devalue the real estate prices the red zone:

> Ja, die Bürgermeister sind meistens sehr froh, weil sie eine gewisse Sicherheit haben und Argumente. Der Bürgermeister ist ja für die Sicherheit in der Gemeinde zuständig und das ist ein Hilfsmittel für ihn. Er kann sagen, schaut, das ist der Zonenplan. Also, da braucht ihr nicht fragen wegen einer Umwidmung. [...] Und tut sich auch leichter im Fall von irgendwelchen Krisen. [...]. Es gibt natürlich auch Leute, die das absolut nicht wollen, weil natürlich da die rote Zone einen Baugrund enorm entwertet. (IA22E, 00:34:04-7)

Giving an example of a less positive form of response, IA21E (notes from pre-interview talk) describes how a mayor in a neighboring country was not grateful for the warning that a newly designated building area would end up in the red zone according to the hazard simulations. Instead of looking for an alternative location, things were hurried up so that, by the time the hazard zone maps were finished, the area was already built-up. Likewise, simulation results that there is no legal obligation to account for are rarely welcomed by local leaders and politicians, as these tend to prefer a focus on local business interests due to close ties with the private sector:

> Sehr häufig oder ich würde sagen meistens sind die Lokalpolitiker, also Gemeindechefs, Gemeindeorgane, so stark von anderen Interessen überprägt in unserem Bereich, dass sie da lieber die Augen zumachen und von den Modellen und dem Modellergebnissen gar nichts sehen und hören wollen. [...] [W]eil wir touristisch ganze Talschaften mit Skigebieten erschlossen haben, Pisten erzeugt haben. [...] Also das hat sich dann auch in der Landnutzung eine Riesenverschiebung gegeben. Und es will dann kein Lokalpolitiker hören, dass da einiges schlechter geworden ist meteorologisch... [...] Aber die Lokalpolitik ist natürlich dort mit den Hauptwirtschaftsfaktoren so eng verknüpft, dass sie sehr große Scheuklappen haben Sachen anzugehen [...] [E]s gibt andere Skigebiete und andere Regionen, wo das wunderbar funktioniert. [. . .] Da arbeiten die Skipistenbetreiber und die Lokalpolitik ohne diese Scheuklappen [. . .] die nehmen solche Modellerkenntnisse gerne an und schauen sich das an und überlegen sich, was kann man da in Zukunft tun? (IA24E, 00:48:48-6)

While IA24E recognizes the presence of exceptions in this regard, then, i.e. in the form of municipal and private actors who welcome modeling results as a tool for achieving sustainable business expansion and safe building planning, he cannot tell what sets these communities apart. In his view, it must have something to do with the respective people in charge and personal animosities and interests (00:49:44-0).

As in the case of Baden-Württemberg, then, local-level decision-makers are generally thought to accept hazard information and to react to it in accordance with their interests. As neither regional planners nor local politicians are noted to fully comprehend or account for the presence of uncertainty, furthermore, the next question is whether this is perceived to be acceptable or framed as problematic.

The answer, it would seem, is that local actors are not expected to inquire about the origin of or uncertainty associated with simulation-based hazard assessments (i.e. IA24E, 01:30:46-4). Likewise, even if it would sometimes be desirable for regional development planners to understand a bit more, it is generally acceptable for them, too, to adopt hazard zones without questioning:

> Also ich würde, ich würde sagen ja. Wenn Sie Bedenken hätten, wäre es gescheiter, sie, sie hätten eine Ahnung. [...] Aber im Grunde haben wir da eigentlich nie Diskussionen oder über Simulationen. Ich glaube auch, dass die Leute sich da nicht wesentlich auskennen, bei diesen Dingen. (IA22E, 01:29:06-4)

As IA23E explains, it is not realistic to expect local decision-makers and regional planners to know enough to be able to appraise the quality of hazard assessments. What they need is a line to use for planning purposes. Consequently, it falls on the experts producing hazard zone maps to ensure that these are good enough to be uncritically accepted:

> Für Entscheidungsträger politisch jetzt zum Beispiel, oder auch für die Raumplanung, [. . .] die brauchen eigentlich eine fixe Linie, mit der sie planen können. [. . .] Wenn man alle Informationen immer hin gibt, dann würde man quasi von jedem (in der Kette weiter verlangen), dass der sich einfach damit beschäftigt und auch gut auskennt, d.h. dieses... dieser Abstraktionsgrad (bei mir mal eben), das soll quasi der Experte regeln. [. . .] [So dass] sich halt auch andere Leute darauf verlassen können. (IA23E, 00:26:05-5)

Even if the consequence of more or less blind trust is that regional planners allow for development right up to the fringe of the yellow hazard zone, this is – all things considered – not the worst imaginable outcome. The opposite scenario, that they would lack confidence in simulation-based guidelines and disregard these would be much worse: "Yes, well, too little confidence would probably be even worse. If one says: 'O.k., I build behind this, in this yellow zone.'" (IA20E, 00:38:35-8).

Even though several of the interviewees would prefer if hazard zone maps could show shaded areas or gray zones rather than sharp lines to make the presence of uncertainty explicit and unmistakable, they also show understanding for why this is not possible. Not only would it require too much effort and skill on behalf of the recipients to interpret something like that and generally lead to chaos if all regulatory authorities would constantly try to provide the full picture (IA21E, 00:10:57-2) but it is also thought to be incompatible with the wish to introduce legal restrictions:

> [D]ieser graue Bereich wäre mir lieber, aber mit dem kann natürlich das ganze Rechtswesen nichts anfangen, wenn ich sage ja, ja, das ist alles da wahrscheinlich, da wahrscheinlich. Die wollen genau wissen, was ist jetzt bei dem Haus. Und ist da etwas oder ist da nichts. Aus, Ende. Ich kann nicht sagen, ja wahrscheinlich. Mit dem kann niemand etwas anfangen. Also (braucht es) eine konkrete Aussage. (IA22E, 01:31:27-2)

In effect, this means that it is not only in regard to riverine flood simulation associated with fairly low levels of uncertainty that it is thought to be acceptable for local leaders and land-use planners to ignore the presence of uncertainty. Even though the uncertainties associated with alpine hazard simulation are much greater, it is still thought to be tolerable for end-users to adopt simulation-based hazard information without questioning respectively not to account for its uncertain nature in development planning. After all, they are not thought to have the right competence for understanding the details and it would be worse if they would lack confidence and *not* abide by this information. Essentially, then, there is indeed a perception of lack of confidence as something that could constitute a problem in the sense of leading to non-use, but no reference, so far, to a risk for sub-optimal decision-making as a result of uninformed use.

10.3.2 Private actors and publicly owned enterprises

Turning to private actors' responses to simulation-based hazard assessments, this is noted to – at least partially – depend on the client's agenda and knowledge resources. Someone who lacks technical know-how and who wants to build something, and needs an assessment for the building permit process, will often adopt this without questioning (IA21E, 00:25:19-7). In comparison, larger businesses wanting to realize new projects will often possess enough resources to hire scientific competence in the form of private engineers. These will have the technical skill to spot weaknesses in simulation results and their interpretation, and will sometimes apply this to question official hazard assessments:

> Ja, es ist so, beim Hausbau (wollen sie) Zahlen, dann sagt man, ja zehn Kilo Pascal, fertig. Zivilingenieure, die Projekte machen, die kommen dann meistens schon und diskutieren. [...] Wird oft recht kontrovers, also das muss man sagen. Das ist nicht immer nur freundschaftlich dann, also das. (IA22E, 00:57:16-0)

Indeed, it even happens that industry actors commission their own counter-zone assessments to question the public authorities' appraisal and be able to present a solid argument for their own position – something that IA22E admits can be useful, too, even if it is generally unwelcome at first (00:59:30-2).

There can also be a difference between accepting and following the results of a simulation run, however. Though IA21E claims that Austrian public enterprises commissioning expert opinions generally trust there to be a risk if this is what the simulation says (often you can even see signs of it in the landscape), it is not always that such information has an impact on what is then decided. In one instance, for example, a project was continued along the original plan in spite of an avalanche simulation indicating a risk of technical damage. Since the predicted hot spot was located in an accessible area, it was decided that it would be preferable to fix the problem if and when it arose rather than to look for an alternative location. When there is no official regulation to follow, IA21E explains, a cost-benefit analysis will often decide whether an indicated risk is acceptable or not:

> Sie haben keine Vorschriften, wie es im Siedlungsraum halt ist. Und die machen das dann eher nach einer Kosten-Nutzen Überlegungen. Also auch wenn sie wissen, es steht im gefährdeten Bereich, aber wir halt sagen: "Gut, es ist halt relativ unsicher. Also es kommt sicherlich nicht jedes Jahr oder alle zwei Jahre, sondern eher alle 30 Jahre." Dann entscheiden sie rein nach Kosten Nutzen. Und da ihr Planungshorizont ich glaube 30 oder 40 Jahre sind, wenn wir halt sagen: "Ja, 150 jährlich. Ja, könnte passieren." Dann sagen sie, o.k., das Risiko tragen sie. Also das... das ist dann egal. (IA21E, 00:12:42-4)

Regarding whether or not uncertainty constitutes a problem, low confidence in simulation output is indeed described as a risk that needs to be managed to avoid rejection and non-use. In contrast to the analysis in chapter 2, though, this is not connected to unrealistic expectations of being able to get certitude (so that uncertainty becomes an obstacle towards use) or to a lack of confidence in modeling as such, but simply to the risk of a client not finding a specific assessment result credible. As IA21E explains, it is not only important for researchers to confirm the plausibility of simulation-based hazard assessments but also for clients to be given this opportunity. Involving the intended users from the start and keeping an open dialog about what goes into a computer model are the best ways of ensuring acceptance and thereby also use:

> Also die [Ergebnisse – Ed.] müssen halt immer verifiziert werden. Und das muss man auch mit den Endanwendern zusammen machen und auch die Ergebnisse durchsprechen und die Plausibilität halt überprüfen. [...] [S]ie sind auch viel aktiver in dem Projekt dabei und liefern vielmehr Informationen, wenn man sie also von Anfang an miteinbindet. Wenn das nicht passiert, sind viele von den Ergebnissen, liegen dann in der Schublade und dann werden sie auch gar nicht mehr... weiter wirklich verwendet. Oder auch nicht akzeptiert. Und wenn sie, man mit ihnen *nicht* spricht und ihnen auch sagt, was in diese Simulation nun eingeht, also als Eingangsparameter, dann... [...] wird es einfach nicht wirklich akzeptiert. (00:17:59-4, emphasis added)

At the same time, though, this is not the same as giving clients full insight into the uncertainty associated with the disclosed results. When more than one model is used to run the same simulation, for example, and the results diverge, this will not be communicated in the expert opinion. This will only contain one value, as that is what the experts were hired for and what clients are competent to deal with:

> Denen, denen sagen wir das gar nicht. Die möchten hinterher einen Wert haben. [...] [W]enn wir zwei Modelle angewendet haben, also eins läuft, weiß ich nicht, 20 m länger aus, als das andere, müssen wir

> halt mit Expertenmeinungen dann interpretieren, wo glauben wir, ist es am realistischsten. Und wir müssen einen Wert liefern. Weil wenn, die Leute möchten nur einen Wert haben. Also wir... sie können mit mehreren Sachen nicht umgehen. (IA21E, 00:08:03-0)

Though it is important to always communicate that some uncertainty is present, IA21E does not think this is anything that clients pay much attention to: "if you somehow say: 'Yes, we have an uncertainty here (...).' People cannot make anything of that." (IA21E, 00:20:05-4).[5] To some actors, a simulation is a way of transferring responsibility from the private decision-maker to the expert community, meaning that clients will not necessarily have an interest in learning of the fine print, as that would defeat the purpose of asking for an expert assessment:

> Ja, ich glaube, ja wenn sie wirklich gar keine Ahnung haben, dann werden sie es entweder einfach so nehmen. Und sie möchten ja dann wahrscheinlich etwas bauen und werden einfach sagen: "Gut, wir haben das in Auftrag gegeben. Die sagen, das ist so, das übernehmen wir." Weil damit haben sie ja im Prinzip nicht die Verantwortung dafür. Sondern dann sagen: "Ja, die haben ja die Verantwortung. Das nehmen wir. Das ist schon o.k." (IA21E, 00:25:19-7)

In this sense, there is not much recognition for the viewpoint of output uncertainty as something that end-users of simulation-based hazard information should have a detailed understanding of to ensure 'sensitive' use. Though clients should be allowed to ask and learn about anything they want in order to develop confidence in the quality of a hazard assessment, it is the job of the researcher to interpret what available evidence suggest is likely and not the job of the client. Hence, it is the researcher that needs to understand the meaning of the various sources of uncertainty built into simulation results and no one else.

[5] What modelers and simulationists can do, it is often commented, is possibly to try to communicate these things in a way that end-users may understand. Though this is something that is heard in several of the interviews, it is never quite explained what this would look like in practice.

10.3.3 Regional-level risk managers

Turning to practitioners responsible for hazard zoning and technical protection at the regional level, the image of how critically or uncritically simulation results are approached varies between the interviewees. According to IA21E, it is generally understood that simulation results (and in extension also simulation-based expert opinions) do not represent certain knowledge but are associated with uncertainty, only technical protection planning has to proceed anyway. Independently of whether or not a value is uncertain, a decision still has to be made:

> Und ich habe auch bei einigen Gutachten, bin ich dann auch heraus gegangen, habe die Ergebnisse interpretiert und habe dann halt gesagt: “Naja, aber vielleicht ist die Anbruchhöhe ein bisschen höher, weil wenn der Stau das...” Dann sagen sie: “Nein, wir müssen das jetzt planen. Wir haben hier unten das Objekt, das möchten wir schützen.” Und sie möchten von mir wissen wie. [...] Und ja, da gibt es keinen, wenig Spielraum. [...] Es wird auch immer beschrieben bei uns. [...] Dass man das nicht hundertprozentig sagen kann, das liegt halt an den Limitationen von den Modellen. Aber... das ist dann ein akzeptiertes Risiko [...]. (IA21E, 00:10:57-2)

In IA21E’s view, this is also somewhat acceptable. First of all, it would be to ask too much to require regional-level risk managers to understand how particular simulation results were arrived at and what different uncertainty sources this involves. Supporting this view, IA23E says that it is one thing for a modeler to point out that a simulation is associated with large uncertainties, and quite another for a practitioner instructed to produce a hazard zone map to interpret what that means for the task at hand (00:21:50-0).[6] Second, the whole reason behind commissioning an expert assessment is to not *have* to possess this competence in-house. In IA21E’s view, then, it normally suffices that the researcher includes

[6] In his view, practitioners do not only need to be told about the strengths and weaknesses of computer models but also be given concrete suggestions in terms of how to handle this (00:21:50-0).

information as to where uncertainty is possible and that the client has an opportunity to ask; only when something is to be built can it be necessary with a more exact uncertainty estimate:

> [F]rüher habe ich gedacht, sie müssten viel mehr darüber wissen. Mittlerweile glaube ich, ja, sie sollten sich bewusst sein. Also man sollte das schon kommunizieren. Also man sollte es nicht verheimlichen und ihnen nur Ergebnisse geben, sondern man sollte halt schreiben, die Ergebnisse sind unsicher, weil ja. [...] [Wenn] die Anwender jemand ist, der wirklich etwas baut, sollte man ihn... auch die Unsicherheiten quantifizieren, was halt relativ schwierig ist. [...] Aber sie [...] brauchen nicht komplett dieses, das nachvollziehen zu können, wie man zu dem Wert kommt. Weil ich denke, dafür beauftragen sie die Experten. [...] Also das, wenn sie, sie sollen die Möglichkeit haben nachfragen zu können. Es sollte auch im Bericht ein bisschen beschrieben werden, wo Unsicherheiten auftreten können. (IA21E, 00:15:37-5)

In contrast, IA19E's assessment is that, at least in relation to technical protection planning, simulation results are often too uncritically accepted – perhaps as a result of a lack of experience:

> Meine Erfahrung oder meiner Einschätzung ist, dass die viel zu sehr akzeptiert werden. Wenn, [. . .] jetzt muss man hier ein, ein Bauwerk dimensionieren, einen Damm oder irgendetwas. Und ich sage, diese Ergebnisse aus der Simulation sind aus den und den Gründen eventuell mit Vorsicht zu genießen und haben einen Spielraum in dem und dem Bereich. Das interessiert niemanden. Was die Leute hören wollen, ist: die Lawine ist an diesem Punkt 5 m hoch... [...] Ja, ich glaube, umso weniger Erfahrung oder ich weiß es nicht, womit es zusammenhängt, werden diese Ergebnisse viel zu sehr akzeptiert. (IA19E, 01:36:41-2)

Often, he says, regional-level risk managers lack the detailed knowledge to be able to estimate how large the errors are that different sources of uncertainty give raise to. Indeed, this is something that even researchers themselves can find difficult

(IA19E, 01:51:40-7). Hence, people will rely on things that they do not fully understand because it is 'easy' (01:25:30-0). As he sees it, it would be better if practitioners at this level would understand more about the simulation-based assessments with which they work. Even if he realizes that this might be practically unrealistic, it is in principle what is called for:

> Entweder muss das Ergebnis oder die, die Prozedur so standardisiert sein, dass derjenige keinen Fehler machen kann. Was aber auch im Grunde genommen am besten nicht so sein sollte. Ja, im Grunde genommen sollten die Leute schon mehr darüber wissen, aber ich glaube fast, dass das zu viel ist. Ich glaube es ist kaum möglich, alles oder richtig viel über so ein Modell zu wissen, wenn man eigentlich nur die Ergebnisse interpretieren soll. Teilweise ist es aber sehr notwendig [...]. (IA19E, 01:25:30-0)

Working with regional-level risk management himself, the practitioner in interview A22 admits that he does not quite comprehend what a computer model does. Knowing that simulation is an uncertain method and having access to experience and other sources of information, though, he can assess whether the input and output with which he is confronted are realistic or not. But for more he depends on external expertise:

> Wir in der praktischen Anwendung haben von diesen ganzen theoretischen Hintergrund wenig Ahnung, relativ wenig Ahnung. Wir beurteilen das Ergebnis, was da herauskommt. Wir, wir schauen, ob die Eingangsparameter halbwegs stimmen oder mit unserer Erfahrung übereinstimmen. Aber der Prozess innerhalb des Modells ist uns relativ verschlossen. [...] Also für uns ist es wie eine Blackbox beinahe. Mit einem Ergebnis und dieses Ergebnis stellen wir mit unserer Erfahrung, mit unserer, unseren anderen Methoden in, in, in Einklang. Aber das andere, also das Prozessuale im Modell, das müsste man mit den, den Spezialisten behandeln zusammen. (IA22E, 00:50:32-4)

In his view, though, this is not a problem. In a world of ever-growing complexity and specialization, everyone cannot know everything. What is important is that one recognizes one's own limitations and makes sure to ask for external support when this is needed:

> Man kann nicht alles wissen. [...] [I]ch hätte auch die Zeit nicht für das. Dazu gibt es die Leute, die sich besser auskennen, [...]. Und da müsste man, wenn, wenn man darauf kommt, das ist ja vollkommen unplausibel, dann muss man in die Diskussion gehen. (IA22E, 00:53:03-5)

In his view, then, a user of simulation results must not necessarily be able to trace the whole process of how these have been arrived at and what model uncertainties this involves. He should, however, be able to assess the plausibility of the parameters used and of the resulting findings, and know who to ask if something strikes him as strange or unlikely. Representing a similar view, IA24E notes that "[t]he practitioner, he musts inevitably incorporate this modeling and develop and have confidence in this modeling. Otherwise he cannot justify this map with good conscience." (01:29:02-8). While there are partially different views as to what regional-level risk managers should know about simulation results and simulation-based hazard information, then, both IA22E's and IA24E's assessments are that practitioners working directly with simulation output should not accept this uncritically. In contrast to local-level and private actor users, furthermore, it is not enough for the output to be scrutinized and found plausible but the inputs, too, (at least those that the practitioner is competent to assess) should be subjected to review.

Hinting towards why it is problematic if simulation results are uncritically accepted without quality control, one may note that what is *really* perceived to constitute a problem is when practitioners or other actors are too self-confident about their own simulation skills respectively too trusting of software programs and output data that they themselves use and produce. For example, compared to their more senior colleagues, young practitioners in regional management offices without much field experience or practice in other assessment methods are thought to be more at risk of accepting output data of questionable quality:

> [D]ass also viele... es sehr viele Lawinenexperten gibt, die relativ neu sind und wenig Geländeerfahrung haben. Und wenn das so ist, [...] ich glaube, es ist halt schon einfach so ein Risiko, dass die Simulationsprogramme sehr einfach bedient werden können und [...] die Ergebnisse halt einfach nicht genug verifiziert werden. [...] [D]ie Anwender oder die Leute, die simulieren, haben oft zu wenig Prozesswissen... [. . .] Und sie haben, glaube ich, zu großes Vertrauen in die Ergebnisse. Also von sich selber. Und da ist es, wäre es halt auch gut, wenn die Leute sich mehr bewusst sind über die Unsicherheiten, wenn sie die dann in ein Ergebnis im Endeffekt halt verpacken. (IA21E, 00:20:05-4)

If an actor running a simulation does not undertake a manual survey of the local terrain, for example, particularities in the local landscape may be overseen, in which case the output will give an incorrect representation of the likely outcome of a hazard scenario. If this is the case and if the output is given out without any effort to confirm it, there is a risk of erroneous predictions being uncritically accepted and made the basis of planning and decision-making. Alternatively, end-users may react on the simulation results not being realistic and lose faith in simulation modeling as a practice altogether:

> [D]ie Gefahr ist halt, dass die Ergebnisse einfach nicht richtig sein können, weil die lokalen Bedingungen einfach stark abweichen. Wenn man sich dessen nicht ganz bewusst ist und die, das Gelände einfach nicht miteinbezieht, dann liefern diese Simulationsergebnisse einfach falsche Werte. [...] Die Karten werden herausgegeben und Leute, die sich nicht damit beschäftigen, sehen die Karte und sagen: "Ja, ja, ja, das stimmt so." Und es wird herangezogen für weitere Planungsmaßnahmen. Und da ist halt die Gefahr, dass diese, dass heutzutage einfach möglich [ist,] so eine Simulation irgendwie laufen zu lassen, man hat schöne Bilder, veröffentlicht die und nur weil es schön aussieht wird das Ergebnis einfach auch von Leuten, die es nicht... genauer hinterfragen, einfach akzeptiert. Und das ist glaube ich halt schon, schon relativ eine Gefahr. Gerade bei Lawinen und alles, wo es wirklich sehr lokal auch unterschiedlich sein kann. Also die Bedingungen. [. . .] Und

> wenn die lokalen oder die Entscheidungsträger das so nicht beobachtet haben [. . .], dann werden sie das Ergebnis auch gar nicht ernst nehmen. Also dann werden sie es nicht heranziehen... (IA21E, 00:23:06-4)

In other words, it is a problem if actors *running* simulation programs take an under-critical approach to the generated results, as this implies a risk of substandard output being given out. Moreover, the reason why this is problematic is both that it can lead to a general lack of confidence if audiences are provided with simulation results that they can see are not right, and that it can lead to planning and decision-making being based on 'bad' research (i.e. a form of misuse) if the audience is not competent to assess the output quality.

Giving a concrete example, some interviewees are critical of the hazard zoning pursued in a neighboring country. Whereas simulation results are used as a complement to expert-based estimates for the hazard zoning in Austria, the zoning in this other region is more directly based on simulation output on account of the bidding system favoring the cheapest assessment method:

> Also da hat jeder einreichen können und sagen: "Ich bin ein Ingenieurbüro oder wir sind ein Forschungsinstitut. Wir können das und würden dieses Gebiet für diesen und den Preis abschätzen." Und das ist teilweise dann auch, gerade bei so etwas, in die falsche Richtung gegangen, dass es eben extremes Dumping gegeben hat. Dann hat jeder gesagt: "Ich kann es noch billiger und noch billiger." Und die billigste Methode ist einfach die Simulation herunter rechnen zu lassen, die Linie nachziehen und sagen: "Das ist es." (IA20E, 00:31:59-5)

Since the cheapest bidder may not necessarily be competent or take the time to review the local terrain, this system is not perceived to be a good guarantor for producing as 'good' hazard assessments as possible:

> Und diese, diese Naturgefahren, also Gefahrenzonenplanung wird jetzt halt häufig übernommen von Ingenieursfirmen. [...] [D]ie Gemeinde, die schreibt das aus. Es bewirbt sich [das ganze Land] darauf, also

> kann es auch sein, [...] dass jetzt aus [der Süden] eine Ingenieursfirma die Gefahrenzonenplanung in den Alpen macht. Und die basieren das dann natürlich auf den Simulationen, weil sie selber die Region ja gar nicht wirklich halt einschätzen können. [...] [I]ch glaube, sie merken das auch, dass es halt nicht so gut funktioniert. (IA21E, 00:34:21-1)

Sometimes, IA21E (notes from pre-interview talk) says, they can see just by looking at the local terrain that the simulation results are exaggerated and that larger areas than strictly necessary (as defined by official regulation) are being placed under legal protection. Generally, it is regarded as somewhat critical when private engineering firms' use alpine hazard simulation programs since they often have even less time than public authorities and research institutes (e.g. IA19E, 01:57:03-9).

In effect, this means that even if some still see it as somewhat acceptable for regional-level practitioners provided with a simulation-based hazard assessment in the form of an expert opinion to rely on the experts' interpretation of available evidence without closer understanding of the uncertainty involved in this, there is also the viewpoint that it is *not* acceptable for risk managers at this level to simply accept simulation output without scrutiny or reflection as to its quality and credibility. Though there is no explicit reasons stated for why this would be bad, it is clear that risk management decisions are expected to rely on the best available research results possible and that the risk of unintentionally relying on 'bad' findings would therefor be serious. Hinting towards the risk of misinterpretation being present at this level too, finally, is the assessment that there are also circumstances under which the uncertainty should not only be qualitatively described but also quantified (as far as that is possible). Here, for the first time, then, it does not appear to be acceptable for simulation results to be uncritically accepted without questioning.

10.4 Reflection on the original case study findings

In terms of implications, the result of the above analysis is that the findings made for the case of flood hazard maps in Baden-Württemberg are both corroborated and nuanced.

Beginning with the risk of non-use, there is no indication of widespread non-use related to credibility doubts. As in the case of flood simulation in Baden-Württemberg, though, it is recognized that errors and/or insecurity about what underlies output results *can* lead to non-use. Hence, here too, active efforts are undertaken to involve target audiences in the research and quality review process to ensure acceptance. A further similarity is that, when results are attacked or not used, this is observed to be tied to political or financial interests rather than related to the simulation quality.

Continuing with the risk of misuse, similar to the results in Baden-Württemberg, there are instances in which the Austrian experts regard it as more or less unavoidable that simulation-based hazard assessments are used without closer attention being payed to the presence of uncertainty. Particularly, this applies to alpine hazard maps at the municipal level respectively when private actors with low skills commission an expert opinion of the hazard at a particular location, e.g. for the sake of a building permit process. In principle, the position taken by the Austrian interviewees is that, not having the right background themselves, some actors need to be able to hire and rely on professional experts. In consequence, it is unsurprising that they have neither time to nor interest in questioning what they are told. Not having the competence to make an informed judgment themselves, this is what they hired the experts for.

At the same time, black-box use is not sanctioned for everyone. Most notably, higher-level public servants should *not* simply accept what they see, but carefully scrutinize the quality of input and output data to ensure that what is eventually decided correspond to what is really truly known about a particular hazard situation. This is particularly emphasized in respect to actors responsible for using simulation results to draw up legally binding hazard zones, but also for those responsible for planning structural protection works. In practice, uncritical acceptance has been observed to lead to hazard zoning based on simulation results of suboptimal quality with the result that larger areas than necessary (in terms of what is stated in formal guidelines) have been designated at hazardous (i.e. a form of negative consequence from officials taking an under-critical approach to modeling output, in line with what was described in chapter 2.2.1.2).

Chapter 11

Conclusion

The backdrop of this study is the growing popularity of simulation technology and predictive data as input to societal decision making at the same time as academic research points to a problem in respect to decision-makers' and civil servants' handling of such input. Specifically, it is pointed out as a risk factor if models are treated as 'answer machines' or 'truth generators' (cf. Wagner et al., 2010). The reason why this is seen as problematic is twofold. First, misconceptions about science's ability to deliver certain answers can lead decision-makers to regard the presence of uncertainty in simulation results as an obstacle towards use, in which case they may prefer to wait for more evidence although action in the present would actually be preferable. Second, misconceptions about science's ability to deliver certain answers can lead public officials to use simulation results as if these represent the truth, without proper consideration of assumptions and uncertainties, in which case the resulting decisions will be based on an incomplete or even misguided understanding of the present state of knowledge.

Recently, a new type of simulation product has become popular, namely the visualization of the predicted outcome of various hazard scenarios on a map or digital terrain representation to support risk management of natural hazards. What motivated this study was the perceived knowledge gap as to what risk managers' dealings with such simulation-based information products look like. Are hazard simulation results at risk of going unheeded due to skepticism about their reliability? Or are they at risk of being misused by non-experts lacking the time and interest in considering the fine print of model output? Do scenario simulation results help risk managers act in foresight or are the potential benefits of being provided with predictive information canceled out by difficulties?

To explore this topic, the use of simulation-based flood hazard maps in the German state of Baden-Württemberg was studied by interviewing both representatives of the intended user group (i.e. risk managers) and representatives of modelers, engineers and actors in higher-level public offices responsible for implementing the state's mapping project (i.e. external experts). The findings pertinent to the three research questions of *how*, *why* and with what kind of *benefits and problems* flood hazard maps are used have already been discussed in chapter 9. In a subsequent step, a small excursion into the field of alpine hazard simulation was made to check whether there was any support for the findings made in Baden-Württemberg in a different context and to seek to understand the origins of the discrepancy identified between how the external experts reasoned around non-experts' use of simulation output and what has been written about this in academia.

Below, the insights gathered from these two case contexts will be brought together to address the study's practical and theoretical purpose and draw lessons for future research.

Revisiting the study's practical purpose

The practical purpose of this study was to develop concrete recommendations for how to encourage the use of available foresight information for local-level risk management. In this regard, a first point to note is that such encouragement is not always necessary. Where risk management has already been prioritized and subjected to comprehensive reform, there can be little need for flood hazard maps without this constituting a cause of concern. Put differently, there is a difference between *knowledge utilization* and *research use*. Where knowledge of the existence of a flood risk has already been responded to, there will not necessarily be much need for marginally different research findings. Where, on the other hand, the risk of flooding has long been under-prioritized, the hope would be for new research results to lead to a change in attitude and contribute to concrete management reform. In this sense, the interesting question is *how to encourage that available* *foresight information is responded to where risk management is not already a local priority.* In this regard, three lessons can be outlined.

First, since non-use of flood hazard maps was sometimes connected to audiences not seeing the point of pursuing relevant risk management measures, doubting that these would be effective or their own capacity to implement them in a successful way, efforts to encourage use could do well by focusing on what underlies these perceptions and how they can be changed. Apart from working on conveying the *sense* of particular strategies and measures (and what is at stake in case of inaction), this could involve, e.g.: busting myths and unfounded fears in terms of what it would mean to engage in particular activities; providing best-practice examples for guidance and encouragement; offering trainings to address incapacity problems and lack of know-how; and developing templates to lower the costs of getting started. Particularly in the field of risk communication, local administrations need to be convinced that telling people about the risk of natural hazards represents an *opportunity* rather than a threat, and be provided with practical guidance in terms of what a communication strategy may look like. Naturally, this also requires some form of organizational structure to be present that can take charge of such tasks and which can work as a point of contact to municipalities in need of support.

Second, usage can be supported by efforts to ensure acceptance of a particular form of research and its results. In this sense, the study confirms the importance of involving the target audience in the research process, both for the sake of ensuring content which matches the intended users' needs and interests and for spreading knowledge about the research method and build confidence in the results (cf. Mitchell et al., 2006a; Cash et al., 2003; Nutley et al., 2007). Even if the target audience lacks the technical skill to make an informed assessment of the different steps and components of the research process, there are still ways of assessing new findings' credibility. In addition to personal contact and involvement of intended users in the plausibilization process, confidence in hazard simulation results could be encouraged if it would be easier to compare these with other sources of information. Online, this could be done by embedding photos and different forms of written and numerical documentation of past hazard events. In printed material, a minimum requirement would be to offer a translation of technical terminology into language that lay-people can relate to (e.g. what gauge level a particular statistical return period corresponds to). With regard to acceptance of simulation uncertainty, this can be facilitated by allowing for dialog and questions, and by making it intuitively understandable why ‘certitude’ is beyond reach by drawing on examples that the users can easily relate to. In respect to the flood hazard maps, arguments that the interviewed risk managers appeared to accept for deviations from flood simulation results included the possibility of unexpected events (e.g. a fallen tree clogging up a bridge or an underpass), changes to the local landscape and terrain (e.g. through local development or mobile objects), imprecision associated with laser scanning, and that a higher level of precision would be financially costly. In principle, these are arguments that resonate with what risk managers already know intuitively, making them sound logic, rather than arguments which require complex thinking or the formation of new knowledge.

Finally, it is not always that there is any interest in reconsidering the status quo. When this is the case, publication of new research findings will not necessarily be able to change this. This confirms lack of interest in *risk management* as such as a major obstacle towards research use. If efforts to convince people fail in this regard, knowledge utilization may ultimately require regulation. Rather than hoping that the publication of research findings will lead to a change in behavior, the cases of hazard maps in Baden-Württemberg and hazard simulations in Austria show that it can be more effective to use research results to define where which type of restrictions and formal requirements should apply. This does not only concern the need to regulate land-use and development planning but also efforts to make preparedness planning and transparent publication of hazard information mandatory elements of local management policy.

Revisiting the study’s theoretical purpose

The theoretical purpose of this study was to analyze whether problems noted in academic literature related to non-experts’ use of simulation are present for risk managers’ use of simulation-based hazard maps as well, and thereby to contribute to the development of empirically anchored theory as to the circumstances under which simulation usage by non-experts is problematic or unproblematic. First, though, for the sake of balance, a brief note on the benefits of simulation technology is called for.

As noted in Chapter 2, computer simulation is commonly associated with advantages in terms of enabling research where access to real target systems and data is limited, and in terms of allowing for cheaper respectively more complex analyses. What this study shows is that it is not only in relation to basic science and knowledge advancement that these benefits apply but also when simulation is used in practice to support public management and regulation. In this regard, a number of further advantages are also noted. Compared to prior assessment methods, a first point is that simulation technology allows for more transparency in terms of how a particular conclusion was arrived at, thereby facilitating for responsible authorities to substantiate and account for the basis of their work and for others to scrutinize the same. Related to this, some note a defined assessment method to leave less space for manipulation or undue influence by stakeholders and affected parties. Moreover, simulation technology can constitute a useful complement to practice knowledge by allowing for better error-quantification and in the sense of giving experienced personnel a chance to compare their assessments with model output as a form of 'digital second opinion'. In general, the study shows that the overt function of science in the policy sphere of offering support and guidance can be complemented with a more latent function of putting audiences under pressure and restricting their maneuvering space.

Turning to the problems, the short story is that there is little support for over- or under-critical approaches to simulation modeling catering for widespread problems of non-use or misuse in relation to (flood) hazard scenario simulation in Baden-Württemberg and Austria. Though undesirable forms of non-use were observed, these were not related to target audiences having such high expectations in hazard simulation's ability to provide accurate decision guidance that the presence of uncertainty became a barrier to use. In principle, lack of confidence in the credibility of output data is something that *could* pose a threat to acceptance and application. But, hitherto, this risk has been successfully managed by involving clients and intended users in the research process and in the review and quality control steps. In this way, local and professional knowledge is used to corroborate simulation results to minimize the risk of biased results due to error or imprecision, and, at the same time, the participatory element of the assessment process creates ownership of the judgment as to the findings' credibility.

In this sense, confidence-related non-use is more of a latent risk associated with the overall danger of hazard simulation becoming the target of a credibility crisis in line with what was experienced for environmental simulations in the Netherlands in 1999 (see section 2.2.1). Indeed, it is largely for the sake of avoiding such an outcome that it is regarded as vital for simulationists to document exactly what goes into a model and what this means for the findings that come out of it. As long as the quality of a simulation is high and the documentation is solid, potential doubts can mostly be settled through constructive dialog. In instances of vocal protest and questioning of results, this is not necessarily tied to the presence of simulation uncertainty, but can just as well reflect local unwillingness to accept a certain conclusion for political or financial reasons. Hence, credibility doubts do not have to be the origin of rejection, but can be what people resort to as a 'legitimate' form of argument when simulation results are unwelcome (i.e. a form of 'uncertainty as ammunition' against specific research findings). In any case, one is left with the impression that it is not primarily for the sake of avoiding misuse that uncertainties should be communicated, but for the sake of keeping science unimpeachable.

With regard to misuse, there was little concern amongst the interviewed experts about it being associated with negative consequences if local-level users accept hazard simulation results uncritically. Judging from the empirical material, this lack of concern is related to two things. First, it is linked to *the hazard simulation results in question being perceived to be of high quality*, and therefore to provide relatively reliable guidance. Second, it is related to *the perception of a low potential for negative consequences* if hazard maps and expert opinions are adopted without question. This, in turn, is related to the circumstance that these are primarily thought of as 'avoidance-tools' in the sense of enabling land-use restrictions which limit the municipalities' expansion in hazard zones. As long as the issue at stake is about where *not* to build, even if simulation results are associated with imprecision or fail to reflect the possibility of an unexpected turn of events, abiding by them will still, on average, help reduce a community's vulnerability level. From this perspective, it is not regarded as particularly problematic if simulation results are treated as more certain than they really are; the main thing is that they are accepted. Likewise, lack of technical training is not regarded as much of a risk factor, other than if it appears to stand in the way of acceptance.

With regard to the flood hazard maps, this implies an implicit focus on simulation results as an instrument for land-use regulation. In other areas of application, it is namely not as risk-free to ignore the presence of uncertainty. This was i.e. shown for preparedness planning when the emergency operation in one community was 'surprised' by water flowing into a building of importance that a literal reading of the hazard maps (i.e. ignoring the uncertain nature of flood simulation) would not have indicated to be in need of protection.

In comparison, audiences at higher levels often possess more technical education and/or practice experience and tend to be in charge of issues of a different nature. When *they* consult simulation results, what is deliberated is not simply whether or not to practice avoidance in a particular zone, but *which* areas are to be marked out as hazardous, *where* to invest in structural defenses, and to *what* level of protection. In short, they handle issues of real consequence in terms of who will be protected or not, respectively which exposure or damage to regard as acceptable. Consequently, the potential for negative consequences in case of a mistake is higher. Under these circumstances, it is *not* regarded as tolerable for findings to be uncritically accepted without scrutiny. This is, first of all, because of the risk of inferior or mistaken simulation output being made the basis of decision-making – a scenario that could both lead to misguided risk management and lay the ground for a credibility crisis. Second, it is because not wanting to hear of or account for simulation uncertainty implicitly places the responsibility for the content of management decisions on the shoulders of the simulation community. Some experts understand that actors in structural protection find it comfortable to adopt science's 'best guess' when a value has to be picked. In principle, though, what level of risk to accept is not for science to determine, but for the responsible public authorities to decide. Hence, it is estimated that risk managers at this level *should* be capable of assessing the credibility of input and output data, respectively be competent to understand and handle the presence of uncertainty (or have guidelines to rely on for doing this).

In short, this means that *it is when there is a mismatch between the potential consequences of ignoring uncertainty and a user's intrinsic capacity of understanding and/or accounting for the distinct epistemology of simulation research that uncritical acceptance may turn into a risk factor.* This can, for example, be the case when predictions are provided to local-level decision-makers for other purposes than for the sake of ensuring avoidance, such as in the case of the Red River forecasts in 1997 (see Introduction). It is also a possibility in relation to national-level policy makers, who lack expertise in the field of modeling but who are still expected to consider the implication of simulation results in regard to the content and direction of various policy proposals. *And* it is the case when risk management experts responsible for protection and regulation lack the capacity, skill and/or experience to interpret simulation output in a way that is sensitive to the character of the model and input data, and which accounts for what local terrain and hazard history suggest to be realistic.

In this sense, it is not that the problems described in chapter 2 are not recognized when it comes to simulation results in the field of risk management of natural hazards. It is still regarded as a risk that users will unknowingly rely on bad data or misuse or fail to use good data. In the case of alpine hazard simulations, there is even a concrete example in the form of a region in a neighboring country to Austria having designated larger hazard zones than necessary as a consequence of relying on simulation work of questionable quality. However, there is a difference in focus when it comes to the *origin* of these risks. In previous writing on the simulation-policy/practice interface, recipients' too high trust in science's ability to deliver 'certain' knowledge (or at least trustworthy guidance) is often emphasized. It is as a *consequence* of audiences' misconception about simulation as a research method in the tradition of the hypothetico-deductive science model that there can be negative implications for the science community (i.e. credibility crisis) respectively decision-making (i.e. non-use or misuse).

In contrast, experts in the daily practice of hazard simulation and risk management are relatively forgiving of users' trusting attitude towards simulation research. In their view, there are many actors for which it is simply vital that they can turn to experts for a reliable assessment, and it would be too much to ask of them to critically reflect on the origins of this. The risk that they perceive as central is instead that those producing simulation results will not be critical enough of these or sufficiently aware of the limitations and epistemological particularities of the models that they are running. Considering that even highly skilled and experienced modelers are at risk of over-trusting their own output data, this is all the more of a risk in relation to engineering consultants and public experts without sufficient education or field experience. If *these groups* (i.e. as *producers* of simulation data) are under-critical, it increases the risk of output being produced which does not meet the necessary scientific standards and which has not been subject to sufficient quality control. If such results are passed on to a community of end-users unable to spot their flaws, it (a) undermines the conditions under which non-experts' trusting reading of simulation findings can be regarded as relatively risk-free. Moreover, it (b) increases the likeliness of a credibility crisis and the risk of misguided policy and practice decisions. This is the background of the experts' worry about the increasing availability of user-friendly simulation programs, intransparent models and data of mixed or unknown quality. Likewise, this is the reason why lack of time and growing competition are regarded as risk factors even for serious actors, as this may aggravate the risk of (accidental) negligence.

The only time that unrealistic expectations in science's capacity to deliver reliable knowledge are regarded as a problem is when interviewed modelers are faced with 'senseless' research contracts in the sense of having to explore phenomena for which data and basic knowledge are largely lacking. When it is uncertain whether the policy community understands the 'guesswork' character of such inquiries respectively how these will be used, it is sometimes unwelcome to have to develop and run such models. Otherwise, it is not unrealistic expectations, but other aspects, which are focused on in terms of creating difficulties. For example, scarce resources and a tendering system that rewards the cheapest bidder are perceived to create circumstances under which public authorities may find themselves being provided with simulation assessments of lower quality than desirable. In this respect, lack of experience with simulation and modeling on behalf of the authorities *commissioning* hazard assessments is pointed to as a risk factor for making it difficult for them to know what requirements to stipulate to ensure high-quality products. Hence, the problem, as the experts see it, is not unrealistic expectations as much as difficulties with respect to the task of having 'realistic' expectations fulfilled.

What does this mean for the question of how to avoid problems associated with non-experts use of simulation products? In principle, the perspective that it can be permissible for non-experts to treat simulation results as more certain and reliable than they really are – as long as the research quality is high and the potential for negative consequences is low – places much of the responsibility for avoiding problems on the shoulders of the simulationists; to avoid a credibility crisis or reliance on inferior findings, *they* must ensure that the information they give out is as good as possible.[1] At the same time, this cannot free actors in the policy sphere from all responsibility in terms of what research is commissioned or how results are understood and used; there cannot be a carte blanche for first ignoring uncertainty and then blaming science if things go bad.

To avoid such an outcome, the presence of uncertainty must be made unmistakably clear. Considering that accompanying documents are not always read, this could be done directly in the visual representations of simulation results or in the legend explaining these. When it comes to hazard maps, this could, e.g., take the shape of an indicative uncertainty area around the calculated hazard lines. If this is unpractical, a minimum requirement would be the inclusion of a written disclaimer directly in the map indicating what it covers respectively does *not* cover and making an explicit reference to the presence of uncertainty (e.g. in the form of a quantitative assessment).[2] Even if this would not eliminate the possibility of uncertainty going unaccounted for, making the presence of uncertainty unmistakably clear would at least (a) lower the risk of non-experts overseeing it by accident or ignoring it by mistake, and (b) prevent end-users not caring to reflect on the meaning of imprecision from blaming science in case things turn out bad. Put differently, it would, ideally, force people to make *conscious* decisions about how to respond to and handle the presence of uncertainty.

At the same time, it is a valid point that not all user-groups are competent to deal with all kinds of uncertainty information. Consequently, there is also a need

[1] Of course this is the conclusion of the experts' reasoning in relation to this specific case. It should not be confused with a factual statement or with implying that this also applies to other situations falling under the realm of the simulation-policy nexus.

[2] For flood hazard maps, for example, it could be specified that these cover the risk of inundation from riverine flooding and not from slope water, over-flowing canals, etc. To facilitate the assessment of where the presence of imprecision might be worth taking into account, furthermore, flood hazard maps could do well by indicating the elevation of the land areas predicted to stay dry.

to actively contemplate who needs to know what to ensure 'good enough' use (i.e. implying a low risk for negative consequences) and to adjust the way uncertainty information is communicated accordingly. For some actors and situations, it might be important with a detailed understanding of the uncertainty associated with simulation results. In other cases, it might be better to focus on ways of conveying a limited set of cues to help the intended users draw a minimum of inferences with regard to the epistemological nature of modeling without much active cognitive effort (as in the suggestions just mentioned above). In principle, these are questions which should be explicitly dealt with for all simulation products entering the policy sphere. From this perspective, challenges in terms of how to avoid problems concern both how to identify cases where there is a mismatch between an audience's competence level and what is at stake, and the question of how this gap can be bridged.

In chapter 2, it was noted that common recommendations for ensuring use that is sensitive to the presence of uncertainty concern (a) more and better uncertainty information, (b) more user-producer interaction to provide for better mutual understanding, competence and trust, (c) strategies for making simulation output less vulnerable to misuse (e.g. by providing value ranges rather than exact figures), and (d) not forgetting alternatives to prediction such as precautionary hedging options and decisions for increased resilience. This study does not question the validity of either of these strategies. Indeed, there is no need to choose since all of them can be pursued jointly in parallel. It does draw attention, though, to the lack of clarity as to when *more* uncertainty information is needed and when this simply needs to be communicated *differently*, respectively to what 'better' uncertainty information would look like in practice. Additionally, one point that this study indicates is the role of intermediaries such as the public authorities commissioning virtual engineering. These play a role both for regulating and scrutinizing the quality of simulation assessments, and for what acceptance these will enjoy at lower levels. Specifically, it does not only matter how authorities manage the contacts with and involvement of intended users but also what kind of research requirements are specified in terms of documentation, on-site visitations, which model to use, whether to use more than one simulation program, how to include uncertainty information, etc. Depending on the circumstances, such institutions can be part of the solution (or of the problem) as well, and should therefore also be considered.

In order to move forward with the issue of how to ensure 'good' use, research needs to become more precise and develop common distinctions as to the different categories of actors, products and application contexts referred to, since both problems and solutions are likely to depend on these details. This could, for example, involve spelling out the risks at the different stations of the simulation-policy/practice nexus, ranging from 'modelers' *developing* simulation programs (in academic, private or public positions), 'simulationists' *using simulation programs* (e.g. modelers themselves, virtual engineers, risk managers, regulators) and different forms of 'users' of simulation *results* (ranging, e.g., from those producing their own output, over those commissioning such work, to end-users of processed information products).

Based on the findings of this study, the highest requirements when it comes to who needs to know what certainly apply to producers of simulation results (i.e. including actors in public offices running models that they have not themselves developed), who must know very well what they are doing to avoid the risk low-quality output being released for use. Next to them, actors in public office *commissioning* simulations should be well enough informed to be able to assess the quality of the results that they are provided with, in order to spot and inquire about questionable output data. Where appropriate, they should also be in a position to specify simulation requirements for contractors to adhered to, in order to guarantee high-quality results in the first place. In a third category, one could place users receiving simulation-based risk assessments to use as input to decisions about whether or not to invest in public protection measures (where, to what extent, etc.) or where to draw the line for a risk zone. These actors should be (or made) aware of the presence of uncertainty to ensure that the resulting decisions are made by risk managers, whose job it is to accept this kind of responsibility, and not pushed onto simulationists or the science sphere as such. Finally, there are those who are more or less 'affected parties' when it comes to simulation results, in the sense of being supplied with assessments together with instructions or regulations regarding what is allowed where. For these individuals (e.g. in local administrations or private households), it is primarily important that the assessment results are accepted and adhered to, since this will (provided that the results are not mistaken) help reduce further increases in risk. Awareness of underlying uncertainties is not a priority for this group in the same way as it is for the other categories mentioned.[3]

Though this can only be said to represent a first suggestion for how to theoretically differentiate between different users of simulation models, it could serve as a starting point for further work in this direction, including for research about how different audiences respond to and deal with the presence of uncertainty and how uncertainty should best be communicated, e.g. to ensure that research recipients of different backgrounds are able to tell its meaning for their particular field of work.

[3]It may be noted that one explanation for the interviewed experts' lax view on the need for local-level risk managers to be aware of simulation uncertainties could be that they unconsciously place these in the fourth category described above. As shown by some of the situations found in the data material, this may however be a mistaken view, and these individuals should at least sometimes be placed in the third category (e.g. emergency managers in charge of defining an emergency response plan or administrators in charge of planning local technical protection measures). All in all, it is not to be avoided that the responsibilities of a single individual can fall into more than one category.

Appendix A

Translations of German quotes

A.1 Quotes in chapters 2-5

Chapter 2

A model can mean two different things, on the one hand the display of a state of affairs in the form of a representation [. . .], on the other hand a statement about the relationship and interdependencies among several objects (which makes it related to theories). [. . .] Abstract models are the basis for assumptions on which a simulation rests. Hence, a simulation represents the concrete implementation of such a model. (Spath, 2009, pp. 50)

In simulation-related deficit analyses, mainly aspects of the models themselves are being used as factors for explaining low and/or false effects. These studies concern themselves with uncertainty and limits of models and the resulting insufficient reliability of the results. As a further explanatory factor raised is the complexity and opaqueness of models, so that decision makers do not understand the how the results were arrived at and accordingly misinterpret them. In deficit analyses that refer to context, on the other hand, models are viewed in their socio-political setting. The focus is less on the limitations of the simulation instruments and more the actors and institutions producing (or commissioning), communicating or using them. (Scheer, 2013, pp. 86)

Chapter 4

The smaller the catchment area, the more difficult the provision of the hydrological data. In isolated cases it can be necessary to regenerate the hydrology for small catchment areas. At the same time, there are generally no records of past flood events for small catchment areas, so that the hydrological data situation – due to the lack of calibration data – cannot be significantly improved by producing a precipitation-runoff model (P-R-Model). (Moser et al., 2011, pp. 23)

Chapter 5

[T]he experts [represent] a complementary acting-unit to the target group, and the interviews aim to gather information about the contextual conditions of the actions of the target group. [. . .] The interviews with experts are a source of data among others, for example interviews with members of the target group, participatory observation, document and file analysis. (Meuser and Nagel, 1991, pp. 445-446)

A.2 Quotes in chapter 6

Section 6.1.1

In the past one did not know. One did not have the opportunity to create such hydrodynamic, numerical models. Someone just said: "Yes before, there was water here once, or there." It was not recorded properly. And now one simply knows. Through the flood hazard maps, one sees it and then one also knows that one must build technical flood protection, if what is there is not enough. (I02RMb, 00:32:59-3)

After we knew from the flood hazard maps where the water can or where it spreads out or... where the protected areas are, we have now examined the existing flood protection facilities and did an analysis of the stability of the flood defenses. And it has been found that not all facilities are stable but that they must be improved or perhaps even renewed. And in some areas it has been found that the facilities are not high enough. And that was the second step then. First, look where the danger is and, then, what is there: is that enough? Is it stable? And additionally of course: where is there something missing. (I02RMb, 01:31:07-4)

As I said, on the one hand, the municipal council was informed and then the decision was made that the administration, that's us, was commissioned..., on the basis of this report, to develop an action plan and a financing concept. (I02RMa, 00:42:23-9)

I02RMa: [. . .] That was another issue then. Previously, we had a safety level that was different depending on the facility. There was no uniform protection objective. And, through a municipal council decision, the city resolved to create a technical defense against a larger flood along the main river. So not for a 100 year flood, like along the small waterways, but – due to the much higher damage potential... You see, these areas, which are so nicely blue here, that's all, those are the industrial zone. If that stands under water... it causes huge damage. And because of that they decided to implement a higher level of protection. 00:28:55-4

I02RMb: And then we could of course also present it well in the municipal council because such a simulation is much more impressive than when one just tells someone: "Everything here will be blue" and they say... -It's just difficult. But I think through this visualization... the acceptance is just of a different kind. 00:36:25-9

On the administrative side, we must ourselves, of course, still do some homework that this questionnaire drew attention to. For example, because of the new insights, which one has from the flood hazard maps, to revise our technical protection concept. [. . .] To analyze the weaknesses exactly and which measures, technical measures can be implemented. (I04RM, 00:07:35-3)

SK: Do I understand it correctly that the maps have perhaps not played a significant role for your work? 00:39:59-1
I03RM: Yes, you understand that right. Because, at the time that the maps were published, the Water Association had already developed its concept. [. . .] 00:40:32-9

So it has not triggered that we've said: "Oh look, we need to do something here." Because it was already clear from before that we have to do something here. [...] Elsewhere, it is perhaps, then [the] flood hazard map is the trigger for this thought process to even start. That was not the case for us. (I03RM, 00:55:09-9)

So before the flood hazard map, we had already had all these calculations made. Where flood protection systems must be built and how large they should be, that was already clear. And that also has not changed through the calculations for the flood hazard map. (I06RM, 00:17:53-2)

I03RM: [. . .] If you're suddenly standing in someone's garden, who is only in the HQ100-line, who has never been flooded [...] if you then come and say you want to build a flood defense and because of that he might need to dismantle his greenhouse, [...] he will have no understanding at first. But if you show him, last time was HQ50. Now we assume that at some point HQ100 will come and then the water will stand 20 cm high here. And then we go inside, what is affected by those 20 cm. Then he will suddenly be very open towards flood protection measures. [. . .] 00:34:36-6
SK: And did you have such cases where you brought the maps along and (. . .)? 00:34:42-8
I03RM: We rather had the discussion here. And had, could then visualize it with the PC, to display the inundation depth. We had two cases, yes, which till today, I think, are not 100

Section 6.1.2

If you look at this kind of map, you see: Which areas in my municipality are inundated? Where must I potentially evacuate? How should I evacuate? And then there are various hazard points: hospitals, sewage treatment plants, whatever. Points where I must consider in advance where I have to act, how I have to act, and then fixate the respective alarm stations. That's just easily possible with the flood hazard maps. Like escape routes, for example. And roads: Which roads are inundated, which areas can no longer be reached. Such things one can simply read very well with the help of the maps. (I11Ea, 00:23:04-6)

I16E: They are useful in those areas where no information has been present previously. [...] [S]o that the municipalities contemplate: What must I do? Or: I have to do something. [...] [But] in a hazard map in the sense of a HQ100, whether there will be many new insights there – I find doubtful. Because, in principle, most will perhaps already have experience of that. [...] So I mean, if I have a river here and I have 25-year flood, the fire department will say: "That you've calculated nicely. We know that too." [...] So flood risk maps, well hazard maps, are already a bit obsolete by now, so to say. Nowadays, one only speaks of flood risk maps. [. . .] And... that is, in my opinion, the nuts and bolts, that one knows which objects are somehow present in the area. (I16E, 01:00:10-8)

Here, we can judge by rule of thumb, but with such a computer simulation, in which I have these aids with the elevation points that I can use, there I actually get an exact value in the end. So I don't think that's bad! As I said, for us locally too large. Too far. (00:38:52-4)

I02RMb: Right. We have intensified our preparedness planning activities somewhat. Realized that many areas had not been considered before. [. . .] that has become much more intense. It has been properly worked out now, for example, where along a street of houses along the brook is inundation to be expected? Where must be closed off? That has been looked at in detail and compared with the maps. And now it's also really worked out. And, previously, it was a bit crude. Or it wasn't at all. 01:04:03-3

I02RMa: [. . .] If either a failure or a flood larger than the design flood occurs [. . .] we have developed an exemplary emergency response plan for one district. What is to do if it fails. Because people live with the understanding: we are protected. And now that protection is questioned. [...] There is still a lot to do. Also for the main river. It requires time and... well human resources. [...] Someone has to sit down and make a plan. And there we're still at the very beginning. As I said, for this district, we made a plan for a conference. [...] And... But for downtown, we don't have any yet... because we are not yet in a position staff-wise... to. . . finish it. 01:23:25-8

[D]uring the time that I've been here now, it came about that the law demands that you, as a municipality, create a [plan – Ed.]. There was a legal specification. But, for us, it then still took a while, simply because the time is not there. In such a small administration, we are responsible for so many things [...] And I took it now, because I said: "We must do something now." And then I took a week off from everything else and made the plan. (I08RM, 00:32:29-0)

One needs the maps to produce this plan because one had to say, one must know, when a water level of, for example, 5 meters is reached, what is affected? [...] And then one must be able to tell, when that area is affected, which protection measures are to be implemented in order to have further areas or other areas be protected. For this, such a map is very important. That is clear. Together with our building department, with our on-call service department, we specify which measures we require on the basis of these maps and these water levels. [...] You have a parking lot right down at the river and there are 150 vehicles. You know very well that, when the river comes to 4.50 m, the vehicles must be gone. You only see that, however, when you have produced such a hazard map beforehand, to see, at 4.50 m, which areas are affected. (00:33:43-4)

The plan was originally produced by my predecessor. Without flood hazard maps. [. . .] They made a plan after they had participated in several flood episodes. [. . .] And on the basis of these insights, it was defined which measures to take. It is, of course, a process of continuous updating, nowadays as well. If you open up a new building zone today, for example, this will naturally have ramifications for the next flood. [. . .] We often hear from people, who call and tell us: "We have water in the basement, suddenly." [...] And that is then recorded by us and when the next flood comes we can say: "Stop! 20 cm before we have to call these people. Take action, something is coming." (I10RM, 00:35:30-1)

I07RM: [. . .] They are, however, five years ago, they said that we'll get something like that too, but I think that, for starters, these maps, for the adjoins of the Neckar, the Rhine valley, that they will, for starters, prioritize the larger rivers and do those first, that we will perhaps get them too then. As I said, we need them, if we have a centennial flood, we will normally need them every 100 years (laughs). [...] 00:28:35-8

I05RM: Well we know, we already had a couple of big floods here. In particular in the region where the streams meet up. [...] That's the area where [...] there can be damage, really. And that is known. [...] In the past, the terrain there was raised so that [...] the danger of flooding would no longer be so great. So these areas are known. One knows, when there is flooding, this is the area where there will be problems. But the problems are not such that one would make alarm plans. There is no fuel oil storage or something like that, regarding which one would have to warn the fire department or which would make oil-barriers necessary or something along those lines... 00:28:08-7

SK: So for the emergency management, the map will not play that great of a role, you think? Because of- 00:28:17-9
I05RM: Well, I can't imagine it. 00:28:21-1

I made a round here in the house as these flood hazard maps became binding for one of the brooks, to everyone where I thought they could have something to do with flooding. So starting with the on-call service department, which must go out in case of floods and close off areas, fill up sandbags, and who knows what, to our office of public order, which has the organizational leadership in these kind of emergency situations. [...] And their first reaction was: "Hm? What do we need these maps for? We know exactly what happens when a flood comes." We have a warning system. There is a gauging station. And [...] a corresponding response plan [. . .]. (I09RM, 00:12:47-6)

This was triggered by the hazard map. The town had seen that their new development zone from 20 years back would be inundated already at HQ10. [...] Then he [the mayor – Ed.] initiated for an emergency management plan to be made. [...] Then, on the basis of the hazard maps and the sequencing, and with external support, [...] they looked up what actually happens in town when the water arrives and starts to rise. (I13E, 00:27:08-3)

But then it got stuck somewhere, too, because it is a lot of effort and the municipality short on cash, little staff. And then it was pushed. Often, it is also the case that the mayor that triggered it is perhaps pushed out of office. And when there is a new one... And then nothing further happens... (I13E, 00:27:08-3)

Section 6.1.3

I05RM: In the area of real estate, agriculture, when we lease our parcels of land. In construction law, whether one may build or store this and that at this location. Surely also in water maintenance, how do I care for the brook (...). [...] 00:25:51-5

I05RM: [...] If I receive a landfill permit application from a farmer and I see that that is floodplain area, then [...] I will say in my response to this application: “No, wait a moment, this is an area that is regularly flooded. So we don’t do it.” If I lease a plot of land, which belongs to the city, then I will [...] tell the property department: “Listen here. This is now farm land, but try to lease it as meadows, because: if it is leased as farm land I will have the dirt in the brook afterwards.” In our brook there are rare types of fish, such as souffia and bullheads. If there is a flood and the dirt is flushed into it, the habitats or cavities where the fish lay their eggs are lost. [...] 00:22:15-7

I09RM: Well, for us it is certainly very helpful, definitely, to have this overview. [...] And we have information on flood depths. That’s very important now when, as is possible here, there are building projects intended [...] then we can tell the architects: “The depth of a 100-year flood would now at this place of your land be 50 cm, over there 70 cm. Plan accordingly so that the potential for damage is minimized.” [...] So it is very, very helpful for us. [...] 00:41:42-1

[T]hat when people apply for a building permit, that we write into it: “Caution flooding! Flood-aligned building required.” Or ”not permissible here.” Things like that. They weren’t followed up on very strictly in the past because one just didn’t have these maps and didn’t know how far the blue areas extended. Today with the maps we can look closely and say: “Ok, here is blue.” [...] (I02RMb, 00:55:02-8)

And [...] we had to modify the development plans in some areas, had to revise them, what then often for the affected landowners, who according to the old planning law had a building lot and now only have a flooded piece of land, in terms of planning law, this is a problem for local politics. (I02RMa, 00:56:56-8)

In everyday life, it’s a huge help. I mean this geographical information system in general. [...] I always say, I have a telephone in one hand, in the other hand the mouse to the PC and, if someone asks me something regarding any of the relevant issues that we administer here, I can provide information directly. I can retrieve this flood information. I see where pipes are. I see which building law applies, what the zoning says, where protected areas are and so on. And, in this respect, this information is simply a very important building block, too... (I09RM, 00:41:42-1)

Say, in the case of the field that is to be leased [...]. Rather than the city having to maintain it as meadow, it will be leased as farm land. As I said, it's not as if what it says in there is written in stone. But it's the information that the local decision process must consider. What finally comes out of it is a different story. (I05RM, 00:24:29-5)

You see that other communities have erected buildings, public buildings, in the HQ100-area in the recent past. [...] Ultimately, politics does not always decide rationally, but interests are pursued. And there you must weigh flood protection against other interests. (I08RM, 00:20:37-3)

I06RM: Yes, I find them very good. Flood hazard maps provide insight about the theoretical inundation area. But you already see that communities nevertheless try in these areas, especially in the HQ-extreme area, that they still try to designate building zones. And there should still be a means to prevent that. [...] 00:13:47-3

There are acceptance problems insofar as that, naturally, many municipalities do not want these maps. Because then they are provided with stipulations. For example, an industrial zone that they wanted to designate, they are not allowed to designate. Or a development zone. They want to expand, every municipality wants to expand [...] And the hazard maps stop that in the river valleys. (I18E, 00:34:16-3).

[T]he municipalities are in these... how's that called? In these municipal associations, they are involved in the financing. And they play along, enforcedly. Because it's an EU directive, which is then implemented via state laws. But the municipalities are not enthusiastic about it because maps come out of it showing certain areas as flooded. Where then, possibly, originally planned development areas cannot be realized any more, or only with much more difficulty, because, if one builds the development area there, one has to do landfilling, which consumes volume, a reduction volume, that one must then win back somewhere else. That's the municipalities' daily struggle, not only against flooding but also against the... these flood hazard maps. (I14E, 00:29:38-8)

Section 6.1.4

And the state has or is in the process of creating flood hazard maps and then you see it in blue and white: That's what it looks like. And then it's real. Then one knows: Ok, that will come at some point. (I02RMb, 00:32:59-3)

So, simulation and animation are ways through which this flood hazard can be made real and with which to sensitize people. (I18E, 00:25:39-1)

[T]o affect that some form of precaution is taken in these [protected – Ed.] areas. That people do something, that they say: "Whoops! We may actually be affected." And, for that, these maps are important. That one can record: there is something! [...] That is exactly the point where we can do something today in terms of precaution. Where we have the possibility to accomplish that citizens do something themselves. Which is often important. I mean, we cannot always only say: "Build flood defenses!" The public can take a lot of precaution itself. So that there is less damage, and, through that, it is perhaps more worth than us building the hundredth retention basin somewhere along a waterway. It can very well be wiser to use the maps to generate precaution.

That the citizens themselves start taking precaution, very important point. That they do not say, as just mentioned, "the state must take care of it" or "the municipality must do something". Instead, everyone can do something themselves simply by saying: "Well, how do I use my basement? [...] What can I do if I build anew? [...]" (I12E, 00:28:45-5)

Then one can then say or show the population: "Up to this point it is dangerous. Above that, you can think of yourself as being on the safe side." Or, if he's within the HQ100-flood, say: "Build accordingly." Or, what do I know, if the heater is to be rebuilt or whatever, that one can arrange oneself accordingly. (I05RM, 00:29:56-6)

I10RM: They are of course very important when it's about building things. That is, when it's about development plans or preparing development plans. Or if it's about, people who want to rent an apartment in a certain area often come to us and ask: "From when on will we have inundation there?" For that, the maps are of course very important, that one must really say clearly. Or it is very helpful that they exist. [...] 00:25:16-2

I think it [the hazard map – Ed.] is an important tool for the residents for clarifying, and for showing: "Careful, even if you were never flooded or only very rarely, you live in a flood-prone area." That is very important for the presentation of measures that we were just talking about. Because if you come to someone and tell them: "We're building a wall through your garden", even if that wall is just 50 cm high, they're not going to be thrilled. But if you say you're doing it because you want to protect them, and if you can also support that with a flood hazard map, then they're suddenly open towards such measures. Because they'll say: "Yes, I'd rather have a wall than water in my basement." (I03RM, 00:29:01-1)

It's like this, those who want to build there and have a building site – given to them, inherited or whatever – are very unreasonable. They'll say "there has never been flooding here" because they really want to build at this spot. And then we often convince them with photos, when we have photos. Or with these blue maps. [...] And it is often difficult to convince them. (I02RMb, 00:55:58-5)

When citizens come and ask. . . . [T]hey want to rent a flat somewhere or buy a house or so. Maybe there's a plot of land somewhere, where they would like to build. Of those, there is certainly the one or the other who inquires: "Is it a flood plain? When can we expect flooding there? As of what water level?" Every now and then there's a request, and then we refer to the map. (I10RM, 00:40:53-5)

I mean the individual builder or architect who comes to us and says: "How is it there?" And I can tell him relatively quickly: "In the case of a 100-year event, which is when the buildings insurance will take care of it and when there are also certain consequences in terms of construction law, the flood depth is that and that for this piece of land." Then they are of course very grateful when they can quickly obtain reliable information. (I09RM, 01:02:12-4)

I02RMa: That's right, when, by real estate transactions nowadays, they inquire. 01:40:18-8
I02RMb: Right. [. . .] [S]ince the Oder and Elbe were gracing through the TV [...] And then, of course, flood events in states that never used to have flood problems. [...] [P]eople living near the creek or who want to buy a house [are] already more sensitized. They also come and ask: what does it look like? [...] That was not the

case in the past. Before, no one was interested. Because it just wasn't on their minds, flooding... 01:41:23-0

I03RM: We have also arranged information events and again explained how the flood hazard maps work, which information I can draw from them. And, especially after the flood, there was of course again and again the request: "Yes, how is it at my place? [...] Am I actually in the hazard zone, or am I already outside?" [...] If the water comes, is it only my coal cellar that is wet or my living room too. [...] 00:34:36-6

And the information, well, it was also publicly presented. It was a fairly brief affair. It was somewhat politically motivated. They wanted to show, outwardly, that they are here now, the maps. There was some explaining involved, too. (I01RM, 00:43:59-5)

I04RM: Yes, has just been discussed. The top of the administration definitely wants to organize an information evening. Here at city hall with a large audience, with invitation by the Regional Administrative Authority, through which the maps are produced, and by the Administrative District Office, of course. And we, as involved party that is, want to organize an information evening during the public display period. Because then the topic is new and that is when people have the most questions. [...] 00:06:14-1

The city [Name] did that. They invited the whole population of this development area to an information event. Said: "This is what it looks, people. Errors were made, alright. Now, the case is that, if we are flooded, the water will stand at 1 meter. Check that you have enough material to protect yourselves. We can also give it to you." They showed how to do it, how to water-proof a basement window, like all these site protection measures. (I13E, 00:35:07-7)

So, the maps were printed in color in the daily newspapers. And there was no outcry. "Oh, that's what it will look like if we're flooded." It also wasn't used somehow politically to say: "So, you've now seen it in the maps, in the Rhine-Atlas. Now we must do something! [...]" (I12E, 00:34:59-3)

Section 6.2

Well... there is certainly preoccupation with it. And, I would say, in 90

We have two different kinds of reactions from out there. [...] And we have regions, for example, here... They're already finished, the dark green ones. That was no problem. The municipalities, yes, there was discussion and alright. Here, in this area down there, they are only just being finished. There, there was massive resistance: "The map is not correct. It cannot be that we have spent millions on retention basins and our settlements, future settlement area is still flooded." [...] "It cannot be. The maps are wrong. The Regional Administrative Authority has miscalculated." And tried to mobilize politically to prevent that the map is produced. That there is as well . . . [...] [T]here is the whole bandwidth. [...] I've already heard people say: you bring the flood to us with your maps. (I13E, 00:14:47-0)

A.3 Quotes in chapter 7

Section 7.1.1

Our river basin investigation was already done at this time. So much of what is shown as risk-zone in the flood hazard map was already known since before. Because it was known what the catchment area looks like and what this means for the water surface profile in the affected communities. (I03RM, 00:29:01-1)

I06RM: Well, we don't use them for our daily work. They're more something for the municipalities themselves to use when some building areas are being discussion and new ones are being devised for future development or the like. Because our mission is the implementation of predefined flood protection facilities at specified locations. [. . .] 00:16:58-2

It is nevertheless, in spite of everything, always easier to take action and get support just after the occurrence of flood damage than on the basis of flood hazard maps, for example (...). No municipality is willing to open up its wallet unless it's in great distress. (I06RM, 01:01:58-2)

Because [...] it has changed over the decades how flooding happens. Today floods turn out differently than 20, 30 years ago. [...] And if you compare the flood hazard maps now with old maps, earlier maps, then that alone shows how necessary it was to redo them to have a basis for planning in the water sector and in the area of flood protection. (I01RM, 00:39:55-7)

Section 7.1.2

Then you can see exactly at what time which area, which block is flooded. And, well, that really helps. Because then, since we also knows through the forecasts what water level we will be getting, we can already take protective measures there in advance. (I10RM, 00:25:16-2)

Well (...) it's not the most urgent thing for us. Because we know in this type of town, we already know. We know, by this and that event, it will be this and that area. We also have simple aids down here at the bridge. We have, after every major flood, we add a new mark in color and note the year and then we know exactly, when the creek runs over the embankment to this and that level, then we know, down here, in this and that area the basements will be flooded. This is the advantage of a smaller city, that we still know these things. (I07RM, 00:30:24-1)

I07RM: They don't bring us much, that is-. Because maybe we can put up a flexible flood barrier at some road, but we already know that by ourselves. [...] When there is heavy rain, I simply drive out to the first bridge out there and look how high the water is standing. And then I know in two hours I'll have this and that water level in town. These are just experiences that we have [...] where we then need to or can take action. Whether to issue a warning [...]. 00:34:24-8

But the biggest problem are small rivers, small streams, which are only this wide, normally, and perhaps this deep [shows with his hands]. And when you have a geographically concentrated flood episode, then it can be that it is river three meters wide or, yes, and deep. Those are the main problem. But that cannot be handled even with such maps. Because you would have to calculate every little river that comes out from somewhere in the woods. Which overflows perhaps every 200 years. [. . .] In 15 years it is over there and in 20 years it's moving in that direction. The effort is much too great. You won't even find the plans anymore by then (laughs). (I07RM, 00:32:46-7)

I13E: Well, where we still encounter trouble is when it comes to the local understanding of it being necessary. To do this or that. For example, for the municipality to set up an emergency plan. That this is necessary even if there are technical protection measures in place in the form of a dike or retention basins. That it is necessary anyway because there can be an event which is greater than what these reservoirs or this dike were dimensioned for. The municipality must nevertheless be prepared. And that continues to be very difficult to get across to the municipalities. [...] 00:14:47-0

Section 7.1.3

It [GIS – Ed.] is basically like an onion that has different layers which I can then look through. Then I see that at this point, [. . .] it's a natural monument, it's floodplain, it's this or that. [. . .] When I have this flood hazard map as well and know that at this point, I see it in the aerial view, it extends this far, I can check: is the project that I'm planning affected too? Or is it not affected? Then I can make decide much better than what was possible before when one only had this in the form of cartographical material. (I05RM, 00:15:36-1)

...you can very quickly find out everything electronically now, what the situation is like. Previously we had to either, as I mentioned, rummage through our files or we had no data at all. [...] And it's really important to us to have this information accessible. (I09RM, 00:43:46-1)

Locally, there are land-use plans which cover all districts. And in a recent update, at least here locally, it of course had to be taken into account. [...] At some locations, you cannot designate any land-use anymore. Whether it's for housing or commerce or something else. So, that was a very concrete opportunity for use, or it was mandatory, ultimately, to consider it. (I01RM, 00:49:58-9)

[O]ften, the case is that precisely commercial zones are located in these areas. And if those are no longer useable and no longer open for modifications, then that poses a problem to the local business community and, hence, also to the municipality. Because if a company cannot grow, it won't [...] necessarily satisfy with being offered a different location in the area, but will eventually call the whole site [into] question and possibly relocate. And that's very dangerous for a community and also expensive. Because, to a great extent, a municipality is financed by trade tax. [...] If we have good protective works, which function reliably, this must also have an [...] effect. Currently it is handled very strictly, that these protected areas may not be built-up. (I03RM, 00:39:11-4)

Basically there is fear of contact or resistance. One doesn't really want to know. Because a municipality, if it has businesses in flood-prone areas, it prefers to have them work and pay taxes and so on and not to strain them and somehow-. It's regarded as if it would be to hassle people to say: "You however live in the flood-prone area." Many municipalities want to continue building in such areas. (I06RM, 00:27:39-3)

I14E: Yes, there's always the question, if a municipality has a problem and wants to be informed and wants to have an idea of how it can protect itself, what it can do, then it's a big advantage. But if in the municipality there's, so to say, a very dedicated mayor, who mainly regards it as his task to attract more business, to designate development areas, and to develop the community, and then has the problem that he is located in a narrow valley and only has development opportunities along the stream, for them it's a problem and they don't always appreciate it. [...] 01:35:16-3

You have to count with, that the municipalities, which of course – these are interesting plots of land along the waterways as long as there's no flood – that the municipality of course has a great interest in securing such land parcels and use them for building, for urban development. And this will, there is much conflict potential in this [...] (I17E, 00:23:22-4)

Section 7.1.4

Well, you cannot say: "We alone know best and this is how we'll do it. And, citizen, you should simply accept it." Instead one should involve the citizens at a very early stage [...]. (I03RM, 00:15:50-8)

[W]hen the flood hazard maps will be published in the near future, then the reaction from the population, from those directly affected. Because that is still a large question mark. Will there be a storm of protest coming our way? Because many people see: "Oh, I'm in the flood area", which they might previously not have been aware of. And whether some of that will come crashing down over us. My boss currently fears so, for example. (I04RM, 00:02:47-9)

But, as I said, right now, what is rather perceived is the danger that something will be unleashed, which we don't know where it will end or what will come out of it, and that the municipalities will be faced with a lot of questions. (That) we'll be covered in inquires and we, as a municipality, weren't even who came up with this thing. So, it's a bit ambiguous. (I04RM, 00:17:55-2)

I08RM: Yes, it's like this, when we've expanded our basins, I assume that we'll, of course, promote that. Because, naturally, positive things you can market well. But, currently, we lack the funds to, concretely at this moment, extend or build something new. And, naturally, you don't market something negative... That could give people the idea that they might not be perfectly protected. Therefore, in this area – that has political reasons – we only communicate positive news in this area at our small level. (Pause) 00:11:41-6

For us, it's currently more important to establish the structural defense than to invest the time and to prepare material to inform the public, only to have to say: "We must still do this and that." It's perhaps more meaningful to make a start first, saying: "We're building. We're doing it." And then inform parallel. Because otherwise it kind of has the effect of making citizens afraid and an extreme pressure building up. And, this way, we can simultaneously say: "We don't only know about it but we're also working on it." (I02RMb, 01:42:32-1)

I05RM: Well, I don't really see the necessity for that. Especially since the affectedness is limited to a few residential houses and a couple, or probably only a single store. They know the fact of the matter, because they've already experienced it. [...] [I]t's not a huge area that is inundated, here. Insofar, there's also no reason to raise panic. Those who are directly affected by flooding [...], they know it... [...] 00:34:51-1

SK: And the people who already own a house close to the river? 01:02:55-3
I09RM: Nothing changes for them... 01:02:59-1
SK: Is there no interest in coming here, see the maps and see how high the- 01:03:04-1

I09RM: The depth. They know exactly how high the water stood in the basement at this and that time. At the most they would start discussing, saying: “That’s not correct.”

Well, one needs special knowledge about flood protection to make it palatable for the citizens. What the positive purpose, the purpose and the sense of the flood hazard map is. And that is not being communicated by the municipality, the community. And the staff is not there and the expertise doesn’t exist. And it’s a shame that one produces such a good instrument as the flood hazard map, only to then not communicate the positive sides of it to the population in several steps... (I06RM, 00:30:31-4)

The state of Baden-Württemberg has issued the flood hazard map, but then, really, a group of people would have to say: “Now we introduce it in every community and offer consultations and also have discussions with individual companies threatened by flooding.” There is no structure in place to communicate it in a positive way to people... It’s left to depend on itself. (I06RM, 00:28:22-8)

Because, as a mayor, one has to take care of services of general interest to the citizens and one doesn’t want to worry them with these hazard maps and these issues. And will then, owing to the circumstances, also say: “Well, it’s not a non-issue here, flooding. Hence, we don’t care about it any further. We have it here [the maps – Ed.] and whoever wants can have a look, but we don’t do anything actively. We still have that construction site over there and the kindergarten that is still to be built and this and that.” And then the resources are simply differently used. [...] 00:40:57-1

I18E: [. . .] [T]here are municipalities which approach it very responsibly, in my view, and never talk about the risk of flooding in diminishing way, but always say: “There is this danger.” Which don’t have a problem with us depicting flooded areas located in industrial zones [...] They deal with this issue very proactively. And there are other cities, which say: “Oh, what? Flood hazard? No, we cannot tell anyone about that.” Because they’re afraid that the industry will move somewhere else and they pay a lot of taxes. And they’re afraid that people will panic and move away from the area. [...] So, as you can see, there are many who prefer not to mention the risk of flooding and who hope that nothing will happen during

their tenure as, for example, mayor. And, if it does, then it was an evil natural phenomenon. [...] 00:19:08-3
SK: What does it depend on, in your view, that some handle this well whereas others don't? 00:19:15-7
I18E: Well I guess that's really a purely individual question, which people are there. [...] Really it must be that. Because the two cities that I'm thinking of [...] are economically very stable, both have large industries in their diked areas, both are exposed to a similar risk of flooding, both with huge loss potential. [...] But they respond to it completely differently. [...] [T]hey'll only face damage from HQ100 or HQ200 events. That's very rare. The one says : "Yes, still important. It can happen, I have to inform people." And the other says: "HQ200. Once in 200 years. Whether that will ever affect me? Better to do good politics now, collect lots of trade taxes." [. . .] 00:22:36-0

Section 7.2

It's always a problem when there are consequences. And when there's suddenly an ordinance [...] Then I say: "Hm, maybe it's not right. [...]" Then there are always acceptance problems. When people see disadvantages from it. (I18E, 00:38:02-0)

When we're around in the flood partnerships, there's often reports of the many measures that have been carried out. But these measures are usually taken because of negative experiences. I.e. because flood events have happened. And very little happens in advance. I must admit I don't have very high hopes that we'll get many municipalities to bother about these things in advance. (I11Ea, 00:30:36-3)

In Baden-Württemberg, the municipalities were present at the table from the start, the municipal associations. [. . .] And, hence... there is [...] a great desire, I also want to have the results. I have shared the costs, so I can also say what I want. And there's a greater acceptance from the outset. That means the municipalities ask: "When will we finally get our map?" And they also want to know what the map shows. And partake in the plausibilization of it. Look at them and say: "I do not like that there. [...] Or there's the bridge which has been newly built. We have to change that." So, the municipalities are strongly involved. [...] And that's simply not the case elsewhere, in other states. And that's just exemplary, that so much has happened. And you see it in the sum that is spent. Like [...] they're really spending big and not saving on it. (I12E, 00:21:07-5)

And the [flood partnerships – Ed.], for example, are a really great tool or a great method for keeping the issue of flood risk management continuously present in the municipalities. There are many events, flood partnerships, where the local authorities can exchange information with each other, where there's a lot of material. [...] Where the municipalities help each other, support and, I would say, motivate each other. (I16E, 00:17:12-8)

Section 7.2.1

it must be well-founded. There I'd say: "thoroughness before speed." Because there's no sense in – no matter in what context – relying on a faulty data basis. Then, what is there in errors, will diffuse down the line. Even if what one was developing, what one was planning, was correct with regard to the input used, if this input is wrong, then what is done will also be wrong. Or at least not effective. Not like you'd want it to be. (I01RM, 00:39:55-7)

We also had photos of the flooding taken from a helicopter back then and, as you can see, in fact, the map, the area, that is shown in blue on the flood hazard map, corresponds to the area that you see on the ground from a helicopter. It actually fits very well [...]. (I06RM, 00:43:25-2)

And the state is the higher authority to the municipalities. And what comes from above is usually accepted. It's almost always the case in administration that one doesn't doubt the results that a higher authority provides you with. (I08RM, 00:14:19-6)

[O]f course, it always depends on the municipality, how good people there are or how the relationship with the state government or the Regional Administrative Authority is. Sometimes, if there's as much as the slightest suspicion that something that the engineering bureaus working for the Regional Administrative Authority have mapped is wrong, it will very quickly be explosively stirred up in the municipal councils, sent out to the press, etc. (I14E, 00:29:38-8)

Well, I think they're well compiled, these maps. Methodologically, they've not only based them on what is known by the administrations alone. The administrations cannot know everything. Instead, they've asked the people out there and have acquired everything anew. Like, here, for example, I think the experts talk about debris lines, or whatever the things are called. [...] And all of that was recorded. And they also asked the people what it was like in their gardens or I don't know where. So I think the maps are very well produced... (I01RM, 00:39:55-7)

We then also talked to this colleague from the Administrative District Office, which was directly involved in the creation of the maps, discussed things very directly and asked: "Can this really be the case?" Or "how do you come to the conclusion that it looks like that there?" And, like that, a lot was clarified. In that way, the basis of trust was certainly strengthened. (I09RM, 00:50:54-8)

And we said: [. . .] before they can be issued by the Administrative District Offices and are done and determine what counts as floodplain, the municipalities must be given a chance to respond to them, to review them and voice their suggestions and concerns. Otherwise, they won't get accepted. (I13E, 00:27:08-3)

Of course, small errors can be present, but that's not decisive. Only the result, the bottom line, counts. And that's correct, I think. (I04RM, 00:22:35-2)

Of course you can discuss about 10 meters more or less, maybe, but I still trust the flood maps very much. (I06RM, 00:43:25-2)

It must always be proportional, or the cost-benefit must stand in proportion. I cannot perform 100,000 different calculations. [...] Data or research certainty just to be able to say: "I know it 100 percent accurately." [...] I don't really see that as necessary. (I05RM, 00:46:27-4)

Whether it's correct down to 5 or 10 or 20 meters in the terrain, it actually doesn't matter that much to us. Because, as I said, most of it is anyhow out in the open countryside and, there, a few meters doesn't play any role... (I05RM, 00:39:16-0)

Well I am aware that it's never 100 percent accurate, but, in any case, it will be more accurate than the previous floodplain assessment [...] [L]ike, at large, it will surely be more reliable. (I05RM, 00:39:16-0)

We haven't had something like this in this form before. At most, there were some experience values, which, however, were never properly recorded. [...]. But these delineations, these very precise delineations, which are very exact – from what I have been able to tell and compare based on my experience – that is simply something entirely new. (I04RM, 00:16:39-4)

Well, somewhat exaggerated, I would say that if one doesn't want the inundation area the way it's being shown for political reasons... That's usually the motive for raising doubts about the model. (I13E, 00:59:35-0)

A.4 Quotes in chapter 8

Section 8.2.1

[I]t is certainly clarified where exactly the flood frontiers are by which type of inundation event. [...] And, previously, one simply didn't have anything like that, where it's so clear or so palpable [as it is] illustrated in the map. (I04RM, 00:16:39-4)

[T]he new maps can't be as easily ignored. And when you refer to old maps, which are 20, 30, 50 years old, of course those don't interest the citizens, in particularly not the one intending to build or to change something. He will say: that's not an up-to-date data basis. (I01RM, 00:52:19-5)

I02RMa: In the past, when we planned flood protection measures at some place or another, we were toled: "There has never been flooding..." And that is the main problem. Today, due to the technical possibilities, I can simulate or calculate where I have a flood hazard. Even if there hasn't been a flood in 50 or 100 years. And that's what we want to protect people from, so that such an event will perhaps never materialize. 00:33:40-7

I02RMb : Well, [...] what's really impressive [is] when we show photos of past flood events. Then no one can say: "I don't see it. I don't want to see it." Instead people start to think. And some will still say: "Oh, it will never happen again and that was only once." Then I often say: "Yes, alright, but even if you don't have to experience it again your children will, such damage to the house at some point of time won't be fun." But, of course, the most impressive is if you show photos or these blue maps. And we didn't – until recently we didn't have these maps. 00:57:40-4

Together with the administration, our municipal council decides whether we'll designate any new development areas or commercial zones. And, in our case, the areas that we are thinking about, which we may at some point designate, are all outside of the areas that could be at risk of flooding. So, this consequence it has already had for us. There we eliminate all risks from the outset. (I08RM, 00:18:36-3)

Section 8.2.2

It's definitely a relief. [...] Now it's quite clear, we don't need to discuss it in the municipal council. If someone has the idea "well there's still a lot of space, one could still make a nice commercial zone there and my brother owns a plot of land right there" or something along those lines, there is a clear decision basis. It's not possible! And we don't need to waste any time, effort and nerves on such discussions. And that's definitely positive. (I09RM, 01:01:08-3)

I02RMb: (. . .) But, naturally, if you have something like that and the municipal council knows about it, then there's also an obligation. Then you can no longer pretend: "I don't know anything about flooding. I don't know anything about the hazards." But, instead, when something like that is there and known about, you have to decide. Do I accept this, do I take it into account, or do I try to build protection measures according to the damage potential and take some form of action. 00:47:17-3

During this [previous – Ed.] designation process [...] there were massive problems. Farmers and affected residents near the brook were vehemently disturbed by it. Demarcations based on debris lines or from previous floods established partly through local cross section analyses were also called into question. Because there hadn't been any flooding there as far back as people could remember [...]. So it was very strongly questioned. [...] Now, though, that it can be calculated on the basis of a topographical terrain model, because one knows exactly this and that much catchment area, this and that much rainfall will lead it to spread out like this and that in the valley area, it's not as easy to question anymore. And it's simply de facto (...) floodplain. Whether the residents think it's legally or professionally tenable or not doesn't really play a role anymore. (I05RM, 00:09:13-0)

If a mayor knows the flood hazard and nevertheless designates a development area, then he's making himself liable to prosecution. And there's not any mayor anymore that will say: "I'll turn that into a construction area" knowing very well that it's flood-prone. Wanting to make money off it. He won't take the risk. Then flooding occurs and the houses are under water and it gets out quickly, how those things are related. So, it's no longer the way it was 20, 30 years ago: "Oh, I didn't know that. If only I'd known, I'd never have sold that land parcel." It's, by now, the liability question has been unambiguously clarified. (I12E, 00:24:35-2)

It cannot be hidden in the desk drawer because: once out in the open, these are facts. And, if something happens, every mayor or every responsible flood risk manager knows he'll be in trouble. (I16E, 01:02:38-9)

The advantage is that it's there's an obligation to implement changes. This is sometimes difficult to achieve on a voluntary basis because flooding, if it's an event every 100, 200 years, rare events in other words, for many that have to spend money to protect themselves from damage in 50 or 100 years maybe. Of course, it can happen tomorrow, too. But many think: "Every 100 years? Well that won't happen to me. It's uncertain." (I18E, 00:56:12-1)

Initially, our plan was to show the hazard through these maps. And the rest would sort itself out. According to the motto: Then the municipalities will know what to do. They see the danger and the rest... is obvious. Everything is in there. But that was not the case. In 2005, we had the first hazard map of the Neckar on display... [...] And a little later I asked the contact from the Administrative District Office: "Well? What was the reaction by the municipalities? What happened?" "Well, two weeks later, the request for permission for the next development plan and the next building project plan located in those dark-blue areas came in." As if nothing had happened... (I13E, 01:14:40-2)

I14E: The old flood areas were mostly mapped following actual events. So one had a flood event, that was mapped and then flood plains were declared. And these flood plains were discussed intensively with the municipalities. That is why it took years sometimes [...] But the flood hazard maps are not discussed with the municipalities. One doesn't agree to leave out an area just because a municipality plans to designate a development area there. 01:56:29-7
SK: Was that the case in the past? 01:56:31-3
I14E: Yes, that was the case. It was haggled about. And, now, flood hazard maps are created using these methodical, technical procedures [...] It's a huge difference. No municipality, no one has the chance to fight off the legal obligation of these HQ100-areas. [...] 01:57:20-5

[T]hey often come and say: "Well couldn't you change a little something in your calculations" and so forth. [...] There's a conflict, the client wants a positive result. And then we have, then this hazard map provides a much better argument for saying: "No, we don't do that on principle and especially not since we always have to count on someone else doing a form of control calculations..." (I14E, 01:30:38-6)

Because up until 2004 we had the usual procedure via ordinances. And for years we had the problem that the Administrative District Offices didn't get going on these ordinances, [...] [that] the assessments didn't proceed and weren't brought to an end. Because... there were appeals, there were delays, questions were raised [...] We set out some floodplains but not like now when I'll soon have set out 12, designated 12.300 kilometers of floodplains, finished and done, which are binding. I couldn't have done that with the old procedures. (I13E, 01:18:26-3)

When I think about what it requires to determine a water conservation area [...], to issue an ordinance for a specially limited area, to work it out, clear it with all parties involved. It takes a lot of work and a long, long time. If I imagine that we would have had to do that along all the water bodies in Baden-Württemberg, it wouldn't have been possible, not from a human resource perspective. (I17E, 00:39:21-3)

Section 8.3

Quite some persuasion work is still needed, to make sure that the personnel working in City Hall, for example, or in various places at the Administrative District Office, that they are also convinced that the maps bring a blessing for people. It always resonates like: “Oh, those flood hazard maps, they just cause trouble.” [. . .] We see them as a blessing and say: “Yes, now people can get information and prepare in advance.” On the other hand many see it like this: “Yes, there will be costs for flood protection and we won’t be able to build in certain areas anymore, as we wanted to.” One can see it from two sides. [. . .] But, officially, they’re not recognized, these reservations that some have against the flood hazard maps. (I06RM, 00:27:39-3)

I06RM: [...] [T]he only ones who resort to the flood hazard maps are those who have a direct interest in them... Regional planning and land-use planning, of course, for the larger public authorities, who know how to use them. But at the individual (. . .) of a municipality, there’s not much use... 00:30:31-4

I06RM: I’m an expert when it comes to flood protection and I say: the maps themselves are great. With them you can explain wonderfully. If you use them as a basis and you have people affected by flooding, you can say: “Here, the flood depth is this and that high, and in this area, building is not permissible. And when you want to prevent flooding, or protect yourself against flooding, you have to stack the doors this and that high with sandbags, or whatever.” So, for someone who’s familiar with the flood problematic, it’s a blessing, the flood hazard maps. But they must be better conveyed to the population. [. . .] It’s really a question of what you do with them. At the moment they’re just standing there on the Internet, waiting to be used. 00:32:51-9

Because we have often made the experience that, on the one hand, the information content of the map is very high and that it’s difficult to convey all that information... respectively to convey it is easy since we’re experts and know what is in there. But, across from us, not everything hits home... and only parts of it. And then only parts of it are implemented. Or not. (I13E, 00:02:29-2)

...the only conflict with these flood hazard maps is the problem that one knows, now we have areas displayed as being at risk about which this was not always previously known [...]. And the problem is that individuals, well I see the main problem as being that the private individual or the firm or the municipality finds itself to be located in such an area, possibly having difficulties with insurances or the real estate and so on. So there can be cases in which the existence of new knowledge can lead to an individual... even if this wasn't intended, suffers a financial loss or that an insurance company refuses to insure him... [...] want to sell [a house – Ed.] and has the huge problem that they cannot get it to sell because knowledge about this risk has been published [...]. (I14E, 01:50:22-5)

And there came a young man [...] He would like to build a house and enquired about the building regulations, what he would have to consider. And then the alarm bell went off, that's not a 100-year flood area but a 50-year one. [...] At the same time, there are older buildings around. And, consequently, there's a building right [...] And, in this case, the land owner delivered numerous arguments which we couldn't ignore. [. . .] He said: "I have three brothers. Each of us inherited a building lot from our grandfather. That's my inheritance. If I can't build there or sell it as a building lot, I've been disinherited. [. . .] Next point: I pay a high property tax for that land parcel for years because of it being registered as a building lot. Do I get my money back if I can't build there?" [. . .] And one can't say that that's water under the bridge and now the property is only worth a euro. (I09RM, 00:29:29-3)

It definitely affects the real estate value and can-. Well the owners talk about cold-hearted expropriation and stuff like that and feel robbed of their values, which is, in part, I think, cannot be denied. (I09RM, 00:32:38-7)

Section 8.3.1

And many models used in engineering suffer from this. That one says: "Quickly, quickly we have to know now, and we know the physical relations so let's calculate." And as long as a model hasn't been checked and validated with the help of measurement data, one must have big reservations. And this is also the reason why much mischief is being done with computer models. (I15E, 00:07:29-8)

What I view as negative or problematic is that many try and say: "We can do that. We'll do that. We buy such a model." But do not look at the boundary conditions that have to be met. [. . .] So doing these simulations is one thing... [. . .] But to prepare the data for a simulation is an equally large and as elaborate task. And one can't simply say: there's high-resolution data available today, I'll just buy that and then I'll be able to simulate. And that's where I see the danger. That more and more people try, the models are becoming increasingly user-friendly, that more and more is being done, more and more is calculated. But the models... are maybe even discredited because they're being used the wrong way. And then models might be attributed with the wrong characteristics although they may actually be good. Only because someone used them in the wrong way [...]. (I12E, 00:07:56-8)

Well I want to say: either the representation is completely scrapped because one doesn't want it. Or there's constructive discussion about the details. In the sense of: We had a flooding event there but that area was never inundated. Why is that? How come it's flooded in your calculations? Then it's constructively discussed around the model. The engineer goes there, of course [. . .] And then there's a normal and good process, at the end of which the municipality agrees: "Now it is correct, the map." Although there's imprecision. But that... that it's argued: "[...] And it's all so imprecise and uncertain. I can anyhow not use that for anything." That is rare, I think... Rather there's the general rejection because of other reasons, political reasons, I'd say. (I13E, 01:03:18-0)

These are technical instruments, there are boundary conditions. If I say 3,42 m, the modeler who made it knows exactly: I assumed that scenario, I assumed that curve, I assumed this roughness of terrain. I know exactly what has gone into it. How many uncertainties and [where] every stage of modeling came from. And the civil servant clicks on the table, 3,42 m: "Well, then 3,42 m is what I'll use. I'll implement property protection up to 3,42 m and I'll be safe." And that somehow shows [. . .] that one should maybe categorize the results in classes. That one should rather say: "Yes, it could come up to this and that many meters, the water. It could of course also be worse." (I16E, 00:23:34-1)

I18E: Well the only problem that I see is the issue of the maps only showing riverine flooding. And can distract from the fact that inundation is possible anywhere. [. . .] And that, because one only thinks of riverine flooding, which these maps are there for, that one forgets that there are also flash floods caused by direct precipitation.

That's why I would say that that's a thing that should actually be improved, that every map should have it written on top: "Flash floods possible everywhere", so to say. [...] And, when you ask like that, that would be a thing that I'd consider to constitute a downside of such a map. That one feels safe in areas where there isn't really any safety. [...] Because it focuses our attention to a specific area and distracts from other areas. 00:50:24-2

And that's of course a challenge, to make a map as precise as possible while knowing that it cannot be 100

And there has to be a clear distinction, a clear delineation. And this delineation, if I say: "Alright it could be here or it could be there" and in-between I have an area of uncertainty, that doesn't amount to a legal guideline. I have to define clearly, that is the frontier. And I have to do that according to my best knowledge and my best conscious even though I know: "Well, it could be here, it could be there." [...] [W]hat is expected of us is that we define a definite line. And that's what we do, of course. But we do it at the same time as we are well-aware of there being something else. But such things are difficult to document. Nobody wants to hear it... [...] 00:58:20-3

I18E: I don't think it's of great importance, generally, because, when, then it only concerns the boundary. The most of such a map is very robust. It's not like that (in) one area lots is inundated and the location isn't at risk. At least with the maps in Baden-Württemberg, that will not happen. It will always be about whether this building is affected as well? Or that building? Or this transformer station? All the rest, the main part of the map, is pretty definitive. [...] And then it triggers discussion. And that's the most important part. [...] 00:40:16-7

But to misunderstand directly... not really. Because I think misunderstandings always arise when there are classified values. [...] When I say I have damages ranging from 0-200 Euros, from 200-4000 Euros and... I don't know, above 5000 Euros, above 4000 Euros. [...] And that is, [...] depending on what one chooses, also a source of danger... [...] I assume an environmentally relevant facility to have a high vulnerability and assume that for the whole area. Things like that can somehow happen. But regarding the flood hazard map itself... maybe at most there could be a misunderstanding concerning what it's based on. [...] 00:48:26-0

No, I don't know what could come of that... Rather lack of trust, that causes us problems, of course... (I13E, 01:08:59-9)

Well that one considers the scale in which it's sensible to think. That is, I think, necessary. If one takes such thoughts into account it is totally legitimate, I think, to work with results of models even if one doesn't completely comprehend them scientifically. One has to do that... one cannot follow the tiniest detail of every piece of information... (I16E, 00:51:30-8)

It's futile. [...] We try to make it clear that it's a scenario and that it's as good as possible. We're making a tremendous effort in the surveying. We're making a tremendous effort in the modeling. We're really very precise. [...] But... more than that we cannot communicate. Because more is simply... the background is missing or it's, one notices it when one goes into detail in a discussion, that the eyes of the counterpart start wandering off and they're only listening with effort and it's not reaching them anymore. (I13E, 00:55:16-7)

Though, I have to say, I hadn't informed myself very intensively regarding the measurement inaccuracy in advance. It is possible that this was communicated along with the rest, but that I didn't register it as information. (I03RM, 00:47:19-7)

I think that's always the most important thing, not that one is provided with 300 pages of information that nobody will read. But that, if one has a specific question, one is given information by the relevant office. (I03RM, 00:53:26-0)

A.5 Quotes in chapter 10

Section 10.2.1

[I]t is the case that these models for avalanches show the dependency on terrain very strongly. [...] [And] what happens outside of that to the left or right, one didn't know about that. Well it was always a longitudinal profile. And with these 2D sometimes 3D models one gets an extensive spatial image. And I have to say, that has really done a lot, that one gets a kind of certitude. Not that it's always correct, interpretation is always necessary. But it did do a lot. [. . .] It was, it really was a quantum leap in, in, in the, in the, in the calculation of these phenomena. (IA22E, 00:24:16-7)

What it can be well used for, in my opinion, is as decision-support in [. . .] expert opinions. When one sees things in the simulation that one, for different reasons, didn't necessarily see out there in the terrain. (IA23E, 00:09:19-6)

And what also, it's natural that there's building or development in areas now, where in the past no avalanches, where nobody settled before or nothing was built. And the area is unknown then. So one doesn't have historical documentation by which one could show: there's been an avalanche here. One simply doesn't know. And that's where, I believe, simulations will play a larger role in the future. Because then that somehow, one can then possibly estimate that better... (IA21E, 00:29:18-0)

Well the difference between modeling and the experience of the torrent managers, the practitioners, isn't that staggeringly high. [. . .] Many old torrent managers say: "We wouldn't have needed a model for this. We would have known that anyway." But knowledge alone isn't enough today. Because it can be claimed that one possesses this knowledge, but it's difficult to prove... (IA24E, 01:16:40-9)

I think that a quite decisive factor is the legal safeguarding of the practitioner. In the past, when [. . .] the public authority that decided that, they weren't questioned. [. . .] But now, in all walks of life, coming from America, the legal systems are increasingly striking back and saying: "Well excuse me. Somebody decided something here and how did that person get to that decision?" And if somebody is affected and there's been damage and that person can show, legally, that the public authority didn't decide according to the state-of-the-art of science, the public authority can find itself in a tight spot. [. . .] [T]he practitioners know, one has to protect oneself. [. . .] And the models can be used as instruments for this. (IA24E, 00:42:50-8)

Well it is certainly the case that it's more common, if there's an accident or something like that, that people ask: "Your decision, what is it based on? Would one, if one would have had a simulation or a prognostic model, what would the results have been?" That's correct. It's certainly the case today that it has to be hedged. Regarding the avalanche models it's also the case, they are also being used, I think, to rethink one's own decisions once more. [. . .] [I]f, in a simulation, one sees that an avalanche-branch suddenly heads into a different direction, one will take another detailed look at that area on-site and consider: Is that possible? (IA21E, 00:27:47-0)

In Austria, the highest building authority is for example the mayor. [. . .] And the mayor, we have a lot of small municipalities, is often biased. We always talk about the ram and gardener problem in this instance. If one chooses the ram to be the gardener one shouldn't be surprised when the salad is missing. If the mayor issues a building permit to his son... in an area where he shouldn't have... Whom does it surprise? When it comes to hazard zone planning, it's consciously located far away. And that's good... Because these personal biases can't take hold most of the time. (IA24E, 01:11:44-6)

Section 10.2.2

Really, many models need a weapons permit... because in many models the parameters, just the parametrization and the whole model sequence in the background make it impossible for many users to see what the model does in the first place. (IA24E, 00:16:38-7)

A model is often only as good as its user. And good relates to experience in most cases. A model user who doesn't know what the model actually does and pours something in and gets some result, if he trusts this result, I'd say he has missed the mark. Then he's in the wrong place. (IA24E, 01:26:50-0)

[H]ow one arrived at this image is in my opinion one of the most important points for being able to interpret it at all. [. . .] And then it's about the model again but also about the numerics. It's about everything, really. [. . .] Because if I don't know [. . .] where its limits are or how all of it works, I, personally, find it difficult to interpret something like that right. (IA19E, 01:13:16-2)

Well it's often a topic that colorful, beautiful images [. . .] in which pressure or something is depicted somehow convey to the viewer: Yes, that's the reality. Or that's the avalanche, it goes (. . .). It's like that. If I was to simply write that down myself and was to say: “At point X there’s pressure of 15 kilopascal and so on”, that one may question. [. . .] But, well, if you have a beautiful, colorful image, especially with decision-makers or so, that they can show or that they can tell when a citizen comes. Then he says: “Look here, the avalanches, it has been simulated. It looks like this.” And that is deceptive because a colorful image partially doesn’t have to tell you much. But the acceptance of them is, like, very, very high. (IA20E, 00:42:55-1)

The more of a lay person someone is, the more likely he is to believe these images. Especially if they move. [. . .] That’s convincing, of course. And the more one knows, the more intensively one deals with these phenomena, the more critical one becomes, naturally. And doesn’t only see the pretty colors and the great impressive films but knows, of course, that all of that is very rough [. . .] [A]t core, the experts are much more critical. (IA22E, 01:45:21-4)

Section 10.3.1

[F]or regional planning offices, the simulation results aren’t really of interest. [. . .] How we arrive at our red and yellow zones is relatively uninteresting. They trust us in this and accept the zoning plans, well, I don’t want to say in blind trust, but in trust. (IA22E, 01:27:57-6)

SK: Are the development officers aware of it actually being difficult to draw a line? 01:31:35-5
IA22E: I think so, yes. We communicate that again and again. Those things, well, yes, great uncertainties (. . .). Well that is being communicated. The people that deal with us know that. 01:31:53-7
SK: Is it also taken into account? 01:31:58-4
IA22E: It’s not being taken into account. No, it’s, cannot be taken into account. It’s that this, this line is simply necessary, that one says alright, with a very high likeliness, that’s where it will come to a halt. [. . .] 01:33:24-6

When it’s the mayor as the building authority, he probably doesn’t know what’s involved in this line. What has been modeled here? With what model? With which specificity? With what input? He has to rely on the prior authorities having produced this, has to rely on them having produced it according to their best knowledge and conscience. Meanwhile, I think that most of them also accept it... (IA24E, 01:29:02-8)

Yes the mayors are very happy most of the time because they have a degree of certainty and arguments. The mayor is responsible for safety in the municipality and that is helpful for him. He can say: look here, that's the zoning plan. So you needn't ask for a reclassification. [...] And also has it easier in the case of a crisis. [...] Of course, there are people who really don't want it because, naturally, a red zone will devalue a building site immensely. (IA22E, 00:34:04-7)

Very often or I would say in most cases the local politicians, heads of municipalities, of municipal offices, are so strongly influenced by other interests in our area that they rather close their eyes and don't want to know or hear about models and results of modeling. [...] [B]ecause we developed skiing resorts in whole valleys, have created pists. [...] So there has been a huge shift in the use of land. And no local politician wants to then hear that things have worsened meteorologically... [...] But local politics is of course so intimately linked to the main economic factors there that they are very reluctant to address these issues [...] [T]here are other skiing resorts and regions where this works very well. [...] There, ski-resort operators and local politicians work without this reluctance [...] they are happy to get modeling results and look at these and contemplate: what can one do there in the future? (IA24E, 00:48:48-6)

Well, I would, I would say yes. If they would have concerns, it would be better if they would have a clue. [...] But basically we don't ever have discussions or about simulations. I also think people don't know much about this, about these things. (IA22E, 01:29:06-4)

For political decision-makers, for example, or for development planners, [...] they need a fixed line to plan with. [...] If one would always pass along all information, one would (demand from each in the chain) that they preoccupy themselves with this and know about it, so this... this degree of abstraction (as in my case) should be dealt with by the experts. [...] [So that] other people can rely on it. (IA23E, 00:26:05-5)

[T]his gray area would be preferable, but the whole legal establishment couldn't deal with it, if I say alright, yes, all of it is likely there, likely there. They want to know exactly what is with this house. And is there something there or not. That's it. I can't say: yes, probably. Nobody knows how to respond to that. So a specific statement (is required). (IA22E, 01:31:27-2)

Section 10.3.2

Well, it's like this: when it comes to construction of houses, (they want) numbers, then one says: yes, ten kilopascal, that's it. Civil engineers carrying out projects, they mostly come to discuss. [. . .] Often becomes quite controversial, admittedly. It's not always just friendly, then, that. (IA22E, 00:57:16-0)

They don't have any provisions the way that settlement areas have. And then they rather do it according to cost-benefit-analyses. Even if they know that this is in a hazardous area but we say: "Alright, it's quite uncertain. It doesn't come every year or every other year but rather every 30 years." Then they decide on the basis of cost-benefit alone. And since they plan for 30 or 40 years into the future, if we say: "yes every 150 years. Yes, could happen." Then they say alright, we'll accept that risk. So it... it's then inconsequential. (IA21E, 00:12:42-4)

Well they [the results – Ed.] always have to be verified. And that has to be done together with the end-users and the results have to be discussed and the plausibility has to be checked. [. . .] They are also more actively involved in the project and provide much more information if they are included from the beginning. If that doesn't happen, many of the results are, end up in a drawer and will then not be.. utilized any more really. Or accepted. And if they, one does *not* talk to them and also tells them what goes into this simulation, I mean as input parameters, then... [. . .] it won't really be accepted. (00:17:59-4, emphasis added)

We don't tell them that. They want to have one value in the end. [. . .] If we have used two models and one runs, I don't know, 20 m further than the other, we have to interpret this as experts: what do we believe is more realistic. And we have to deliver a value. Because people only want a single value. So we... they can't deal with more things. (IA21E, 00:08:03-0)

Yes, I believe, yes, if they really have no idea, they will either simply accept it. And then they probably want to build something and will simply say: "Alright, we commissioned it. They say, it's like that, we accept it." Because, then, they're in principle no longer responsible. But say: "Yes, they are responsible. We take it. It's okay." (IA21E, 00:25:19-7)

Section 10.3.3

And, in some expert opinions, I've gone out, have interpreted the results and have said: "Well, maybe the starting altitude is a bit higher, because if the congestion..." Then they say: "No, we have to plan this now. We have this structure down here, we want to protect it." And they want me to tell them how. [. . .] And yes, there's no, little leeway. [. . .] It will always be pointed out by us. [. . .] That this can't be said with a hundred percent certainty, it's due to the models' limitations. But... that's an accepted risk then [. . .]. (IA21E, 00:10:57-2)

[B]efore, I thought that they must know much more about it. Meanwhile, I think, yes, they should be aware. One should communicate it. One shouldn't keep it a secret and only give them results, instead one should write that the results are uncertain, because yes. [. . .] [If] the user is someone that really builds something, one should... also quantify the uncertainties, which is relatively difficult. [. . .] But they [. . .] don't need to completely comprehend this, how one arrives at this value. Because I think that's what they're commissioning experts for. [. . .] So, if they, they should have the option to ask questions. In the report, it should also be described where uncertainties can arise. (IA21E, 00:15:37-5)

My experience or my assessment is that they are accepted way too much. If [. . .] one has to plan a building here now, a dam or something. And I say: these results from the simulation have to be taken with a pinch of salt for this and that reason and there's some latitude in this and that area. Nobody cares. What the people want to hear is: at this point, the avalanche is 5 m high... [. . .] Yes, I think the less experience or I don't know what it depends on, these results are much too accepted. (IA19E, 01:36:41-2)

Either the result or the, the procedure has to be standardized to such a degree that mistakes cannot be made. Though, actually, it shouldn't be that way either in the best case. Yes, fundamentally, people should know more about it, but I tend to believe that that's too much. I believe it isn't possible to know everything or a whole lot about such a model if one is only supposed to interpret results. Partially, though, it's very necessary [. . .]. (IA19E, 01:25:30-0)

We, working in the practical application, know little, relatively little about the whole theoretical background. We judge the result, what comes out. We, we look at the input parameters if they are somewhat right or correspond with our experience. But the process within the model is relatively unknown to us. [. . .] To us, it's like a black box almost. With a result and this result we compare with our experience and our, our other methods. But the other, the procedural within the model, that one would have to deal with together with a specialist. (IA22E, 00:50:32-4)

One cannot know everything. [. . .] I also wouldn't have the time for that. For that, there are more well-versed people. [. . .] And there one must, if, if one realizes that it's completely implausible, then one must enter into discussion. (IA22E, 00:53:03-5)

[T]hat many... that there are many avalanche experts who are relatively new and have little field experience. And when that's the case, [. . .] I just think it's a risk that the simulation programs are so easy to run and [. . .] the results just won't be verified enough. [. . .] [T]he users or the people who do simulations often possess too little process knowledge... [. . .] And they have, I think, too much trust in the results. I mean, in themselves. And there it's, it would be good if people would be more aware of the uncertainties, when they then pack these into the results, ultimately. (IA21E, 00:20:05-4)

The danger is that the results can be simply not correct because the local conditions just deviate strongly. If one isn't aware of this and doesn't take the terrain into account, the simulations will simply give false values. [. . .] The maps are published and people who deal with these things see the maps and say: "Yes, yes, yes, that's right." And it's consulted for further planning measures. And that's the danger, that these, that [it's] possible today to somehow run such a simulation, one has beautiful images, publishes these and – only because it looks good – the result is accepted by people who don't... question it in detail, simply accept. And that, I think, is certainly a relative risk. Especially with avalanches and everything, where it can really be very different, locally. I mean, the conditions. [...] And if the locals or the decision-makers haven't observed things this way [...], they won't take the results seriously. So then they won't use them... (IA21E, 00:23:06-4)

Well, everyone was able to hand in and say: "I'm an engineering office or we're a research institute. We can do this and would analyze this area for that price." And that has partially, especially with something like this, taken a turn for the worse, that there's been extreme price dumping. Everyone then said: "I can do it even cheaper and even cheaper." And the cheapest method is simply to run the simulation, trace the line and say: "That's it." (IA20E, 00:31:59-5)

And these, these natural hazards, well hazard zone planning is now often being done by engineering companies. [...] [T]he municipality puts out a tender. [All of the country] applies for it, so it's possible [...] that an engineering company from [the south] does the hazard zone planning in the Alps. And then they of course base it on simulations because, themselves, they cannot really assess this region. [...] I think they're noticing, too, that this isn't working all that well. (IA21E, 00:34:21-1)

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Declaration of Authorship

I, Stina Kjellgren, declare that this thesis titled, 'Chance at foresight - risk of misuse?' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
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- I have acknowledged all main sources of help.
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Signed: ______________________________

Date: ______________________________