CRUE
FLOODING ERA-NET

*Integrate, Consolidate and Disseminate*
***European Flood Risk Management Research***

# CRUE Research Funding Initiative SYNTHESIS REPORT

Addressing the key findings of research:

## Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures

**CRUE Flood Risk Management Research Monograph Series** **2009**

CRUE Co-ordinator: John Goudie (Defra)
Project Contract No: ERAC-CT-2004-515742
Project Website: www.crue-eranet.net

DISCLAIMER

**Key findings of research related to Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures**

CRUE Research Funding Initiative Synthesis Report No I-2009

The Synthesis Reports are intended to provide relevant information and stimulate discussion between those with an interest in flood risk management. The results and conclusions of all reports produced under the **CRUE Flood Risk Management Research Monograph Series** are made available to governments at all levels, research funding bodies, universities, industries, practitioners, and the public by way of the CRUE website (**http://www.crue-eranet.net**).



## Author Contact Details

**Andreas Pichler** ◄ andreas.pichler@lebensministerium.at
**Thomas Deppe** ◄ thomas.deppe@ptka.fzk.de
**Vicki Jackson** ◄ vicki.jackson@environment-agency.gov.uk

## CRUE Contact Details

CRUE Co-ordinator
Area 3D, Ergon House
Horseferry Road
London SW1P 2AL. United Kingdom

Email: info@crue-eranet.net
Web: http://www.crue-eranet.net/

Published in February 2009

ERA-Net CRUE is funded by the ERA-Net Scheme under the 6th Framework Programme
General Directorate for Research in the European Commission
Contract number: ERAC-CT-2004-515742

CRUE Flood Risk Management Research Monograph Series, 2009

CRUE
FLOODING ERA-NET

## Key findings of research related to:

# Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures

# SYNTHESIS REPORT

February 2009

**Written by:** Andreas Pichler, Thomas Deppe & Vicki Jackson

**1st ERA-Net CRUE Funding Initiative on Flood Risk Management Research**

| Defra | BMBF | BMLFUW, BMVIT |
|---|---|---|
| defra | Bundesministerium für Bildung und Forschung | lebensministerium.at bmvit |
| **SG-EQD** | **MICINN** | **MEEDDAT** |
| SCOTTISH EXECUTIVE | MINISTERIO DE EDUCACIÓN Y CIENCIA | |

# Preface

The EC funded 'CRUE European Research Area-Network (ERA-Net)' project is a network of European government departments who directly fund flood risk management programmes and related research actions. In order to tackle the challenge of rising flood risk and to develop effective policies and risk management practices, policy-makers and key stakeholders require a strong evidence base. Evidence-based policy-making is the key to modern, forward-looking strategies for dealing with increasing flood risk. Trans-boundary and trans-national flood risk management issues are becoming more important, requiring, in particular, joint research and development initiatives. The creation and implementation of a European research area in flood risk management – as intended by the CRUE ERA-Net - is an important contribution to an improved trans-national perspective for flood-related research across Europe.

In addition to co-ordinating research between Member States, CRUE contributes towards the identification and delivery of Flood Risk Management (FRM) research with its own trans-nationally based funding initiatives. With the launch of the first CRUE common call, we made a first step towards the integration of flood research in Europe.

The topic of CRUE's 1st Research Funding Initiative on "Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures" was selected by six of the CRUE partner countries through an intensive consultation process and is to a great extent based on developments in European flood risk management policy (e.g. EU Floods Directive). In particular, the call was designed to investigate and critically assess the effectiveness and efficiency of non-structural measures in comparison to structural measures and also to identify barriers to implementation of these "soft" techniques. The call was an incentive to develop innovative methodological approaches. Moreover, it challenged researchers across Europe to integrate knowledge across different disciplines such as natural and social sciences, and engineering.

Each of the seven successful joint projects within CRUE's 1st Funding Initiative for FRM research was designed to understand different national approaches to the use and appraisal of non-structural measures, explore what is successful, and what can be improved in terms of efficiency and effectiveness of such measures themselves. The research results described in this report will provide both politicians  and policy-makers with a better understanding of how flood risk management, as a part of integrated river basin management, can deliver multiple benefits, for example, reduced flood risk and improved environmental quality.

On behalf of all the funding partners involved in this initiative I am confident that the outcome of this research will be a valuable contribution to national policy development and the improvement of flood risk-related practice, and support wider discussion of the common threat of flooding. In particular, a first survey among CRUE partners showed that the findings of this research initiative are of relevance to them, e.g. in Flanders, mapping requirements for technical implementation plans will be based on the outcomes of CRUE's first funding initiative and the CRUE results about effectiveness and efficiency, especially for non-structural measures will be incorporated in the social cost benefit guidances.

**John Goudie**
ERA-Net CRUE Co-ordinator, Defra, UK

# Table of Contents

# 1. Introduction

## 1.1 The Report

This report synthesise the seven CRUE Funding Initiative joint research project reports. These seven studies are published alongside this report as a set, with their respective abbreviations (cf. Table 1):

- FLOODERA
- RISKCATCH
- Room for the River
- EWASE
- PRO_Floodplain
- Simulation of Risk
- Small Urban Catchments (SUCA)

This report primarily addresses key research findings related to Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures. The report has two main aims: to provide hints for improving flood management policy and strategies, and to give practitioners a high quality basis for improving mitigation strategies on Flood Risk Management.

## 1.2 Background

Due to climate change and the concentration of larger populations, plus more infrastructure and greater economic activity in flood risk areas, the potential impacts of future flood events are likely to be significantly greater than in the past. There is a risk that sustainable development in Europe will be affected unless sufficient action is taken to tackle these challenges.

In recent years there has been an increasing focus away from traditional approaches of "flood defence" towards an "integral flood risk management" (FRM). This new, multidisciplinary approach goes beyond traditional engineering approaches and requires the integration of non-structural measures too. It recognises that we should also consider a range of regulatory, social and economic approaches in our mitigation responses, including tighter planning controls and alternative land use schemes in floodplains, the role of insurance to spread risk, and improved information and maps on flood risk to inform and involve citizens. This greater focus on environmental and social implications of water and flood risk management in each Member State is also a demand of both the EU Water Framework Directive as well as the EU Floods Directive, which has to be implemented on a European national level by 2015.

## 1.3 Requirements for research on "non-structural measures" (NSM) in FRM

Non-structural measures (NSMs), as part of a modern Integrated Flood Risk Management (FRM) approach, are critical to water management, land use control, financial relief, and loss reduction. They comprise issues such as flood forecasting and warning, spatial planning regulation, flood insurance and public flood awareness and risk perception. These measures strive to reduce flood impacts without altering flood characteristics effectively and unduly expanding the costly infrastructure, and will contribute to tackle shortcomings still prevalent in European flood management. Examples of shortcomings include:

- poor international/regional harmonisation and scattered organisation of flood management
- competing demands from planning, demographics and climate change
- limitations to, and inappropriateness of, financial instruments, such as insurance policies, flood damage recovery and state relief
- deficits in improving public perception of flood risk or hazard awareness and education.

Given the importance NSMs play in modern flood risk management, it was interesting to see that very little evidence exists on the efficiency and effectiveness of NSMs. This makes it difficult to

assess the appropriateness of NSM approaches and impedes decisions on the ideal mix of structural or non-structural measures determined at a strategic level.
It is also interesting to understand to what extent NSMs are sustainable in the long-term, particularly in the face of climate change and if NSMs offer greater environmental benefits than traditional approaches. By its nature, NSMs engage increasingly with social and environmental science understanding and complement the more traditional, economic/market forces-related approach to FRM. In this context it is important to understand what physical, socio-economic and institutional factors can facilitate the effectiveness and efficiency of non-structural measures in order to know whether or not a new or adjusted suite of considerations are required to assess and appraise flood management measures.

## 1.4 Call objectives

In order to tackle these demands and challenges, six partners of ERA-net CRUE (Austria, England, France, Germany, Scotland, and Spain) agreed in 2005 to collaborate in CRUE's 1st Research Funding Initiative, exploring the potential of NSMs in a modern flood risk management approach. The call objectives can be summarised as follows:

- to survey the perception of flood risks on various societal and spatial levels and within different sectors, and to work out its influence on flood risk management decisions within a selected set of partner countries
- to investigate and compare existing concepts / ideas of flood risk management with particular regard to the relevance of NSMs
- to identify and systemise NSMs for risk reduction as part of existing flood risk management plans, considering the present importance of these NSMs
- to investigate and compare existing approaches which quantify the effectiveness and efficiency of NSMs, compared to structural measures.

# 2. Executive project overview

By the beginning of 2007, seven transnational research projects tackling these issues had started.[1] The projects were designed to understand each Member States' approach to the use and appraisal of non-structural measures, explore what is successful, and what can be improved in terms of efficiency and effectiveness of such measures. Table 1 (next page) provides a project overview. Details of the collaborators in the projects can be found on the project websites.

**NSM "land use / spatial planning"**

The aspect of "land use" was addressed by the joint projects "Room for the river", "PRO_Floodplain", "Simulation of Risk", and "Small urban catchments". The "Room for the river" project, coordinated by the Spanish Technical University of Valencia and including partners from Austria and Germany, focused on specific measures suitable for increasing the retention capacity in catchment areas, such as micro-ponds and small dams, and investigated the effect of deforestation / afforestation on peak runoff. "PRO_Floodplain", a consortium of Austrian, German and French partners coordinated by the University of Natural Resources and Applied Life Sciences, Vienna, identified benefits of floodplain enlargement by examining the hydromorphological contribution of water retention in preserved and restored flood plains. The study also examined to what extend floodplain restoration contributes to achieving a "good ecological status" as demanded by the EU Water Framework Directive. Dealing with urban areas which are unique in their accumulation of damage potentials, and their complex setting, the joint project "Flood risk management in small urban catchments", coordinated by the Technical University of Hamburg with partners from the UK and France, provided a trans-national synopsis of urban FRM strategies, together with recommendations for flood managers on how to improve urban FRM concepts. The 'Simulation of Risk' project looked at how land use planning approaches could be modelled and so influence decisions.

[1] Details to each of the seven joint research projects are available at http://www.crue-eranet.net/project_list.asp?Call_ID=1

This comprised a consortium lead by IWSÖ, Germany, with partners from Scotland and England. Using a completely synthetic river basin model, the project contributed to the enhancement of fundamental knowledge and methodology concerning the long-term effects of non-structural measures.

**NSM "flood warning"**

The joint project "EWASE" focused on the appropriateness of early warning systems in small catchment areas prone to the occurrence of flash floods. The research explored the optimum between a potential increase of lead time, which may increase the benefit of the alert, and the simultaneous decrease of reliability, in order to find better solutions for the operation of early warning systems in use.

**NSM "perception / evolution of risk"**

The perception of risk formed the background for the joint projects "RISKCATCH", "FLOOD-ERA" and "Simulation of Risk". "RISKCATCH" is a consortium coordinated by the University of Natural Resources and Applied Life Sciences, Vienna, with partners from France and Germany. It focused on the perception of information contained in risk maps on political decision makers, practitioners and the general public and delivered user specific recommendations for a better design of risk maps, which will help flood risk managers to meet the goals of the European Floods Directive. In "FLOOD-ERA", a consortium lead by IOER in Dresden, Germany, with partners from England and Austria, had a strong research emphasis on the influence of political and cultural factors on FRM planning procedures, the allocation of large amounts of public money and operational flood management. By the causal analysis of decision processes flood risk management strategies require on the one hand, and an analysis of the unused potential of NSM on the other hand, FLOOD-ERA contributed to optimising of the allocation of resources in FRM. Concerning the aspect "evolution of risk", the 'Simulation of Risk' project investigated ways to predict the long-term evolution of risk, considering the complex interactions of NSM, such as regulations, market instruments, changes in land use and future changes in flood risk.

**Table 1:** Overview and reference number of the seven joint research projects from CRUE's 1st Research Funding Initiative

| Titles and main objectives | Co-ordinator and further information | Ref. # |
|---|---|---|
| Efficiency of non-structural measures: '*room for the river*' and '*retaining water in landscape*'<br><br>Main objectives:<br>▪ Examine the relative efficiency of non-structural flood mitigation measures<br>▪ Explore efficiency through scenario analysis involving land use changes, local retention measures in the landscape through micro-ponds, and flood retention using methods such as inundation | Felix Frances, Universidad Politecnica de Valencia<br><br>www.iiama.upv.es/roomfortheriver/home.html | 1 |
| Development of flood risk in mountain catchments and related perception – RISKCATCH<br><br>Main objectives:<br>▪ Deliver new, practical and viable solutions for integrated risk-based management of natural hazards in Alpine environments<br>▪ Generate and assess maps that are influenced by different scenarios of temporal development of risk<br>▪ Use the maps to aid assessment of the how risks change over time using the 'temporal development of values at risk' approach | Sven Fuchs, University of Natural Resources and Applied Sciences (BOKU)<br><br>www.riskcatch.info | 2 |
| Effectiveness and efficiency of Early Warning Systems for Flash Floods – EWASE<br><br>Main objectives:<br>▪ Relate the concept of risk analysis to the evaluation of early warning systems; itself a non-structural measure<br>▪ Compare forecast reliability and economic benefits across systems used in Spain and Austria<br>▪ Analyse uncertain factors of the warning production chain and risk analysis | Kai Schröter, Technische Universität Darmstadt<br><br>www.ewase.net | 3 |
| Risk Assessment and Risk Management in Small Urban Catchments - SUCA<br><br>Main objectives:<br>▪ Analyse and evaluate effectiveness and efficiency of non-structural measures in an urban catchment context<br>▪ Illustrate options to implement effective non-structural solutions to minimise flooding from urban sources<br>▪ Evaluate efficiency of non-structural measures at raising awareness and managing flash-flooding in urban catchments | Erik Pasche, Technische Universität Hamburg-Harburg<br><br>www.suca.wb.tu-harburg.de | 4 |
| Flood risk management strategies in European Member States - FLOOD-ERA<br><br>Main objectives:<br>▪ Systemise/analyse existing and possible new flood risk management concepts with non-structural / structural measures<br>▪ Identify under which conditions effectiveness and efficiency evaluations converge or diverge between practice and scientific analysis<br>▪ Show how strategies of flood risk management can be improved by assessing measures with project methodology | Jochen Schanze, Leibniz Institute of Ecological and Regional Development (IOER)<br><br>www.FLOOD-ERA.ioer.de | 5 |
| Flood risk reduction by Preserving and RestOring river FLOODPLAINs – PRO-Floodplain<br><br>Main objectives:<br>▪ Evaluate the hydrological contribution of water retention in preserved and restored flood plain systems across various settings<br>▪ Examine the social acceptance of non-structural measures<br>▪ Consider the theory concerning the efficiency of non-structural measures relating to flood plain preservation and restoration | Helmut Habersack, University of Natural Resources and Applied Sciences (BOKU)<br><br>www.pro-floodplain.eu | 6 |
| Simulation of Flood Risk and Non-structural Risk Management<br><br>Main objectives:<br>▪ Examine techniques for incorporating non-structural measures into risk analysis<br>▪ Illustrate the effect of non-structural measures on long-term evolution of flood risk using coupled land use and flood risk simulations | Konrad Thürmer, Institut für Wasserwirtschaft, Siedlungswasserbau und Ökologie GmbH (IWSÖ)<br><br>www.floodrisk.info | 7 |

# 3. Key findings & conclusions

To ensure consistent reporting, the CRUE partners developed overarching questions to guide the respective project teams. All projects were asked to provide detailed answers to these questions (wherever possible), essentially to show how the research has contributed to further knowledge and understanding in each of the NSM areas.

## 3.1 Conclusions on overarching topics

**How appropriate is the conventional distinction between structural and non-structural measures?**

In contrast to structural measures the term "non-structural measure" is not clearly specified and often used ambiguously. Given the fact that dozens of definitions of "structural" and "non-structural" measures exist, a common systematisation would help to overcome the problem of understanding when discussing flood intervention measures on a trans-national or international level. Additionally, a clear and common systematisation would allow a precise evaluation of the effectiveness of both structural and non-structural measures and would guarantee the comparability of the evaluation results on an international level.
FLOOD-ERA analysed and compared existing SM/NSM systematisation concepts and proposed a new systematisation of structural and non-structural measures (see Table 2). The underlying concept of the new systematisation was to include the intended effects of SM/NSM, but simplify functions and mechanisms and led to the overall understanding that

- Structural measures (SM) are interventions in the flood risk system based on (structural) works of hydraulic engineering, and, as a consequence,
- Non-structural measures (NSM) are all other interventions.

This proposed systematisation now allows the evaluation and comparison of different SM and NSM with regard to their effectiveness and efficiency by referring to the reduced risk and not just to the hazard or the vulnerability.

**How to interpret the terms "effectiveness" and "efficiency" in respect to NSM and to what extent are NSM more/less effective and efficient compared to SM?**

The terms "effectiveness" and "efficiency" are often used when describing how appropriate a system, decision or intervention is. But in almost all disciplines where these two terms are used, different definitions and interpretations exist. This may cause confusion when applying them in practice and therefore it is vital to understand the difference between the two terms, especially with respect to NSM. Summarising all the approaches used in the seven joint projects to assess the effectiveness and/or efficiency of NSM or respectively SM, a definition of these two terms could be:

*Effectiveness* is a result-based term and describes the degree of goal achievement in terms of risk reduction or effects towards risk reduction.

*Efficiency* is a yield-based term and describes how economically an intended risk reduction or an effect towards risk reduction has been achieved. The term "economically" relates to the expenditure of both time and effort.

In FLOOD-ERA, a comparative evaluation of both effectiveness and efficiency for NSM compared to SM has been accomplished on a set of case studies in Austria, Germany and England (cf. Tables 3 – 5). As a conclusion of this study, NSM appears often to be less effective but more efficient (in terms of cost-effectiveness and benefit-cost ratio). In EWASE, the conclusion on a comparison of the efficiency of SM to NSM was that no FRM strategy appears to be more efficient than the combination of local protection (in the sense of SM) and early warning.

**Is "uncertainty" (in data, decisions, methods, or results) a limiting factor concerning the success or failure of NSM?**

Overall: Yes.

Managing the risk of flooding requires a broad range of methodologies, data, technologies, practices and decisions. The role of uncertainty is still a major factor in each of these issues and has to be considered when choosing a decision on the appropriateness of a planned risk reduction strategy. Concerning the implementation of NSM, whose successful implementation is often driven by the governance regime in place and the behavioural response of the population, the "Simulation of risk" project recommended frequent monitoring of the success of such measures and where necessary adapting their implementation to respond effectively to changes in behaviour or the policy regime. Because of all of the uncertainties, and considering all the context conditions in decisions to better balance SM and NSM in future risk reduction strategies, FLOOD-ERA expressed that a complex spectrum of requirements will be needed in order to achieve a change from "pure flood protection" to finding a "Balance of SM and NSM" (cf. Table 6).

**Do NSM offer a wider range of social and environmental benefits compared to SM?**

Understanding and assessing multiple benefits of flood risk management strategies (such as flood damage reduction, erosion control and sediment management, improved water quality and water supply, fish and wildlife habitat, habitat for endangered species, outdoor recreation etc.), and measures that support multiple user-functions of a water system and its surroundings, are the key to a holistic FRM approach. This is especially in densely populated areas (not only deltas) where multiple requirements have to be satisfied in one go. Balancing NSM and SM could contribute to a holistic view of management of flood risk, taking account of social and economic development and long-term change in the natural environment. In this context, EWASE found that the NSM aspect "early warning" offers a significant potential to transfer responsibilities from the state to the individuals, (especially in the economic sectors) because of the ongoing presence of people at least during the day. Probably 60 to 70% of the flood risk arises in the economic sectors, there is a high potential for damage reduction due to early warning. Moreover, early warning systems induce very low detrimental effects on the natural environment and support the protection of the weak by enabling better evacuation responses.

With respect to NSMs aspects like "more room for the river" or "floodplain enlargements" (represented here by "Room for the river" and "PRO_Floodplain") it is obvious that NSMs offer a wider range of social and environmental benefits than SMs. Given the fact that existing connected floodplains offer more or less cost-free flood management, with considerable effects for floodplain ecology, it should be highlighted that the preservation of those areas should be a top priority when new flood management strategies are discussed.

## 3.2 Key research findings

**NSM "land use / spatial planning"**

The increasing demand for land provokes a tension for governments and policies because of the loss of land for flood mitigation. Moreover, humans have extensively modified the natural landscape, often amplifying the impacts of extreme weather events on communities and the environment. Agriculture and urban sprawl with its associated development impair the natural tendency of the land to slow down, store, or dissipate flood water — which is considered as an important ecosystem service that benefits society. Reducing the natural resilience of the land and its ability to recover from extreme events can lead to greater future impacts.

Land use and spatial planning is therefore key to substantially reducing the flood risk. In this context, a frequent question to decision makers is the impact of a respective land use or land cover change in a given area on the effectiveness to reduce the peak run-off from this area. In "Room for the river" the research has shown that the peak runoff reduction of "retaining water in the landscape" measures (such as afforestation or the use of micro-ponds in the landscape) is a function of flood return period, reducing its effectiveness with the flood magnitude (cf. Figure 1). On the other hand, the concept of "room for the river" is more effective for medium return periods (cf. Figure 1).

Considering urban flood management, the project SUCA has found that many urban planning authorities appear to be unaware of the importance of surface water flood risks. This must be addressed in future planning strategies.

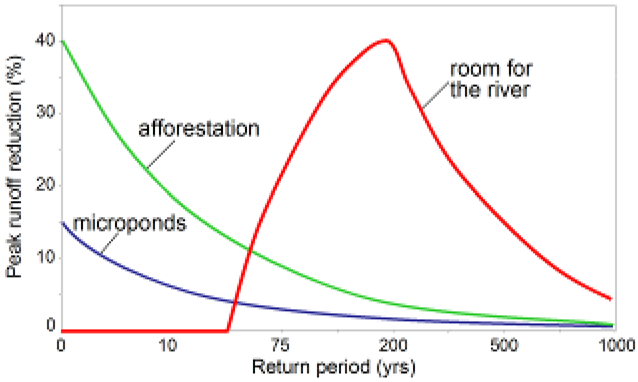


Figure 1: Estimated flood peak reduction of the "room for the river" method (retention basins and flood inundation along the river reaches), and the "retaining water in the landscape" methods (micro-ponds and afforestation) for the Kamp catchment (Austria). Courtesy "Room for the river", 2008.

The role of river floodplains in integrated flood risk management was addressed from a hydromorphological, ecological, and social point of view in "PRO_Floodplain". It is a fact that since over the last few decades an enhanced loss of floodplains for being used as land for further settlements, infrastructure etc. has to be observed in Europe. This circumstance in combination with a significantly higher vulnerability of the society for flooding and the insensibility of ecological needs, flood risk reduction by preserving and restoring river floodplains gains increasing importance.

The research had shown that river floodplains contribute significantly to the reduction of peak flows and to the prolongation of flood wave translation not only for a certain design discharge (such as structural measures) but also for higher discharges. They also fulfil other important functions such as serving as sediment buffers or improving local hydraulic conditions. In order to allow the evaluation of the impact a certain floodplain area within a river catchment may have on technical, ecological and sociological aspects, "PRO_Floodplain" developed a so called "floodplain evaluation matrix (FEM)" (cf. Figure 2). The result of FEM allows a priority ranking of floodplain areas within a river catchment or river reach, which supports the decision making process, i.e. whether to preserve or restore river floodplains or not.

| Hydromorphology* | floodplain 1 | floodplain 2 | floodplain 3 | Ecology | floodplain 1 | floodplain 2 | floodplain 3 | Sociology** | floodplain 1 | floodplain 2 | floodplain 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Peak reduction | 5 | 5 | 1 | Adapted land use | 5 | 3 | 1 | Type of usage | 3 | 3 | 5 |
| Flood wave translation | 5 | 3 | 1 | Dynamics of the water level | 5 | 3 | 1 | Channel of communication | 3 | 3 | 5 |
| River-kilometre parameters | 5 | 5 | 1 | Flow velocity | 5 | 1 | 3 | | | | |
| Secondary effects[1)] | 3 | 5 | 3 | Surface relief | 3 | 3 | 1 | | | | |
| Other processes | 5 | 3 | 1 | Connectivity of water bodies | 5 | 1 | 1 | | | | |
| | | | | Potential for development[2)] | 5 | 5 | 3 | | | | |
| | | | | Endangering of habitats | 5 | 5 | 1 | | | | |
| **Hydromorphology total** | **5** | **5** | **1** | **Ecology total** | **5** | **3** | **1** | **Sociology total** | **3** | **3** | **5** |

*) not including hydraulic considerations which are important anyway (incorporation within FEM+)
**) not including economical considerations which are important anyway (incorporation within FEM+)
1) Secondary effects in case of discharges larger than design discharge
2) Potential for development of typical habitats

Legend:

| | |
|---|---|
| 5 | top priority |
| 3 | medium priority |
| 1 | low priority |

| | Hydromorphology total | Ecology total | Sociology total |
|---|---|---|---|
| floodplain 1 | 5 | 5 | 3 |
| floodplain 2 | 5 | 3 | 3 |
| floodplain 3 | 1 | 1 | 5 |

Figure 2: Illustration of the "FEM" approach on floodplains along the Kamp river (Austria). Courtesy "PRO_Floodplain", 2008.

Coupling socio-economic and climate change scenarios with long term land use modelling and flood risk analysis methods – as accomplished in "Simulation of Risk" - offers the opportunity to explore their effectiveness under more complex and realistic scenarios of change – on their own or in conjunction with other measures. "Simulation of Risk" demonstrated that this modelling methodology can provide higher resolution analysis than previous studies, and can take more explicit consideration of the local effects of local or national drivers of development and land use policies.

**Key findings on the NSM "perception / evolution of risk"**

Perception of flood risk has become an important topic to politicians and policy makers concerned with risk management and safety issues in the last few years. The question of how people perceive, tolerate and accept flood risks is of vital interest in modern flood risk management, because it steers the development of effective and/or efficient flood mitigation strategies.

Flood risk and hazard maps are considered as valuable instruments when informing the public about flood risk. In many European countries they are also used to implement land-use regulation. These maps are primarily designed to support people to identify the risk areas that could be affected by hazardous natural processes like floods.

However, until now little information has been available related to the content and design of such maps, apart from overall principles of map production. RISKCATCH showed that the structure of maps influences the visual strategies of the readers. Presumably related to culture and education, textual elements were considerably attractive for perception. Furthermore, the central elements of the map have to contrast with the background and should be designed in bright and dark colours respectively. Additionally, the position of various elements in a map, i.e. the title, the legend, and the central figurative element, is of particular importance for the visual comprehension; map perception is therefore, iconographic. The more accessible visual information is, the more effective it will be in terms of visual transmission of information.

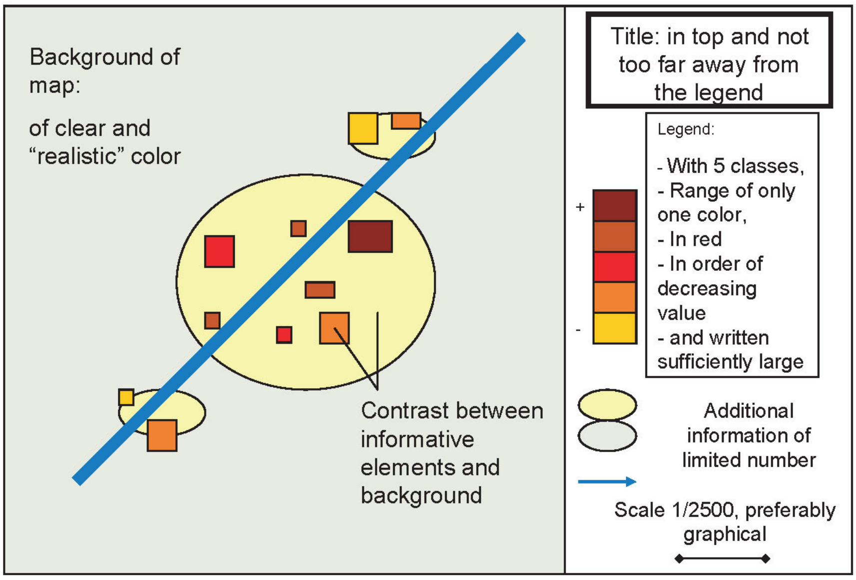


Figure 3: Suggestions for the compilation of risk maps in order to allow for efficient and target-oriented risk communication (Courtesy "RISKCATCH", 2008).

Moreover, the reading behaviour of specialists, sensitised people and laypersons led to the conclusion that perception is anthropic. Hence, risk maps should be compiled according to these different needs, in particular bearing in mind that approximately 65 % of the observation time of subjects is devoted to less than 25 % of the map surface. As a result of RISKCATCH, the framework for the production of an optimum risk map that allows for efficient and target-oriented communication of flood risk was developed (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.**). Adoption of the proposed framework will lead to enhanced risk communication by increasing the level of individual perception and understanding and will deliver information in a visually efficient manner.

When discussing the main aspects influencing the social acceptance of NSMs, "PRO_Floodplain" has found that the type of usage of a respective NSM (e.g. enlarging a floodplain area) and the channel of communication in which information about measures is disseminated, are both important. They draw the conclusion that, involving the public in the early decision-making process is a way to create another relationship between society and environment (in the case of, for example, floodplain areas). It is a method to re-adapt the population to frequent natural events in anticipation of climate change and to help people to become accustomed to flooding processes in their environment.

**Key findings on the NSM "flood warning"**

Warning and early warning are considered to be important factors in reducing people's risk of flooding. Flood alerts provided by early warning systems (EWS) provide information on expected flows and water levels prior to the actual occurrence of a flood peak, and generate alerts in order to take preventive measures for avoiding damage.

The potential benefit from the anticipation of imminent floods is unquestioned. Nonetheless, reliable forecasts are a basic requirement to enable warning system operators and responsible authorities to take robust decisions. Especially in river basins prone to flash-floods, critical situations develop quickly and make high demands on the warning lead time. To consider a EWS to be efficient, the decision about a flood alert has to trade off the prolongation of the warning lead time and the decrease of forecast reliability. In this context, it is important to bear in mind that a successful warning will bring about (socio-) economic benefit whereas a false alert leads to (socio-) economic loss. EWASE showed that flood forecasting involves a considerable degree of system-inherent uncertainties because the knowledge about the future development of meteorological conditions as well as the state and the behaviour of the hydrological system is still limited. Considering these aspects in an integral measure to quantify the reliability of a flood forecast, the "Warning Reliability" can now be expressed as a function of lead time (Figure 4). This function shows that even for short lead times the reliability of a forecast may decrease significantly. This is especially important if EWS are applied and operated as a single risk reduction approach.

EWASE also questioned what an indicator for optimal alerts could be and stated the indicator "warning expectation" serves as a good example (cf. Figure 4). Exploring the indicator "warning expectation" in the industrial sectors in the Besòs basin (Spain), they found a correlation between warning reliability and avoidable damage. The expectation of an alert is therefore defined as the product of the warning reliability and the avoidable damage and results in a curve with units € per alert. Warning expectation is not constant but changes with lead time. The maximum of the warning expectation curve defines the optimal point of time for releasing an alert with respect to reliability and consequences.

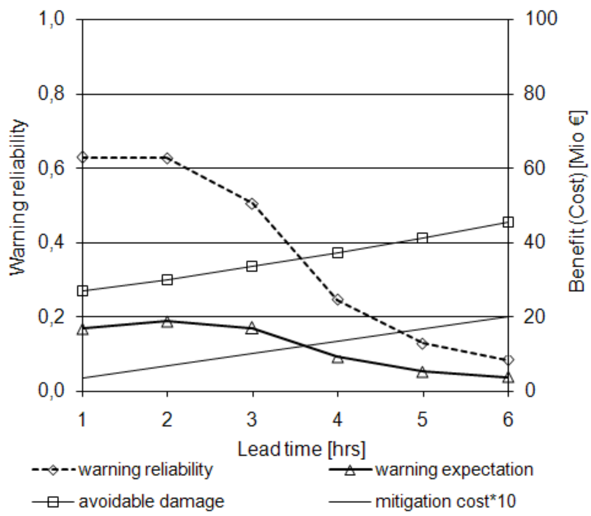


Figure 4: Warning Expectation as indicator of optimal alert for the industrial sectors in the Besòs basin (Courtesy "EWASE", 2008)

# 4. Recommendations & Implications

The aim of this section is its use by policy makers, practitioners, and academics in order to improve flood risk management approaches in all cases where NSMs are involved. In order to have maximum understanding, it is recommended to first read the previous section (Key findings & conclusions). To ease further understanding, each recommendation given in this section will have its reference to the initial project background (as identified in Table 1).

## 4.1 Recommendations & Implications for policy makers

- The research indicated that a clear preference between SMs and NSMs is not determinable. However NSMs seem often to be less effective but more efficient (Ref. #5).
- 'Balancing SMs and NSMs' in decision making is not just a matter of evaluation capabilities. Other factors could be even more important. Land use planning and market-based methods (e.g. insurance) provide a powerful means of managing flood risk and should be more explicitly considered in strategic flood risk management planning. However, the most effective reductions in flood risk come from deployment of portfolios of flood risk management measures, including structural measures where appropriate (Ref. #5 & #7).
- The proposed systematisation of SMs / NSMs should be considered as a common basis for implementation and evaluation procedures as well as a way to facilitate communication among decision-makers, practitioners, scientists, and the public (Ref. #5).
- Instead of "hazard" or "vulnerability" it is recommended to use "risk" as a common currency in evaluating and comparing the effectiveness and efficiency of NSMs with SMs (Ref. #7).
- Climate change and socio-economic change must be considered in flood risk management planning. Climate change is now considered in most EU states, but long term changes to economy and population are generally not yet taken into account in flood risk management (Ref. #7).
- Development and implementation (and subsequent updating of guidance) of methods for robustness analysis is needed in order to test the long term effectiveness of non-structural measures against different conditions of climatic and socio-economic change (Ref. #7).
- The preservation of connected existing floodplains should be the most important objective of all flood protection measures and further planning (from an economic, ecological and social point of view) (Ref. #6).
- Legally binding provisions for floodplains and hazard zones in regional planning laws and building laws should be created in order to prohibit the development of land that is important for flood runoff or retention (Ref. #2 & #6).
- Volume matters. Overall, the effect of the reduction in flood risk depends on the retention volume a given area can provide compared to the magnitude of the flood (Ref. #1).
- The suggestions on the design of optimum risk maps should be applied to support future risk communication strategies (Ref. #2).
- The FEM method is recommended to be applied at a variety of prototype rivers across Europe to test the applicability and improve the approach (Ref. #6).
- For risk reduction strategies, multi-dimensional concepts/approaches are needed to deal with multiple issues and should consider structural and non-structural issues, entire basins and the

whole cycle of risk management (recommended by all projects involved).
- Further capitalising on Early Warning systems (Ref. #3).
- Team building process is at the front of improving FRM: representatives of different institutions responsible for FRM should be included from the outset of a respective risk reduction strategy (Ref. #5 & #4).
- Availability and quality of data are essential to continue research and enhance development on NSMs (recommended by all projects involved).

## 4.2 Recommendations & Implications for practitioners

- Updating EU and National Flood and Coastal Project Appraisal Guidance and other relevant guidance or procedures as necessary to implement non-structural flood risk management into practise (Ref. #7).
- Further to the current restrictions in land-use planning, typically designed for river flooding, additional restrictions should be considered for all types of flooding, including those in small urban basins, from local rainfall. In this context, further urbanisation has to be outlawed if this contributes to an increase in damage potential and consequently in flood risk (Ref. #4).
- Improve the accessibility of risk-related information to the public (e.g. risk maps or early warnings) in order to allow them to respond effectively (Ref. #4).
- Create a single point of contact for help and advice on FRM. Property owners and operators need advice and assistance to increase the flood resiliency of their properties (Ref. #4).
- Public stakeholders need to be involved in a learning process to enhance their capacity both to be willing to engage, and to engage effectively, with the communities they serve (Ref. #4).
- Creating value from uncertainty estimates by applying the Warning Expectation approach (Ref. #3).
- Extending and using EU statistics as a common warranty of reliability when developing risk reduction strategies and measures (Ref. #3).
- Introduction of urban runoff standards into FRM plans (Ref. #4).
- Increase the use of Sustainable Drainage Systems (SUDS), especially in urban areas (Ref. #4).
- Include sewer flooding in risk maps (Ref. #4).
- Consider the "floodplain evaluation matrix (FEM)" method during the implementation of the new EU Floods Directive (Ref. #6).
- The parameters developed for evaluating the effectiveness of floodplains for flood risk reduction can be used within practical projects (Ref. #6).
- When exploring the potential of risk maps to deliver appropriate risk information, certain additional map features, such as evacuation paths, escape routes and the localisation of shelters, should be included (Ref. #2).
- A more frequent (or better real-time) update of the information necessary for the assessment of risk, i.e. information related to values at risk such as land register plans, development plans and data related to population density, would help to respond effectively to the variable changes in risk (Ref. #2).

## 4.3 Recommendations for further research

- As the level of uncertainty in damage and risk information and data accounts for about 45%, more research is necessary to provide statistically sound foundation of damage functions and risk indications (Ref. #3).
- Further studies are needed to analyse the appropriateness of traditional cost-benefit methods for the appraisal of certain non-structural flood risk measures such as land-

use planning and insurance. The focus should be on developing whole life measures of costs and benefits to reflect the real 'benefit' or 'cost' of these policies (Ref. #7).

- Dynamic modelling on the local scale in view of uncertainty is required (Ref. #3).
- With respect to the overall aim of building hazard-resilient communities, future studies must include the applicability of risk maps within flood risk management plans (Ref. #2).
- Considering the possible effects of afforestation or deforestation on the changes in the infiltration capacity, more research is needed to perform local infiltration experiments to complement the model-based assessment of the effects of land use change on flooding (Ref. #1).
- Considering the "floodplain evaluation matrix (FEM)" method, the synthetic model and parameter variation should be extended to cover the whole range of European floodplains (Ref. #6).
- Further develop methods that allow the combination of the criteria "effectiveness" and "efficiency", with non-monetary criteria such as sustainability, robustness and flexibility (Ref. #5).
- More empirical research is needed in order to allow fair comparison between SM and NSM or, respectively, to determine the „ideal mix" of SMs and NSMs (Ref. #5).
- The definition and applicability of urban runoff standards across Europe as well as possibilities for further development of risk communication and participation in urban communities should be explored (Ref. #4).

# ANNEX

## Abbreviations

| | | |
|---|---|---|
| BMBF | • | Federal Ministry for Education and Research (Germany) |
| BMLFUW | • | Federal Ministry of Agriculture, Forestry, Environment and Water Management (Austria) |
| BMVIT | • | Federal Ministry for Transport, Innovation and Technology (Austria) |
| CRUE | • | Coordination de la Recherche sur la gestion des inondations financée dans l'Union Européenne |
| Defra | • | Department for the Environment, Food and Rural Affairs (UK) |
| ERA-Net | • | European Research Area - Network |
| EU | • | European Union |
| EU Floods Directive | • | Directive 2007/60/EC |
| EU Water Framework Directive | • | Directive 2000/60/EC |
| EWASE | • | Project of CRUE's 1st research funding initiative: Effectiveness and efficiency of Early Warning Systems for Flash Floods |
| EWS | • | Early Warning System |
| FEM | • | Floodplain Evaluation Matrix |
| FLOOD-ERA | • | Project of CRUE's 1st research funding initiative: Flood risk management strategies in European Member States |
| FRM | • | Flood Risk Management |
| MEEDDAT | • | Ministry of Ecology, Energy, Sustainable Development, and Territorial Development (France) |
| MICINN | • | Ministry of Science and Innovation (Spain) |
| NSM | • | Non-structural measure |
| PRO_Floodplain | • | Project of CRUE's 1st research funding initiative: Flood risk reduction by Preserving and RestOring river FLOODPLAINs |
| RISKCATCH | • | Project of CRUE's 1st research funding initiative: Development of flood risk in mountain catchments and related perception |
| Room for the River | • | Project of CRUE's 1st research funding initiative: Efficiency of non-structural measures: 'room for the river' and 'retaining water in landscape' |
| SG-EQD | • | The Scottish Government, Environmental Quality Directorate |
| Simulation of Risk | • | Project of CRUE's 1st research funding initiative: Simulation of Flood Risk and Non-structural Risk Management |
| SM | • | Structural measure |
| SUCA | • | Project of CRUE's 1st research funding initiative: Risk Assessment and Risk Management in Small Urban Catchments |
| SUDS | • | Sustainable Drainage Systems |

# Additional information used in the main text

**Table 2: Proposed systematisation of structural and non-structural measures (Courtesy FLOOD-ERA, 2008)**

| Functional group | Type of measure | Measure (Examples) | Underlying instrument |
|---|---|---|---|
| Structural Measures | | | |
| Flood control | Flood water storage | Dam | Flood protection standard; investment programme |
| | | Flood polder | |
| | River training | By-pass channel | |
| | | Channelisation | |
| | Flood protection | Dike | |
| | | Mobile wall | |
| | Drainage and pumping | Urban sewer system | |
| | | Pumping system | |
| Non-structural measures | | | |
| Flood control | Adapted land use in source area (catchment of the headwater) | Conservation tillage | Restriction of land use in source areas; priority area "flood prevention" |
| | | Afforestation | |
| | River management | Dredging of sediments | Investment/maintenance programme |
| Use and retreat | Land use in flood-prone area | Avoiding land use in flood prone areas | Restriction of land use in flood zones; building ban; hazard and risk map; insurance premium according to flood zone |
| | | Relocation of buildings from flood prone areas | |
| | Flood proofing | Adapted construction | Flood forecasting and warning system; civil defence or disaster protection act |
| | | Relocation of susceptible infrastructure | |
| | Evacuation | Evacuation of human life | |
| | | Evacuation of assets | |
| Regulation | Water management | Restriction of land uses in flood plains and source areas | |
| | | Flood protection standards | |
| | Civil protection | Civil protection and disaster protection act | |
| | Spatial planning | Priority area "flood prevention" | |
| | | Building ban | |
| Financial stimulation | Financial incentives | Investment programmes (e.g. for river works) | |
| | | Subsidies for relocation or adaptation | |
| | Financial disincentives | Insurance premium according to flood zone | |
| Information | Communication/Dissemination | Information even | |
| | | Brochure | |
| | Instruction, warning | Hazard and risk map | |
| | | Forecasting and warning system | |
| Compensation | Loss compensation | Insurance payments | |

**Table 3: Comparative evaluation of effectiveness for NSM compared to SM (Courtesy FLOOD-ERA, 2008)**

| SM | Compared NSM | Effectiveness of NSM compared to SM (case study; boundary conditions) |
|---|---|---|
| Diversion channels | - Flood forecasting and warning as basis for the evacuation of inventory<br>- Emergency response<br>- Community based flood protection measures<br>- Flood proofing<br>- Floodplain spatial planning controls<br>- Flood insurance<br>- Public response | - 4.46 to 11.06 % based on public response and depending on the warning time (see Parker *et al*. 2007) compared to 100 % of the channels (Thames River; design level 100 yrs, considered recurrence intervals up to 100 yrs)<br>- "medium" to "high" (but not tested) compared to 100 % of the channels (Thames River; see above)<br>- "uncertain" compared to 100 % of the channels (Thames River; see above)<br>- "uncertain" compared to 100 % of the channels (Thames River; see above)<br>- "high" (but only curtailing the development of the floodplain in the future) compared to 100 % of the channels (Thames River; see above)<br>- "high" (but not universal) compared to 100 % of the channels (Thames River; see above)<br>- "low" compared to 100 % of the channels (Thames River; see above) |
| Dikes and/or flood walls | - Resettlement (hypothetical)<br>- Local warning system<br>- Flood proofing and evacuation of inventory | - 100 % compared to 100 % of ring dike (Mulde River - Erlln; design level 100 yrs, considered recurrence intervals up to 100 yrs)<br>- 2.1 % compared to 100 % of flood wall (Mulde River - Grimma; see above)<br>- 64 % compared to 94 % of protection line (Elbe River; design level 100 yrs, considered recurrence intervals up to 100 yrs) |
| Defence systems (dikes, flood walls, flood polder) | - Spatial planning<br>- SM + spillway | - 25.6 % (due to effects for urban development of the last 10 yrs only) compared to 91.3 % of SM portfolio (Raab River; design level 100 yrs, considered recurrence interval 300 yrs)<br>- 95.1 % compared to 91.3 % of SM portfolio (Raab River; see above) |

**Table 4: Comparative evaluation of cost-effectiveness for NSM compared to SM (Courtesy FLOOD-ERA, 2008)**

| SM | Compared NSM | Cost-effectiveness of NSM compared to SM (case study; boundary conditions) |
|---|---|---|
| Dikes and/or flood walls | - Resettlement (hypothetical)<br>- Local warning system<br>- Flood proofing and evacuation of inventory | - 67, 872 €/% compared to 39,210 €/% of ring dike (Mulde River - Erlln; design level 100 yrs, considered recurrence intervals up to 100 yrs)<br>- 137,000 €/% compared to 230,000 €/% of flood wall (Mulde River - Grimma; see above)<br>- 86,596 €/% compared to 139,388 €/% of protection line (Elbe River; design level 100 yrs, considered recurrence intervals up to 100 yrs) |

**Table 5: Comparative evaluation of benefit-cost ratios for NSM compared to SM (Courtesy FLOOD-ERA, 2008)**

| SM | Compared NSM | Benefit-cost ratios (BCR) of NSM compared to SM (case study; boundary conditions) |
|---|---|---|
| Diversion channels | - Flood forecasting and warning as basis for the evacuation of inventory | - "low" (BCR likely to be <1.0) compared to "high" (4:1 till 11:1) of the channels (Thames River; design level 100 yrs, considered recurrence intervals up to 100 yrs) |
| | - Emergency response | - "very low" (BCR ~1.0) compared to "high" (4:1 till 11:1) of the channels (Thames River; see above) |
| | - Community based flood protection measures | - "low" to "medium" (BCR 1.75 to 2.2 (8.0)) compared to "high" (4:1 till 11:1) of the channels (Thames River; see above) |
| | - Flood proofing | - "medium" (to "low"?) compared to "high" of the channels (Thames River; see above) |
| | - Floodplain spatial planning controls | - probably "very high" compared to "high" of the channels (Thames River; see above) |
| | - Flood insurance | - "high" (BCR > 1.0) compared to "high" (4:1 till 11:1) of the channels (Thames River; see above) |
| | - Public response | - "medium" to "high" compared to "high" of the channels (Thames River; see above) |
| Dikes and/or flood walls | - Resettlement (hypothetical) | - BCR 0.28 (mean) compared to BCR 0.45 (mean) of ring dike (Mulde River- Erlln; design level 100 yrs, considered recurrence intervals up to 100 yrs) |
| | - Local warning system | - BCR 0.97 (mean) compared to BCR 0.58 (mean) of flood wall (Mulde River - Grimma; see above) |
| | - Flood proofing and evacuation of inventory | - BCR 11.6 compared to BCR 7.2 of protection line (Elbe River; design level 100 yrs, considered recurrence intervals up to 100 yrs) |

**Table 6: Balance of SM and NSM: Context conditions and intended change (Courtesy FLOOD-ERA, 2008)**

| | Context condition | Overall conclusion with regard to intended change |
|---|---|---|
| *Human agency* | Risk perception | It is unlikely that risk perception is a major limiting context conditions for change |
| | Perception of Responsibility | Change requires a broad understanding of responsibility among politicians and officials (e.g., responsibility as accountability and commitment). |
| | Beliefs about measures | Change requires unlearning that *only* "big solutions" in terms of large-scale engineering work can solve "big problems" like severe consequences of major flood events. |
| | Response repertoire | Significantly enlarged response repertoire will probably develop only over a considerable time span. |
| | Leadership and networks | Change requires multi-level networks with relationships between different policy fields. |
| *Social structures (in a broad sense)* | Availability of guidelines, indicators and methods | Change requires new guidelines, indicators, and methods to reduce uncertainty of measurement the effects of NSM relative to the evaluation of SM (*see Chapter 5 of this report*). |
| | Funding | Change requires new funding mechanisms that are more suitable for NSM. |
| | Formal institutions | Decentralisation within the public sector could facilitate change. |
| | Informal institutions | Informal institutions are difficult to change (e.g., expectations of the public based on flood experiences). Cultural change as the outcome of changing informal institutions is to be expected in the long run, if at all. |