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FLOODING ERA-NET

Integrate, Consolidate and Disseminate European Flood Risk Management Research

2nd ERA-NET CRUE Research Funding Initiative
Flood Resilient Communities – Managing the Consequences of Flooding
Final Report

CRUE Final Report

SUFRI - Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk

Prepared by the Joint Project Consortium consisting of

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Second Era-Net CRUE Funding Initiative: Flood resilient communities – managing the consequences of flooding

CRUE Research Report

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The intent of the research reports is to provide relevant information and to stimulate discussion of those having an interest in flood risk management. The results and conclusions of all reports produced under the **Second CRUE Funding Initiative on Flood Resilience** are made available to policy-makers and stakeholders at all levels, research funding bodies, universities, industries, practitioners, and the general public by way of the CRUE website (**http://www.crue-eranet.net**).

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ERA-Net CRUE was funded within the Sixth EU Framework Programme and introduced structure within the area of European research on flood risk management (FRM). Its vision was to support and develop an extensive co-ordination and integration of regional, national, and European research programmes, projects and policies in the field of Flood Risk Management. Within the CRUE ERA-Net two funding initiatives were introduced.

The second ERA-Net CRUE Research Funding Initiative **"Flood Resilient Communities – Managing the Consequences of Flooding"** was launched in support of the EU Floods Directive 2007/60/EC, which was introduced as a result of several severe flood events causing loss of life and property. Within this initiative seven joint research projects with test sites all over Europe are funded and focus on a broad spectrum of issues related to the enhancement of resilience. Besides, the scientific coordination project CORE CRUE is funded within this second call, to support the implement of the call and to disseminate its results.

SUFRI - Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk

CRUE Research Final Report

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Ministry of Science and Innovation of Spain	GOBIERNO DE ESPAÑA / MINISTERIO DE CIENCIA E INNOVACIÓN **MICINN (E)**

A project fact sheet can be found at the end of this document.

Summary for Decision-Makers

The project **SUFRI** aspires an improvement of flood risk management in case of disaster flood especially in respect of non-structural measures. As flood protection and management are major tasks and of high public interest transnational strategies are needed to implement sustainable flood risk management, aiming for advanced warning systems, vulnerability analysis, and risk communication to optimize the disaster control management.

What the report is about and why the work is important
Aims/Objectives, including who may benefit from the research

Flood forecasting for large trans-national river catchment areas are widely used. By contrast flood warning and floods in urban areas, especially for small catchment areas, are still research topic. Many recent research projects have focused on these topics like URBAS 2008, EWASE 2008, UrbanFlood 2010. Experiences of practical applications are still seldom.
Therefore, the project intention was to provide an overview about flood characteristics in urban areas to improve flood management, and about general components and benefits of early warning systems.
Different approaches have been used to reach this goal (experiences with analogue warning systems, weather data, rainfall and flood forecast models, flood maps and flood management plans). The entirety of all themes related with warning systems shall lead to recommendations for practitioners and authorities.

In recent years the aspect “risk estimation” has become of more research interest, in consideration of measures to address consequences of floods because of the recognition that floods can never be absolutely prevented or predicted.
In order to study the flood threat, the concept of flood risk has been established. Flood risk can be defined as the combination of probability of a flood event, called hazard, and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event (*Directive 2007/60/EC*), called vulnerability.
For appropriate risk estimation different tools need to be analysed and lead to an alternative approach for pluvial and river flooding risk assessment in urban areas. This developed methodology provides a tool to support flood risk evaluation in urban areas and it can be applied to inform authorities, local entities and stakeholders on decision-making to establish strategies for risk reduction.

Regarding the basis principles of ERA-Net CRUE, resilience and community, the aspect of public participation gains in importance. According to Wiedemann (2005), risk communication consists of "all communication that concerns the identification, the estimation, the evaluation and the management of risks. It aims to convey information about the potential for risk, to minimize differences in the evaluation, and to prevent escalating conflicts in the confrontation with risks. Particularly important is communicating with the general public, meaning the affected as well as interested citizens.”
The participation of the public is seen as an important prerequisite, because, in the case of a flood, the actions of citizens are also actively required. In order to be able to design a risk communication for a crisis effectively, the following factors must be taken into consideration: people's behaviour as well as the needs of those affected by the flood. In this respect, science currently provides us with limited empirical data.
Therefore, the project fills in two research gaps: it provides empirical data on the subjective view of the citizens regarding natural hazards, particularly regarding flooding, as well as the desired communication and information in the case of a flood occurring. Furthermore, an international comparison between the chosen investigation areas can take place.

All in all, the project is aimed at an interdisciplinary approach that will combine societal and technical visions, beginning with advanced warning and communication chains, over risk estimation and public participation to crisis management planning.

Results/Key findings in relation to report objectives

The key findings of the project are:

- Compilation of advanced warning systems
- Compilation of risk communication strategies
- SUFRI Methodology for pluvial and river flooding risk assessment in urban areas
- SUFRI Method for risk awareness of the population
- SUFRI Approach for crisis management planning
- Examples of use in Austria, Germany, Italy and Spain and their trans-national comparison
- International symposium UFRIM for communicating the research results

Implications for stakeholders (policy-makers, practitioners, others where relevant)

The produced compilations and guidelines are easy applicable tools to optimize the disaster control management. Further, the results of the applied methodologies in different European case studies increase the understanding of the guidelines, as well as the occurred problems and experiences. Due to the comparison of the case studies, it is possible to gain new knowledge. This applies for policy-makers and practitioners.

The public opinion poll was conducted in Graz, Dresden, Lodi, Benaguasil and Arenys de Mar/Munt and reflects a clear picture of people`s behaviour and knowledge regarding floods. With this data it is possible for authorities to develop and implement adequate communication strategies. E.g., the official fire brigade of Graz was very interested in the population`s satisfaction with their work wherefore this topic has been included into the questionnaire. Further, the action forces can get valuable information of the analysis about their crisis management. The willingness of the public for participation is intimately connected with taking their requirements seriously. Therefore, the standardized questionnaire, is an ideal tool to strengthen public participation for integrating their requirements in future flood risk management plans.
The outcome of the risk estimation (F-D and F-N curves) can support the authorities and governance in decision-making processes. The results show the benefit of different protection measures (structural and mainly non-structural).

Recommendations for decision-makers

The research work of SUFRI causes the following recommendation for decision-makers:

- The tool for risk estimation can assist in the decision making process. It provides a clear overview of the social and economic flood risk and evaluates the effects of several structural and non-structural measures. F-N and F-D curves describe the quantitative results of the analysis of social and economic loss regarding the probability in an understandable and easy way.
- An analysis of the public opinion poll can point out a clear picture which kind of measures, information or assistance is needed in the population`s view. This kind of information can assist in the decision making process for setting tasks and measures respective the flood management process.
- The compilation of advanced flood warning systems delivers a reference work for authorities and policy maker. It covers the state-of the art of flood warning and their advantages as well as disadvantages.

Contents

1 Introduction

This chapter introduces the topic of risk management with respect to flooding in urban areas. It provides the contribution of the project SUFRI to the flood directive and the basic principles of the European initiative. Further, the scientific objectives and the layout of the project with its main topics and the framework of the work packages will be explained.

Regarding disaster flood events in the recent past the importance of an integrated flood management is increasing in European countries.

The project **SUFRI** aspires an improvement of flood risk management in case of disaster flood especially in respect of non-structural measures. As flood protection and management are major tasks and of high public interest transnational strategies are needed to implement sustainable flood risk management, aiming for advanced warning systems, vulnerability analysis, and risk communication to optimize the disaster control management.
To achieve this goal, five project partners from four European countries (Austria, Germany, Italy and Spain) and one subcontractor from Austria were working within the ERA-Net CRUE initiative for the period of 2009 - 2011. This document represents the end report for the ERA-Net CRUE initiative and gives a brief overview of all developed and implemented methodologies, case studies and results and the linkage between the project aims and objectives and the scientific and socio-political necessity and vision of the ERA-Net CRUE to strengthen the European research area. Detailed applications of the methods will be published in separate reports, in total three guidelines and two research reports.

Resilience and **community** are keywords of an integrated flood risk management and the basic principles in the ERA-NET CRUE initiative for national and international research.

Resilience considering natural or other disasters like flood events has been defined as the capacity of individuals, families, communities, businesses or institutions to withstand and/or to respond to, cope with, resist, and quickly recover from catastrophic events. Anticipation and planning for the future as well as adaptation and transformation is fundamental to gain a better resilience.
Therefore, an effective flood forecast and warning system has to be attended by public awareness and participation. In a first step, people concerned have to be integrated in the planning concept; their understanding of the threat and their willingness to protect themselves have to be captured. Further, the current situation regarding flood risk, warning systems and emergency planning and coordination has to be factually analysed. Based on these data effective warning systems, information campaigns, communication chains, public education and emergency action plans can be developed and / or improved to benefit the resilience.

Community will be perceived as a group of interacting people that are organized around common values and is attributed with social cohesion within a shared geographical location – community as a comprehensive and integrated body of the population and entities. Depending on the point of view a community can be either a small group of people (e.g. citizens group, neighbourhood) or at a large scale all affected people (including e.g. action forces, politics) also on a trans-national level.
From that point of view, we developed a method for involving people living in a flood prone area into the flood management process. With a questionnaire, developed in cooperation with regional and local authorities and action forces, amongst others, the willingness of neighbourly help and the satisfaction with the action forces can be measured and analysed. Further, a complete and quantitative tool for flood risk assessment in urban areas can inform decision-making and determine flood risk reduction strategies. As a

result, the different parts of a community will be involved into the management process which can cause sympathy one another and improve cooperation.

1.1 Scientific objectives

In the recent past, flood events occurred ever more frequently, and with snowballing effects for the landscape and its habitants. As a result of the current situation in many European cities affected by floods the demand of the population for absolute safety becomes top priority. In terms of the implementation of the Floods Directive in 2007 a broad basis of knowledge and tools, as well as the development of improved strategies for flood risk management are required. Particularly in regards to urban areas flood protection and retention are more problematical than in rural areas due to limited space in combination with a high density of population. Flood analyses have shown that structural measures of flood protection are limited applicable and that absolute protection is not feasible. The residual flood protection has to be achieved with non-structural measures such as forecast models, risk communication, and disaster control. Improving the risk awareness and increasing, thus, the public participation, respectively, is essential for coping with the effects in order to achieve an effective flood management.

The project aims for a risk based management of the consequences of disaster flood in flood-prone urban areas especially in consideration of the national differences, and will lead, thus, as a consequence to recommendations for good practice. To analyse national proceedings, infrastructure, the efforts of rehabilitation, as well as the public's risk perception, case studies of vulnerable European cities where flood events occurred in the recent past have been undertaken: Graz (AUT), Dresden (GER), Lodi (I), Benaguasil (E) and Arenys de Mar/Munt (E).

To achieve a stable and effective flood event management, primarily the recent situation with the projected structural measures has to be evaluated to detect the weak spots in the technical system, infrastructure, as well as in the crisis coordination. Based on this information case scenarios had been worked out to get estimation of the vulnerability and the risk situation, and additionally due to the analysed interaction of the differing consequences general arrangement drawings can be improved.

The main focus of the project is on risk identification and estimation, in connection with non-structural measures, risk communication which entails awareness raising, sensitization, public participation, as well as individual precaution measures, and highly advanced warning systems of small catchment areas. It is essential to optimise the crisis communication as well as coordination with the action force and the people involved. For an efficient flood risk management the public participation is an obligatory precondition, because they are familiar with the local flood history, and, in case of flooding, the habitants are requested to act.
As flood protection and management are major tasks and of high public interest trans-national strategies are needed to implement sustainable flood risk management, aiming for advanced warning systems, vulnerability analysis, and risk communication to optimize the disaster control management. With the results of the case studies national similarities and differences can be analysed and a trans-national approach may be located.

1.2 Work plan

This section describes the work plan of the project, consisting of 6 work packages. While work package 1 represents the project management, the other five work packages are closely related as it is shown in Figure 1. For a clearer visualization, the proposed approach will be described afterwards.

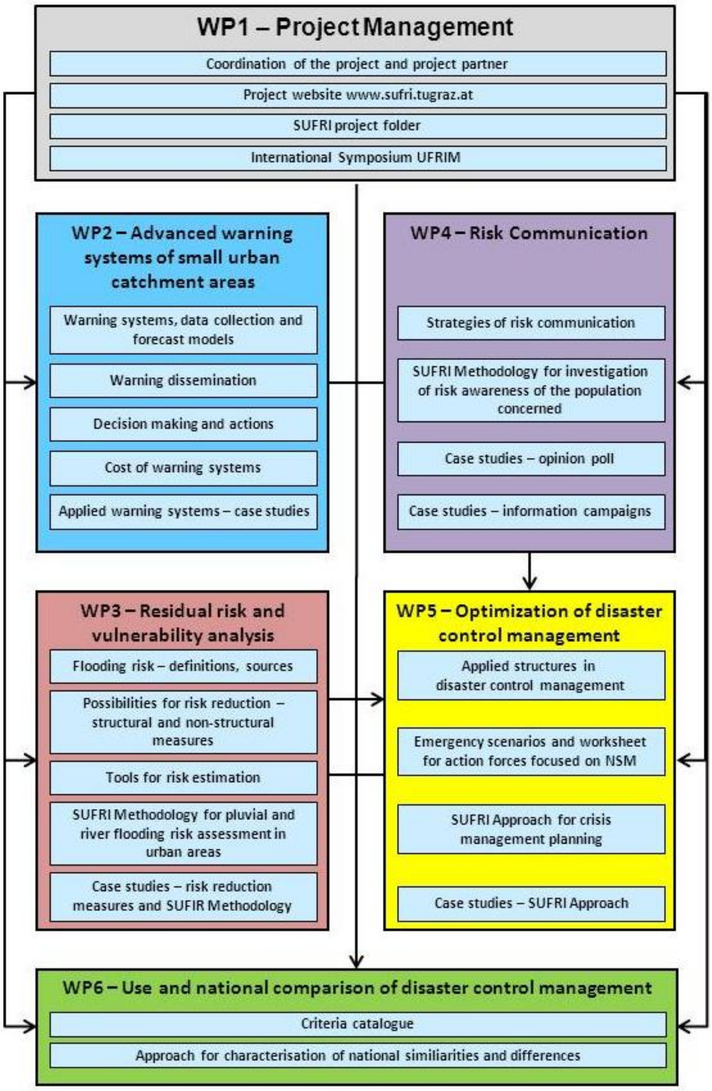

Figure 1: Scheme of the SUFRI project

The project objective was devided into four main themes:

- Warning systems
- Risk assessment
- Risk communication
- Crisis management

Resultant three guidelines and two research reports have been developed (Figure 2). The guidelines explain three developed methodologies in detail and include case studies and practical experiences. The research reports consist of compilations of warning systems, respectively communication strategies.

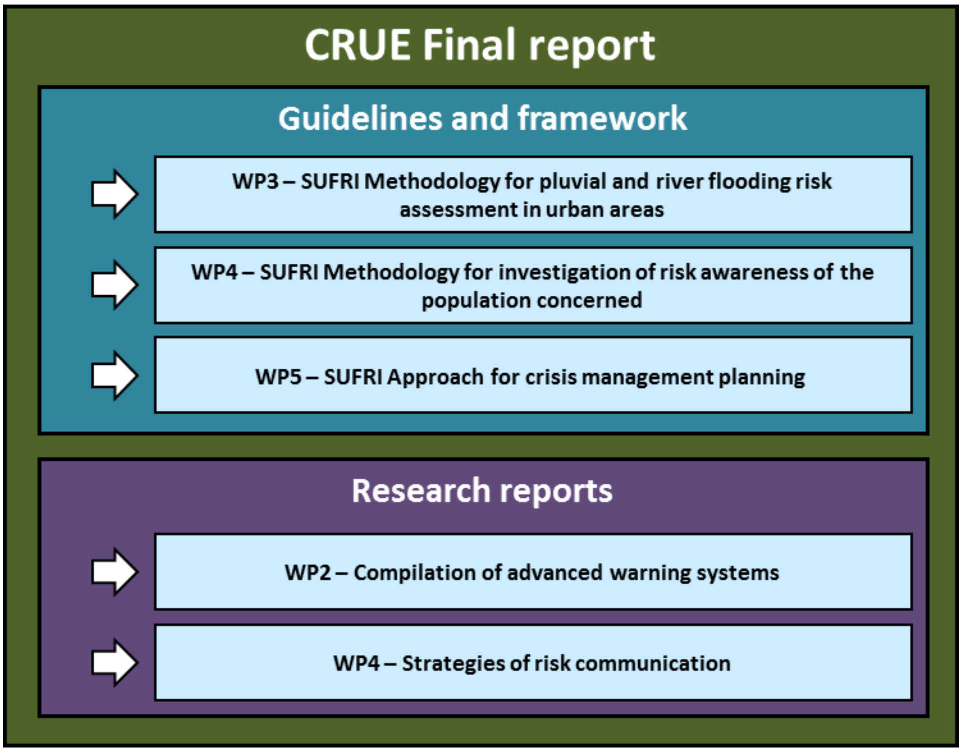

Figure 2: Scheme of the SUFRI outputs

The compilation of warning systems combines available and applied systems, practical experience and detected problems and needs. The guideline for risk estimation gives an overview of possibilities for risk reduction and different risk estimation tools. A specific developed methodology for the estimation of pluvial and river flooding is explained in detail and different application fields show results and experiences with the method. The aspect of risk communication can be devided into overall strategies of risk communication, a methodology for the survey of risk perception of the population and application field including the opinion poll and information campaigns. The disaster management will be captured with applied structues in the management process, problems and needs of special investigation areas and an approach for crisis management planning. An international comparison completes the project to filter out similiarities or differences in the chosen investigation areas and to lead to supports and recommendations.

2 Objectives

This chapter provides a short survey of the scientific and socio-political necessity of SUFRI, the vision of the partners in the context of this project, and the activities to implement and to incorporate this vision within the framework of a pan-European initiative to strengthen the European research area. It will provide the background of research and development in connection with "advanced warning systems, tools for risk estimation and communication strategies", and deals with new approaches regarding "risk estimation and communication", in particular "participation of the population concerned" and leads to an integrated approach for "crisis management planning".

The establishment of settlements was often triggered by the availability of water. That's why urban areas are often situated in river valleys or natural flood plains and are vulnerable to floods. Flooding from rivers, estuaries, the sea or rainfall poses a risk to people and causes significant economic costs. In the 20th century floods accounted for 12% of all deaths from natural disasters, claiming about 93,000 lives across the world (Flood Risk to People, Defra, UK). As a very recent example, in August 2010, the media reported 3 fatalities in Córdoba (Spain) due to an extreme rainfall event of 286 mm in just three hours.
For flood protection structural measures have been standard in the last decades. Due to the massive growth of urban areas these measures are often restricted by limited space. Non-structural measures as mobile flood protection elements, early flood warning systems or disaster control management cannot reduce the flooding risk to zero, but they can lead to a significant reduction.
Flood forecasting for large trans-national river catchment areas are widely used. By contrast flood warning and floods in urban areas, especially for small catchment areas, are still research topic. Many recent research projects have focused on these topics like URBAS 2008, EWASE 2008, UrbanFlood 2010. Experiences of practical applications are still seldom.
Therefore, the project intention was to provide an overview about flood characteristics in urban areas to improve flood management, and about general components and benefits of early warning systems.
Different approaches have been used to reach this goal (experiences with analogue warning systems, weather data, rainfall and flood forecast models, flood maps and flood managemnt plans). The entirety of all themes related with warning systems shall lead to recommendations for practitioners and authorities.

In recent years the aspect "risk estimation" has become of more research interest, in consideration of measures to address consequences of floods because of the recognition that floods can never be absolutely prevented or predicted.
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For appropriate risk estimation different tools need to be analysed and lead to an alternative approach for pluvial and river flooding risk assessment in urban areas. This developed methodology provides a tool to support flood risk evaluation in urban areas and it can be applied to inform authorities, local entities and stakeholders on decision-making to establish strategies for risk reduction.

Regarding the basis principles of ERA-Net CRUE, resilience and community, the aspect of public participation gains in importance. According to Wiedemann (2005), risk communication consists of "all communication that concerns the identification, the estimation, the evaluation and the management of risks. It aims to convey information about the potential for risk, to minimize differences in the evaluation, and to prevent escalating conflicts in the confrontation with risks. Particularly important is communicating with the general public, meaning the affected as well as interested citizens."

The participation of the public is seen as an important prerequisite, because, in the case of a flood, the actions of citizens are also actively required. In order to be able to design a risk communication for a crisis effectively, the following factors must be taken into consideration: people's behaviour as well as the needs of those affected by the flood. In this respect, science currently provides us with limited empirical data.
Therefore, the project fills in two research gaps: it provides empirical data on the subjective view of the citizens regarding natural hazards, particularly regarding flooding, as well as the desired communication and information in the case of a flood occurring. Furthermore, an international comparison between the chosen investigation areas can take place.

All in all, the project is aimed at an interdisciplinary approach that will combine societal and technical visions, beginning with advanced warning and communication chains, over risk estimation and public participation to crisis management planning.

3 Methodology

This chapter provides a short overview of the developed and applied methods. Thereby, the aims, application fields, input data and resources, as well as results and the degree of implementation are described. Because of the limited characters this chapter only provides excerpts of the methods, detailed instructions how to apply the methods and all applied study examples will be described in separate reports:
Pohl R., et al (2011). "Compilation of advanced warning systems". Research Report.
Escuder-Bueno I., et al (2011). "SUFRI Methodology for pluvial and river flooding risk assessment in urban areas to inform decision-making". Guidelines.
Jöbstl C., et al (2011). "SUFRI Method for risk awareness of the population". Guidelines.
Bateman A., et al (2011). "SUFRI Approach for crisis management planning". Guidelines.

3.1 Compilation of advanced warning systems[1]

3.1.1 Context and Aim of Method

In urban areas structural flood protection measures are often restricted by limited space, environment protection or the attempt to conserve the cityscape. That's why non-structural measures like mobile flood protection elements or early flood warning systems might be more welcome by the inhabitants to mitigate flood damage. For large transnational river catchment areas flood forecasting are widely used. By contrast, in urban areas they are still research topic and experiences of practical applications are still seldom. Thus, the literature survey aims at providing a compilation about warning systems, rainfall and flood forecast models, concerning applicability, benefits and experiences. Further, possibilities about flood warning dissemination are discussed and practical experiences in four case study areas have been collected. These information leads to recommendation for authorities, practitioners and stakeholder.

Field of Application

Forecasting & Warning, Risk Communication, Crisis Management

The compilation gives an overview about flood characteristics in urban areas to improve flood management. The general components and benefits of early warning systems were described. In order to get additional information experiences with analogue warning systems considering dam break, rockslides and landslides and accidents and disasters involving hazardous material were summarised. The availability of weather data, rainfall and flood forecast models considering small catchment areas are specified and flood warning message dissemination is presented in detail. The use of flood maps and flood management plans as a basis of flood damage mitigation measures and rescue actions and the costs of early warning systems are explained.
The overall study consists of results from a literature review and information of four case studies which are the smaller rivers Gabriachbach, Andritzbach and Schöckelbach in Graz (Austria), river Weißeritz in Dresden (Germany) and river Arenys near Barcelona (Spain). Case study Benaguasil (Spain) considers

[1] Pohl R., Bornschein A., et al

four intermittent brooks within the city area which are prone to pluvial flooding. Recommendations for an advanced flood warning system are presented.

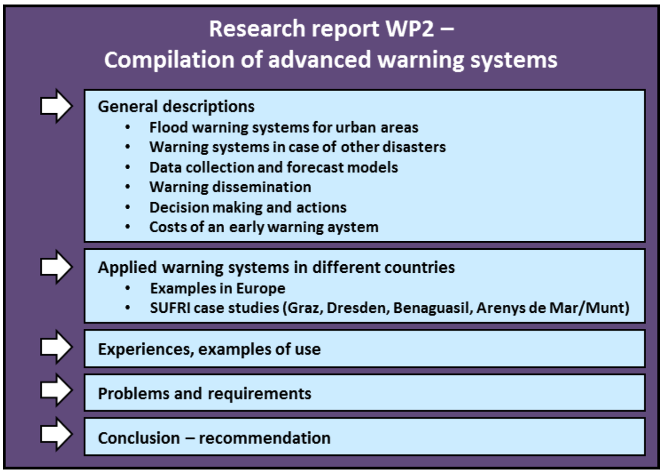


Figure 3: Research topics of the compilation of advanced warning systems

3.1.2 How to apply the compilation

The method is prepared as a compilation about warning systems. It offers an overview about different systems and their characteristics as well as recommendations.
A flood warning system (FWS) or early warning system (EWS) is a non-structural measure to cope with the risk of flooding, protect the inhabitants and to minimize the damages due a flood event. The general components of a flood warning system are presented in Figure 4. In small catchment areas a forecast system is characterised by highly uncertain input data and results almost until the flood arrives. That's why warning dissemination has to be very fast and the focus lies on flood management and damage mitigation. The general components of a flood warning system have to be adapted to the local situation.

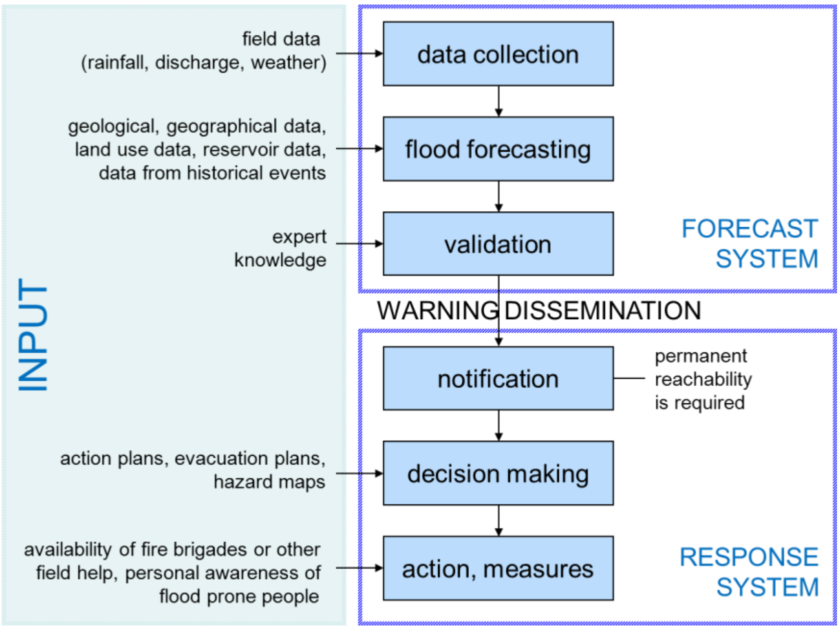


Figure 4: General components of a flood warning system

Therefore, each local situation has to be analysed regarding the characteristics of the catchment area, last important flood events, existing flood forecast systems and practised warning dissemination procedures. Afterwards, the overview of existing warning and dissemination systems as well as the recommendations of the compilation shall lead to an improved and individual crisis management, well adapted for each specific situation.

Input and Resources

- Analysis of the existing flood warning systems (data collection, existing forecast models, information paths, warning message distribution)
- Analysis of the responsibilities in crisis management (who needs which information) and the information exchange between all stakeholders during a flood event

Expected results

- Recommendations for a time-efficient organisation and short information paths within a flood warning system
- Measures to improve data acquisition for forecast models
- Recommendations how to phrase warning messages

Assessment of Results

A new installed or an improved old flood warning system should be analysed after every flood event and continually analysed and reviewed. Statements from inhabitants as well as from responsible entities should be included in the assessment process.

Scale of Application

The compilation can support towns and cities on the scale of communities or counties which are responsible for flood forecasting and early warning in most of the European countries.

Degree of implementation

The compilation can be used by entities which are responsible for flood warning message creation and distribution and disaster control.

3.1.3 Example

The research report was compiled on basis of analysis results of four SUFRI case study areas Graz, Benaguasil, Arenys de Mar/Munt and Dresden as well as additional literature and information.
Recommendations and measures will be implemented e.g. in Benaguasil and Lodi after the SUFRI project is closed.

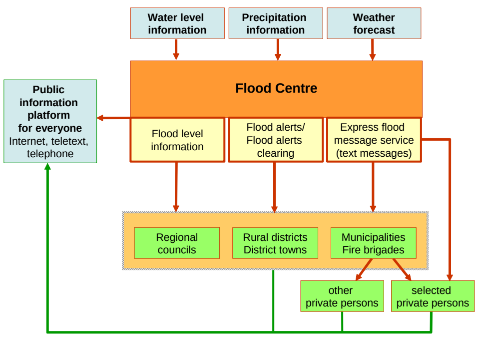


Figure 5: Example for a time efficient flood warning message distribution system

3.2 SUFRI Methodology for pluvial and river flooding risk assessment in urban areas[2]

3.2.1 Context and Aim of Method

The focus of flood protection changed from only prevention of floods to capture its consequences over the last years. The recognition that structural measures always retain a residual risk and a complete flood protection is not feasible enhances efforts in risk estimation to reduce flood consequences. There is a requirement for methods to estimate flood risk (societal and economic risk) and the effect of non-structural measures on risk reduction.
The SUFRI Methodology describes how to estimate probabilities and potential consequences of flood events and deals with "residual risk and vulnerability analysis" for pluvial and river flooding risk assessment in urban areas. The expected results shall inform policy maker and stakeholder in their decision-making process.

Field of Application

Risk Analysis, Risk Assessment, Risk Reduction

The SUFRI methodology describes how to estimate probabilities and potential consequences of flood events. The approach is based on comparison and analysis of different methods found in a literature survey, including the state-of-the-art of risk analysis, to evaluate consequences in case of river and pluvial flooding. It deals with two main aspects:

- The use of risk models to enable risk calculations
- The use of F-N and F-D curves to represent risk results for the case study

F-N curves present values in both axes (cumulative annual exceedance probability and estimated loss of life) and the area under this curve is the total societal risk. If economic consequences are represented, these curves are called F-D curves.
With these curves the flood risk distribution of an area is not displayed, but they can be very useful for defining tolerability criteria for flood risk. These curves provide a basis for planning and managing.
Additionally to the methodology itself, applied fields have been studied to test the developed methodology.

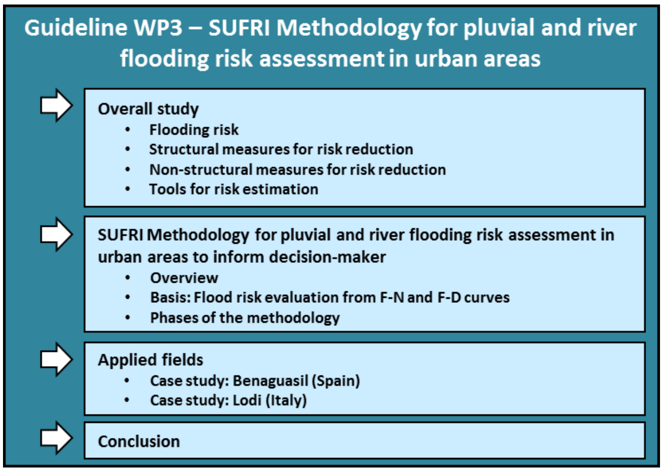
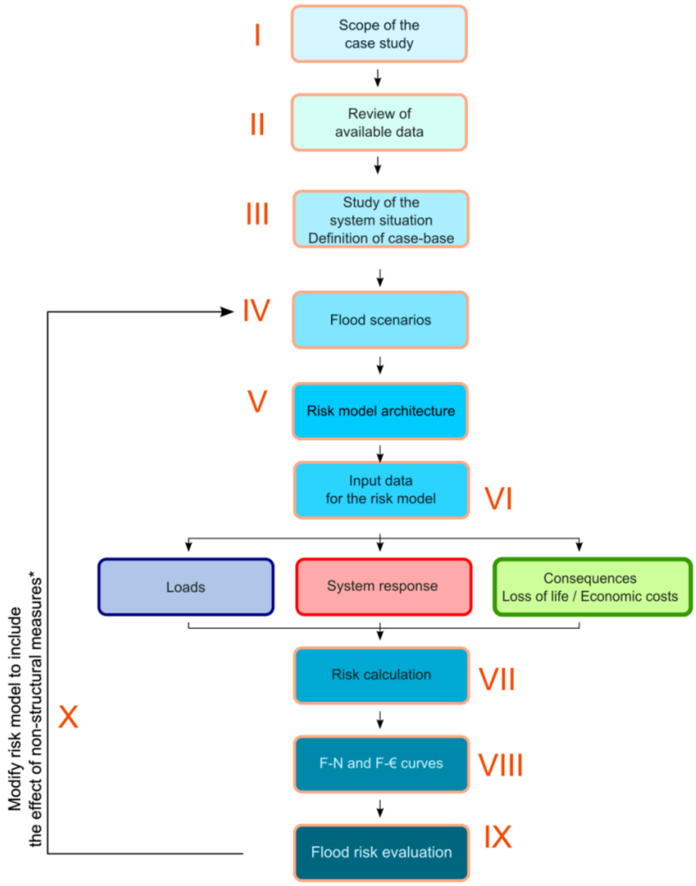


Figure 6: Research topics of the risk assessment

[2] Escuder I., Castillo J., Morales A., Perales S., et al

3.2.2 How to apply the method

The SUFRI procedure for the risk assessment consists of ten different phases shown in Figure 7. The risk analysis of an urban area consists of different study scenarios to evaluate the effect of non-structural measures on flood risk reduction (Figure 8, left). Some key concepts describe flood scenarios, structural and non-structural measures and study scenarios. Flood scenarios define potential flood events; study scenarios scenes with different kind and number of non-structural measures or alternatives for comparison of effects of non-structural measures with the current situation of an area.



*Natural flow regime of the river or new structural measures can also be studied, and may be helpul to understand the benefits from existing defence systems.

Figure 7: Phases of the SUFRI methodology for flood risk assessment

The SUFRI methodology is based on aspects as “risk models for risk calculations” and “F-N and F-D curves for displaying risk results”. The risk quantification can be developed by using a software containing influence diagrams.

To represent a specific situation of an affected urban area a risk model has to be developed which contains information required to compute all possible flood events and related consequences. Several case scenarios, such as the current situation, a scenario with non-structural measures, construction of a new flood defence infrastructure, and so on can be analysed.

The results of the risk model can be illustrated in a diagram with different F-N and F-D curves. Figure 8, right shows F-N curves for societal risk of a hypothetic case study. It represents a situation without any measures, a situation with only structural measures, and a situation with structural and non-structural measures.

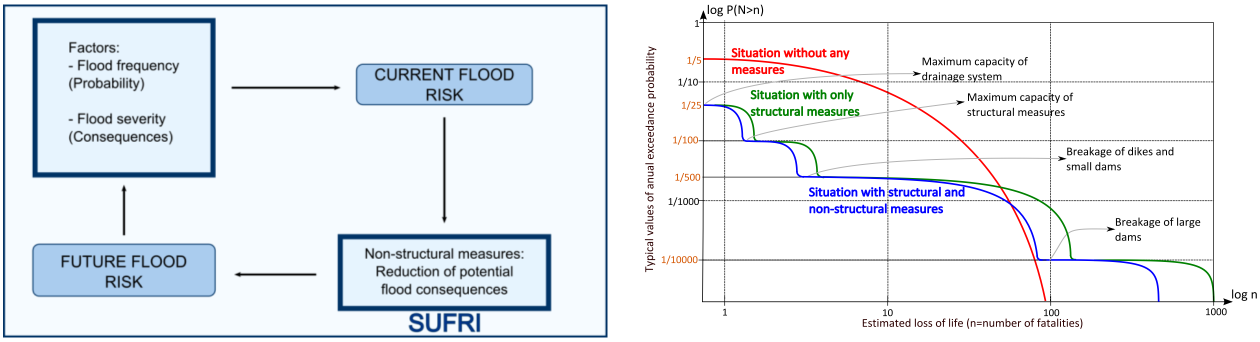


Figure 8: left – Scheme of interaction between flood risk and non-structural measures; right – Effect of structural and non-structural measures in F-N curves

Input and Resources

The methodology is based on the identification of important factors that influence risk quantification: sources of flood risk (river, heavy rainfall, defense failure, inefficient drainage system, etc.), vulnerability of the study area, socioeconomic data, hydrologic/hydraulic studies, flood maps, existing structural and non-structural measures.

Expected results

F-N and F-D curves show the societal and economic flood risk, respectively, in an understandable way, as they are useful to evaluate the effect of the several measures on it. Although these curves do not indicate the flood risk distribution in an area, they can be very useful for defining tolerability criteria on flood risk for a specific case study.

Assessment of Results

The risk profile of the current situation can be compared with different case scenarios (application of non-structural measures for flood risk reduction).

Scale of Application

Uncertainty on the results will depend on available data and the level of detail of hydrologic and hydraulic models or calculations as well as time requirements. However, SUFRI methodology provides a scheme that can be applied for different levels of information: from basic evaluations on flood risk to highly detailed estimations.

Degree of implementation

The method can be applied by a wide range of people such as technical personnel of municipalities, stakeholders, researchers, etc. It will depend on the scale of application and degree of complexity of the study.

3.2.3 Example

The societal and economic risk of the case studies Lodi and Benaguasil have been analysed. For the case study Benaguasil the current situation of the urban area (base-case) and the case scenario with non-structural measures (PFR+WS-case) has been analyzed.
As a result, economic risk has more significance than societal risk. However, there is no doubt that public education and warning systems have an effect on risk reduction. For example, societal risk decreases 67% in potential fatalities for an annual cumulative probability of exceedance equal to 0.001. Additionally, economic risk for an annual probability of exceedance equal to 0.01 decreases 32% for the situation with non-structural measures (Figure 9, right).

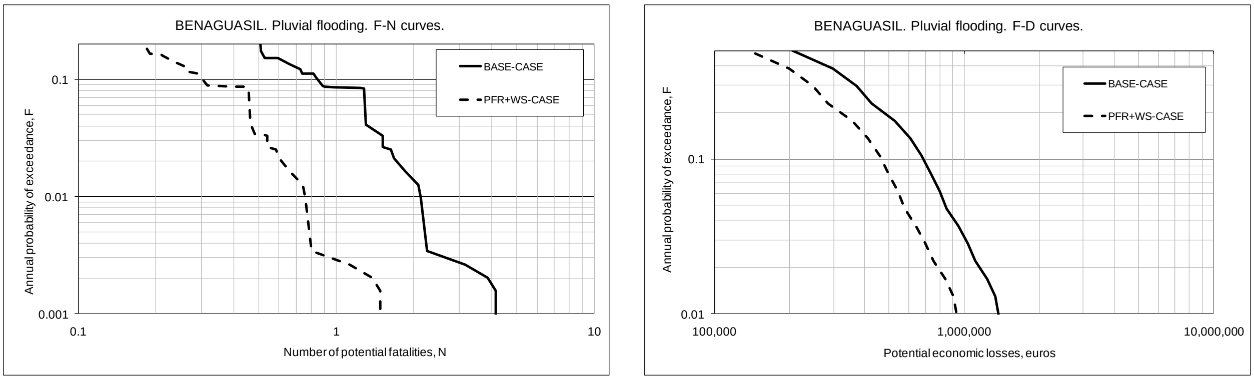


Figure 9: F-N (left) and F-D curves (right). Benaguasil. Pluvial flooding. Base-case and PFR+WS-case

In Benaguasil, these risk profiles will be used to develop the Municipal Action Plan for the city.

3.3 SUFRI Method for risk awareness of the population[3]

3.3.1 Context and Aim of Method

An effective risk communication includes besides action forces also the population concerned, because in case of a flood event the citizens are in great demand in their handling. For an effective development of risk communication in case of crisis, factors like human behaviour as well as the needs of the aggrieved party during a flood event have to be involved. Thereto, the science offers only limited empirical data until now. Regarding this lack of science, the SUFRI methodology provides empirical data of the subjective view of the citizens about natural threats, specially flood, as well as the desired communication and information in case of a flood event. Further, with the choice of the investigation areas an international comparison can be achieved.

Field of Application

Risk communication, participation

The standardized questionnaire was chosen as a suitable instrument for establishing the required information for the development of adequate strategies of an effective risk communication system. The standardized questionnaire has the advantage to ask a high number of people. (Atteslander, 2010) Further, because of the standardisation of the questions and the possibilities for answering, the evaluation of the answers is made easier. However, these default possibilities of answers limit the behaviour of answering of the respondents. For solving this difficulty some open questions have been included into the questionnaire, where the respondent can answer optional. The whole questionnaire consists of 69 questions and an additional field for comments at the end of the questionnaire to include possible requests. For facilitation of completion the questionnaire is divided into 6 chapters:

- Natural hazards and floods in general: attitude of the citizens regarding natural threats and flood
- Consequences of flood events: flood concernment of the respondents as well as the sanitary effects
- Communication and information: previous communication / information during a flood event, desires for future communication / information
- Self-protection and individual precautions: previous used self-protection measures, need of resources for more effective self-protection
- Financial consequences of flood events
- Questions about yourself: relevant demographic data

The questionnaire is available in English, German, Italian and Spanish. The analysis of the opinion poll can be done e.g. with the statistic software SPSS. First part of the analysis is the descriptive analysis of the questions of the opinion poll (frequency distribution); the second part includes a hypothesis and connectivity testing regarding predefined questions (factor / cluster analysis).
Based on the results of the public opinion poll adequate strategies of risk communication can be developed and realised (development of a risk based information campaign, etc.).
The results of five opinion polls all over Europe show the approach of flood events in different cities (Graz, Dresden, Lodi, Benaguasil, Arenys de Mar/Munt) and lead to recommendations and requirements.

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[3] Jöbstl C., Zechner S., Knoblauch H., Grossmann G., Kulmhofer A., Seiser T. et al

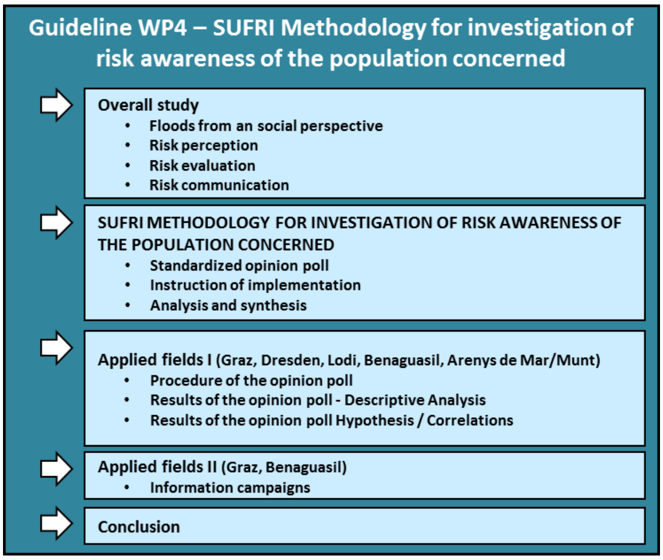


Figure 10: Research topics of risk communication

3.3.2 How to apply the method

The methodology consists of three different phases:

Phase I:
A demographic analysis of the investigation area is necessary.

Phase II:
The questionnaires will be distributed by the interviewers to the individual households. For collecting the completed questionnaires a further appointment can be agreed or, if the situation in the investigation area requires a more anonymous way, the questionnaires can also be sent back to the interviewer by mail.
The interviewers compose a record in writing about the investigation, e.g.

- was the questionnaire completed or not
- reasons for a possible refusal

Phase III:
After filling up the data base with the answers, e.g. with the statistic software SPSS, the descriptive analysis can be done. Therefore, a data matrix consisting of numerical values of all questionnaires can be statistically analysed, the answers of the open questions have to be qualitatively analysed.
For the hypothesis and connectivity testing predefined questions can be analysed, e.g.

- The estimated meaningfulness of self-protective measures and the willingness to take self-protective measures in future depend on the information access.
- The higher the educational level of a person is, the more they know about measures of self-protection and the likelier they took self-protective measures prior to the last flood.
- The greater the damage caused by floods had been, which had to be born with individual resources, the likelier people are willing to take measures of self-protection in future.
- Dependent on the level of education differs the need for information in case of floods, especially the wish of information from the media, an on-site information centre, task forces (emergency services), as well as from communities/ authorities (local council).

Input and Resources

To implement the opinion poll socioeconomic data and the extend of flooded areas is necessary. The investigation area can be limited with the inundated area of e.g. a 100-year flood, dependent of the specific situation. The survey will be carried out random according to the households in the flooded areas.

Expected results

- Clear picture of the current risk perception and requirements of the population and their cooperativeness regarding flood protection measures
- Guidance for a successful risk communication strategy

Assessment of Results

For measurement of the success of the application a second opinion poll can be performed after the implementation of diverse information campaigns respectively after a predefined period of a risk communication strategy.

Scale of Application

The method should be implemented on the scale of communities (cities, villages) or counties to improve the emergency planning and crisis management, as well as the general flood management.

Degree of implementation

The opinion poll and the analysis can be applied by a wide range of people such as personnel of municipalities, stakeholders as well as researchers. The interpretation of the results shall be done by social experts.

3.3.3 Example

As an excerpt of the research results of the opinion poll in the investigation areas, there is an insufficient passing of information among emergency services and general public in case of a flood event. A deficit of information can lead to a decreasing sense of safety in the population.
Respective results (Figure 11, left) show that people in Lodi have a great information demand. 89% of them start to feel uncomfortable because of missing information, followed by Arenys de Mar/Munt with 45%, Benaguasil 43%, Dresden 38% and Graz 31%. In Graz the highest number of those who don’t feel uncomfortable has been achieved with 30%.

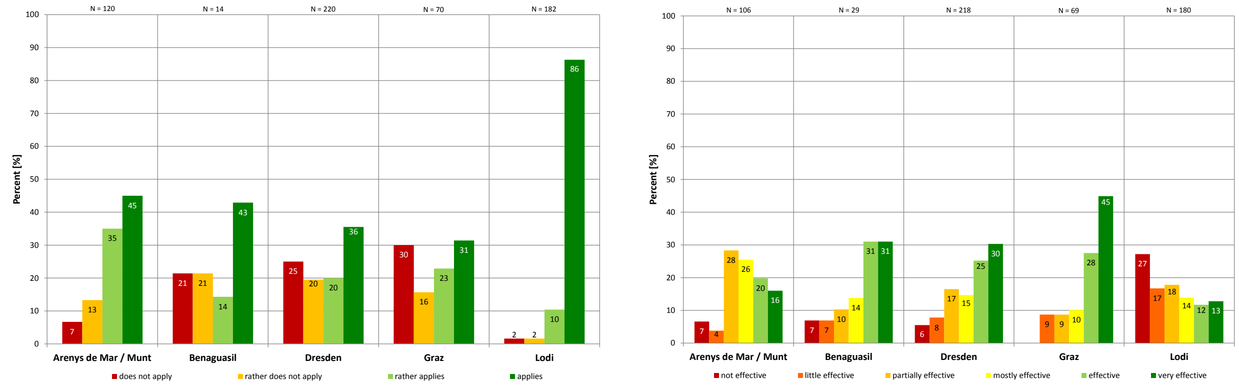


Figure 11: Q 25 Because of missing information I start to feel uncomfortable (left); Q 39 How reasonable are self-protection measures in respect of flood events in your opinion? (right)

Further, in Benaguasil, Dresden and Graz, there is a clear tendency towards a positive assessment of self-protection measures (Figure 11, right). In Arenys de Mar/Munt the agreement is lower with 36%, although 54% indicated that these measures are partly effective or mostly effective. By contrast, in Lodi 44% think that self-protection measures are not effective or only little effective.

3.4 SUFRI Approach for crisis management planning focused on non-structural measures[4]

3.4.1 Context and Aim of Method

Generally there exists no detailed guidance how to develop an action plan. The basic principles are defined in the European Flood Directive of 2007, but the implementation and the layout itself depends on different stakeholder criteria and characteristics of each country and / or region. Beside general data of an action plan the development requires cooperation between diverse entities involved in the flood emergency process. The developed approach tries to provide a guideline for improving the process of crisis management planning.

Field of Application

Emergency planning, Risk reduction, Long term Planning

To increase the flood emergency management, in a first step, it is necessary to detect the detailed knowledge about the national structure of the entities, responsibilities of the entities and actors involved, the communication chain between all involved parties and, as a consequence, the advantages and disadvantages of the current scheme. A set of non–structural measures (NSM) shall couple the risk assessment, risk mapping and risk management plan (RMP) by following the main issues of the Flood Directive of 2008. The set of non-structural measures can include insurance mechanism, urban planning, communication, evacuation plans etc. Evaluation criteria for them have been studied to quantify the risk reduction and visualize the risk zones in maps. Further, the preparation of worksheets for the set with the best risk mitigation will be provided. For developing this procedure a literature survey about applied structures in disaster control management has been done, and case studies have been undertaken to test and evaluate the approach (Figure 12).

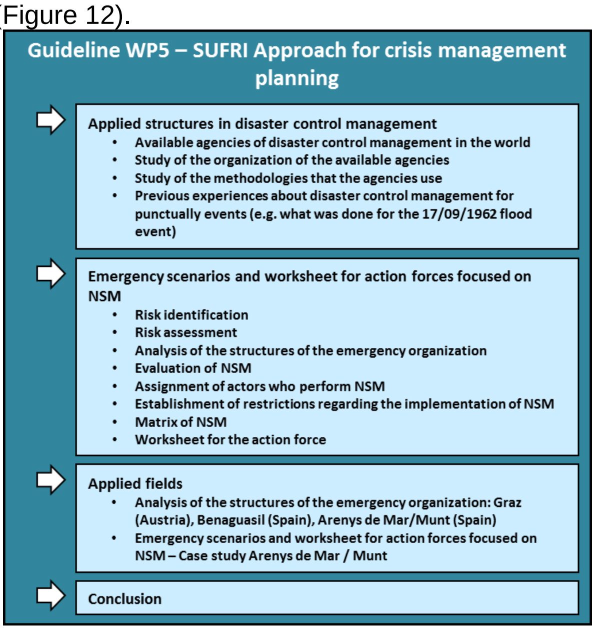


Figure 12: Research topics of crisis management

[4] Bateman A., Medina V., Diaz A., et al

3.4.2 How to apply the method

The methodology for developing a risk management plan shall include the following items:

- Risk identification (residual risk of flooding)
- Risk assessment:
  The amount of the risk (societal or economic) is captured numerically. Finally, risk maps should be developed to translate the results of the risk assessment graphically (see chapter 3.3, page 14).
- Analysis of the structures of emergency organisations
  The analysis of the organisations can lead to identify weak points and deficiencies/disadvantages.
- Evaluation of NSM
- Assignment of actors who perform NSM
  Actors, institutions and population who have to act in emergency cases need to be identified.
- Establishment of restrictions regarding the implementation of NSM (e.g. monetary, human or time)
- Matrix of NSM vs mitigation:
  Due to the restrictions different combinations of possible non-structural measures applications shall be analysed. Different combinations can lead to different values of societal or economic risk mitigation to achieve the optimized application.
- Worksheet for the action force (for the case with the maximum risk mitigation):
  Figure 13 presents a worksheet for the action forces (entities) of Arenys de Mar/Munt. This worksheet clearly exposes the role of each entity in case of flood emergency.

Entity	Pre-	Pre-Alert	Alert	Emergency Type 1	Emergency Type 1
CECAT	Warnings emission	Warnings emission	- Warnings emission - CECOPAL conformation	- Warnings emission - CECOPAL conformation. - Ask for Regional aids	- Warnings emission - CECOPAL conformation. - Ask for National aids.
Catalonia Governemnt	-	-	- Watch the established protocols	- Watch the established protocols - Aids Management	- Watch the established protocols - Aids Management -Follow the emergency and physical resources
ACA	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission
Arenys de Munt municipality	- Follow the Advice	- Mayor and Police warn implication	- Manage the warning to the population. -Specific Orders to the police	- Provide all the available resources for the affected people. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia	- Provide all the available resources for the affected people. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia.
Police	-	-	- Follow the situation - Warn the population	- Warn the population. - Streets Clousre (for Pedestrian)	- Warn the population. - Streets Clousre. -Help in the evacuation
Firefighters	-	-	- Follow the situation -Attend emergencies	-Attend Emergencies -Start evacuation	- Evacuate affected people -Help the injured persons
Population	-	-	-	- Tajaderas Implementation	- Tajaderas Implementation -Sand bags implementation

Figure 13: Worksheet for the action forces and population for flood emergencies. Arenys de Mar/Munt

Input and Resources

- Risk estimation:
  Results of SUFRI Methodology for pluvial and river flooding risk assessment in urban areas
- Structures of emergency organisations
- Assessment of available NSM

Expected results

- Matrix of NSM
- Worksheets for action forces

Assessment of Results

The iterative tool "SUFRI Methodology for pluvial and river flooding risk assessment in urban areas" can be used to quantify the success of the application of NSM.

Scale of Application

The methodology can be implemented on local and regional scales to improve the emergency planning and crisis management, as well as the general flood management.

Degree of implementation

The methodology can be applied by technical personnel of municipalities and stakeholders or researchers. It will depend on the scale of application and degree of complexity of the study.

3.4.3 Example

The procedure has been applied on the case study Arenys de Mar/Munt. Figure 14 presents the delimitation of the streets that do not satisfy vulnerability criteria with the uncertainty analysis. The red signed cells define streets which failed the vulnerability criteria in the risk analysis for different rainfall intervals. These streets are exposed as "dangerous zone". However if one event is not dangerous (with the upper or lower interval) and the other one is the opposite, it is assigned the yellow colour and named as "risky zone". Finally if in both case (with upper and lower analysis), no events are detected, the green colour is assigned and is classified as "safe zone".

	Return Period						
Street	T=2	T=10	T=20	T=50	T=100	T=200	T=500
Panagall	Yellow	Red	Red	Red	Red	Red	Red
Puig	Yellow	Yellow	Yellow	Yellow	Red	Red	Red
Bellsolell	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Calle Real de Pascual	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Carretera de Torrentbo	Green	Green	Green	Green	Green	Green	Green
Carrer de la Rasa	Green	Yellow	Red	Red	Red	Red	Red
Carrer can Borrell	Green	Green	Green	Green	Green	Green	Green
Carrer de la nou	Green	Green	Green	Green	Green	Green	Green
Carrer Pau Casals	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow
Carrer Lluis Companys	Green	Green	Green	Yellow	Yellow	Yellow	Yellow

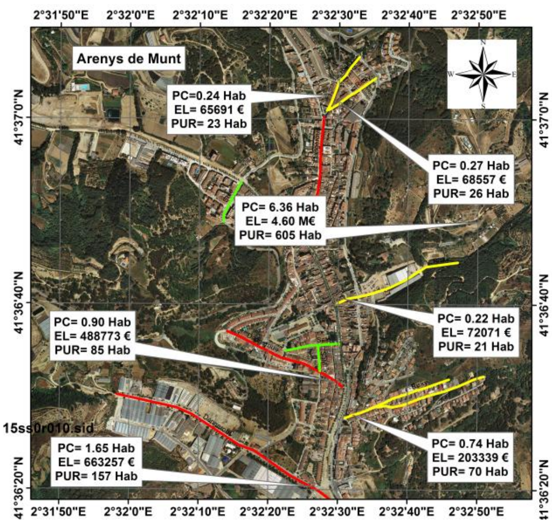


Figure 14: Arenys de Mar/Munt. Affected streets under the uncertainty analysis (left); Risk flood map for urban surface runoff by Least Square Method (right)

4 Case studies

This chapter provides a short overview of the five case studies of the SUFRI project: Graz, Dresden, Lodi, Benaguasil and Arenys de Mar / Munt. These European cities are familiar with different kind of floods, river and pluvial flooding. The main selection criteria have been experience with flood events and small catchment areas. Dresden is an exception regarding small catchment areas, therefor it has a long flooding history and population, stakeholder and authorities can introduce a lot of experience in handling with floods and its consequences.
The developed methodologies have been applied to these case studies to evaluate them and to analyse the different experiences in order to learn from each other. The public opinion poll has been conducted in all chosen cities to reach a good international comparison, whereas the other methodologies have been applied to selected case studies because of determining factors of the project itself or the case study area.

4.1 Andritz, district of Graz, Austria

Graz is situated in the province Styria in Southeast Austria.

4.1.1 Main Characteristics

Major Type of Flood: fluvial
Size of Catchment Area: 3 brooks: 18 / 2.7 / 34 km²
Past Flood Events: e.g. Aug. 2005, July – Sept. 2009
Environmental Settings: Andritz is a densely populated as well as agriculturally used area, including residential areas and centre zone next to the brooks.
Socio-economic Settings: about 19,000 residents (2008); growth of population of 0.60 %; in general a quite high level of education; living nearby the brooks

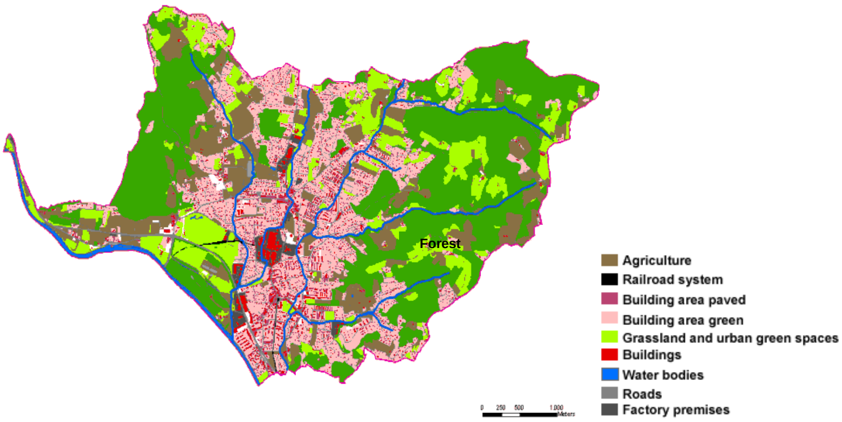


Figure 15: Land use in the case study area Andritz, Graz (GIS Steiermark)

4.1.2 Level of stakeholder Involvement

- Periodical working groups with responsible authorities: involvement in process, receipt of data
- 2 workshops about risk communication
- Meetings with representatives of the Department Civil Protection and National Defence, Professional Fire Brigade, Mayor office, State Central Warning Control Unit, Department Water Protective Economy and Groundwater Resources, Citizen's Initiative …

4.1.3 CRUE Activities

- Review and analysis of characteristics of the catchment area
- Compilation of advanced warning systems
- SUFRI Methodology for pluvial and river flooding risk assessment in urban areas – analysis, synthesis (unpublished)
- SUFRI Method for risk awareness of the population
- SUFRI Approach for crisis management planning (Analysis of the structures of emergency organisations)

4.2 Dresden, Germany

Dresden is situated in Saxony in East Germany.

4.2.1 Main Characteristics

Major Type of Flood: fluvial
Size of Catchment Area: 384 km²
Past Flood Events: major flood events in July 1897, July 1927, July 1958, Aug. 2002
Environmental Settings: Forests and agriculture dominate the upper part of the catchment area, densely populated urban areas characterise the lower parts.
Socio-economic Settings: About 4,700 inhabitants live within the possible inundation area of a 100-year flood of river Weißeritz in Dresden.

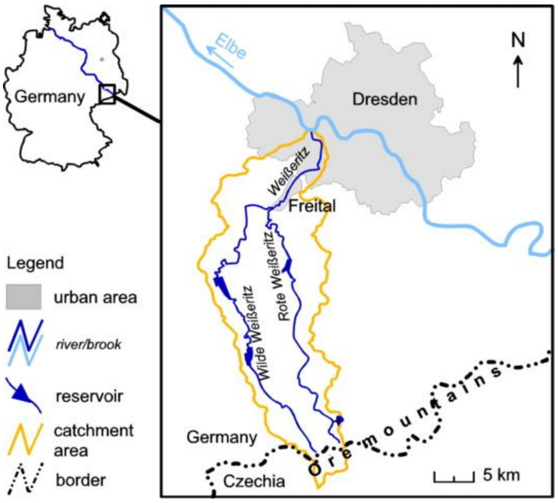


Figure 16: Catchment area of the case study Dresden

4.2.2 Level of stakeholder Involvement

- Expert interviews (Department of Fire and Disaster Control, City of Dresden; Saxon Flood Centre; Saxon Dam Authority)
- Scientific Stakeholders: Several diploma thesis with topics related to the case study area and the SUFRI-project area

4.2.3 CRUE Activities

- Review and analysis of characteristics of the catchment area
- Compilation of advanced warning systems
- SUFRI Method for risk awareness of the population

4.3 Lodi, Italy

Lodi is located in Northern Italy, in Lombardy region.

4.3.1 Main Characteristics

Major Type of Flood: fluvial
Size of Catchment Area: 5,990 km²
Past Flood Events: 1960, 1963, 1966, 1976, 1978 and 2002
Environmental Settings: The urban area is mainly composed of residential areas. Also, there are agricultural areas located at the border of the urban area
Socio-economic Settings: about 39,000 residents (2001). The population lives nearby the Adda River and has in general a quite high level of education.

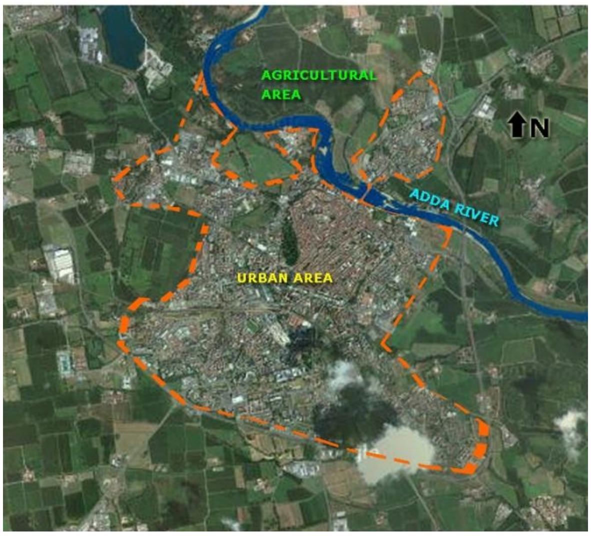


Figure 17: Case study area Lodi

4.3.2 Level of stakeholder Involvement

- Periodical working groups with the responsible authorities (City of Lodi, Civil Protection, Committee of flooded people in 2002): Information, involvement in process, receipt of information and data, discussion of current situations
- Workshop about risk communication for presenting the results of SUFRI project and their drawbacks to Lodi Protection system.

4.3.3 CRUE Activities

- Review and analysis of characteristics of the catchment area
- SUFRI Methodology for pluvial and river flooding risk assessment in urban areas – analysis, synthesis
- SUFRI Method for risk awareness of the population

4.4 Benaguasil, Spain

Benaguasil is located in the province of Valencia in the East of Spain.

4.4.1 Main Characteristics

Major Type of Flood: pluvial
Size of Catchment Area: 1.86 km²
Past Flood Events: September 2009, 2010
Environmental Settings: The catchment in Benaguasil is a densely populated area, including mainly residential as well as small industrial areas.
Socio-economic Settings: about 11,000 inhabitants (2010); population increases about 2,500 residents in summer; population has own experience on non-structural measures.

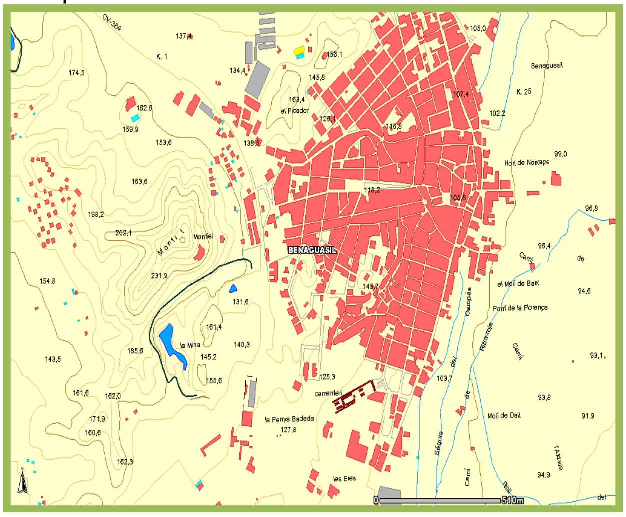


Figure 18: Case study area Benaguasil

4.4.2 Level of stakeholder Involvement

- Periodical meetings with representatives of the municipality and consultants involved in on-going projects
- Meetings with representatives of the Department of Civil Protection and the Department of Homeland Security of United States
- Workshop on “Flood Risk Characterization, Evaluation and Management”

4.4.3 CRUE Activities

- Review and analysis of characteristics of the catchment area
- Compilation of advanced warning systems
- SUFRI Methodology for pluvial and river flooding risk assessment in urban areas – analysis, synthesis
- SUFRI Method for risk awareness of the population
- SUFRI Approach for crisis management planning (Analysis of the structures of emergency organisations)

4.5 Arenys de Mar / Munt

This region is sited in the Catalan coast in Spain.

4.5.1 Main Characteristics

Major Type of Flood: pluvial, fluvial
Size of Catchment Area: in 16 km²
Past Flood Events: Sep. 2002, Sep. 2003, Sep. 2005, Mar. 2008
Environmental Settings: Arenys basin (Maresme) includes first mountains range in front of the sea. There is a large area of forests, beaches, resorts and greenhouse production
Socio-economic Settings: The Arenys Basin has about 23,000 inhabitants (2009) and a population growth of 1.5%.

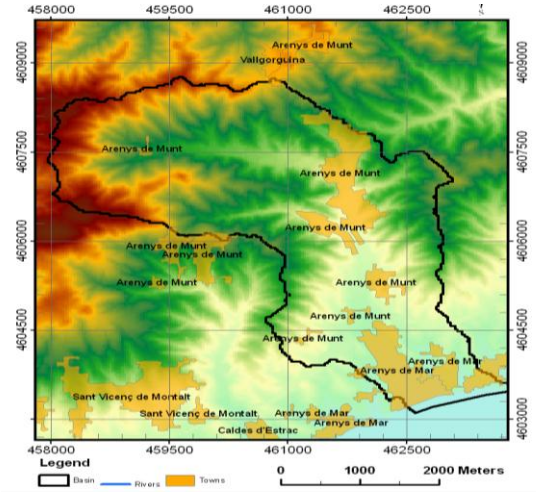


Figure 19: Case study Arenys de Mar / Munt

4.5.2 Level of stakeholder Involvement

- Meetings with almost all the entities involved in flood emergencies: Catalonia Government, Interior Department, Civil Protection, CECAT, Maresme Council, City Hall of Arenys de Munt, Police and Fire-fighters corps in Arenys de Munt
- Field trip to Arenys de Munt basin (with the participation of the mayor)

4.5.3 CRUE Activities

- Review and analysis of characteristics of the catchment area
- Compilation of advanced warning systems
- SUFRI Methodology for pluvial and river flooding risk assessment in urban areas – analysis, synthesis
- SUFRI Method for risk awareness of the population
- SUFRI Approach for crisis management planning

5 Results and discussion

This chapter is subdivided into the six predefined work packages to provide a summarized overview of the main results of the SUFRI project. Further, the specific outcomes and lessons learned of each work package are highlighted. Some selected results of the case studies will be shown as well, regarding the developed methodologies of the work packages.

5.1 Project Management and Coordination

Specific Outcomes

- Website www.sufri.tugraz.at (in English and German)
- Folder of SUFRI to inform about research work (in English, German and Spanish)
- Meetings with stakeholders, population concerned, …
- International Symposium UFRIM to communicate results to a wide range of researchers, users, stakeholders, public, …

Lessons Learned

- Importance of integration of all parties involved (stakeholder, government, population concerned)
- Differences in language can lead to communication problems (e.g. ”Red cross” = ”Rotes Kreuz” (Germany) = “Rettung” (Austria))

This work package consists of detailed project planning and review, regular internal reporting on progress, coordination of public relation activities such as conferences, meetings, and publications, and design of a website for faster and enhanced communication.

A project website www.sufri.tugraz.at exists with a public area with general information about the project (objectives, project partner, case studies, public relations, meetings, contact details and further links. This public area is available in English and German. A special internal communication platform offers all project partner information and data about templates, work plans, internal publications, interesting conferences and all produced reports regarding SUFRI (see Figure 20).

Project folders inform interested people about the main objectives and issues of the project.
An international symposium on flood management in urban areas (UFRIM) offers engineers and scientists a platform to present applications and current research (September 21st till September 23rd 2011).

Figure 20: left: SUFRI project website, right: SUFRI folder

5.2 Advanced Warning Systems of Small Urban Catchment Areas

Specific Outcomes

- Compilation of advanced warning systems of small urban areas
- Experiences in different European countries

Lessons Learned

- Flood warning system is the non-structural measure with best cost-benefit-ratio.
- Rainfall-runoff-models for small catchment areas are still a topic of scientific projects.
- It is beneficial to analyze automatic warning systems in case of other accidents and disasters too to get additional information and input.
- Recommendation of installation of additional rainfall and river gauges at smaller rivers to get better data.
- Sirens, diaphones or loudspeakers are cost efficient methods to disseminate warning messages to a local limited set of affected people even if they have no access to public media.
- Flood warning messages should be clear, simple, understandable and without subjunctives.
- Additional information should be provided by community helpline, TV, radio and the World Wide Web.
- Centralised institutions can provide the needed expert knowledge and should be responsible for centralized data collection.
- The response system should be centralized too, but on a lower administration level.
- Hazard, risk or inundation maps are important for exact action planning in case of flood.
- The review of warning systems and documentation of operation experiences was often only triggered by extreme flood events.
- Early warning systems today can benefit more by establishing short communication and information paths and a tailor-made set of rescue actions and measures.

5.2.1 General description

Flood Warning Systems for urban areas

Characteristics of floods in urban areas

The definition of urban areas regarding floods and inundation is not very specific. On one hand we can describe a river catchment area where urban settlements are the dominated land use as an urban (catchment) area. On the other hand an urban area can be described as urban settlement which could be affected by different types of floods like

- river flooding or fluvial flooding
- coastal flooding
- flash floods
- urban flooding

“Small catchment areas” were defined by Romang et al. 2008 as catchments with a size between one and 1000 km². Within the research project URBAS smaller catchment areas between smaller than 10 km² and at least 50 km² were considered. The term “small urban catchment areas” is more common in medicine to describe a catchment area of hospitals in urban areas considering the possible number of patients. A definition of “small urban catchment areas” considering a river catchment area is still needed.

Urban areas are characterised by paving of natural ground surfaces. Natural watercourses are often restricted by sidewalls, flow into pipes or conduits, are partly or totally blocked or streets were constructed there with all kind of infrastructure thereunder (e. g. wires, tubes). Flood propagation in urban areas is characterised by different propagation paths (river, streets, sewer system) with different propagation velocities.

In urban areas many buildings, infrastructure like streets, railways, hospitals or gas stations as well as business properties are situated near river banks and in river flood plains. Therefore the potential damage due inundation is very high. Flood protection with structural measures like dikes or flood retention basins may be restricted due to intensive land use and the limited open space. The use of mobile elements for flood protection is only possible if a reliable flood forecast with a considerable flood forecast lead time is available.

Damages could be caused by high water level in smaller tributaries or a discharge greater than capacity limit of the river or the sewage system. The flooding of basements and underground garages which are very common in urban areas add a significant amount to the flood caused damage and minimize flood peak by retention of a significant amount of water. But it is not possible and not desirable to take these effects into account in hydro-dynamic calculation. That is because of the lack of exact data about the extension of such underground structures as well as the overall aim to increase flood awareness and to initiate private flood mitigation measures to prevent these structures from flooding.
On the one hand the determination of flood prone area often needs more effort to verify the calculation results considering these aspects. On the other hand more data from historical floods are available in urban areas which can be used to determine flood prone area in case of extreme flood events and the residual risk. Often one can find historical records in newspapers or high water marks at buildings like churches, castles, mills, bridges or archways.

General components of a flood warning system
A flood warning system (FWS) or early warning system (EWS) is a non-structural measure to cope with the risk of flooding, protect the inhabitants and to minimize the damages due a flood event. The general components of a flood warning system are presented in Figure 21.

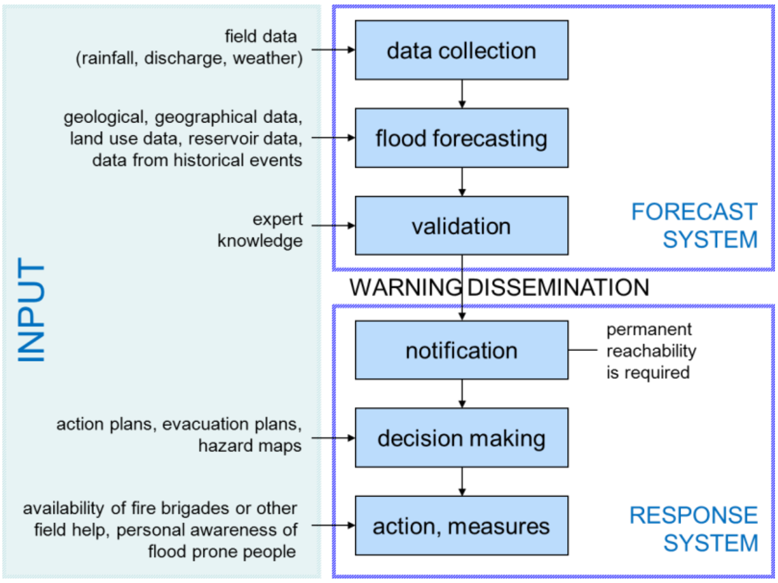


Figure 21: General components of a flood warning system

In small catchment areas forecast system is characterised by highly uncertain input date and results almost until the flood arrives. That's why warning dissemination has to be very fast and the focus lies on flood management and damage mitigation. The general components of a flood warning system have to be adapted to the local situation.

Benefits of an early warning system

Early and exact warning against floods or other natural disasters as well as accidents involving hazardous substances is fundamental to provide time for evacuation of kindergartens and schools, hospitals or retirement and rest homes. A warning system is needed if one would like to use flood prone areas like natural flood plains for recreation purposes like "Parc Fluvial del Besos" near Barcelona, Spain (EWASE 2008), if a damage causing flood often occurs or structural flood protection measures are restricted by high-density areas near the river, existing townscape or infrastructure, urban development or environment protection.

Systematic information in advance and during a flood event enables the inhabitants to minimize the volume of flood water entering their property and to reduce flood damage costs significantly in particular of their own home and belongings. Flood warning systems provide the possibility to transfer responsibilities from state to the individuals.

CRUE-project EWASE (EWASE 2008) tried to quantify flood damage minimization for economic sector due to early warning. The combination of a flood warning system with local protection has the best benefit-cost-ratio of all flood risk management strategies (FRM) considered in the CRUE-project EWASE 2008.

Warning systems in case of other disasters

In order to gather further experiences and to provide additional information about existing warning systems the following chapter is focused on warning and disaster management in the case of dam break as well as rockslides and landslides.

Flood warning in case of dam burst

In case of dam break no structural protection measures are possible due to the very low probability of recurrence commonly assigned to such kind of disaster. A resulting dam break wave propagates very fast. Some data from historical cases are given in Bornschein 2009.

Measures focus on disaster management aiming lifesaving and damage mitigation. Risk maps provide information about potential flooding areas and are a basis for emergency management (see Figure 22). There are some existing public warning systems in case of a potential dam burst. These systems include warning of people by signal hooters or diaphones, mobile vehicle public address system (loudspeakers) or telephone.

One warning system was installed in Zürich, Switzerland. People were warned by means of diaphones. Diaphones give a warning signal if a certain water level is reached in any flood case caused by rainfall or dam burst. Flyers created to inform people include a map with evacuation paths in the case of dam burst. Warning systems were also installed at Stolsvatn, Olsendvatn and Rødungen dam and at Kilen and Svartevann dam in Norway. Both systems were activated in 1981.

A very important task in dam break research is to learn from the past. According to that the following descriptions focus on experiences with disaster warning in case of dam break. Two examples, the Glashütte dam break in 2002 and Witka dam break in 2010, are mentioned.

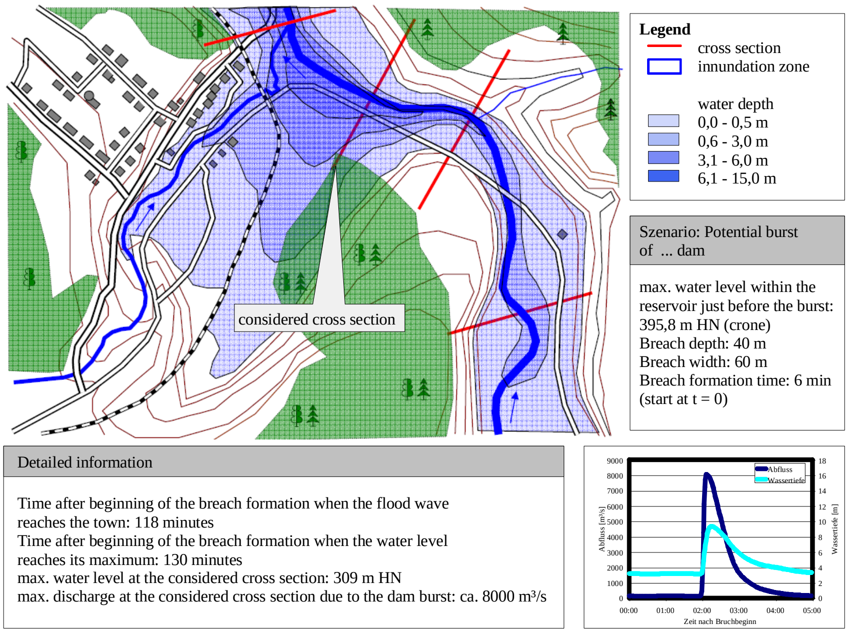


Figure 22: Special hazard map for a hypothetical dam burst scenario

During the flood event in August 2002 in Saxony, Germany the 9 m high dam of a small retention basin broke after overtopping and released more than 50,000 m³ of water which flew through the little town Glashütte situated only one kilometer downstream (Bornschein et al. 2002, Bornschein & Pohl 2003). In Germany there are no extra warning system in case of dam break. That’s why the mayor used the municipal diaphones at 12th of August 2010, 1 pm as the reservoir became full filled and the situation indicated an impending dam break. An acoustic signal was released three times to alarm the inhabitants. In addition a car with blue lights crossed the streets and the police went from house to house to inform people. Inhabitants and curious onlooker were told to leave streets and bridges (Kirchbach et al. 2002). As the dam broke at 4 pm the streets were empty and no one was hurt by the flood wave. Nevertheless great damage occurred at river bed and side walls, houses, streets and infrastructure.

The reservoir Witka in Poland near the border to Germany was built in 1962 and provides the coal-fired power station Turow with water. At Saturday the 7th of August on 6 pm the dam failed due to overtopping and the flood wave run to the river Neiße and through the town Görlitz in Germany. Although general flood warning messages were distributed by the Saxon Flood Centre for the eastern part of Saxony on Friday it was not predicable that the low pressure area released its precipitation only over a relatively small area. No information about flood warning in Poland is available. The manager of the reservoir confirmed in an interview to the newspaper “Sächsische Zeitung” a predicted amount of rainfall of about 60 to 100 l/m² but explained that this put no one on alert (SZonline 2010). When the dam failed the message from the dam owner included only information about an expected maximum discharge of 650 m³/s and no information about a dam failure. In addition the message was distributed from the dam owner to the polish administration, then to Frankfurt/Oder in Germany where an institution is responsible for data transfer between Polish and German municipalities and counties considering flood events. Afterwards, it reached the Saxon Flood Centre and was transmitted to the city of Görlitz. At this time the inhabitants have still not received this information. This was clearly not a short warning message distribution path.

The Witka dam failure enlightens a very specific problem in connecting individuals to information networks, which is called the “last meter problem”. Due to different reasons the content of a message which circulates in the network does not reach the individual. One reason may be that the individual is not permanently connected with the network. Inhabitants do not hear radio broadcasts or watch TV permanently. Another reason is the misinterpretation of messages. When experts talk about ordinary or normal danger or risk they mean normal flood water level as an expected flood water level. When inhabitants hear such terms they might think of no danger at all because situation is normal.

Automatic warning systems against rockslide or debris flow

Several automatic warning systems in Austria and Italy were installed to warn regions which are at risk due to rockslides or debris flow events. The following paragraph presents some examples.

At the river Wartschenbach in Austria an automatic system was installed in spring 2004. The system includes seven sensors measuring rainfall in the catchment area, fill level in the river channel as well as upstream the bed load retention dams and geophones detect earth vibrations caused by debris flow (Sommer 2004). The analysis of collected data helped to identify situations which cause debris flow. The system is now able to create automatic warnings against debris flow and a forecast lead time of 10 minutes is possible (http://sciencev1.orf.at/news/17664.html). Due to the short operation time there are no data about previous events with released warning messages and their impact available.

The slopes at the mountain Maesstobel in Austria are at risk by rockslides and debris flow. An automatic control and warning system was installed which measures the three-dimensional movement of the mountains slope which are at risk to fall down. In addition geophones detect mass movements. In case of a rockslide the system creates and dispatches warning messages automatically and the street section below is closed by means of signal lights which are connected with the warning system (Sommer 2001).

Another considered scenario in the Maesstobel area is the possible creation of a natural dam by the rockslide material which impounds the water of the river Suggadinbach. The early warning system includes the possible case of a dam burst. In that case the warning time is about 10 to 15 minutes (Jäger & Moser 2008).

After debris flow event in 2000 a warning system was installed in the mountains above Nals in Italy (Sommer 2002). The measurement system includes two precipitation sensors (rainfall, snow and hail), three geophones (earth vibrations), one ultrasonic sensor (flow depth) and one video camera was established (see Figure 23). The propagation of the debris flow downstream to Nals allows a warning time between 20 to 60 minutes. The system releases warning messages automatically but it is possible to validate the warning by means of the video camera. There are no data about previous events with released warning messages and their impact available.

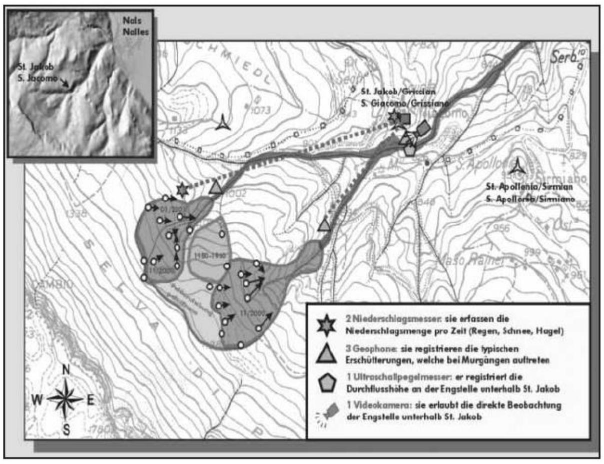


Figure 23: Map of the early warning system against debris flow near Nals, Italy (Sommer 2002)

In 1892 a pocket of water (poches d'eau) under the Tête-Rousse glacier at an altitude of 3,200 meters burst and released a big flood wave which destroyed the small French village of Saint-Gervais. In 2009 it was discovered that there is a new sub-glacial cavity filled with 65,000 cubic meter of water. To prevent another catastrophe like in 1892 it was decided to pump the water out of the cavity which started in august 2010. The water will be pumped out within a month and gradually released. Before pumping could start an automatic warning system, costing $640,000, was set up. Input data came from local observers, satellite observation and two metal probes (see Figure 24). The two cables were placed across the glacier to trigger a siren in the valley below. In case of sudden water release the two cables would broke together with the ice and induced the alarm. The nearest inhabitants have been informed about 17 rallying points on high ground, and would have 10 minutes to reach the nearest one if the alarm sounds (le Hir 2010).

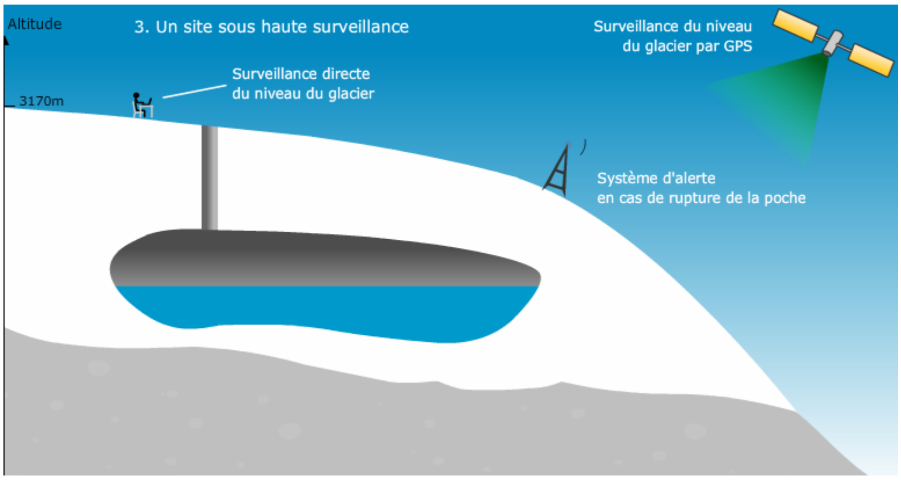


Figure 24: Warning system including local and satellite observation of the Tête-Rousse glacier during draining a pocket of water.

The permanent systems presented above are quite new and started as scientific projects. They become now practical applications. But no data about released warning messages and their impact in risk management are still available.

Nevertheless some points can be summarized regarding automatic warning systems in small catchment areas:

- automatic warning systems in small (catchment) areas should be highly equipped with different types of sensors to obtain valid data and to provide the opportunity to check released warning messages
- self-learning systems and an operation test phase are important because the system has to “learn” which situation would create a hazard
- in case of a temporarily warning system with little information about hazardous situations local observers and redundant observation and/or measurement systems can help to compensate for this lack of knowledge

Analogy warning in case of disaster in chemical industry

Other emergency cases in which automatic warning systems are installed are disasters in chemical industry. Here warning systems with diaphones are very common in several countries in Europe. Information about the warning systems and the appropriate behavior in case of emergency are distributed to the inhabitants who live

- near chemical industries or
- at main transport routes of hazardous material

and could be affected.

Information sheets regarding such kinds of disasters which are available for the public recommend not only waiting until the alarm signal starts but also to take active measures for personal protection like stay indoors, close doors and windows.

In case of accidents or disasters involving hazardous substances immediate action is necessary, because time until damage occurs is very short and almost equal the time which is needed to discover and report the accident and disseminate the alarm messages. That’s why these automatic warning systems have a very fast message distribution system. In case of smaller disasters or disasters with only local effects (e. g. transport accidents) the warning and information distribution path has to be local too.
The following warning dissemination devices are common (e.g. Albert 2002, Hoechst 2009 and Homepage of the Association of Civil Protection in Lower Austrian (Niederösterreichischer Zivilschutzverband NÖZSV), http://www.noezsv.at/frame/ notfaelle_was_tun/chemieunfall/frame.htm):

- acoustic signals by diaphones
- public address announcements (loud speaker on cars)
- radio/TV
- community helpline

Diaphones are in action immediately and have a wide range of coverage but are more expensive. If only acoustic signals can be transmitted, no information about the kind of disaster is possible. In that case a community helpline and radio or TV broadcasts can provide additional information.
Loud speakers on cars need more time to get in operation and are people intensive (two people at last, a driver and a speaker) and time consuming. But they can give more information to the inhabitants locally affected. It is recommendable to use a standard form with predefined text. The speaker should articulate loud and clearly. A maximum speed of the car of 15 km/h and announcements every 100 m are recommended (Albert 2002). The covered distance should be documented. Special objects like kindergartens, schools, hospitals, retirement and rest homes, administrations and companies with many employees, gyms, festival halls, large stores and camping sites should be informed personnel.

Diaphones and loud speakers are owned by both:

- the company on which property the disaster take place, and
- fire brigade or police

Only the combination of all information paths makes sense and assures that the warning message is received by every inhabitant at risk.

Out of the description above it can be stated, that:

- diaphones and loud speakers are a very appropriate device to disseminate warning messages very fast
- additional information should be provide by community helpline or TV and radio

Data collection and forecast models

Data collection in flood forecasting includes all data which are needed to establish a rainfall-runoff-model and/or a hydraulic model for flood propagation and real time measurement data.
Needed data to establish the calculation models include digital terrain model, land use data, information about soil material, river bed material as well as data about buildings along the river or near the coast like bridges, weirs, culverts or houses within the floodplains.
Real time measurement data comprises rainfall measurement by radar and/or rainfall gauges, water level at river gauges to calculate river discharge by means of stage-discharge-curves or sea water level together with upcoming storm events. In mountainous regions snowfall together with a sudden increase in temperature could also cause floods which should be considered too.
Weather forecast is necessary to predict future events but is less reliable than measurement data. In small catchment areas the weather forecast is the weakest point within the warning system.

Weather forecast and rainfall measurement
In all European countries weather forecast is well established but according to the fact that rainfall prediction for a certain location is more complex than temperature forecast and due to limitations in spatial resolution of the models rainfall forecast is quite uncertain. Although there were many improvements in weather forecast in the last decade rainfall prediction seems to be the weakest point in flood prediction and warning considering small catchment areas or flash floods.
Rainfall measurement and radar data provided by national weather services are available in all European countries.

Warnings against critical weather conditions are provided commonly by means of webpages.
In Austria every province has a hydrographical service that is in charge to provide a forecast in case of an approaching flood. Meteorological precipitation and temperature forecast are made at the ZAMG (Austrian Central Institute for Meteorology and Geodynamics). Hydrological and hydrodynamic models on basis of measured and forecasted data are widely used by the provincial authorities. The hydrological service predicts tendencies (increasing, decreasing, constant) and provides data on flow rates and water levels.

In Spain different measurement networks exist which operate nationwide or local. The National Meteorological Institute (INM) owns rainfall gauges all over Spain. Local organisations like Jucar River Authority or Catalan Water Agency (ACA) maintain a network of rainfall gauges (SAIH). Weather radar stations are operated by local organisations like Meteorological Service of Catalonia.

The German Meteorological Service (DWD) monitors weather and meteorological conditions over Germany and offers weather services for the general public as well as specific services. It provides information about future precipitation and temperature in Germany calculated by means of so called local model COSMO-DE (Deutschlandmodell). The model is characterised by horizontal mesh size of 2.8 km and 50 vertical layers. Information (qualitative) about heavy rainfall events are available two days before. Rainfall forecast lead time is usually 24 hours (Flath 2004). After the extreme flood event in 2002 a new network of automatic rainfall gauges was put into action in Germany.

Small catchment areas of a size of 1 to 100 km² which are at risk of flash floods are smaller than spatial resolution of today operational hydrologic forecast models in Switzerland (Zappa & Vogt 2007). However forecast due to combined models (numerical weather forecast and hydrologic models) is technical possible but not useful because missed events and false alarm more often occurs. Today models cannot calculate convective rainfall due to their spatial resolution (e.g. 10 x 10 km COSMOLEPS, 7 x 7 km COSMO7).

For project MINERVE (Jordan et al. 2004) at the river Rhone in Switzerland meteorological data including rain intensity, equivalent snow intensity, air temperature, snowfall limit and snow cover surface) are available every 12 hours and 72 hours in advance with a spatial resolution of 7 x 7 km. The model has elevation layer every 100 m. Data come from Swiss Weather Service (MeteoSuisse).

Research projects in Switzerland deal with semi-operational probabilistic models and information and warning systems for small catchment areas (IFKIS-Hydro) which can provide comprehensive and reliable information in the case of a flood event in real time (Zappa & Vogt 2007).

But still small catchment areas might be under-equipped and fall through the cracks. This is congruent to a result from research project URBAS (Einfalt & Hatzfeldt 2010) that the actual density of rainfall gauges are not sufficient in some areas of Germany to get appropriate information about rainfall events which could cause flash floods. Considering pluvial flooding it is evident that modeling and forecasting of these events requires short term rainfall prediction with high spatial and temporal resolution.
In order to get spatial rainfall distribution radar measurement was introduced in the last decades. But radar data are qualitative. Measurement Data from rainfall gauges are necessary to calculate quantitative information. And here the same problem is evident as described above that in a considered small catchment area too few or none rainfall gauges might be installed.
The installation of additional rainfall gauges within a small catchment area is a possible solution of this problem but is very expensive.

Another possible solution is to include local observers within the operational system like it is suggested and tested by IFKIS-Hydro in Switzerland. It is noticeable that data collection by means of local observers needs real time and reliable (redundant) information transfer, data storage and integration in forecast models by experts.

Regarding weather forecast and rainfall measurement it is obvious that:

- available weather forecast might miss small but heavy rainfall events due to the spatial resolution of the national weather models
- rainfall data in small catchment areas with no or too few rainfall gauges should be improved by information of local observers and installation of additional rainfall gauges

River gauges and flood wave propagation

If no proper rainfall-runoff-model can be implemented the simplest method to warn people downstream is to use a river gauge which is situated a significant distance upstream the point of interest. Reservoir outflow gauges of retention basins can be used as well. This can only be applied if the river reach upstream is long enough and the discharge which is added by the catchment area between the river gauge and the point of interest is relatively small or can be estimated by means of simple formula.
Many historical systems used this kind of warning system. Early examples for warning systems in small catchment areas are river Müglitz and Gottleuba in Saxony, Germany where flood observation and information services were established by government in Saxony after an extreme flood event in 1897 (Pohl 2004). The police was responsible for flood warning. River gauges to measure the water level were built in the Ore Mountains.
Warning messages were first disseminated by telegraph and then by telephone. The problem was, that the cables were mounted at masts standing within the valleys and often demolished during flood events so if the warning system was needed it was out of operation.

The definition of different alarm stages at a river gauge in order to connect a certain water level with appropriate actions is usually until today. The flood warning gauge could be situated at or a certain distance upstream a point of interest, e. g. a town. If there is a small catchment area with no significant additional catchment below or flood propagation is very fast it is better to refer to a flood warning gauge which is situated upstream our point of interest. A warning gauge situated at the point of interest suits more the situation at bigger rivers with water level forecast. The information about inundation in the last case is more precise helping to put appropriate measures into action.

The different terms for flood warning levels or alarm stages can describe on one hand the degree of flooding or on the other hand the connected actions. The research project TELEFLEUR suggested a classification by three thresholds (mild/significant/severe) to describe the degree of flooding. In Czechia three flood warning levels (flood watch/flood warning/flooding) are defined for every flood warning gauge. Four alarm stages (observation, inspection, guarding and flood defence) are defined for all flood warning gauges in Saxony, Germany.

In Austria there are warning levels for rainfall and river water levels (EWASE 2008).

Four warning levels are defined for rainfall:

- no identifiable
- attention (less than 18 times a year)
- greater attention (less than 4 times a year)
- extreme event (less than 2 times in 3 years)

The warning levels for river gauges are defined together with the communities and local companies. If no warning level is defined the responsible actors uses the water level of a one year flood as a first critical limit.

If one combines the knowledge about actual water level at a warning gauge with weather forecast than a flood forecast by expert knowledge is also possible. It is very essential for this type of forecast system to consider the wave propagation time between flood warning gauge and the location where flood affected people live as well as the degree of flooding. If the forecast time is short together with a severe degree of flooding only warning dissemination und rescue actions are possible. The warning system can help to prevent that people will be hurt or die during a flood event. If forecast lead time is longer or degree of flooding is milder flood damage mitigation by means of mobile elements or other flood protection measures is possible too. In such case flood warning information helps to minimize economic losses.

For flood warning systems considering only measurement data of river gauges it is essential that the data will be measured and transmitted during a flood event regularly and certainly. It has often been observed that gauges were destroyed during extreme flood events. During the flood event 2002 in Saxony, Germany more than 30 of 108 warning river gauges failed or were destroyed. The effect was that in case of emergency no data about the local situation and the development of the flood wave reached the administration and coordination of work between fire brigades, THW and others became complicate. After the event all gauges were repaired or new installed. Today the buildings and measurement installation are more resilient against floods and redundant systems of data communication were installed.

Measurement data of river water level are also necessary to predict water level at locations downstream by means of simple flood routing models e.g. translation-diffusion-model or Kalinin-Miljukov-Model. The method is often applied to middle size catchment areas.

Considering the European countries river gauges are available at bigger rivers but only few or none river gauges are installed at small rivers. Therefore it can be recommended:

- to install additional river gauges at smaller rivers
- to check the flood resilience of the flood warning gauges so that they can withstand and measure extreme flood events too
- to assure redundant data transmission

Flood forecast by rainfall-runoff-models

If there are enough data as well as a valid rainfall-forecast it is reasonable to establish a rainfall-runoff-model for flood forecast. The main purpose is to increase forecast lead time significantly.

Different types of flood forecast models exist in Saxony, Germany. To predict floods at the river Weiße Elster in west of Saxony a rainfall-runoff-model together with flood wave propagation model using Kalinin-Miljukov-model is applied. All these models capture only middle sized catchment areas.
Zappa & Vogt 2007 gives a good overview about flood forecast models in Switzerland. At the river Rhine a first model was implemented 20 years ago. The current model (platform FEWS) includes the whole Rhine catchment area as well as the Austrian and German tributaries. The smallest catchment area which is calculated within FEWS is river Emme (near Eggiwil). This catchment area is 124 km² and because of uncertainties the information is only intern and not public. FEWS provides forecast information for organisations responsible in disaster management or other customer only for catchment areas larger than 400 km² and with no anthropogenic effect on flow regime. Nevertheless the training of end users is necessary to interpret forecast information properly. Public forecast information via internet is only provided for catchment areas larger than 1000 km².
Project MINERVE (Jordan et al. 2004) at the river Rhone aims on a numerical model using deterministic and physically oriented approach to describe rainfall-runoff and flood routing considering operation of 12 reservoirs. The model includes the whole Rhone River catchment area upstream Lake Geneva of about 5500 km². Data needed are weather forecast from Swiss Weather Service (MeteoSuisse), real-time measurements of rain at different rain gauges and discharge measurements at different river gauges. In addition operation data of the main hydropower schemes are necessary.
A general problem of these empirical models is to calibrate the parameter set which is necessary to convert the rainfall volume into the runoff volume. It was often observed that a calibrated parameter set for smaller flood events does not cover extreme flood events and vice versa (Pohl et al. 2009). Therefor we need different parameter sets which have to be applied automatically regarding actual input data like rainfall intensity. If there are reservoirs or retention basins within the catchment area the implemented model has to include their operation rules to get satisfactory results.

From this short overview it can be summarised, that:

- flood forecast models including rainfall-runoff-calculation are more common in middle and large catchment areas due to inaccuracy of calculation results

Flood prediction errors and their impact on flood management

Possible errors in flood forecast can refer to both peak discharge and/or peak arrival time. On one hand the flood can arrive earlier or later than predicted and on the other hand the peak discharge can be higher or lower than predicted. This is shown in Figure 25 using simplified discharge hydrographs.

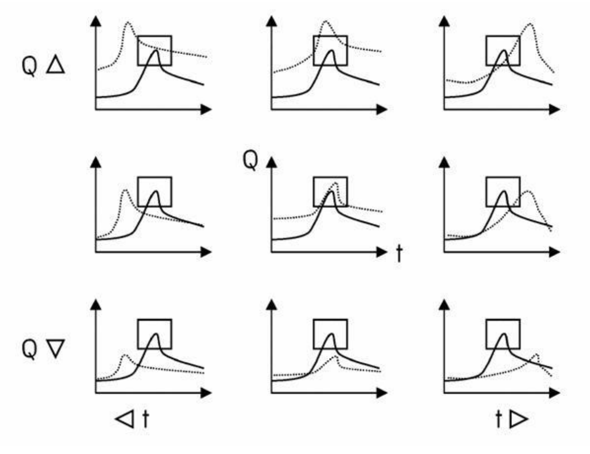


Figure 25: Possible errors in discharge hydrograph forecasting with differences in peak discharge and peak arrival time: (─) observed; (···) predicted (OPAQUE 2009)

For flood protection purposes it is important to predict the maximum river discharge at a certain point of interest very accurate because mobile flood protection elements have to be higher than the water level at

flood peak to fulfill their task. If the predicted flood peak is higher than the observed one flood protection is sufficient but mobile flood barriers are too high and this extra work might cause a lack in rescue work at other hot spots. If the forecasted flood peak is lower than the observed one there will be a flow over the flood barriers. A barrier failure might occur which can increase flood induced damage because of an increasing discharge with high flow velocities near the breach.
The prediction of flood peak arrival time is important too because it set a time limit to possible flood protection measures. If the flood peak arrives faster mobile flood protection elements might be still under construction and flood damage could be higher than without.

It is often observed that the output of rainfall-runoff-models is more valid if the forecast-lead-time is short (which was also a result of the EWASE project in 2008).

New research and the development of new models in flood forecast are often triggered by extreme flood events. For example many projects were initiated after extreme flood event in Germany in 2002 e.g. within the research program RIMAX. Many improvements and excellent results in flood management were realised. But no applicable output was achieved regarding flood forecast in small catchments.

A research project considering a small catchment area (50 km²) was OPAQUE (operational discharge and flooding predictions in head catchments) within the German research program RIMAX (OPAQUE 2009). The aim was to increase forecast-lead-time for reservoir operation using a rainfall-runoff-simulation combined with a medium term ensemble forecast. The project considered river gauge Ammelsdorf at the river Weißeritz in Germany as a case study. The gauge is situated at the inflow in the Lehnmühle reservoir. Nevertheless calculation results indicate no significant advantage of using calibrated weather radar data instead of rainfall gauge data (Kneis & Heistermann 2009). In such small catchment areas the quality of discharge prediction is less good even in the case of a "perfect" weather forecast. Causes are imperfect measurement data, problems in regionalization, model structure, model parameter and discretization. It was suggested to use the created model as a warning system against critical weather conditions. A discharge prediction as a basis of reservoir operation was not possible.
The four SUFRI case studies confirm the statement that weather forecast and rainfall-runoff-models are the weakest point in flood warning systems Case study Dresden, Germany has to deal with an overestimation of future rainfall. In Graz, Austria there is no prediction possible, if a thunderstorm remains over the considered Schöckelbach catchment area or not until it starts to rain. Unpredictable heavy rainfall events causes flash floods in Benaguasil and Arenys de Mar, both in Spain.

These explanation shows, that:

- rainfall-runoff-models for small catchment areas are still a topic of scientific projects
- flood forecast in small catchment areas should consider more simple black box models to deal with uncertain rainfall prediction and short forecast lead time

Warning dissemination

Flood risk communication to inhabitants of urban areas differs between countries and is probably affected by historical flood experiences.
Nevertheless a very detailed study about flood preparedness in the Netherlands (Terpstra 2009) gives some good points regarding risk communication. People will only prepare for floods if they perceive that flood preparedness is personally relevant. It is therefore most important that risk communication is tailored to the local needs of the people at risk. Dutch people are most interested in flood preparations that increase their safety during evacuation and floods (e.g. providing with flashlight) but largely decline to take responsibility for flood damage because they have a great trust in flood defence measures taken by government. This confirms the behaviour of many inhabitants of Arenys de Mar, Benaguasil and Graz (SUFRI case study areas) which adopt self-protection measures after a weather warning or a flood warning message is released. The main reason is to mitigate flood damage at private properties which these inhabitants have suffered from during recent flood events.

General information paths

The general information distribution depends on the general components of a warning system. Warning messages are created by flood warning centres or local water authorities. Two kinds of messages distribution can be distinguished after that. Either the message proceeds along the official channels (flood centre → county → towns & cities → inhabitants) or the message is distributed to county, towns, cities and inhabitants and of course fire brigades simultaneously. Because warning messages are in general forwarded by humans and not automatically, it is obvious that a simultaneously message distribution needs less time which is important regarding flood forecast lead time in small catchment areas.

The improvements of flood warning in Saxony, Germany enlighten this problem. Before the 2002 flood 4 regional flood warning centres exist in Saxony. After the flood event 2002 flood warning in Saxony was centralised in the Saxon Flood Centre (LHWZ) in Dresden. Today flood warning messages are dispatched directly to municipalities and private companies with higher risk of flooding e. g. hospitals, business companies. In addition flood warning messages are available in the World Wide Web (www.landeshochwasserzentrum.sachsen.de) or via TV (Video text) or telephone (Flath 2004).
The communication system has to assure that all affected inhabitants can receive and understand a warning message as well as that the concerned inhabitants can get information about the actual situation. This is only possible by a combination of different information distribution paths or means of communication (acoustic devices, TV, radio, Internet).

It can be stated that effective warning message distribution needs:

- short ways of information distribution
- multiple information distribution paths (acoustic devices, TV, radio, Internet)
- simultaneous distribution to local administration, rescue workers and inhabitants

Acoustic signal devices

In case of flash floods or other fast advancing floods one has to create flood warnings very fast just during the rainfall and to provide this information to the public body about short information paths. Diaphones or sirens are devices creating acoustic signals in order to warn or alarm e. g. fire brigades or the public. There are mechanical, pneumatic or electronic diaphones. In German and Austria they are called “Sirenen”.

A central or local controlled area-wide network of diaphones in a country provides a good, simple and cost efficient opportunity to warn the inhabitants of a certain region in case of floods, disaster in chemical or nuclear industry (ABC-Alarm) by means of different acoustic signals. The warning dissemination is often faster than by means of radio or TV, could be limited to the affected area and reaches those people too which do not watch TV or hear radio at this time.

Before 1990 there was a diaphone network in Germany of about 100,000 sirens. Because the cities and municipalities had to buy the sirens back from Federal Republic of Germany and to take over responsibility many of them decided to demount the diaphones in the 1990ies (Roßberg 2002). Causes were high operation cost, trouble because of loud function tests and the certainty that the cold war was over. Fire brigades often use silent alarm devices. The only opportunity to transmit a warning message to many people was than radio or TV.
Only a few cities have a siren network today (www.wikipedia.de). The city of Hamburg needs a siren network especially for warning against storm tide. After many extreme flood events in 1997 (river Oder), 2002 (river Danube, river Elbe and many smaller rivers) many cities have decided to reinstall siren networks e. g. Passau, Dresden and Augsburg. Function test are common but the date and time are determined locally.

In Austria there is a nationwide network of 8,170 diaphones. Different acoustic signals are possible.
A function test of every diaphone is scheduled every week at noon on Saturday. At the 1st of October a function test of all diaphones in Austria take place.

The central controlled network in Switzerland includes 7,750 diaphones. The aim is that 99 % of the inhabitants can hear a released acoustic signal. Residents of places far away get warning messages by means of phones. In addition mobile diaphones or loudspeakers (mounted on vehicles) are available. Public warning with diaphones takes place in case of natural disasters as well as disaster in chemical industry. A function test takes place at the 1st Wednesday in February at 1:30 pm. All diaphones in Switzerland release a warning signal at the same time. (www.wikipedia.de)

Another example of an acoustic warning device is the bell which is situated at the building of the municipal market in Arenys de Mar, Spain. This bell was installed in 1930s to warn against bombing raids but was used from the 1950s to the 1990s as a warning system against floods. Because floods occur several times every year people know what to do if the bell rings.

The explanations above shows that:

- sirens, diaphones or loudspeakers are the best tools to warn the affected and not all inhabitants of an urban area in case of flood
- to provide more information sirens which can disseminate voice messages too or megaphones are helpful
- it is noticeable that the acoustic reach of megaphones is smaller than of diaphones

Other information systems

Besides diaphones other dissemination systems for flood warning messages can be divided into three groups:

- dissemination of information to people who are involved in disaster management (e. g. administration) or in rescue work and flood defence (e. g. fire brigades)
- dissemination of information to the public which is affected including signals which are necessary to close a public space and start evacuation or to stop traffic and block a street, railway or others (acoustic and light signal in the area affected)
- dissemination of information to the public which is concerned (e.g. by means of community helpline, World Wide Web)

People who are responsible in disaster management and flood defence get their information often by text messages on mobile phones or via fax machine. An uninterruptible electrical power supply is necessary if the information via fax machine is recommended. Furthermore it has to be ensured that the fax message reaches a responsible person even in time when the office is closed. Another aspect to consider is that in case of emergency mobile communication networks are often disrupted. In case of fast arriving flash floods fire brigade has to put on alert when the rain starts to fall down or there is a forecast about a probable heavy rainfall event. If the uncertainty of such forecast is too high fire brigade can put on pre-alert, which includes the preparation for flood mitigation measures but no actual actions.

For information distribution to people in the flooded area public address announcements can also be used. Modern electrical diaphones or sirens or mobile system are able to broadcast text messages in addition to acoustic signal.

Additional information about a flood alert could be given by megaphones like in Graz, Austria. Megaphones provide the opportunity to give clear recommendations about what to do in case of a flood. Since megaphones have to be installed on cars they can only be of use before a flood event not during a wide inundation. Megaphones have a smaller acoustic reach than diaphones.

If there is a long lasting flood event information boards, light signals and traffic road signs can inform people about necessary closing of streets, footpaths or others.

A permanent task considering floods is to increase public flood awareness (public information via TV, radio and flyer, risk mapping, insurance, etc.) and to initiate preparation of a disaster supply kits by people.

The concerned public can get information about forecasted or on-going flood events via TV (teletext) or the Internet. Weather information and/or warning against heavy rainfall together with more general information about impending flood events are often provided by national or regional weather services via World Wide Web in all European countries. For the inexperienced public it is often not easy to transfer the provided information about actual water levels and discharges into personal flood protection measures and rescue action. Additional information via telephone (emergency telephone code or community helpline) could provide significant help.
To provide more general information about flood events in an urban area municipal administration can distribute leaflets or brochures. Scientists of the two research projects URBAS and MEDIS within the RIMAX research program in Germany established a web-based brochure which enables communities to create tailor-made information about floods in their communities (http://nadine.helmholtz-eos.de/Vorsorgebroschuere.html). Some general modules about possible private flood mitigation measures can be combined with local information to get cost-efficient brochures with high information standards which can be distributed to the inhabitants or put on the homepage of the community.

It can be summarised that other measures informing people:

- should give addition information which only acoustic signal cannot provide (information about proper behaviour, evacuation, development of situation)
- are necessary to block roads or close other public places

Warning messages

Weather and flood forecast is characterised by increasing uncertainty considering higher forecast lead time. So very early flood warning messages are often vague and refer only to lower flood water levels which cause no extra precautions. If an event proceeds higher flood levels are expected but then there is only very short time to prepare for flood damage mitigation actions. This is why experts often confirm the existence of flood warning messages but inhabitants report that there was no early warning (see e.g. Jeschke et al. 2010). Here an honest description of what information actual forecast models can provide is necessary.

In many European countries there are different kinds of warning messages before or at the beginning and during a flood event. In the city of Graz, Austria these text messages were between 2008 and 2010 phrased as follow:

> 1st Level: „Attention, there is a risk of thunderstorms and intense rain in the next hours! Please pay particular attention! The professional fire brigade Graz! "
>
> 2nd Level: „Attention, there is a risk of flooding in the area of …..! Please pay particular attention! The professional fire brigade Graz!"

Since 2011 the following phrases have been used:

> Information 1 (a thunderstorm in Graz is possible, but still not arisen) "Thunderstorms (intense rainfall, storm, thunderstorm etc.) are expected in the next hours. Please pay particular attention! The city of Graz, Department disaster control and fire brigade"
>
> Information 2 (thunderstorm in Graz has arrived) Attention, there is an imminent danger by thunderstorm (intense rainfall, storm, thunderstorm etc.). Pay attention to measures of self-protection! The city of Graz, Department disaster control and fire brigade"

The agency of fire and disaster control in Dresden, Germany gets flood warning messages from Saxon Flood Centre by text messages and by fax. These text messages have to be answered for checking purposes. The text message regarding flood alarm stage 1 includes the following phrase:

> "The flood alarm service for the Weißeritz catchment area is open"

The fax includes information about the hydrological and meteorological conditions, water level data at the river gauge, information about current water level and free flood storage capacity in the upstream reservoirs and a remark about the next flood warning message. During a flood event in smaller catchment areas messages are disseminated twice a day. If a flood event is forecasted a flood warning messages with the following phrases is disseminated:

> "The weather forecast of DWD indicates extreme rainfall in area z. The water level at river gauge y can reach alarm stage x in the near future."

Warning messages to the inhabitants can be disseminated by means of diaphones using predefined text messages. In case of flood the following phrase would be used:

> "There is danger of flooding! Move to higher ground!"

or in case of a thunderstorm:

> „Thunderstorm danger! Protect your building and stay indoors!"

All examples confirm that flood warning messages should be clear, simple, understandable and without subjunctives. In case of emergency they can include requests to inform and help neighbors and to get more information about the actual situation.

After a flood event it is common to send an all-clear-information to end the alert.

Decision making and Actions

In case of emergency there is no time for disaster management planning. We have to know what could happen during flood events and which flood defence measures are required. Disaster protection management plans have to be at hand and up to date including required action. The planning should be reconsidered after every flood event when flood protection actions were needed. But flood maps and management plans are only as good as the hydraulic-numerical calculations or analysis of historical events they are based on. Flood defence measures are the inspection on rivers, dikes, dams, retention basins and bridges, the removing of blockage in river bed or at bridge and culvert cross sections, the installation of mobile flood damage mitigation elements like sand bags or others and evacuation of flooded buildings and rescue work considering valuables.

Flood hazard or risk maps and management plans

Different CRUE projects consider this topic in detail. Project RISK MAP (Improving Flood Risk Maps as a Means to Forster Public Participation and Raising Flood Risk Awareness: Toward Flood Resilient Communities) focus about actual legal frameworks und current practice of risk mapping in four European countries in order to improve graphical design as well as information content of risk maps. Project IMRA (Integrative flood risk governance approach for improvement of risk awareness and increased public participation) includes in working step 3 the assessment of the performance of existing management systems in terms of attention paid to risk governance principles. Project FIM FRAME (= Flood Incident Management – A Framework for improvement) aims for assessing the effectiveness of flood management plans, also flood emergency plans and some guidelines how such plans can be improved.

As written in EU Flood Directive (directive 2007/60/EC) the member states have to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. This Directive also reinforces the rights of the public to access this information and to have a say in the planning process. The Directive requires Member States to carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015.

Many European countries had established flood risk assessment before the EU flood directive. In Austria each province department, district commission and community has to develop a disaster protection management plan for its line in action (EWASE 2008).

In Germany the responsible authority has to establish risk management plans considering areas at risk of flooding. This flood defence plan (Hochwasserabwehrplan) includes lists with institutions, private persons and companies which would like to receive warning messages if the river water level reaches a certain alarm stage. The guidelines for establishing flood protection concepts in Saxony published at the 18th of March 2003 consider experiences in flood management from Switzerland. Inundation maps for all major rivers were elaborated between 2003 and 2008.

The used terms for flood maps or flood risk maps are often not consistent within or between European countries. Although EU Flood directive try to establish standard terms many older expressions are in use until now. A study of different national and international publications was conducted and is summarised in Appendix 2. It shows that there are many different designations as well as different contents of flood maps. Although it is desirable there is by no means a consistent use of terms like flood hazard map or inundation map. Besides flood related data like inundation area, flow depth, flow velocity or river reaches with possible depositions or erosion it might be helpful to add information about land use as well as population density and to mark the locations of police stations, fire stations or other rescue units as well as hospitals and emergency accommodation to these maps.

In Switzerland a tool called intervention plan was established (Romang et al. 2008). It is combined with an intervention map which shows affected areas as well as possible consequences and according measures. The intervention map is based on a hazard map. According to intensity and reoccurrence period of a hazardous process (flood event, snow or landslides or other) different areas are marked in red (high hazard), blue (medium hazard) and yellow (low hazard) in that kind of map.

In addition many European countries have established different computer aided platforms and tools in disaster management during the last decades. Starting in wider river catchment areas like river Rhine in Germany science and administration try to meet the needs of smaller river catchments in the last ten years.
A tool in disaster management is the decision support system DISMA (TÜV Rheinland) which is widely used in Germany and can provide information about people at risk due to accidents in chemical industry, in case of flood or other. The interactive data supply system can be used by fire brigade or fire defence agencies to get information about the number of people living in the affected (in case of flood: inundated) area including number of children and the number of elderly people (> 70 years) as well as kind and location of objects worth protecting. Data base includes possible inundation area of a 20, 50, 100 and 200-year-flood and necessary flood damage mitigation measures (e. g. temporarily structural measures).

Another tool was established in Switzerland. A pilot study tried to adapted the already established system IFKIS (warning against snow slides) as IFKIS-Hydro for flood warning and management (Romang et al. 2008). This system is used in combination with the intervention maps mentioned above.

It is noticeable that flood maps and management plans are only as good as the hydraulic-numerical calculations or analysis of historical events they are based on. If we have not calculated an extreme event or if in a certain catchment area a big flood event is long ago we could not be certain what we have to do in case of extreme flood event even there are maps and plans for smaller events.

River alarm stages and flood defence actions
It is useful to establish certain water levels as river alarm stages at river gauges to define the degree of flooding or to couple required flood defence measures, mainly for rivers with wide river catchment areas.

In case of small catchment areas the extreme flood event in 2002 in Saxony/Germany had shown some difficulties in implementation the required action. In small catchment areas time between the water level rises from one alarm level to the next is very short, most of actions are required at once and not only these which are defined for the actual alarm stage. In 2002 all rescue forces were in action long before a red alarm was sounded (Kirchbach et al. 2002).

Therefore it might be appropriate to define only one or two alarm stages at rivers with small catchment areas and the risk of flash floods. In addition alarm stages should be connected with rainfall forecast or rainfall measurement data. Such as in “Parc Fluvial del Besos” near Barcelona (Spain) where the warning protocol starts if one of the following criteria is satisfied (EWASE 2008):

- the rainfall monitoring system measures a rainfall accumulation above critical threshold
- the estimated cumulated precipitation based on the radar data confirms an actual or now-casted exceedance of a critical threshold
- the civil services informs about an imminent risk period
- the hydrological model forecasts flooding in the fluvial park

In case of emergency it is essential to take quick and adequate actions. Often fire brigades are responsible for disaster management as well as flood management in order to achieve synergies, to improve locally organized responsibility and to use their knowledge about local hot spots. When fire brigades have prior responsibility in flood protection their stuff should be alerted simultaneously with communities. In several municipalities in Europe they are also responsible for warning dissemination to the inhabitants.

In case of flood fire brigades usually conduct the following measures:
- inspection on rivers, dikes, dams, retention basins and bridges
- removing blockage in river bed or at bridge and culvert cross sections
- installation of mobile flood damage mitigation elements like sand bags or others
- evacuation of urban areas and salvage of valuables (e. g. from churches)

Private persons and business companies are requested to take action to mitigate flood damage to their property. They use mobile flood protection elements like stop logs, wooden logs and sand bags or put their valuable belongings or electrical devices on a higher level. In the SUFRI case study area Arenys de Mar/Munt, Spain inhabitants prevent their cars from floating away by chaining them to an avenue tree.
Today mobile elements become more important because there are limits for structural measures like technical, financial or ecological limits. In addition the approach to control and reduce potential flood damage due to regional planning takes significant effect only after a long period. But mobile elements need a certain forecast lead time for erection and a constant effort in employee training and control of operational readiness.

As a summary it can be stated that:
- flood management plans together with decision support systems and appropriate maps provides information to take quick and adequate measures in case of flood
- management plans and flood maps should contain information about often as well as seldom and extreme flood events to cover all possibilities
- fire brigades should have prior responsibility in flood protection
- personnel measures of inhabitants and company stuff considering their private and business property are important in flood mitigation

Determination of flood risk

To create flood risk maps out of inundation maps the estimation of possible flood damages considering flood events with different reoccurrence periods is necessary. Flood damage depends mostly on land use, population density and degree of flooding.

A very complex and time consuming task is to collect data about costs per building and household and the kind of properties within potential flood plains and to estimate the degree of damage considering a certain flood level. Stage-damage-curves are helpful but only valid in that area where the data were collected they are based on. They cannot be generalised for whole Europe and even on a national scale obtained values are uncertain.

In Germany a Natural Disasters Networking Platform (NaDiNe) was established (nadine.helmholtz-eos.de) during the RIMAX research program (2005-2009). This platform includes a model to calculated flood damage on the scale of municipalities (see Figure 26). The model is called “FLEMOps” which stands for “Flood Loss Estimation Model for the private sector”. Input data are the extension of the flooded area together with water level information as GIS data. Output data are amount of possible damage for private households obtained with different calculation models and damage functions.

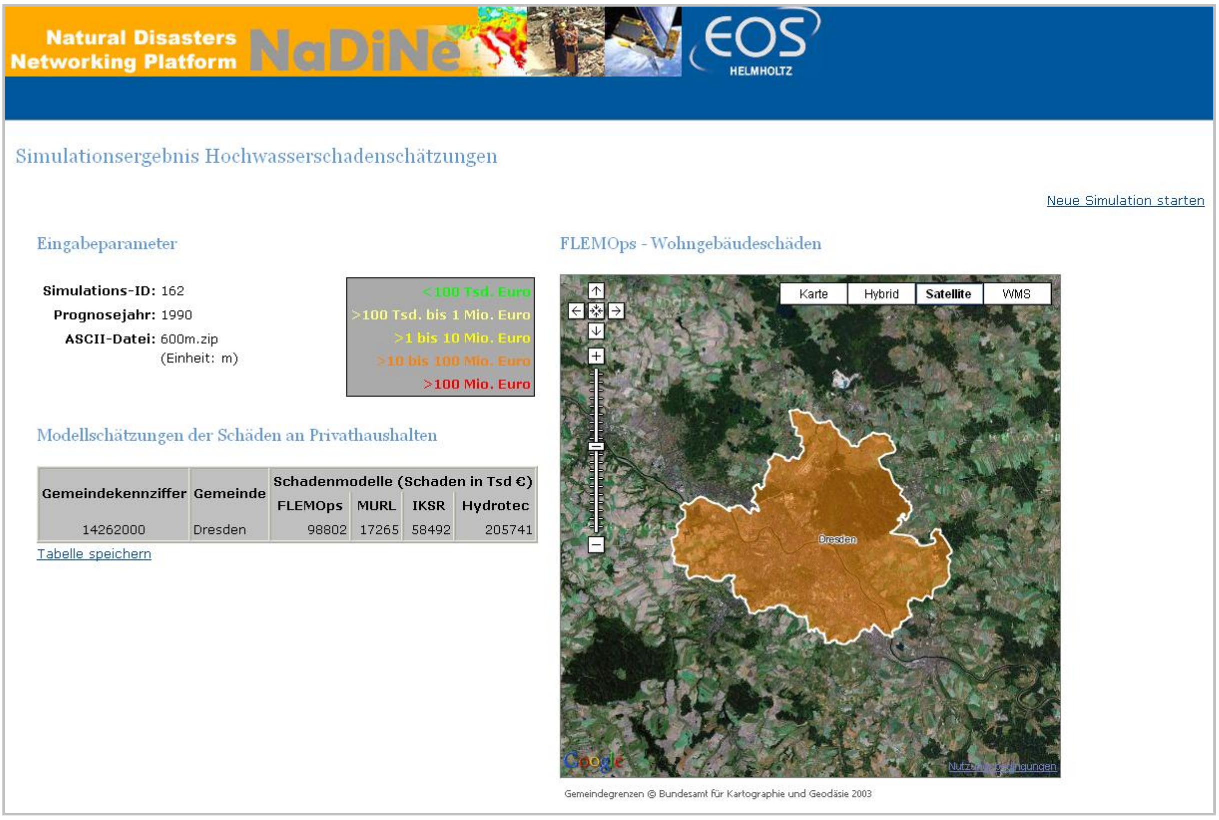


Figure 26: NaDiNe-Website: results of damage estimation with different models for private households (FLEMOps)

The internet platform NaDiNe provides in addition a model for possible damage in business and industry (FLEMOcs – Flood Loss Estimation Model for the commercial sector).

Information about flood damage is necessary to determine the flood risk and conduct cost-benefit-analysis for structural flood defence measures. From a case study conducted using data from a flood event of the river Mulde in the town of Eilenburg, Germany (Apel et al. 2009) it can be concluded that a combination of a flood plain calculation by means of a 1D/2D-model (LISFLOOD-FP) and an damage estimation by a meso-scale model (FLEMO+) seems to be the best compromise between data requirements, simulation effort and accuracy.

Costs of an Early Warning System

It is a complex task to estimate the real costs of a flood warning system. Administration is only besides others responsible for flood warning. Weather and water level data were collected by other institutions and often provided under special conditions. And even fire brigades, as the name indicates have more tasks than flood damage mitigation.

The CRUE project EWASE (EWASE 2008) has tried to estimate the cost of an early warning system. Two case studies were considered. The cost of radar data, personnel, structures (river gauges) and software were estimated and added.

Considering larger river basins software costs is much lower. EWASE recommends the following formula to determine cost reduction for larger river basins:

cost reduction [%] = 8 · 10-9 · AE2 – 0.00016 · AE + 1.1574
with AE = basin size [km²]. Nevertheless in case of small catchments up to 1,000 km² no reduction is recommended.

The total system cost for an early warning system in a 1,000 km² river basin amounts at a present value of 81.64 million EURO for an operation time of 20 years at a bank rate of 3 %. The annuity is 2.58 million EURO, corresponding to the annuity for a 54 km stretch river dike (EWASE 2008).

Table 1: Cost for the software system of an early warning system, as percentage of total software system cost and as cost for a 1,000 km² river basin (EWASE 2008)

item	share [%]	cost [EUR]
data base	3	6,146
meteorological forecast model hydrological forecast model	34	67,602
hydraulic model on existing data economic model	23	46,430
interfaces	2	3,780
control and visualisation	4	8,758
hardware upgrade	12	23,968
start of operation	15	29,960
project management and controlling	6	12,967
TOTAL	100	199,609

Table 2: Cost of an early warning system, present value per km² in EURO (EWASE 2008)

item		operation	investment	reinvestment
input data		338		
personnel for EWS operation		1,570		
structures	gauges		180	101
	data transmission		45	
software system cost			200	90
subtotals		2,290	425	191
total PV (20 a, 3 %)		2,905		

5.2.2 Applied warning systems in different countries

Examples in Europe

Weather information and/or warning against heavy rainfall together with more general information about impending flood events are often provided by national or regional weather services via World Wide Web in all European countries. The concerned public can get information about forecasted or on-going flood events via TV (teletext) or the Internet. Screenshots from the internet show such webpage for Styria, Austria (Figure 27), Czechia (Figure 29), France (Figure 30) and UK (Figure 31). But these web pages cover generally only large or medium size catchment areas.

By means of a map of a region different levels of risk or flood are usually marked with different colors. In general the color red is assigned to the highest level of danger or risk. Green indicates a low risk level or no risk. An evaluation of information required by municipalities during the flood event at the Neiße River in Germany 2010 has shown that only a qualitative description of risk by means of colors was insufficient. Administration stuff like to know quantitative date like exact water level in metres.

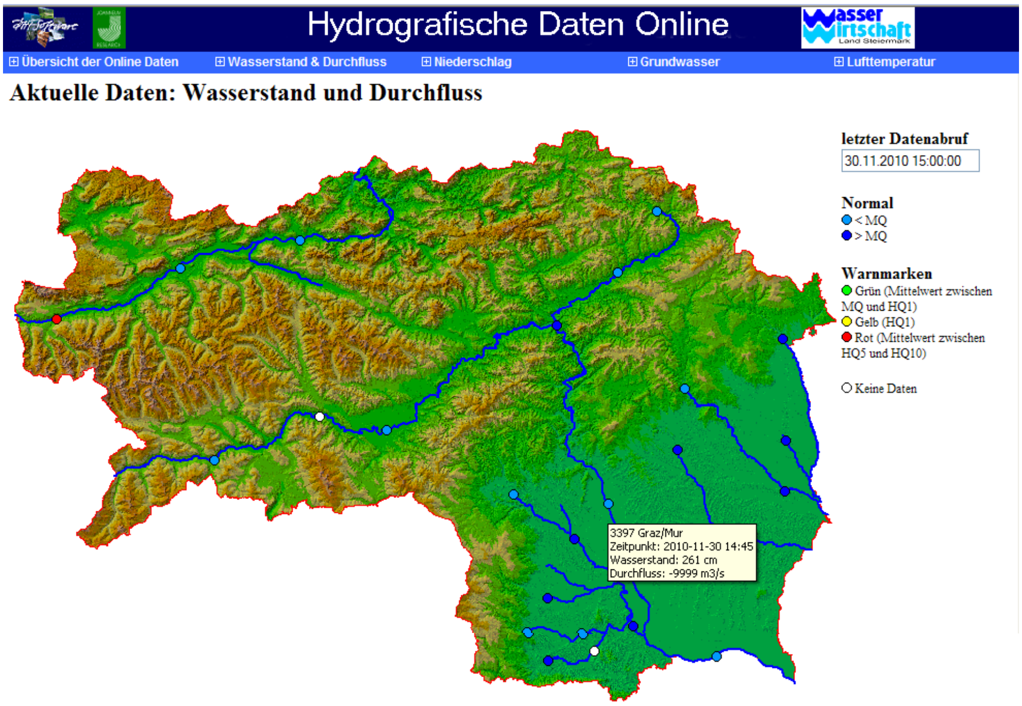


Figure 27: Water level and river discharge data in Styria (Austria) on http://app.hydrographie.steiermark.at/bilder/Internet_online/Index_pub.htm

For each region in Austria an alarm centre (e. g. Warning Alarm Centre of Lower Austria LWZ) exists which decides with predefined warning levels if an alert is necessary. Warnings were disseminate from the alarm centre to the regional authorities (Bezirkshauptmannschaften) which are in charge to arrange a team of regional controllers (Einsatzleitung). The team consists of the head of the region (Bezirkshauptmann) and members of the blue light organisation. Communities and local blue light organisations get informed and stay in continuous contact to the operation controllers. Inhabitants are alerted by megaphones and sirens from local fire brigade or municipalities (as example Figure 28, EWASE 2008).

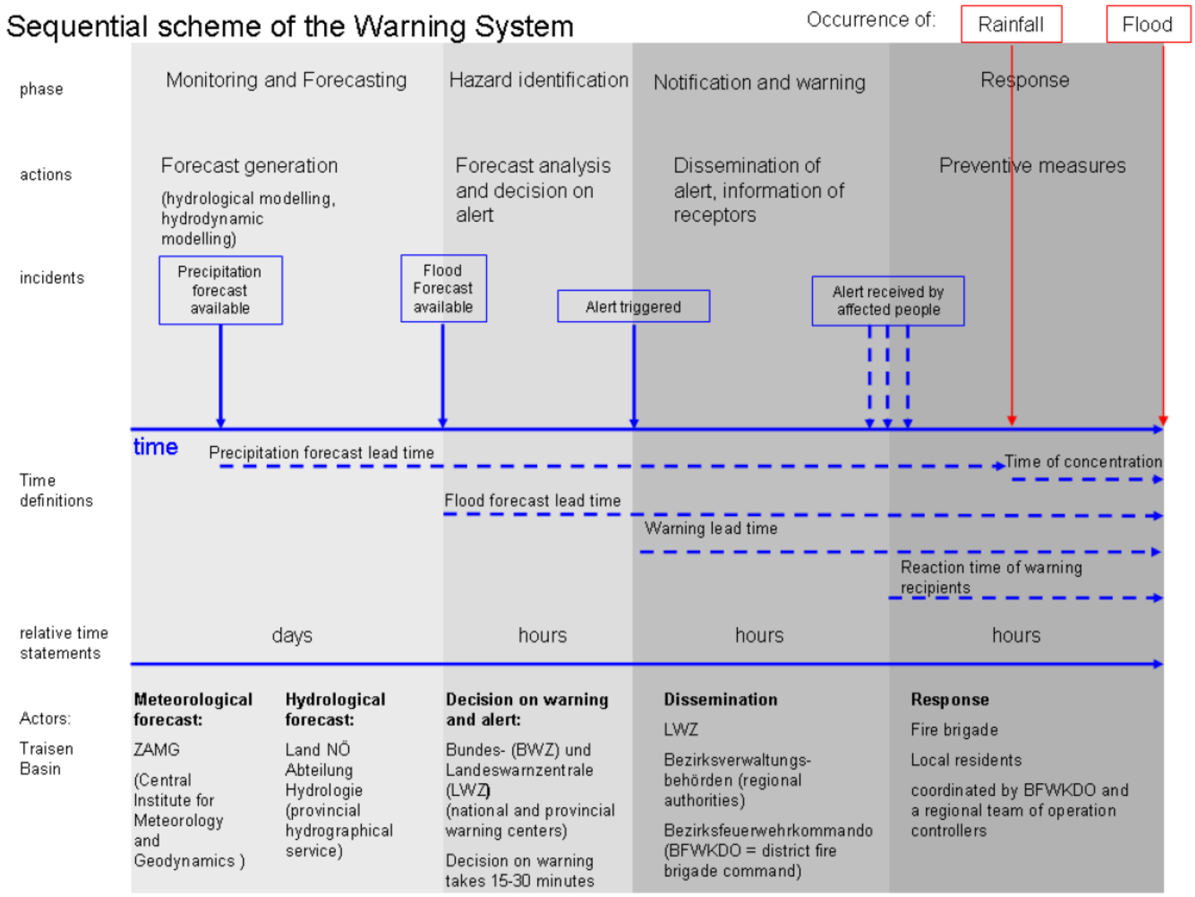


Figure 28: Early warning system in the Traisin Basin as example for Austrian warning systems: time scheme with actors (EWASE 2008)

Figure 29: Flood forecasting and warning system in Czechia (left) and homepage of the national meteorological service CHMI (http://old.chmi.cz/katastrofy/warnsys.html)

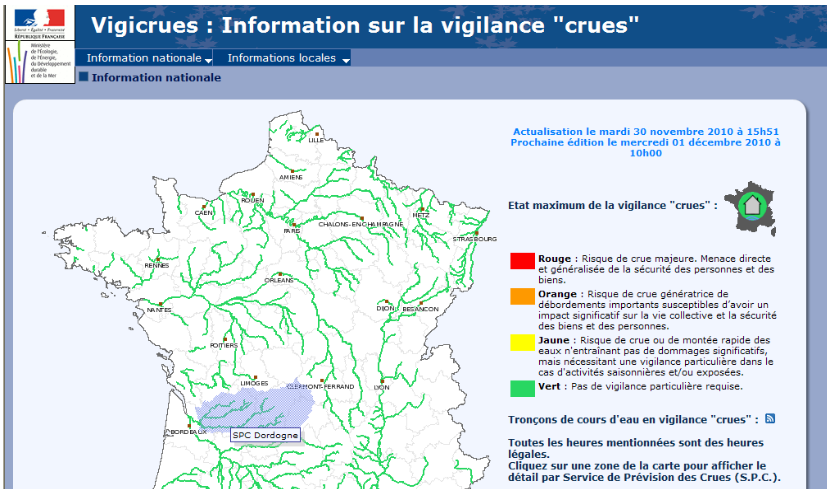


Figure 30: Flood information in France (http://www.vigicrues.ecologie.gouv.fr/)

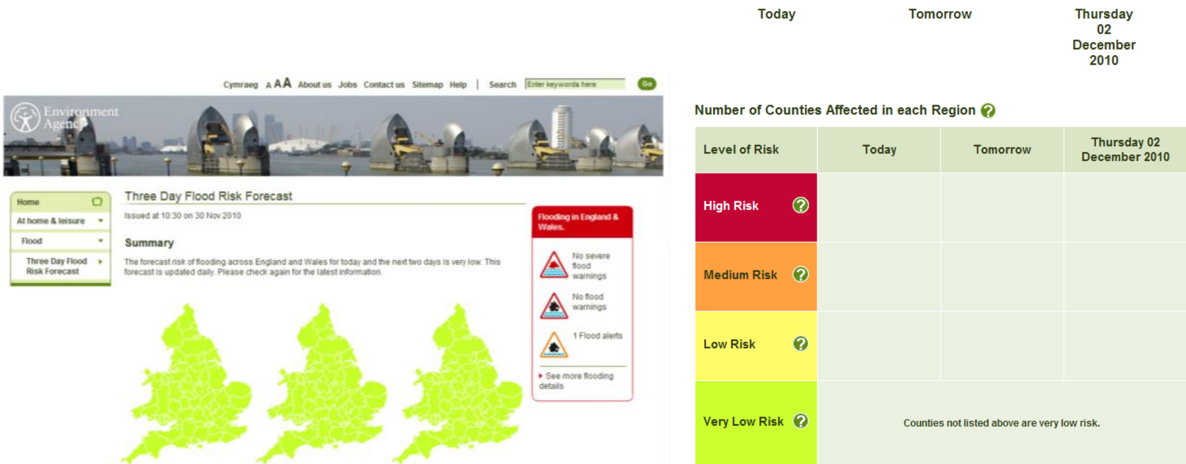


Figure 31: Flood risk forecast in Great Britain (http://www.environment-agency.gov.uk/homeandleisure/floods/125305.aspx)

Besides the river Elbe the city of Hamburg, Germany is also responsible for flood management at its confluence with smaller catchment areas between 6 und 285 km² (LSBG 2009). Since 2005 the information and warning system is organised as seen in Figure 32 and got its input data from the fire service information system (Feuerwehrinformationsdienst FeWIS) of the German Weather Forecast (DWD). The system considers current measurement data at several river gauges in addition. The responsible authority LSBG (Landesbetrieb Straßen, Brücken und Gewässer der Hansestadt Hamburg) collects all data and classifies the situation. If a flood event is possible flood warning messages reach the subordinal authorities (Bezirksämter) and fire brigade. The latter is responsible for river inspection. If necessary fire brigade clears river bed or bridge cross section from blocking material. The planning of current action considers analysis results from previous flood defence activities. The actual task is to establish an automatic warning system without human interference in warning message dissemination. The aim is to validate measured and calculated values, create and disseminate flood warning automatically via email, text and voice messages or fax.

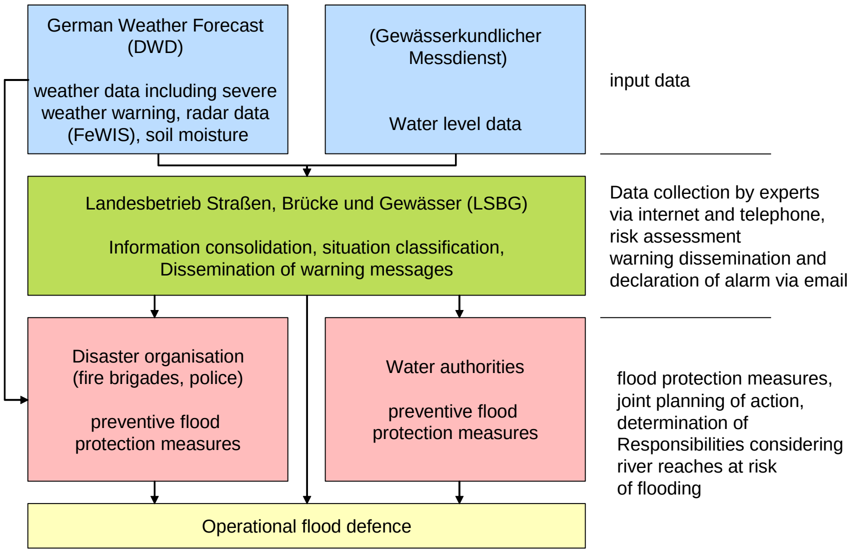


Figure 32: Information and warning system in Hamburg, Germany (LSBG 2009).

Case studies

All case study areas have suffered from severe flooding in the last decade (see Table 3). The flood forecast lead time is short between half an hour and three hours.

Table 3: Overview SUFRI case studies: last important flood event

case study	Benaguasil	Arenys de Mar / Munt	Graz	Dresden
year	2009	2002	2009	2002
damages		1.5 million (not verified)	80 million EUR for whole Styria for different flood events between May and September 2009	340 million EUR
flood forecast lead time or time of concentration	between 41 and 63 minutes	35 minutes	Due to structural measure-ments the rule of thumb to estimate lead time used by the professional fire brigade for the Schöckelbach is not correct anymore. There is no information about the lead time for the 3 streams.	wave propagation time between Freital (flood gauge Hainsberg 6) and Dresden: 3.5 hours

Weather forecast is available in all case study areas by means of national weather services. Since 1980s weather warning in Graz, Austria was maintained by a skilled weather observer, who interprets arriving thunderstorms as well as the weather radar data at the Reicherhöhe, where she lives and provides warning messages to the fire brigades in Graz. But this observer is retired now.

Few river gauges are available or newly installed. E.g., at the brook Schöckelbach and at the flood retention basin Gabriachbach in the case study area Graz newly installed gauges are still in validation and calibration. There are no river gauges at the intermittent brooks in Benaguasil and Arenys de Mar/Munt, both in Spain.

Rainfall-runoff models are not in operation for the considered case study areas. A rainfall-runoff estimation of the brooks in the urban area of Benaguasil was realised within the SUFRI project. Some new results considering the rivers in Graz, Austria are expected from the actual research project AWAS-net which deals with similar catchment areas about 25 km far from Graz.

Table 4: Overview SUFRI case studies: data collection

case study	Benaguasil	Arenys de Mar/Munt	Graz	Dresden
weather forecast	weather forecast by institutions of central government (State Agency of Meteorology) and regional organizations	rainfall forecast on basis of actual radar data using TREC algorithm (in operation but not implemented in the warning system until now) and a Meteorological model (Ensemble Method)	Central Institute for Meteorology and Geodynamics (high resolution weather forecast model), forecast time: 6 hours; warnings against intense rainfall and thunderstorms for districts of Styria	German Weather Service (DWD), COSMO-DE model, estimation about the future precipitation with occurrence probability of 10%, 50 % and 90 % for the whole area of several left tributaries of river Elbe, forecast time between 2 and 48 hours
measurement of precipitation	network of rainfall gauges = Automatic Hydrological Information System (SAIH) by Jucar River Authority (two rainfall gauges); rainfall gauge at the city hall, operated by INM	three weather radar stations operated by Meteorological Service of Catalonia; to correct radar data measurement data from network of rain gauges (SAIH) operated by ACA is used; three rainfall gauges in region of Maresme operated by INM	weather radar operated by Austro Control (aviation weather service) and Styrian Hail Suppression, 13 rainfall gauges within the urban area of Graz	network of rainfall gauges maintained by German Weather Service (DWD)
measurement of river discharge	no river gauges	no river gauges, no discharge information	newly installed gauge at the small brooks in Graz	flood warning messages refer to the river gauge in Freital
rainfall-runoff-model	no rainfall-runoff-model for flood forecast	distributed hydrological model (DichiTop*)	no rainfall-runoff-model	no rainfall-runoff-model due to inaccuracy of model results
flood forecast model	analysis of rainfall data at SAIH	see rainfall-runoff-model	no flood forecast model	flood forecast by experts of Saxon Flood Centre considering precipitation forecast and actual river discharge
results from forecast models	non	probability that a rainfall event causes flooding: little (0 – 30 %), probable (30 – 70 %) or very probable (70 – 100 %)	non	estimation if a certain flood level can be reached in the near future

*The DichiTop model in Arenys de Mar is a combination of SCS loss transformation method in urban areas and ToPmodel in rural and forested areas.

Table 5: Overview SUFRI case studies: Historical and today warning system

case study	Benaguasil	Arenys de Mar/Munt	Graz	Dresden
first installation	no warning system	warning against floods by means of a bell at the municipal market between the 1950s and the 1990s	weather warning: since 1980s, flood warning system: after 2005	probably in the 1910s; installation of sirens for flood and disaster warning began in 2006
historical information distribution	---	information run from Arenys de Munt to Arenys de Mar via phone, bell in the marketplace of Arenys de Mar	---	telephone calls from upstream communities
warning message distribution to communities (today)	weather warning from State Agency of Meteorology (via television or radio)	automatically distribution to municipalities (city hall), more than 300 alerts per annum (different natural and human hazards), distribution from guard room of CECAT by fax and recently by SMS and Email	weather warning from ZAMG to LWZ (written form) and from them to responsible and affected entities (e.g. communities and fire brigades) by email and text messages Also weather warning from the Central Institute for Meteorology and Geodynamic directly to the professional fire brigade	flood warning messages from Saxon Flood Centre to communities by means of fax and text messages, receiving of message has to be confirmed
warning message distribution to inhabitants (today)	weather data available via TV, radio or internet*	in case of extreme flood: warning messages from the Municipality; other information available via TV, radio or internet (e.g. web pages of ACA and Meteocat)	alarm stage 1 and 2: text messages from professional fire brigades of Graz to registered people (1st and 2nd level), alarm stage 3: warnings via megaphones in addition to media (TV, radio, internet), Private companies, e.g. insurances provide additional warning messages for a special group of people	text messages from Agency of Fire and Disaster Control Dresden to third parties including private persons; sirens; information via TV, radio, internet
alert of police, fire brigades and other rescue forces	?	simultaneously with communities	simultaneously with communities	simultaneously with communities by means of fax and text messages from Saxon Flood Centre

* http://www. benaguasil.com/cas/inici.php

Flood warning at river Weißeritz in Dresden, Germany depends on water level measurement at flood information gauge Hainsberg 6 in Freital which is situated about 10 km upstream. In addition rainfall forecast information from the German Weather Forecast (DWD) is considered by means of expert knowledge in the Saxon Flood Centre to estimate the future river discharge and the possible maximum flood level. Flood propagation time between Freital and Dresden city is about 3 hours. The data about actual water level and discharge is available to the public within the World Wide Web (see Figure 33).

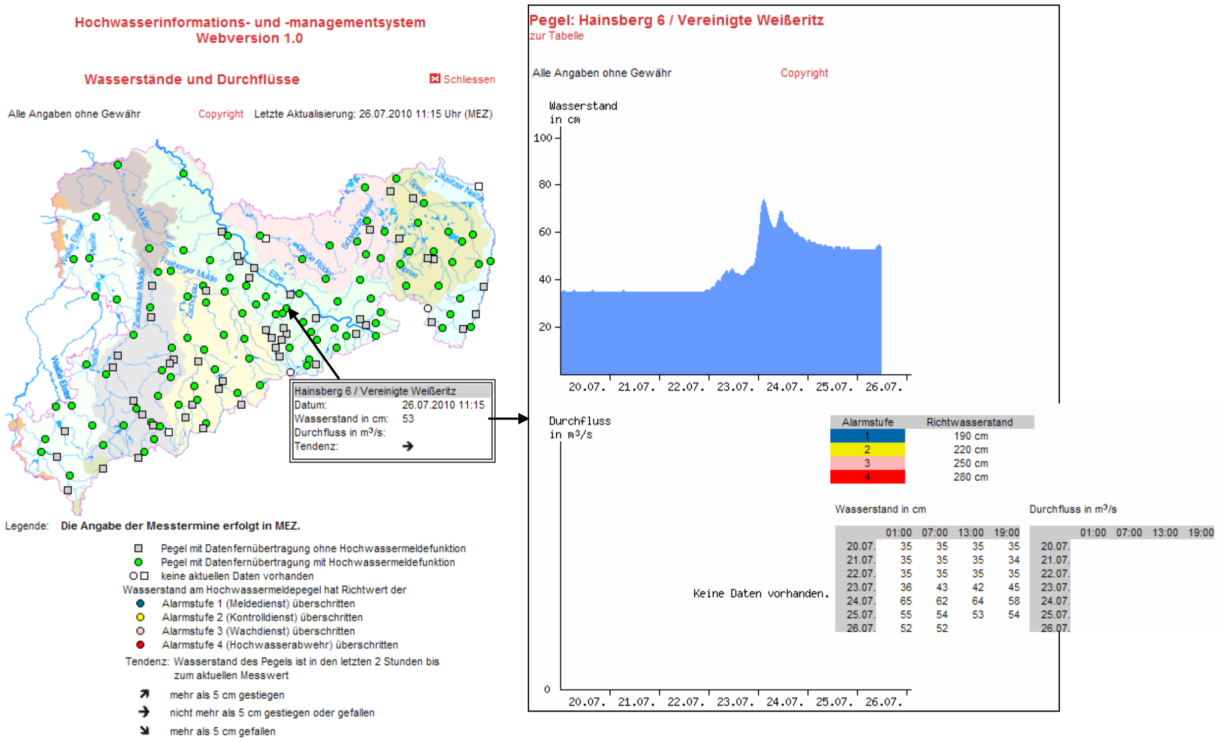


Figure 33: Presentation of the measurement data at a German flood information gauge (Hainsberg 6, water level = Wasserstand and discharge = Durchfluss) between the 20th and the 26th of July 2010, because the river gauge was newly installed recently no stage-discharge-function and no discharge data are available (homepage of the Saxon Flood Centre: www.hochwasserzentrum.sachsen.de)

During the last years especially after the extreme flood event in august 2002 in Saxony there were many research projects dealing with rainfall-run up-models in smaller catchment areas. The Weißeritz catchment area was considered too. But a just-in-time flood forecast was not possible with sufficient accuracy regarding time to peak and peak discharge. So the Saxon Flood Centre decided to refrain from establishing a forecast model for the Weißeritz catchment area.

Available data about historical and today flood warning systems are summarised in Table 5. An exceptional device was used for releasing flood alerts in Arenys de Mar, Spain. A bell at the municipal market, which was installed in 1930s to warn against bombing raids, was used from the 1950s to the 1990s as a warning system against floods.

There are different kinds of structural measures in order to mitigate flood damage in all case study areas. Inhabitants have used mobile wooden barriers to prevent their houses from flooding in Benaguasil, Spain and Arenys de Mar, Spain or sand bags like in Graz, Austria and Dresden, Germany. But also retention basins and dams were constructed to reduce flood peaks.

Table 6: Overview SUFRI case studies: Flood protection measures

case study	Benaguasil	Arenys de Mar/Munt	Graz	Dresden
structural, permanent	inlets into sewage system to drain streets, retention basin (in planning)	demarcation and first urban planning; movement of Saulo (typical sand of Arenys basin), construction of first sewage system; final conformation and channelling (encroaching) of Arenys river start at 1860 and was finished in 2010, construction of a flood retention area in 2010.	four flood retention basins (two in the catchment basin of Gabriachbach were already built, two more will be built in the catchment of the Schöckelbach until end of 2012); Schöckelbach: River bed widening, linear measurement; 2 detention basins planned; Program “Streams of Graz”, which includes structural measurements for most of the streams in Graz, also for those in the case study area from 2006 - 2015	Malter dam (1908-1913), Klingenberg dam (1908-1914), Lehnmühle dam (1926-1931), Altenberg dam (1988-1992); creation of a new river bed in Dresden in 1893, river widening and deepening of river bed, heightening of river bank walls, construction of new bridges with wider open cross section (mainly after 2002)
structural, mobile	barriers and other elements used by inhabitants to avoid flooding in the ground floor	barriers used by inhabitants to protect their households and chains used to tied cars at trees and prevent them from floating away	inhabitants: sand bags and to some extent barriers and other elements to protect their households; professional and auxiliary fire brigade: sand bags, big-bag-system to heighten river banks, tubing systems	big-bag-system to heighten river banks and prevent flooding of railways and main station
non structural	city is not included in flooding maps and emergency action plan (flood risk due to pluvial flooding is more relevant than river flooding)	flood plan of Catalonia (2002): identify flood prone areas, design of guidelines in case of emergency, responsible entities, functions, re-sponsibilities of action forces annual modifications	flood maps, risk communication with: flyer, website, open councils, open discussions, information events; SMS-information, land developing plan	flood maps, warning system, emergency action plan

An evaluation of the benefit of existing early warning systems in the SUFRI case study areas is still not possible. Only general estimations of quantitative economic benefit by means of the possible amount of damage are available (Table 7).

Table 7: Overview SUFRI case studies: economic benefit

case study	Benaguasil	Arenys de Mar/Munt	Graz	Dresden
qualitative economic benefit	Damage reduction by private measures is obvious but not accountable	Possible economic loss differs during the course of the year because tourist industry has their prime time between June and September	---	---
quantitative economic benefit	---	potential damage (industry) T = 50 y: 16.52 million EUR T = 100 y: 28.23 million EUR T = 500 y: 63.81 million EUR	---	Potential damage (only private households) FLEMOps/MEDIS Q = 400 m³/s: 68.92 million EUR Q = 600 m³/s: 98.80 million EUR

5.2.3 Experiences, examples of use

A warning system provides the information about flood arrival and peak water level necessary for flood damage mitigation and rescue measures by fire brigades, private persons and companies. There are many warning systems in operation but only few are applied on small and urban catchment areas.
The review of warning systems and documentation of operation experiences is often triggered by extreme flood events. Two examples are the reports after the extreme flood event in Saxony in 2002 (Kirchbach 2002) and the flood at the Neiße River in 2010 (Jeschke et al. 2010). These reports were initiated by the federal states government and tried to evaluate the flood management actions and warning message distribution during the flood event in more than one community and more than one river catchment. Major improvement within the flood warning system were established for instance after the 2002 flood event.
Experiences with floods which occurred only in a small catchment area and perhaps affected only one community might be evaluate too but this process is often internal and reports are often not published.

Table 8: Overview SUFRI case studies: Experiences with the today warning system

case study	Benaguasil	Arenys de Mar/Munt	Graz	Dresden
improvements	---	continuously	continuously	major improvements in 2002/ 2003, after than continuously
experiences/ problems	---	system does not satisfy the needs of the entities due to false alarm	system does not satisfy the needs of the population due to false alarm	decreasing confi-dence in the system due to false alarm

Automatic warning systems considering rockslides or landslides are in operation lately but operational experiences are still not available.
False alert are a serious problem in flood warning systems. The confidence of the inhabitants might decrease and future flood alerts might not take as serious as needed. All three alarm systems in the SUFRI case study areas Arenys de Mar, Spain, Graz, Austria and Dresden, Germany confirm this problem (see Table 8).
As intended by EU Flood directive and due to the great number of flood events all over in Europe the improvement process regarding flood warnings systems has become more continuous in the last two decades and should go on.

5.2.4 Problems and requirements

Flood warning systems for small catchment areas in urban areas have to deal with
- uncertain information about upcoming extreme rainfall events
- short forecast lead times
- multiple damage inducing processes
- uncertain information about on-going flood events
- many concerned but not necessarily affected people

The prediction of rainfall in small catchment areas is not exact today. Small catchment areas are often prone against convective rainfall events which are smaller than spatial resolution of today operational national weather models. Measurement data of rainfall are only local (weather stations) or only qualitative (radar data). Transformation in quantitative areal data needs time and errors can occur.
Flood forecast models including rainfall-runoff-calculation are more common in middle and large catchment areas due to inaccuracy of calculation results. Rainfall-runoff-models for small catchment areas are still a topic of scientific projects.

A general problem of these empirical models is to calibrate the parameter set which is necessary to convert the rainfall volume into the runoff volume. It was often observed that a calibrated parameter set for smaller flood events does not cover extreme flood events and vice versa. Therefor we need different parameter sets which have to be applied automatically regarding actual input data like rainfall intensity.
The numerical method of ensemble forecasting is in discussion regarding uncertain input data but this method does not solve the problem it only transports the uncertainty to the entities responsible in flood management. Responsible stuff needs a preparatory training to understand the meaning of the calculation results.

A flood forecast with a longer forecast lead time is very uncertain and following measures may be inappropriate whereas a more certain flood forecast can only be provided a very short time or eventually too short time span before the flood will arrive and it might be too late for rescue actions or evacuations.
Because reliable information about upcoming flood events in small catchment areas is available, not until the flood is almost coming it is very important to have than a very fast warning message distribution. Short warning dissemination chains are important for quick warning and give the inhabitants the vital time needed for their own flood protection measures or rescue actions. All entities which are responsible in flood management have to be informed at the same time to reduce a loss of time due to a long information path.

Historical flood events have shown that it is very difficult to take proper measures if there is information about an impending flood from different entities responsible for flood forecast at different administrative levels. Warning messages may differ and a mayor or the inhabitants do not know which information is correct.

Automatic warning message dissemination is not common in flood warning systems. The warning chain is often discontinuous in order to check the measurement results of river discharge gauges or to validate the results of flood-forecast-models. Automatic flood warning systems are today research topics or in planning stage. Here linking between the forecasted rainfall and the flood induced damage is very complex.
Beside a river bed flood water can travel along many different paths in an urban area like streets, the sewer system or railroads. Furthermore different areas like housing areas, industrial areas, parks or recreational areas may be affected. Hazards and damages could be caused by flooding, accumulation of debris, erosion or landslides. In industrial zones flooding or other processes may cause subsequent accidents and disasters combined with emission of toxic substances into the air or water. In these cases a special network of sensors could help to monitor the toxics. A complete overview of all processes together with an analysis of different flood scenarios can improve flood management plans.

The analysis of historical flood events have shown that the inhabitants often felt a lack of knowledge what was going on and what had they to do. The responsible entities have to analyse the message distribution paths focussing on message reception. Many problems can occur during a flood event preventing the reception of warning messages - power supply may fail, mobile networks may be overloaded or there is no radio or TV available. And of course Information about the actual situation (e.g. water level information) has to be available for the affected as well as for the concerned inhabitants.

Information in flood warning messages and in public information platforms or flood maps is often not consistent. Questions and problems of understanding may occur when the inhabitants or fire brigades get information about a certain alarm stage which will be reached at a river gauge and the look at the corresponding flood map shows only flood plains considering flood events with certain reoccurrence periods (10-years-flood, 100-years-flood).

5.2.5 Conclusion and recommendation

Comparative studies showed that a flood warning system is one of non-structural measures with best cost-benefit-ratio. But in small catchment areas forecast lead time is very short and appropriate actions in case of emergency are difficult. That's why structural measures are necessary, too.

Accuracy of weather forecast was improved over the last decades but there are still problems regarding small catchment areas and convective events. Better models, higher spatial resolution and faster computers will provide improvements in the next years as well but it is a slow and long process. Rainfall-runoff-models for small catchment areas are still a topic of scientific projects. Flood forecast in small catchment areas should consider simpler black box models to deal with uncertain rainfall prediction and short forecast lead time. Rainfall data in small catchment areas with no or too few rainfall gauges can be improved by installation of additional rainfall gauges.

We can learn from automatic warning systems in case of accidents and disasters involving hazardous material or considering rockslides or landslides that an automatic warning system in small (catchment) areas should be highly equipped with different types of sensors to obtain valid data and to provide the opportunity to check released warning messages. In addition local observers and redundant observation and/or measurement systems can help to compensate for the general lack of knowledge. Self-learning systems and an operation test phase are important because the system has to “learn” which situation would create a hazard.

It is also recommended to install additional river gauges at smaller rivers to get better discharge data. Flood warning gauges should be flood resilient that they can withstand and measure extreme flood events too. It has to be assured that all data transmission to and from the flood centre is redundant.

Considering all these aspects of weather and flood forecast in small catchment areas early warning systems today can benefit more by establishing short communication and information paths and a tailor-made set of rescue actions and measures.

The communication system has to assure that all affected inhabitants can receive and understand a warning message as well as that the concerned inhabitants can get information about the actual situation.

Multiple information distribution paths (acoustic devices, TV, radio, Internet) assure that affected as well as concerned inhabitants get all needed information if available. Sirens, diaphones or loudspeakers are cost efficient methods to disseminate warning messages to a local limited set of affected people even if they have no access to public media like TV, radio or internet. In case of flood people must know what the signal means and what measures are required. To provide more information sirens which can disseminate voice messages too or megaphones are helpful. It is noticeable that the acoustic reach of megaphones is smaller than of diaphones.

Flood warning messages should be clear, simple, understandable and without subjunctives. In case of emergency they can include requests to inform and help neighbors and to get more information about the actual situation.

Additional information (information about proper behaviour and measures to mitigate flood damage to personnel property, evacuation and development of situation) should be provided by community helpline, TV, radio and the World Wide Web. Light signals or traffic signs are necessary to block roads or close other public places. But information in flood warning messages and in public information platforms or flood maps has to be consistent.

Centralised institutions like flood centres can provide the needed expert knowledge and should be responsible for centralised data collection, running of forecast models and warning messages distribution to all affected entities at the same time. They should be established on national scale in smaller countries or on scale of federal states, regions or wider catchment areas in larger countries. In Figure 34 an example of an advanced flood forecast and warning distribution system is shown with short information paths and simultaneously warning distribution to local administration, responsible fire brigades or other rescue workers and inhabitants.

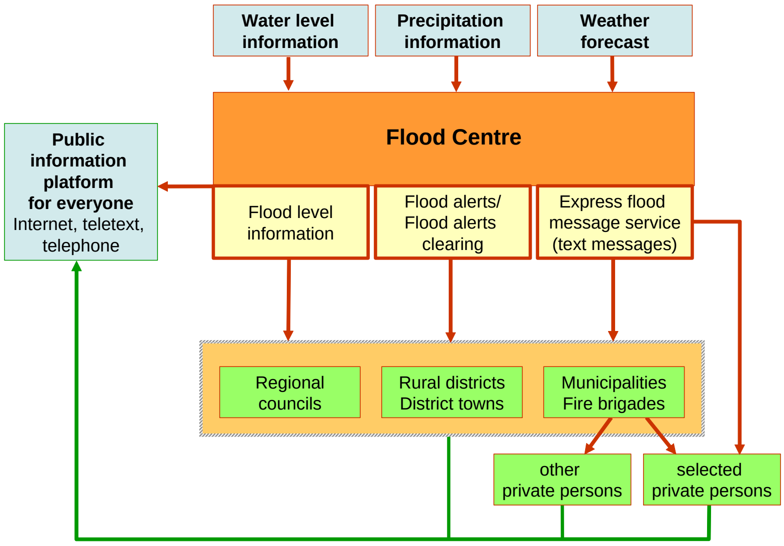


Figure 34: Example for a central organized flood forecast and warning dissemination system with short distribution paths

The response system (notification, decision, actions and measures) which is the other part of a warning system should be centralised too but on a lower administration level. Only one entity should be responsible for flood management in a city, town or a rural district. Because there are many synergies between flood management and general disaster management fire brigades should have prior responsibility in flood protection. Nevertheless personnel measures of inhabitants and company stuff considering their private and business property are important to mitigate flood damage.

Hazard maps, risk maps or inundation maps are important for exact action planning in case of flood. Flood management plans together with decision support systems and appropriate maps provide information to take quick and adequate measures. Operational forces need information about the area affected, required measures as well as lists with affected people and companies, hospitals, senior residents, schools and others. Management plans and flood maps should contain information about often as well as seldom and extreme flood events to cover all possibilities.

And at last the review of warning systems and documentation of operation experiences was often only triggered by extreme flood events. As intended by EU Flood directive and due to the great number of flood events all over in Europe this improvement process has become more continuous in the last two decades and should go on.

5.3 Residual Risk and Vulnerability Analysis

Specific Outcomes

- Tool to support flood risk evaluation in urban areas, applicable to inform authorities, local entities and stakeholders on decision-making for establishment of strategies for risk reduction
- F-N and F-D curves to represent risk results (societal and economic flood risk), useful for defining tolerability criteria for flood risk
- Evaluation method of the effects of several flood protection measures
- Applicable for different levels of information: from basic evaluations on flood risk to highly detailed estimations
- Case study examples

Lessons Learned

- Risk evaluations from low level of information require assumptions → more conservative because uncertainty in results is high (particularly in the number of people exposed to a flood and hydraulic characteristics)
- In case examples, economic risk has more significance than societal risk. However, there is no doubt that public education and warning systems have an effect on risk reduction.

5.3.1 Overall study

The overall study includes general information about flooding risk, structural and non-structural measures for risk reduction and tools for risk estimation.

Structural measures

Structural measures for flood risk reduction are all measures that involve construction of civil works to protect areas against floods. Strategies can vary widely depending on the situation. In general, they can be divided into three groups:

- Retention structures: Their mission is to retain flood water in order to avoid floods with high discharges, which can produce important damages and the failure of protection structures. The most common retention structures are dams and ponds upstream urban areas.
- Protection structures: These structures protect directly urban areas from water, avoiding it to enter inside the city, like dikes, or forcing it to flow faster through the city inside a delimited protected bank, like embankments. These structures provide protection from river floods and also from maritime floods, like maritime dikes.
- Drainage systems: Drainage systems are designed to manage runoff generated in the urban area and their surroundings.

In addition, structures must be designed taking into account the natural river dynamics, understanding its changing nature. Ideally, they must be designed allowing as much as possible the natural behaviour of the river (Ureña & Teixeira 2004).
Structural measures have a really high importance on flood reduction, as they avoid numerous floods

Non-structural measures

Non-structural measures for flood risk reduction do not involve construction of civil works. They refer to policies, awareness, knowledge development, public commitment and methods and operating practices, including participatory mechanisms and the provision of information (Graham 1999).
Structural measures are usually designed for a hypothetic severe event, with a probability of exceedance, related to the failure of the structure. However, non-structural measures can also reduce significantly flood consequences.

There are several groups and classifications of non-structural measures. Based on the classification given in Escuder-Bueno et al. 2010 (Full SUFRI Methodology report), they have been divided into six general groups.

- Urban planning and policies
- Flood forecasting
- Communication
- Mobilization
- Coordination and operating practices
- Insurance and aids mechanisms

Non-structural measures are efficient and sustainable methods of reducing flood risk, but there will be some residual flood risk, whose value depends on the reliability and functionality of these measures:

- Functionality defines the maximum reduction on consequences due to their limitations. In some cases, warning systems or evacuation procedures do not achieve to move all people at risk.
- Reliability defines the possibility of a failure on its structure or procedures. For example, there might be an error in the warning system or a failure in flood pre-characterization models.

Tools for risk estimation

Risk is commonly expressed by the notation Risk = Hazards x Vulnerability. Tools for flood risk estimation can be divided in partial, if they only evaluate either hazard or vulnerability, or complete, if they evaluate both components. Additionally, they can be classified depending on whether they provide or not a numerical value for the risk (quantitative or qualitative).
Consequently, tools for risk estimation can be classified in four categories:

- Partial and qualitative: based on the knowledge of the reality and historical flood events (i.e. tools for estimating environmental and cultural losses – ACA 2009).
- Complete and qualitative: these methods estimate both risk components by combining qualitative methods to obtain flood components separately (i.e. risk maps).
- Partial and quantitative: these tools compute numerically one of the risk components: probability of occurrence (i.e. flood hazard maps) or consequences. Tools which compute only flood consequences may be useful to make a first approximation to the consequences of a severe flood. However, more sophisticated methodologies include shelter, warning and evacuation procedures, such as the LIFESim model (ANCOLD 2003).
- Complete and quantitative: these tools obtain a numerical value of both risk components. F-N curves are an example of these tools. These curves represent the relation between the probability of occurrence of a hazard and the number of victims.

Examples of each category are described in Escuder et al. 2011 (Full SUFRI Methodology report).

5.3.2 Methodology for pluvial and river flooding risk assessment in urban areas

A methodology for pluvial and river flooding risk assessment in urban areas has been developed. The methodology provides a tool to support flood risk evaluation in urban areas and it can be applied to inform authorities, local entities and stakeholders on decision-making to establish strategies for risk reduction.
F-N and F-D curves show the societal and economic flood risk, respectively, in an understandable way, as they are useful to evaluate the effect of the several measures on it. Although these curves do not indicate the flood risk distribution in an area, they can be very useful for defining tolerability criteria for flood risk. These curves are the basis to illustrate risk quantification and the effect of different measures on flood risk reduction, thus providing a guide for planning and managing.
Therefore, risk model results and F-N curves from the established alternatives (base-case, non-structural measures, etc.) can provide information in terms of flood risk to assist the following applications:

- Preliminary evaluations on flood risk.
- Management of flood defences and appraisal of new flood defence schemes.
- Flood hazard and risk mapping.
- Flood warning and emergency planning.
- Identification of high-risk areas to prioritise flood warning and emergency response.
- Flood awareness campaigns.
- Flood Defence regulation, design and development control.
- Spatial planning.
- Urban planning.
- Flood plans for reservoirs.
- Information for ongoing and new research projects.
- Public education plans.
- Etc.

SUFRI methodology is based on the identification of all the important factors that influence risk quantification: sources of flood risk (river, heavy rainfall, defense failure, inefficient drainage system, etc.), vulnerability of the study area, etc.
The use of F-N curves enables the comparison of the current situation of the urban area with other situations from the consideration of non-structural measures.

Also, it should be emphasized that this method considers the study of total risk evaluation (from the analysis of flood scenarios in case of flood defense failure and non-failures) differing from risk evaluation on dam and levee safety, where typically incremental risk is analysed (from the difference between damages due to the dam or levee failure and the situation with non-failure).

Uncertainty on the results will depend on available data and the level of detail of hydrologic and hydraulic models or calculations. However, SUFRI methodology provides a scheme that can be applied for different levels of information: from basic evaluations on flood risk to highly detailed estimations.

In addition, it should be emphasized that risk evaluations from low levels of information require assumptions and should be more conservative. Consequently, uncertainty in the results is high, particularly in the number of people who will be exposed to a flood and hydraulic characteristics of the flood event. However, it should be kept in mind that people can be very resilient during floods and the number of deaths is often less than expected.

5.3.3 Applied fields – Benaguasil / Spain

In this section the analysis of flood risk in case of pluvial flooding for the case study of Benaguasil is described.

Flood risk in Benaguasil is mainly due to pluvial flooding. The main cause of the development of flood events and flood propagation in Benaguasil is the incapacity of the drainage system. When heavy storms take place with precipitation rates higher than 20 mm in a few minutes, the drainage system reaches its maximum capacity and runoff flows along several streets reaching high water levels, flooding garages, ground floors, houses and roads.
The inability of the drainage system is the most important problem with regard to structural measures to reduce the flood risk of this town. It produces flooding of basements and ground floors of many houses every year and, consequently, important economic damages. Furthermore, new impermeable areas have been connected directly to the drainage system, without taking into account its problems. Consequently, flooding problems have increased in the last years.

Scope of the work

The scope of this analysis is focused on the study of the current situation of Benaguasil in case of pluvial flooding and the effect of non-structural measures regarding a public education program on flood risk and the existence of a warning system.
Data related to demography, building typologies, land uses, drainage system, hydrological studies, economic rates, etc. has been collected to characterize the urban area and obtain input data for the risk model that will be used to calculate flood risk in the two established study scenarios.
This section describes the main characteristics of this case study. Further information is included and listed within the description of each study scenario.

Demography

Population in Benaguasil is estimated in 11,144 inhabitants (2010), with a distribution of 5,739 men and 5,405 women. Data of daily and seasonal variability of population in Benaguasil shows that the number of inhabitants increases around 2,500 people in summer, and 2,000 people leave the urban area during the day and move to the agricultural zone due to working reasons. Consequently, four time categories are set as it is listed in Table 9.

Table 9: Time categories.

Time category ID	Category	Density (inhabitants/km²)
TC1	Summer / day	10,457
TC2	Summer / night	12,253
TC3	Winter / day	8,212
TC4	Winter / day	10,008

Each time category is related to a number of people at the urban area. These values are shown in Table 10.

Table 10: Population at the study site.

Time category ID	Category	Population (inhabitants)
TC1	Summer / day	11,644
TC2	Summer / night	13,644
TC3	Winter / day	9,144
TC4	Winter / day	11,144

Building typology

Benaguasil is mainly composed of one-family houses and multifamily buildings of concrete ranging from 2 to 4 floors. Building height is quite constant in the entire city. As there is no detailed information about the construction materials of each building, the following mean values are used:

-Average number of floors per building: 1.8 floors/building

-Average building height: 1.8 x 3.5 = 6.3 m (height of one floor = 3.5 m)

-Average number of households per building: 1.5 households/building

Table 11 shows the total number of households, buildings and business in Benaguasil.

Table 11: Households in Benaguasil.

Building typology - Benaguasil	
Average number of floors	1.8
Number of buildings	3,014
Number of households	4,529
Number of business	415

Land uses and economic rates

The total surface of the urban area of Benaguasil is 2.8 km², with a density of 433.57 habitants/km². The whole area which belongs to the municipality of Benaguasil reaches a surface of 25.4 km².

Benaguasil is mainly distributed in residential zones with households and local businesses. Also, there are two main industrial areas, one located at the South and one at the North-East of the town. The rest of the municipal area is divided into small agricultural plots.

Direct costs have been estimated based on reference costs, CR, for each land use category, given by the following equation and economic rates in PATRICOVA (COPUT 2002) for five different land uses categories (CU), where:

CR = {Rate} · {82 €/m²} · {IPC variation (2011/2002)}

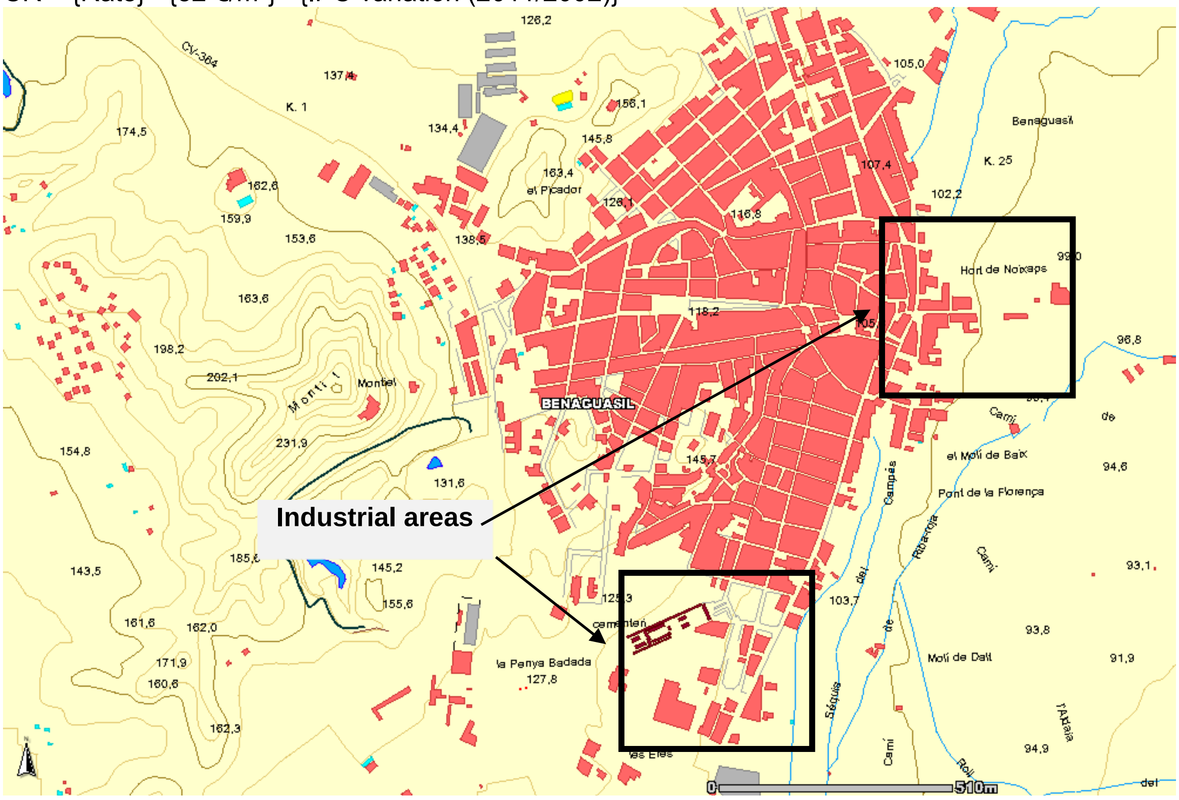


Figure 35: Industrial areas in Benaguasil

- CU1: Residential (Medium density – High magnitude: Rate=56.3/100)
- CU2: Industrial (Medium density – High magnitude: Rate=16.9/100)
- CU3: Residential, without households. It is assumed that the economic value of this type of area is equivalent to a percentage of 5% based on the value of high density residential areas (CU1).
- CU4: Green areas and agricultural uses (Irrigated crops: Rate=0.34/100)
- CU5: Others

The reference cost for each land use category is listed in Table 12.

Table 12: Land uses and reference costs

Land use category	Type	ID	Total Area (m²)	Reference cost (€/m²)
CU1	Residential	CR1	1,113,538	55.5
CU2	Industrial	CR2	84,906	16.7
CU3	Urban area	CR3	91,625	2.78
CU4	Green area	CR4	154,407	0.3
CU5	Other	CR5	423,646	0.3

Hydrology

The series of flood scenarios ranges from 2 to 100 years. Seven flood scenarios are defined (2, 5, 10, 15, 25, 50 and 100 years). The maximum daily rainfall rates were obtained for each return period. Table 13 lists the annual probability of exceedance of each flood scenario and the related maximum daily rainfall rate. These rates are coherent if values are compared with results established by CEDEX (Spanish Public Institution for Experimental Research) as it is shown in Figure 36.

Table 13: Maximum daily rainfall rates

Flood scenario	Return period (years)	AEP (1/years)	P_d (mm)
T1	2	0.5	53
T2	5	0.2	79
T3	10	0.1	98
T4	15	0.067	110
T5	25	0.04	125
T6	50	0.02	146
T7	100	0.01	170

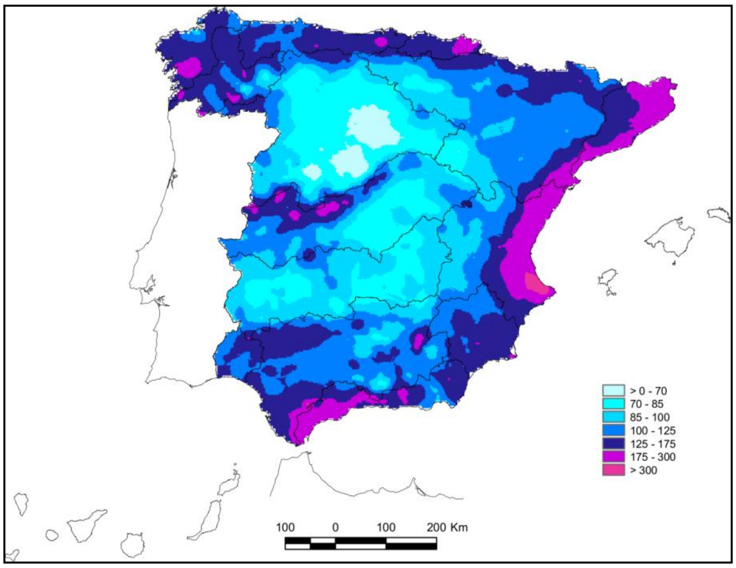


Figure 36: Map. Maximum daily rainfall rates in Spain for a return period of 100 years (CEDEX)

The urban area of Benaguasil is divided into six catchment areas (from BNG1 to BNG6). As an example, Figure 37 shows the location of all catchment areas.

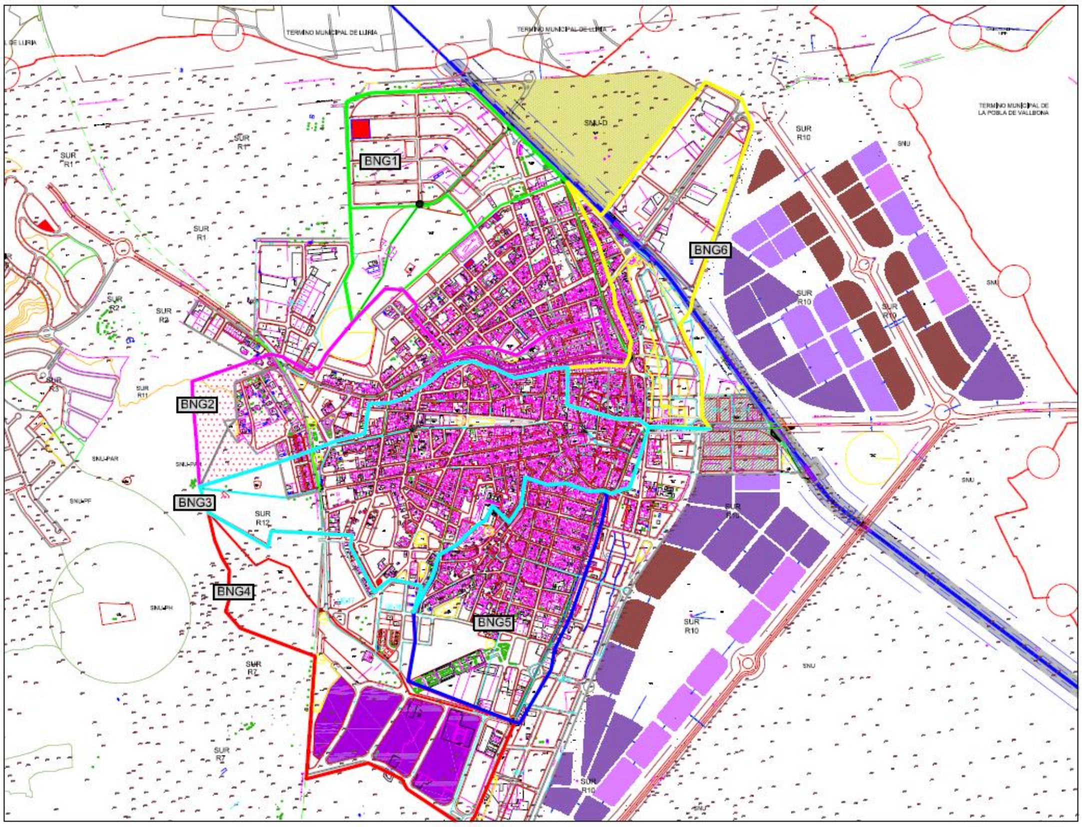


Figure 37: Map: Urban catchments

However, eight different sub-areas are defined for calculations. These areas are denoted by BNG1, BNG2, BNG126, BNG3, BNG4, BNG45, BNG345 and BNG0. In four cases, the defined area is equivalent to a catchment area (and it is denoted by a number, for example, BNG1). Four of these areas are the resulting zones downstream the intersection of two or more catchments areas (for example, BNG126 corresponds with the zone located downstream three catchment areas: 1, 2 and 6).

Each sub-area is divided into three categories and denoted by three suffixes: first, suffix A denotes areas which are located outside the city centre or rural areas (i.e. 1A is the rural area within BNG1); second, B1 denotes low density residential areas and B2 belongs to high density residential areas. These categories have been used for estimating different runoff coefficients.

Additionally, two zones are identified for each sub-area, Af and Af1, which represent a preliminary perimeter of the potential flooded areas in two cases: floods with water depths lower or higher than 0.15 m, respectively. These perimeters have been used to estimate affected areas.

Figure 38 shows a simplified scheme of the defined sub-areas in Benaguasil.

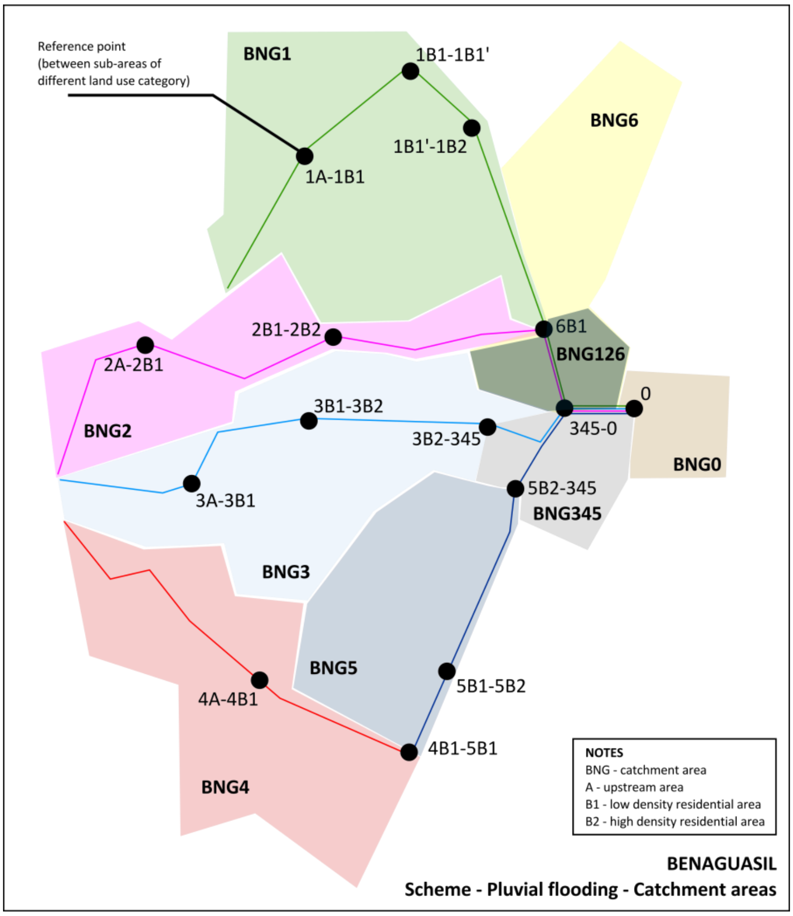


Figure 38: Scheme: BNG areas

Table 14 lists some characteristics of each sub-area. The second column includes the upstream areas that are included for the analysis of the runoff rates in each sub-area (ID). Next, the surface of each catchment area is presented. The last three columns represent characteristics of the main water path in each sub-area: length, width and slope.

Table 14: Characteristics of each sub-area

ID Sub-area	Catchment area	Surface (m^2)	Length (m)	Width b (m)	Slope (m/m)
BNG1	BNG1	423,932	1,482	10.00	0.008
BNG2	BNG2	233,496	1,505	6.00	0.028
BNG126	BNG1+BNG2+BNG6	769,360	1,902	8.00	0.001
BNG4	BNG4	323,195	1,112	12.00	0.072
BNG45	BNG4+BNG5	559,089	1,813	12.00	0.004
BNG3	BNG3	396,014	1,207	10.00	0.038
BNG345	BNG3+BNG4+BNG5	955,103	2,228	8.00	0.008
BNG0	ALL AREAS	1,659,622	2,228	10.00	0.026

Runoff rates have been obtained for each flood scenario and area. The Rational Method (Temez, 1992) is used to estimate runoff rates in Benaguasil.
Three different runoff thresholds are defined according to three categories of land typology: agricultural zones, low and high density urban areas. These values are 23, 8 and 5 mm, respectively, and they have been defined with the aim of obtaining runoff coefficients about 0.40, 0.75 and 0.85, for a return period around 10 years. These values are also in the range given by CEDEX. Figure 39 shows that Benaguasil belongs to the interval 15-30 mm (CEDEX, 2011).

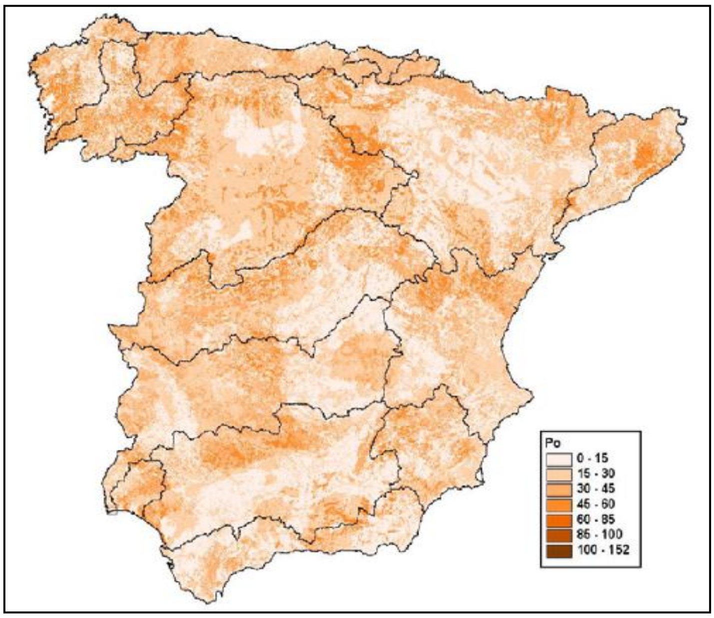


Figure 39: Runoff threshold ranges in Spain (CEDEX)

As a result, three series of runoff coefficients, C, are obtained by using the following equation:

$$C = \frac{(\frac{P_d}{P_O} - 1) \cdot (\frac{P_d}{P_O} + 23)}{(\frac{P_d}{P_O} + 11)^2}$$

where Pd is the maximum daily rainfall rate for each flood scenario and Po is the runoff threshold. Table 15 shows all values of the runoff coefficient, C.

Table 15: Runoff coefficients.

	Return period, T (years)						
	2	5	10	15	25	50	100
Po (mm)	23	Upstream areas					
C	0.19	0.31	0.38	0.42	0.47	0.52	0.57
Po (mm)	8	Low density residential areas					
C	0.54	0.67	0.73	0.76	0.80	0.83	0.86
Po (mm)	5	High density residential areas					
C	0.69	0.80	0.85	0.87	0.89	0.91	0.93

Once all necessary parameters of the Rational Method are obtained, runoff rates are estimated based on the following equation, widely applied to obtain maximum rainfall intensity rates in Spain:

$$\frac{I}{I_d} = \frac{I_1}{I_d}^{\frac{28^{0.1}-D^{0.1}}{28^{0.1}-1}}$$

where I_d is the average daily rainfall intensity (mm/h), I is the rainfall intensity (mm/h) for a rainfall event with an effective duration of D hours, D is the rainfall event duration and it is assumed to be equal to the concentration time (tc), I_1 is the hourly intensity, and the ratio I_1/I_d is the relation between hourly and average intensity rates, depending on the geographic area.
The I_1/I_d ratio was obtained by Temez in 1990 and it is equal to 11.4 in the study region (Figure 40: Map. Coefficient I1/Id (MOPU)).

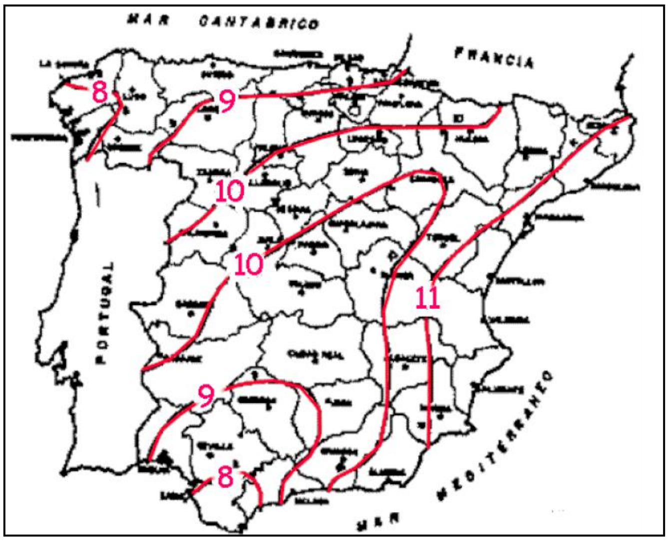


Figure 40: Map. Coefficient I_1/I_d (MOPU)

Regarding the hourly rainfall rates, values of I_d are obtained as $P_d/24$ for each flood scenario.
With reference to the rainfall duration, D is set as the value of time concentration, t_c (min), which can be obtained by two different equations, depending on the catchment. In rural areas, the time of concentration is given by:

$$t_c = \frac{0.30}{60} \cdot \left(\frac{L}{J^{0.25}} \right)^{\wedge 0.76}$$

where L is the length of the main waterpath (km) and J is the average slope (m/m).

For underground drainage systems within urban areas, the value is commonly obtained as follows:

$$t_c = t_0 + \frac{1.2}{60} \cdot \sum_{i=1}^{n} \frac{L_i}{v_i}$$

where L is the length of each pipe (m), v is the velocity inside the pipe if it is considered that water reaches the 100% of its capacity, and t_o is the time required to cross the distance between the furthest point within the catchment area and the first pipe.
In Benaguasil, different typologies of sub-areas within BNG1, BNG2, etc. have been identified, according with the urban development (rural, low density or high density zones). Thus, t_c is established as the combination of the two aforementioned equations:

$$t_c = 0.30 \cdot \left(\frac{L}{J^{0.25}} \right)^{\wedge 0.76} + \frac{1.2}{60} \cdot \sum_{i=1}^{n} \frac{L_i}{v_i}$$

Finally, the last step relies on estimating runoff rates by means of the following formula:

$$Q = \frac{k \cdot C \cdot I \cdot A}{3.6}$$

where k is a coefficient which varies depending on the geographical location of the urban area (Figure 41) and it corrects the runoff coefficient value (in this case, it is equal to 2.2), C is the runoff coefficient, I is the maximum rainfall intensity (mm/h), and A is the catchment area (km²). Due to the existence of different zones in each area, the previous equation is used for each flood scenario as follows:

$$Q = \frac{k \cdot I \cdot}{3.6} \sum_{i=1}^{n} C_i \cdot A_i$$

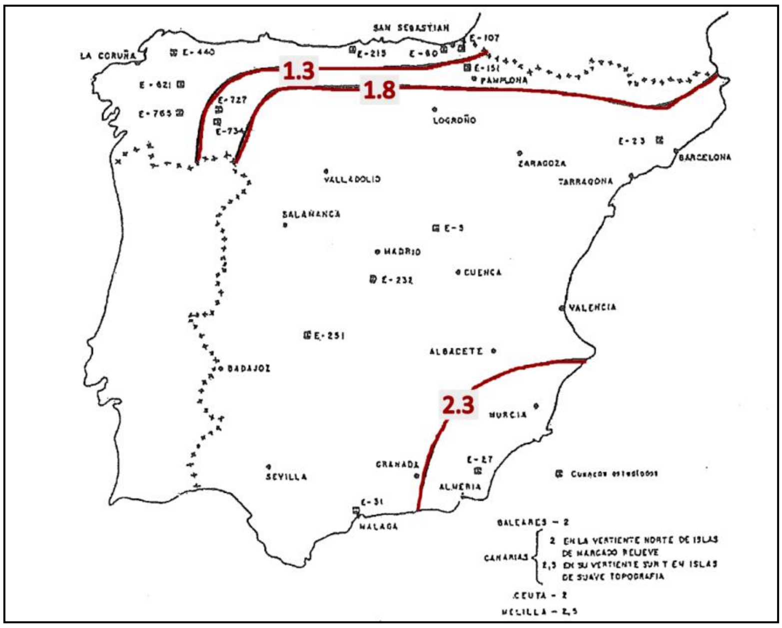


Figure 41: Map: Coefficient k (CEDEX, 1994)

Drainage system

The existing network is shown in Figure 42.

Figure 42: Map. Drainage system

After analysing the drainage system of Benaguasil and past flood events, it is assumed that the existing capacity of the network cannot manage the runoff flows that result from rainfall events with a return period of 2 years or higher.
For that reason, the first flood scenario (return period: 2 years) will produce runoff in the city.

Input data for the risk model

As it is recommended in the SUFRI methodology, the third phase of the process (Phase III: Definition of the Base-case) is focused on the analysis of the current situation of the urban area. Consequently, the analysis of the Base-case is developed before evaluating the effect of non-structural measures. A second case scenario with non-structural measures is evaluated after the analysis of the Base-case.

Base-case

After data collection and review, four time categories and seven flood scenarios have been defined.
Figure 43 shows the overall scheme to estimate data for the risk model.

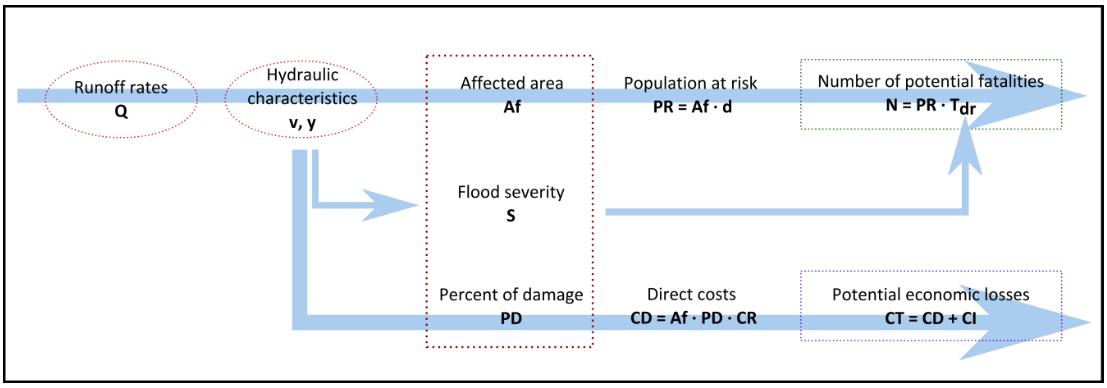


Figure 43: Overall scheme of the process for obtaining input data for the risk model.

Runoff rates

Runoff thresholds are estimated for three different categories: upstream areas, low and high density residential areas. Thus, different runoff coefficients are obtained for each sub-area and flood scenario (return period).

Estimations of runoff rates have been developed using the Rational Method.

Runoff flows due to rainfall events related to return periods higher than 2 years cannot be managed by the current drainage system of Benaguasil. Consequently, water flows through the streets. Thus, hydraulic characteristics of the flood have been obtained by considering width and slope of streets. The main path in each sub-area is identified and water depths and velocities are obtained based on this approach. A deeper estimation of the hydraulic characteristics will require detailed models which are not available. The main objective is providing simplified results for the risk model to analyze the situation with available information.

Table 16 includes the established values to calculate hydraulic characteristics of the flood. The ratio between the runoff flow and the average width of the streets in each sub-area (Q/b) is used to obtain velocities and water depths in each sub-area and flood scenario.

Table 16: Width and slope of main paths in each sub-area and Q/b (m²/s) rates for each flood scenario.

ID	Width (m)	Slope (m/m)	T1	T2	T3	T4	T5	T6	T7
BNG1	10.00	0.008	0.64	1.16	1.56	1.82	2.15	2.62	3.15
BNG2	6.00	0.028	0.51	0.98	1.37	1.62	1.95	2.41	2.96
BNG126	8.00	0.001	1.16	2.12	2.87	3.36	3.97	4.84	5.84
BNG4	12.00	0.072	0.28	0.56	0.79	0.94	1.14	1.43	1.77
BNG45	12.00	0.004	0.52	0.97	1.33	1.57	1.87	2.29	2.78
BNG3	10.00	0.038	0.74	1.33	1.79	2.09	2.46	2.99	3.60
BNG345	8.00	0.008	1.37	2.52	3.42	4.00	4.74	5.79	7.00
BNG0	10.00	0.026	1.99	3.66	4.97	5.81	6.89	8.41	10.18

Flooded areas

Two steps are distinguished to estimate affected areas: first, two zones are identified for each sub-area, Af and Af1. These two zones are the potential flooded areas for water depths lower or higher than 0.15 m, respectively. This threshold has been established to determine two different situations: low water depths that flow through the main street and floods with high water depths that may reach adjacent streets and more households as water exceed the level of kerbs at streets (in general, 0.15 m high). Af' denotes areas with no households that are not used for estimating loss of life but considered for estimating economic damages (these areas are classified as land use category CU3).

Based on topographical data and geometry of each street, both perimeters have been estimated and all streets potentially affected by the flood are identified. Length and width of each flooded stretch are calculated.
Figure 44 shows the scheme which has been identified to obtain flooded areas in BNG1 (first sub-area of Benaguasil). Af and Af1 denote preliminary perimeters used for calculations and lower-case letters denote each stretch that has been considered to estimate the total flooded area in BNG1. In this particular case, 'a' has been used to estimate affected area for low water depths and the whole set shown in includes the flooded area if water depths are higher than 0.15 m. In BNG1, all areas are classified as CU1 and, consequently, no areas denoted as Af' are included in Figure 44.

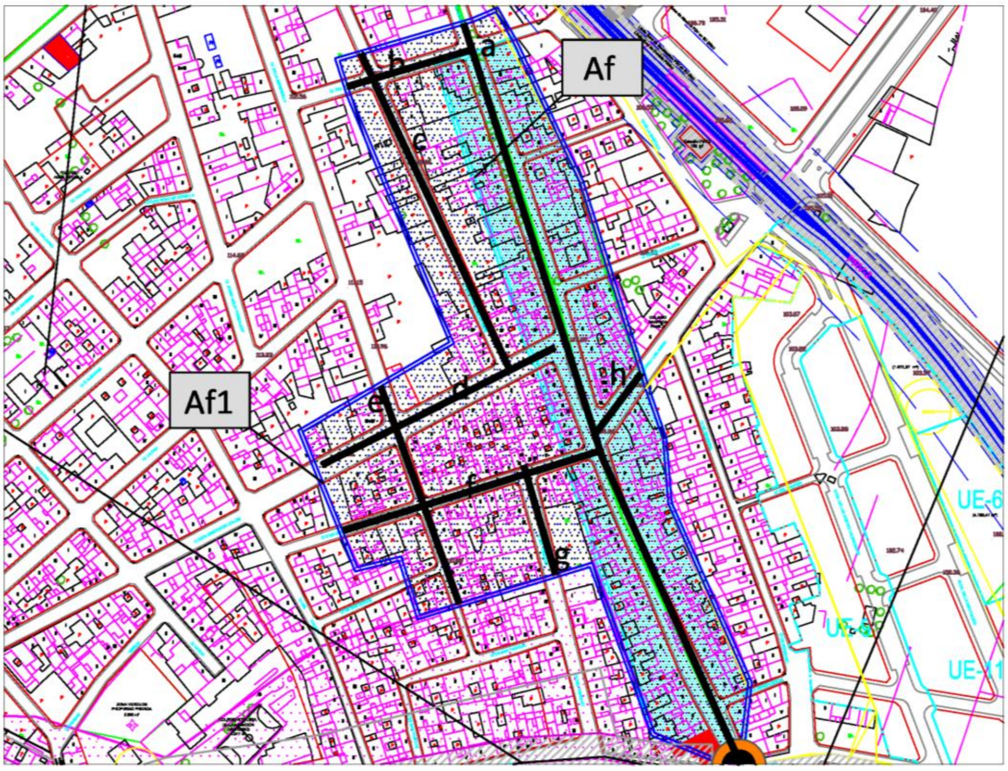


Figure 44: Scheme used for estimating flooded areas in sub-area BNG1

Characteristics of the flood
Hydraulic characteristics of all flood scenarios have been obtained based on the runoff rates described in the previous section and the urban characteristics of Benaguasil (slope, width of the streets, etc.).
Hydraulic characteristics of each flood scenario have been used to estimate three main parameters: affected areas, flood severity levels and percentage of damages in assets.
Flood severity categories in each area and flood scenario are established based on the SUFRI methodology and the classification of five flood severity levels established for pluvial flooding, shown in Figure 45.

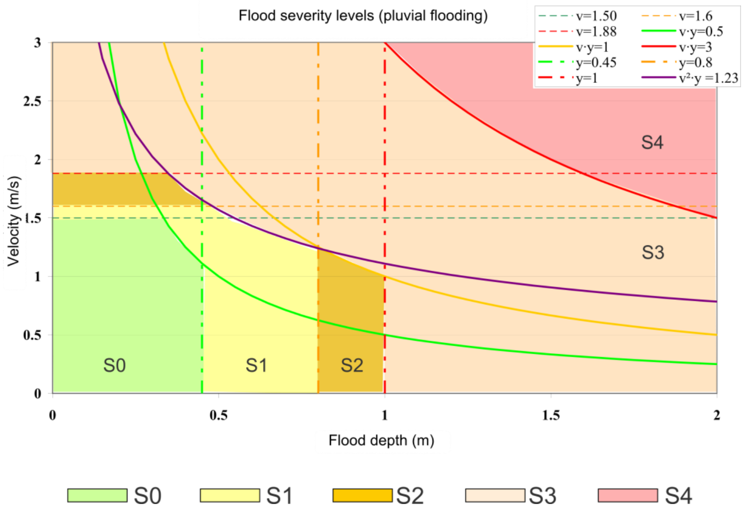


Figure 45: Classification of flood severity levels (SUFRI methodology)

Finally, percentage of damages is estimated by a depth-damage curve which relates water depth to a certain level of damages (see Figure 46).

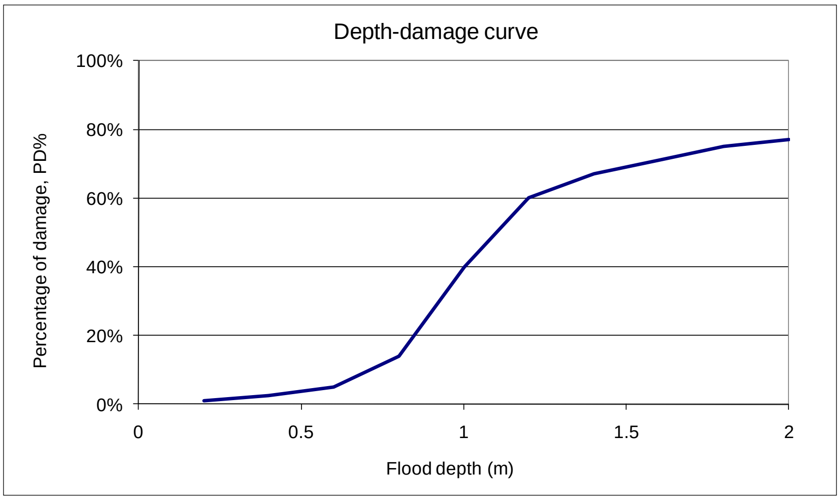


Figure 46: Depth-damage curve (PATRICOVA, 2002)

LOSS OF LIFE

Potential fatalities for each time category and flood scenario are obtained by multiplying population at risk and fatality rates which correspond to the flood severity level of each flood scenario and area.

Population at risk (PAR) is obtained as a percentage of the number of inhabitants in the affected area (P) based on the time category and the level of flood risk understanding of the inhabitants of Benaguasil (Table 17).

Table 17: Population at risk. Base-case.

Time category	TC1	TC2	TC3	TC4
Factor f PAR=f·P ; P=d·A_{ff}	10%	2%	5%	0.2%
Density, d (inhabitants/km²)	10,457	12,253	8212	10,008

No warning systems are available in Benaguasil in case of flood. Therefore, Benaguasil belongs to the first category given in the SUFRI methodology (Escuder-Bueno I. et al, 2011) (Cp1) to estimate fatality rates. These values are shown in Table 18.

Table 18: Fatality rates. Base-case.

Flood severity level	S0	S1	S2	S3	S4
Rate (fatalities / people at risk)	0.0003	0.0021	0.0038	0.0105	0.0448

The number of potential fatalities (N) is estimated by multiplying population at risk (PAR) and fatality rates.

ECONOMIC LOSSES

Economic losses are estimated by the combination of the percentage of damage, which depends on the average flood depth, the affected area and the reference cost of each land use category. Indirect costs are estimated as a percentage of 27% of direct costs.

PFR+WS-case

The same risk model scheme is used to analyze the second study scenario, denoted as PFR+WS-case. Time categories, flood scenarios and hydraulic characteristics of the flood do not vary. However, estimations of potential consequences have to be evaluated based on the existence of warning systems in Benaguasil and the implementation of public education program on flood risk. As a result, better understanding and awareness of the population can be assumed.

LOSS OF LIFE

Fatality rates for this study scenario are obtained based on category Cp3 (Table 19), as the implementation of warning systems is related to a different category in comparison with the Base-case.

Table 19: Fatality rates. PFR+WS-case

Category Cp3					
Flood severity level	S0	S1	S2	S3	S4
Rate (fatalities / people at risk)	0.0002	0.0015	0.0027	0.0075	0.0320

Population at risk (PAR) is estimated. In this case, lower percentages of population at risk are considered (reductions of 50% during the day and 25% at night have been established).This reduction refers to the effect of public education on population at risk. People are supposed to be aware of the hazard, and, consequently, the percentage of people outside their households can be considered lower than for the Base-case. Other actions such as the installation of water stops to reduce economic damages result in a reduction of people exposed to the flood due to the fact that they will not be able to leave their house as easily as if no measures are taken to protect their properties.

ECONOMIC LOSSES

The existence of warning systems and high flood risk understanding of the population can be implemented in the risk model as a reduction on economic damages due to the installation of water stops and barriers in household with the aim of avoiding water entrance. Different studies are found in the literature (*Parker* *et al. 2005*) which relate water depth, warning time and percentage of reduction. Figure 47 shows the values applied in Benaguasil to estimate reduction on assets for this PFR+WS-case.

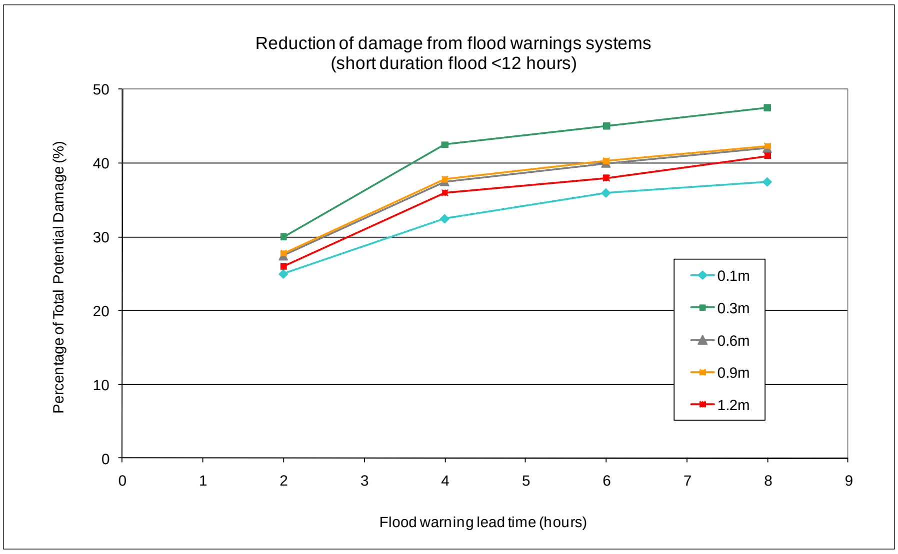


Figure 47: Reduction on damages (*Parker et al. 2005*)

New input data of potential consequences is obtained to analyse the PFR+WS-case.

Risk model

All the aforementioned information is summarized as input data for the risk model of Benaguasil. The risk model can be divided into three main parts: loads, system response and consequences.
Figure 48 shows the risk model scheme for the analysis of Benaguasil. Seven nodes are necessary to develop the influence diagram which represents the event tree of the case study.

Figure 48: Risk model scheme of this case study.

The first node, PF, identifies an overall parameter to calculate total risk by adding the results of societal and economic risk of all branches of the event tree (Figure 49). Other two nodes, TC_i and TC_ii, include probabilities of each time category. Then, all flood scenarios and associated probabilities are included in the next node, Flood. The system response is represented by a node which includes runoff flows in Benaguasil for each flood scenario. Finally, potential consequences are set in two nodes which relate runoff flows and potential fatalities or economic costs.
Figure 49 represents a section of the complete development of the event tree of this case study, where T denotes return period, f is the probability which results of the combination of time category and flood scenario of each branch of the event tree, N the number of potential fatalities and CT are economic costs.

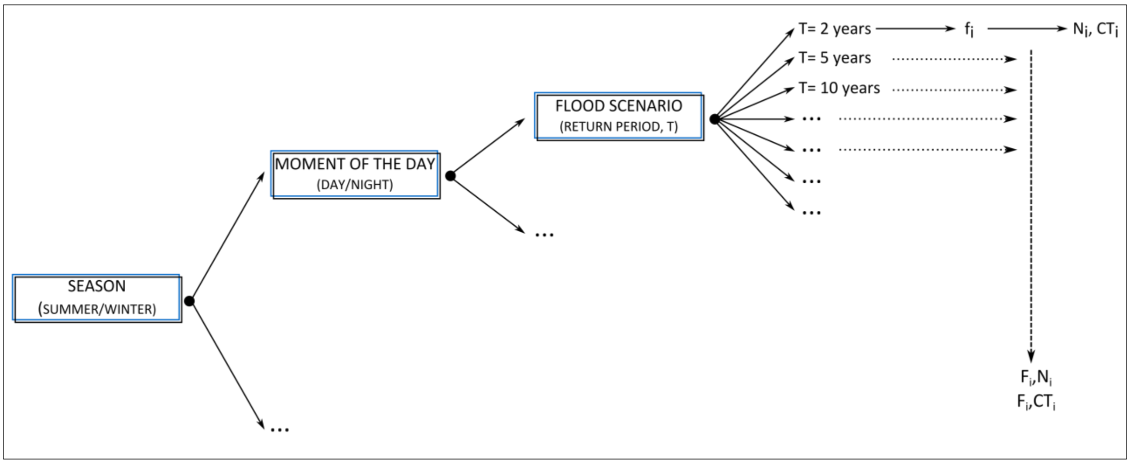


Figure 49: Example of the event tree of this case study.

Two risk calculations are performed with different input data for consequences based on estimations for both study scenarios: Base-case and PFR+WS-case.

Main results

Figure 50 represents the societal and economic risk of two study scenarios (Base-case and PFR+WS-case) of the case study Benaguasil. The illustrated F-N and F-D curves show that economic risk has more significance than societal risk in Benaguasil.

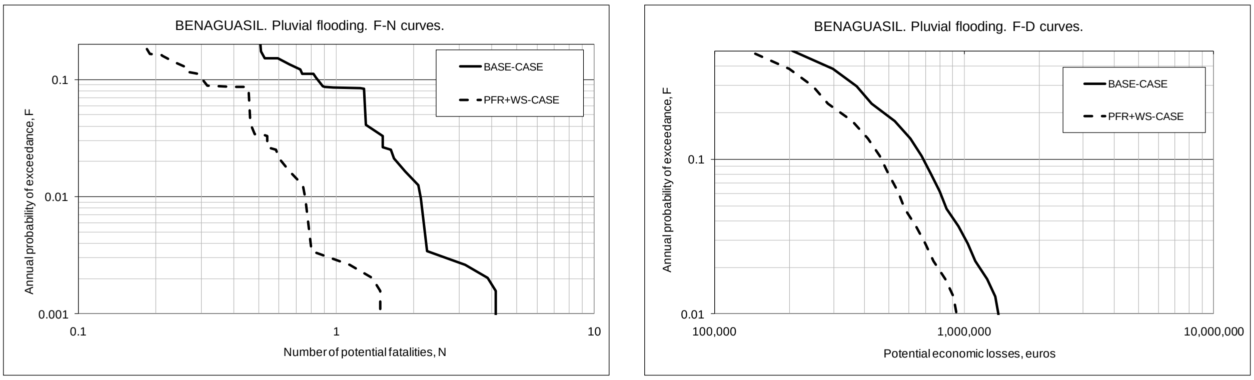


Figure 50: F-N (left) and F-D curves (right). Benaguasil. Pluvial flooding. Base-case and PFR+WS-case. (Universitat Politècnica de València)

These risk profiles will be used to develop the Municipal Action Plan for the city of Benaguasil, following the guidelines of the overall study developed in WP5 of the SUFRI project. This Plan will include organization and communication schemes, procedures in case of flood emergency, risk reduction measures and recommendations.

5.3.4 Applied fields – Lodi / Italy

The case study of Lodi was chosen due to the flood event occurred in 2002. Nowadays, the Administration is still developing both structural and non-structural measures to cope with flood risk in Lodi. For this analysis, the Olginate Dam has not been considered as it is located 75 km upstream the urban area.

Hydrographs with return periods ranging from 2 to 500 years have been obtained from hydrological studies of the river basin. These hydrographs have been used to evaluate flood risk in the urban area.
The urban area is mainly composed of residential areas. Additionally, there are agricultural areas located at the northern of the town

Two case scenarios have been established: the analysis of the current situation and the scenarios with non-structural measures of flood risk reduction. The comparison between both scenarios will show how effective non-structural measures are to reduce flood risk.

This study focuses on the analysis of the existent flood risk in Lodi due to river flooding generated by exceptional rainfall events and to estimate the flood risk reduction achievable through the application of non-structural measures.

Scope of the work

Once the aim of the study is established, all necessary data and information of this location has to be obtained to perform the risk model, including:

- Overall information of past flood events. Full description and simulation of the greatest flood occurred in Lodi in November 2002.
- Mathematical model used to simulate the study case, based on Shallow Water equations written in a conservative form.

Input data can be divided into different categories such as demography, building typology, land uses and economic rates, hydrology, existent structural measures, etc. These categories are described below:

Demography

Statistics of demography. (ISTAT census 2001 data)

- Total population: 38,939 inhabitants (resident population).
- Daily variability: 17,864 inhabitants.
- Seasonal variability: 2,000 inhabitants (no data available, hypothesis for summer season).

Building typology

Average number of floors per building: 2.53 floors/household.

Land uses and economic rates

- Definition of land use categories (CU). Two land use categories are proposed in this example: residential areas (land use category CU1 as it is defined in the methodology) and agricultural areas (land use category CU5).
- Identification of vulnerable areas or sectors: campsites, hospitals, schools, etc.
- There are some vulnerable areas in the city centre (Hospital Maggiore and some schools). No distinction has been made in the analysis.
- No available data has been found to characterize the value of assets in Lodi. For that reason, these values are defined from the table included in the Regional Action Plan against Flood Risk of the Valencian Autonomous Region (COPUT 2002). For this case, an intermediate rate for high density residential areas has been chosen. The following reference costs have been established: residential, 68.7 €/m2 and agricultural 0.34 €/m2.

Hydrology and catchment areas

The catchment area of the Adda River is located downstream Como lake. Adda river has two tributaries, Brembo and Serio river. The catchment area at the inflow in Po is 6,300 km² and the total length of the river is 280 km.

Adda river springs from the Retiche Alps, after collecting Frodolfo torrent, crosses the whole Valtellina and enters in Como Lake approximately in Colico (Lecco) with a length of 110 km and a basin of 2,600 km². Then, the river flows out of Como lake at the Olginate dam with a basin of 4,552 km². It receives water from Brembo river (with a basin of 940 km²) near Vaprio d'Adda. At Lodi town the area of the basin is 5,990 km².

The Serio river inflow is located upstream Pizzeghettone town and then flows into Po River.

Adda flow is regulated by Como lake close at the Olginate dam. The average annual discharge is 190 m³/s, ranging from 18 to 1000 m³/s. There are two small dams used for hydroelectric purposes in its river course. These three structures are classified as "dams" by the Italian Law, that is all regulation structures higher than 10 m or with a storage volume larger than 1.0 hm³. However, they are commonly considered as "barrages". Adda River is a tributary of Po river, which is managed by Po River Agency.

The hydraulic structure on Adda river are classified by the Italian Law as III class (R.D. 3598/1867, 4706/1868, L. 919/1910).

The outflow from Como lake is regulated by the Olginate dam at Lavello section (managed by "Consorzio of Adda" Agency): the flow discharge ranges from a minimum of 273 m³/s (in 1949) and a maximum of 940 m³/s (in 1987 and 2002 during the flood in Lodi).

Downstream Como lake, Adda river can be divided into three reaches: the first between Lavello and Brembo mouth, the second between Brembo and Serio mouths, and, the third downstream Serio mouth.

The first reach is 28 km long with a watershed between 4,552 km^2 and 4,697 km^2. The river channel is deeply embanked, with a limited flood routing capacity. A 3.6 percentage of this area can be considered as rural areas. The maximum elevation of the catchment is 4,050 m.a.s.l., with an average elevation equal to 1,569 m.a.s.l. and the closing cross section is 197 m.a.s.l.

The second reach differs hydrologically from the first one due to Brembo confluence. Its flood wave is very rapidly changing and with high maximum values of discharge, compared with Adda flows coming out Como lake. The reason can be found in the alpine features of Brembo Valley. Moreover, Brembo and Adda floods occur simultaneously. Due to the nature of the floods coming out from the lake (very long in time with small temporal fluctuations), there is often no time lag between Brembo and Adda peak discharges. The maximum discharge from Brembo River can reach 1,000 - 1,200 m³/s. As a result, there is an important discharge addition downstream Brembo confluence. Additionally, irrigation diversions by seven main Agencies have to be mentioned (Martesana, Vailata, Retorto, Rivoltana, Muzza, Vacchelli and Consorzio pianura bergamasca) which diverse from the river up to 220 m³/s and 100 m³/s, during summer and winter season, respectively.

The third reach has a short river length and the characteristics of the river channel show a limited flood routing capacity.

Flow gauging data

Four flow gauging stations are available downstream the Como lake: two in Adda River (Lavello and Pizzighettone), one in Brembo river and one in Serio river (see Figure 51).

The hydrological study has been based on flow measures recorded at these four stations to estimate flood waves (discharge vs. duration) using the Gumbel and GEV (Generalized Extreme Value) probability distributions to evaluate discharges for an assigned return period.

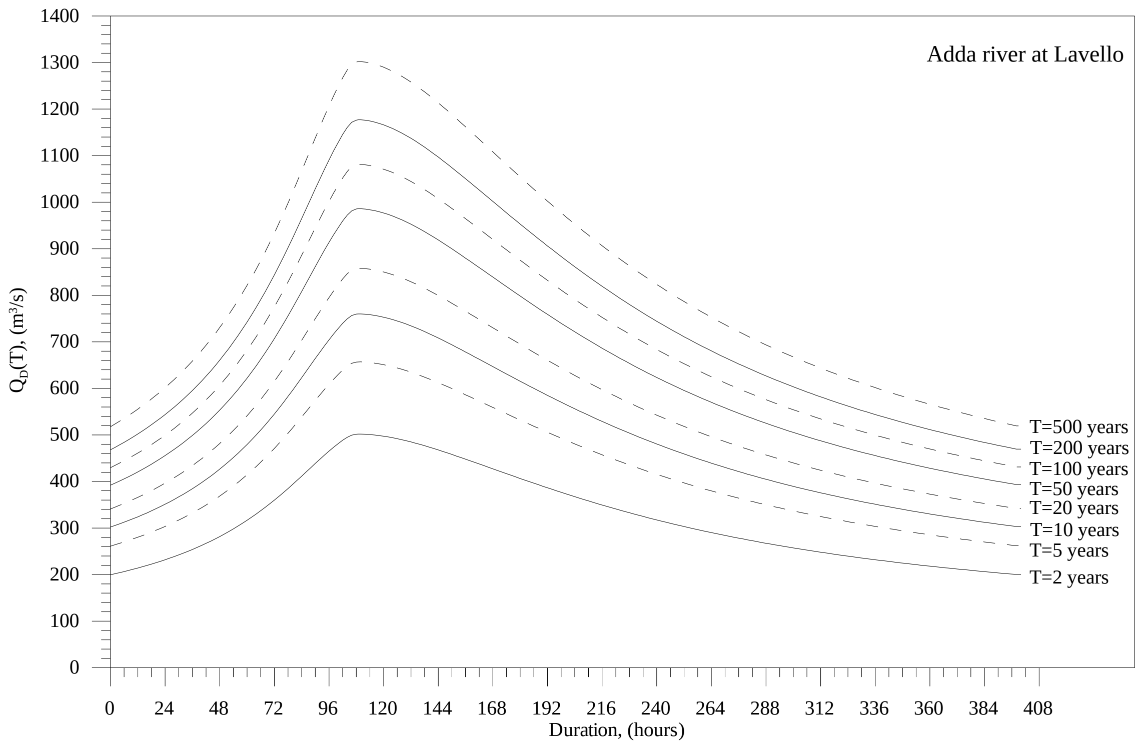


Figure 51: Adda river at Lavello: flood waves for different return periods

Pluviometer Data

There are a several rainfall stations that record rainfall and snow placed mainly in the mountain region within Adda river basin.

Figure 52 shows the position of these stations in Adda basin. Other electronic or automatic stations that are used for monitoring rainfall events might be used for flood pre-characterization as a non-structural measure for risk of flooding reduction.

No rainfall gauging stations has been used for the hydrological study of this case.

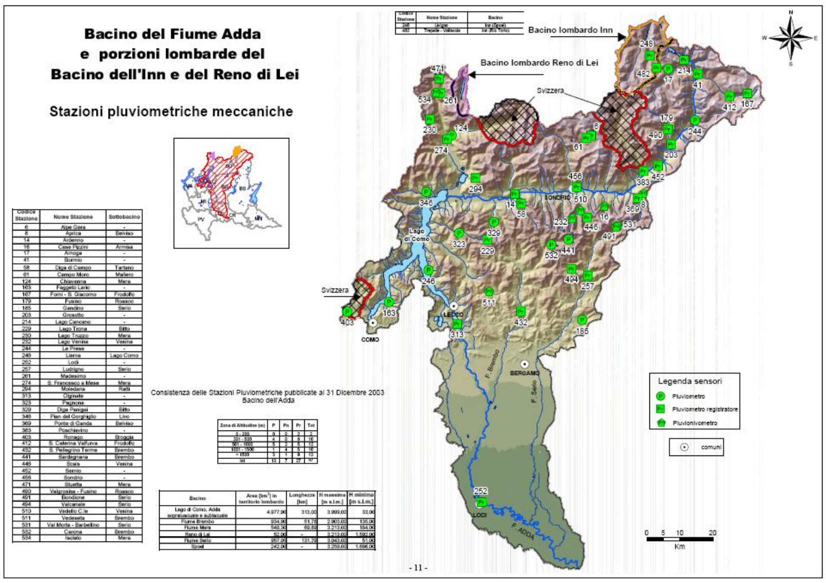


Figure 52: Rainfall station in Adda basin

Information of river characteristics

The following data is available:

- Hydrographs of the natural flow regime of the river with return periods that range from 2 to 500 years.
- Mean annual peak discharge: Q2.33=190 m³/s.
- Peak discharge that reaches the capacity of the river embankment at the urban area: Q= 650 m³/s.
- Peak discharge that reaches the first households at the urban area: Q=1,040 m³/s.
- Flooding maps of Adda river.

Structural and non-structural measures

Como lake is regulated by the Olginate dam. Olginate dam started the regulation of Como lake in 1946. On Adda river, smaller barrages are used for hydroelectric and irrigation purposes that are not able to influence the river flow. Actually, Olginate is more similar to a "barrage" than a dam. In fact, the maximum discharge which corresponds to the full opening of the sluice gate (940 m^3/s) is comparable with the discharge that can occur with the collapse of the structure (1,040 m^3/s).
Table 20 lists the main characteristics of the Olginate dam.

Table 20: Main characteristics of Olginate dam.

Characteristics	Data
Catchment area at Olginate Dam (km^2)	4,552
Como lake area (km^2)	145
Dam height (m)	3.9
Dam length (m)	153
Active storage (hm^3)	245
Max. daily inflow in the lake (18-7-1987) (m^3 /s)	1,836
Max. daily outflow from the lake (20-7-1987) (m^3/s)	918
Min. daily outflow from the lake (4-4-1953) (m^3/s)	18

Drainage system

Lodi city counts about 40,000 inhabitants in a surface of 4,164 ha, of which only 878 are urbanised. The drainage system is 140 km long and ends in a sewer treatment plant in Cascina Maldotta, in the south east outskirts, managed by Astem.
From the hydraulic point of view, Lodi drainage system is divided into two independent basins. The first basin is named "collettore Cotta-Baggia" with a big polycentric section (300 cm x 200 cm) with the original function of irrigation channel in the south of the town. The second pipe has a section of 100 cm x 150 cm. The system is mainly combined. The draining system is divided into combined sewer system (50%), meteoric sewer system (24%) and waste water system (26%). No pluvial flooding due to low capacity of the drainage system is considered.

Other structural measures

Several levees are constructed nearby the urban area. A hydraulic model of the river course is available for calculations.

Non-structural measures

Flood precharacterization and prediction can be considered as an example of non-structural measure for flood risk reduction in this case. These measures may support the town emergency plan described in the following pages.

Land planning as a result of the PAI (Program of the Hydrogeological Assessment) suggests some measures for risk reduction such as:

- Limitation of land uses in zones where exist flood risk with a land planning that supports the delocalisation of all structures that could be damaged;
- Real time forecasting using meteorological data and hydrographic monitoring that, giving a pre-characterization of the flood, allows the beginning of protection actions.

Additionally, other non-structural measures can be mentioned:
- Flooding maps of Adda river to evaluate inundation risk for return periods of 20, 200 and 500 years.
- "Program of the Hydrogeological Assessment" (PAI) of Po River, and all its tributaries, by the Po River Agency in 2001 indicates deadlines to reduce flood risk.
- Existence of an Emergency Action Plan.

Input data for the risk model

Flood scenarios

Flood scenarios are defined from hydrological studies of the river basin. A series of return periods should be established for defining flood scenarios related to the river flow regime. The values used are those from the station upstream Lodi town. Maximum peak discharges for each return period are presented in Table 21.

Table 21: Peak discharges from hydrographs.

T (years) from hydrological studies	2	5	10	20	50	100	200	500
Q_{max} (m^3/s)	807	1,074	1,252	1,422	1,642	1,806	1,971	2,187

Definition of time categories

Based on daily and seasonal variability, four time categories are defined to estimate the number of people located at the urban area.

Total population is equal to 38,939 inhabitants (2001). This value is associated to winter-night period (time category TC_4) and it decreases in winter during the day in 21,075 people due to labour reasons. In summer, population is supposed to decrease an amount of 4,000 people due to the vacancy period. Then, population is estimated in 34,939 people in summer at night and it decreases in 18,075 people during the day.

Study scenarios

Two different study scenarios from river flooding are considered:
- Current situation with structural measures (existence of levees nearby the urban area, denoted as Base-case). The effects of the dam will not be considered due as flood is not supposed to be a consequence of dam failure. Thus, the Base-case is developed without considering the dam.
- Situation with non-structural measures (effect of a Public Education Program on Flood Risk, denoted as PFR-case).

<u>Base-case – Estimation of potential loss of life and economic damages</u>

LOSS OF LIFE

Category for the Lodi base-case to define reference fatality rates

Based on the classification of ten categories proposed in the methodology, category C2 can be used to identify Lodi Base-case. This category will be modified to C9 to analyse the situation with non-structural measures.

Population at risk (PR)

Flooded areas are obtained from comparison of land use and flooding maps. For each flood scenario, population at risk for each time category is obtained by multiplying population for each time category by the ratio between flooded area (A_f) and total area of the urban site (A_T).

Reduction on population at risk is established due to the characteristics of the urban site. An average number of 2.53 floors per household has been estimated. Thus, population at risk is obtained as follows:

$$dC = \frac{d}{np} \qquad PR_{calc}(TC_i) = \frac{PR(TC_i)}{2.53}$$

where *d* denotes density, *dC* is the value of density population for calculations and np is the average number of floors per building.

Consequently, population at risk is reduced by a factor of 2.53 for each time category.

Warning times (TW)

Warning times are defined as the time difference from the first-notice flow, 650 m³/s, and first-damage flow, 1,040 m³/s.

Flood severity (Sv)

Flood severity of each flood scenario is obtained based on the DV parameter. All flood scenarios are within the category of medium flood severity, except for the first one (DV equal to 3.5 < 4.6 m^2/s). Peak discharge values at the study site correspond to the maximum discharge of each flood scenario.

Fatality rates (FR)

Fatality rates are obtained by interpolating reference fatality rates of category C2 based on warning times and flood severity categories.

Number of potential fatalities (N).

The number of potential fatalities is estimated by multiplying population at risk (from each time category) times the estimated fatality rate (FR).

Table 22 includes all estimated parameters to obtain the resultant number of potential fatalities for Lodi base-case.

Table 22: Number of potential fatalities, N. River flooding. Lodi base-case

Q_{max} (m³/s)	TW day (h)	TW night (h)	DV	Sv	FR day	FR night	Time category			
							TC_1	TC_2	TC_3	TC_4
807	-	-	3.5	1	-	-	-	-	-	-
1,074	6	5.75	4.7	2	2.E-04	2.E-04	0.1	0.2	0.1	0.2
1,252	3.00	2.75	5.3	2	2.E-04	2.E-04	0.2	0.4	0.2	0.5
1,422	1.75	1.50	5.4	2	2.E-04	2.E-04	0.3	0.6	0.3	0.6
1,642	1.50	1.25	5.8	2	2.E-04	5.5E-02	0.4	114	0.4	127
1,806	1.25	1.00	6.0	2	4.E-02	4.5E-02	74	304	78	339
1,971	1.15	0.90	6.1	2	4.E-02	6.E-02	128	418	136	465
2,187	1.10	0.85	5.7	2	5.E-02	6.6E-02	205	611	218	681

ECONOMIC LOSSES

Economic losses are obtained from the definition of a reference cost for the flooded area and a percentage of damages from depth-damage curves. Indirect costs are estimated as a 20% of direct costs.
Depth-damage curves are distributions that represent flood depth and the percentage of damage in assets. The flood event of November 2002 has been used for calibration of a more representative percentage based on depth-damage curve found in the literature (*COPUT 2002*).

PFR-case – Estimation of potential loss of life and economic damages

Non-structural measures do not modify the hydraulic characteristics of the established flood scenarios for the Base-case. However, flood consequences vary from the Base-case due to the application of non-structural measures.
The aim of town emergency plan is focused on improving the knowledge of population on flood risk. This case, denoted as PFR-case (Public Education Program), includes the effect of giving guidance on evacuation and shelter in case of flood emergency.

This scenario is studied by including the following variations on the Base-case:

LOSS OF LIFE

If a PFR is implemented, it can be considered that the case example belongs to category C9 (see categories proposed by Escuder et al. 2011. Consequently, reference fatality rates differ from the Base-case.
The same values of population at risk, warning times and flood severity categories have been adopted for this PFR-case.

ECONOMIC LOSSES

According to SUFRI methodology and possible Lodi case solutions, it is proposed that inputs of economic losses are modified from Base-case as follows:

- Reference costs are modified from a starting value of 68.7 €/m² (residential land use - high rate) to 37.55 €/m². This cost is referred to residential medium density land use with an intermediate rate between high and low. This variation on reference cost aims to introduce the possibility to locate vulnerable areas to non-risk zones and to use ground floor of existing buildings for other land uses (storage, parking, etc.).
- Estimation of indirect costs: town emergency plan provides useful devices to keep economic and social activities as normal as possible (no loss of production, traffic or facilities disruption, etc.). Thus, indirect costs are set as a 10% of direct costs (this value was defined as 20% for the Base-case).
- Estimation of percentage of damage (PD): PFR-case is performed with a decrease of 50% on damages. This hypothesis is supported by prevention activities set by the town emergency plan and PAI devices. For example, avoiding residential uses in ground floors and using materials with high resistance.

Risk model

The risk model can be divided into three main parts: loads, system response and consequences. The risk model for the Lodi base-case is performed to represent the current situation of Lodi without non-structural measures. Levees influence the extent of flooded areas and their effects are considered in mathematical model. The risk model of the PFR-case will include the estimations of flood consequences after public education as non-structural measure.
Figure 53 shows the risk model architecture for Lodi. This scheme is used for both study scenarios: Base-case and PFR-case. However, input data for consequences will vary for each situation.

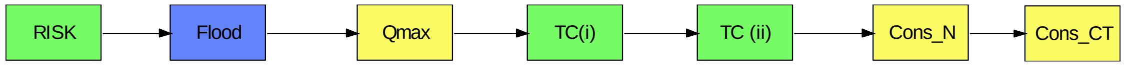


Figure 53: Risk model scheme of Lodi.

LOADS

Flood scenarios from the given return periods are established as loads for the risk model of Lodi.

SYSTEM RESPONSE

System response corresponds with flood characteristics and flooded areas as a result of the previous flood scenarios.

The mathematical model used is based on Shallow Water equations written in a conservative form. The relevance of this study and the detail of the simulation requires a mathematical model written in a complete form without dropping the conveyance term. Indeed, the spatial variations of the velocity may be very high due to the number of constructions that cross the river.

The mathematical model is numerically integrated with finite volumes techniques with two different numerical schemes. Estimation of the roughness coefficient has been performed using a method that refers to the formulation proposed by Arcement 2001.

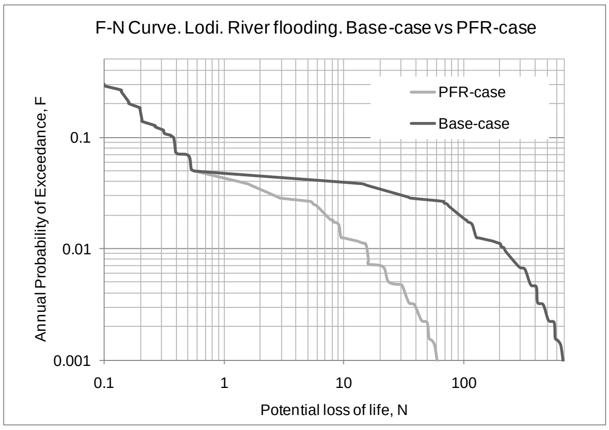
A Geological Survey that correlates the roughness coefficient (using Manning) with the dimension of the grains and vegetation in the river bed has been used.

CONSEQUENCES

Flood consequences are divided into two categories: loss of life and economic losses. Estimations will differ from the Base-case to the situation with non-structural measures.

Main results

Figure 54 represent the F-N and F-D curves for Lodi for both study scenarios, Base-case and PFR-case.



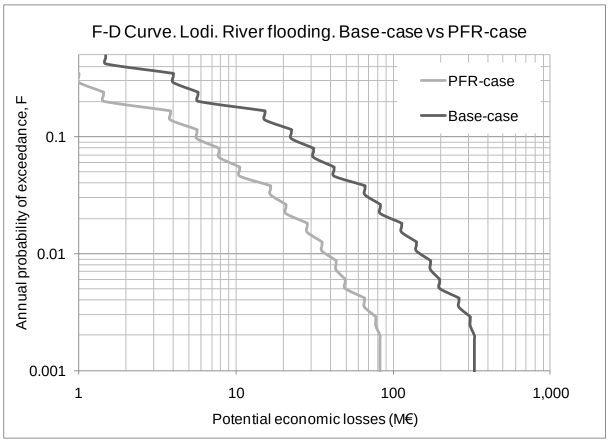


Figure 54: F-N (left) and F-D curves (right). Lodi. River flooding. Base-case and PFR-case. (Universitat Politècnica de València)

Results of Lodi show that the established flood scenarios produce a maximum potential loss of life around 680 fatalities for an annual probability of exceedance equal to $1{\cdot}10^{-3}$, approximately, for the Base-case. Potential economic losses reach a value of 329 M€ for the same annual probability of exceedance. However, results of the PFR-case show a reduction on social risk ranging from 680 to 60 potential fatalities for the aforementioned probability and economic risk decreases in magnitude from 329 to 82.5 M€. If the annual probability of exceedance equal to 0.1 is considered, then a reduction on potential economic losses from 22.5 to 5.7 M€ is expected (75% of risk reduction). This reduction is not significant if potential life-loss is analysed due to the minor social risk associated with low probabilities.

5.4 Risk Communication

Specific Outcomes

- Questionnaire in 4 languages (English, German, Italian, Spanish) to achieve data of the subjective view of the citizens about natural threats (especially flood), the desired communication and information in case of a flood event. (see appendix)
- Guidance for hypothesis and connectivity testing regarding predefined questions (factor / cluster analysis)
- Guidance for successful risk communication
- Experiences in European cities (all case studies): public opinion poll
- Experiences in European cities (Graz, Benaguasil): information campaigns

Lessons Learned

- The population feels a lack of information during a flood event.
- Stakeholder, action forces and population need to be involved in the developing process of crisis management.
- The willingness for cooperation is higher if people have the feeling of taken seriously.

5.4.1 Communication strategies

A compilation of different risk communication strategies has been worked out in order to give recommendations. E.g., factors as message and receiver characteristics, perception of the message, confirmation with social networks and behaviour response of the receiver describe an interacting process in terms of risk communication. (Blanchard-Boehm et al, 2004)
To reach a desired result risk communication does not proceed a straight line, but must be flexible and adaptable. These characteristics lead to capture people`s needs, risk perception and interest. (Lorenz D., 2009) Knowledge about the audience, concerning characteristics, perception, behaviour, needs, is essential for developing an adequate risk message. (Covello V., 1989)

Floods from an social perspective

In general knowledge flood events are still broadly conceived as pure acts of weather und nature. This assumption proofs to be true for the few untouched natural landscapes by civilization, where rivers run in beds formed by their own forces over thousands of years. But such rivers and aquatic systems unchanged by human hand are a minority and not the main habitat of the modern industrialized nations and urban agglomerations. This research initiative specifically deals with the challenge of the modern urban flood problem at European level. Flood disasters do also play a significant role especially in urban areas of the so called less and least developed countries and cause great devastation and loss of live.[5] But it is also important for the sociological analysis and the focus of the SUFRI-research agenda that we are dealing with European cities and urban areas. The following sociological remarks are to be understood from a perspective on the development of European cities and their flood risk problem.
Floods can be defined as *social events*. Human behavior and reactions before, during and after an inundation determine the chain of consequences that are triggered by the primal natural causes of

[5] Berger (2010): 85-86

flooding.[6] This notion provides a perspective to see this form of natural hazards in a more holistic context and not only in hydro-technological terms. The social consequences of flood events are deeply rooted in the socioeconomic and historical development in the specific flooding areas. The historical anthropogenic changes of landscapes in the nineteenth and twentieth century have their impact in the magnitude of floods that occur nowadays. Deforestation, the regulation of rivers and the concentration of human settlements in former retention areas are the mayor factors in this regard.[7] The understanding of the socio-historical development of the modern flood risk in European cities is a vital contribution to find solutions and prevent future mistakes in urban planning.[8]

Risk perception

Risk perception is a complex field and not easy to understand. Many different definitions let assume that risk perception is a multilayer phenomenon who tries to find an adequate explanation. Sjöberg, Moen and Rundmo define risk perception as

"*the subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences*"[9] Other definitions see risk perception as "*one's opinion of the likelihood of risk (the probability of facing harm) associated with performing a certain activity or choosing a certain lifestyle*"[10] or as "*procedure of perception, sensual or rational recording of a danger and the potentially resulting damages*."[11]

All these definitions have a common core - in fact the question: "Why do people perceive risks as they do?"[12] Risk perception is part of our life: we perceive risks and make subjective judgements about severity. The characterization of risks is influenced by many factors:[13]

- **Control:** People feel safer if they control a situation – on this way the risk will probably not appear so great.
- **Dread:** Fear is an indicator for the thinking of severity of risks.
- **Natural risk / Man-made risk:** For many people a natural risk is a lower risk than a man-made one.
- **Choice:** If people choose a risk it appears less risky than one they can't select. This is similar to the question of control.
- **New risk:** New risks give people the feeling that they are more dangerous than the risks we know since a long time.
- **Awareness:** Risk awareness depends on the level of attention that people give to risks.
- **Trust:** An important factor of risk perception is the level of trust that people have in experts and governments.
- **Possibility of personal impact:** The risk seems greater if it is possible that people in my surrounding or I can become a victim. This belongs to the question of risk target. It is a fact that people do not estimate the same risk level to themselves, their family or to people in general. Their personal risk is generally lower than the family risk or the risk for other people. This so called risk denial means that people have an unrealistic optimism in the estimation of their risks.

[6] Weichselgartner (2000): 122
[7] Blackbourn (2006): 259-260
[8] Dix & Röhrs (2007): 230-231
[9] Sjöberg et al., Explaining risk perception. An evaluation of the psychometric paradigm in risk perception research, Norwegian University of Science and Technology, Department of Psychology, 2004, p.8: http://www.svt.ntnu.no/psy/Torbjorn.Rundmo/Psychometric_paradigm.pdf
[10] Risk perception, Centre for Toxicology, University of Guelph: http://www.uoguelph.ca/cntc/files/riskperception.pdf
[11] Hollenstein 1997, p. 20
[12] Sjöberg, L.: Factors in Risk Perception. Risk Analysis, Vol. 20, No. 1, 2000, p. 1: http://paul-hadrien.info/backup/LSE/IS%20490/utile/factors%20in%20risk%20perception.pdf
[13] Risk perception, p. 2 -3: http://www.cepis.ops-oms.org/tutorial6/i/pdf/topic_04.pdf

This is only a fragment of factors which can have an effect on risk perception. Many approaches try to understand the process of risk perception and on which way people perceive risks. The sociological approach focus the main attention on risk perception as social construct which is influenced by institutions and values of society. Like all other approaches - for example interdisciplinary approaches - the cultural theory only explains a fragment of risk perception and is subject to a variety of criticism.

Risk evaluating

It is a thin line between risk perception and risk evaluating. Risk evaluating is the classification of dangers and risks into a system of value and the comparison with the associated benefit.[14] Based on this concept a society makes decisions about the tolerableness of risks. As soon as we perceive a risk we evaluate it. Evaluating risks arouses the question whether the risk is acceptable or not - or maybe only acceptable under determined conditions. The central criteria of risk evaluation are the measure of damages and the probability of occurrence.[15] Any estimation of probability is connected with uncertainty. For this reason it is adjuvant to count uncertainty as another criterion of risk evaluation. Additional helpful criteria according to Renn and Klinke are:[16]

- Ubiquity: geographical range of potential measure of damages
- Persistence: temporal expansion of potential damages
- Reversibility: possibilities of re-establishment before damage event
- Delay: time period between event and consequences
- Potential of mobilization: injury of individual, social and cultural interests and values

Risk communication

According to Wiedemann, risk communication consists of "all communication that concerns the identification, the estimation, the evaluation and the management of risks. It aims to convey information about the potential for risk, to minimize differences in the evaluation, and to prevent escalating conflicts in the confrontation with risks. Particularly important is communicating with the general public, meaning the affected as well as interested citizens."[17]

Responsibilities of risk communication are:[18]

- Information and explanation of risks: increasing the knowledge about risks
- Encouraging preventative measures: prevention and protection measures
- Information in case of an emergency/disaster: Timely warning of the affected in case of a disaster
- Collective problems and conflict solution (reaching a consensus on disputed topics)

Communication goals of effective risk communication:[19]

- Comprehensibility (language and concepts, structure, etc.)

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[14] Hollenstein 1997, p. 20
[15] Renn / Klinke 2003 , p. 27 - 28
[16] ibid., p. 29
[17] Wiedemann, P. M.; Mertens, J.: Sozialpsychologische Risikoforschung; aus Technikfolgenabschätzung – Theorie und Praxis, Nr. 3, 14. Jg, Dezember 2005, p. 42
[18] cf. Covello, V.T.; Winterfeldt von, D.; Slovic, P.: Communicating Scientific Information about Health and Environmental Risks, in: Davies, J.C.; Covello, V.T.; Allen, F.W. (eds.): Risk Communicating: Proceedings of the National Conference on Risk Communication, Washington D.C., 1986; Wiedemann, P.M.; Schütz, H.: Risikokommunikation als Aufklärung: Informieren über und Erklären von Risiken, Jülich, p. 2-3
[19] cf. Kosow, H.; Oertel, B.; Köster, Ch.; Mickler, T.; Ulmer, F.; Wölk, M.: Effekte der Risikokommunikation auf Risikowahrnehmung und Risikoverständnis von Zielgruppen. Verständlichkeit, Transparenz und Nutzbarkeit von fachlichen Stellungnahmen des Bundesinstituts für Risikobewertung zur Lebensmittelsicherheit, (eds.): Kurzenhäuser, St.; Epp, A.; Hertel, R.; Böl, G. F., Berlin 2010, p. 13

- Transparency (reliability of the information and its sources, neutrality of information)
- Usefulness (efficiency, effectiveness, the currency of the information, etc.)
- Allows the addressee to make informed decisions (consideration of the consequences of the identified risk)

Setting goals of official risk communication
Differentiation:[20]

- Educational and preventative communication (e.g. warning of dangers, the basis of behavior commensurate with risk)
- Legitimation communication (e.g. determining a consensus as the basis of management decisions)
- Breakdown and Crisis communication (e.g. Warning about imminent damages, etc.)

Risk communication includes the development of information about risks, the providing of information to the public and the involvement of government and the public in risk assessment.[21] The knowledge concerning risk perception and the influencing elements on perception are important for the creation of an adequate information and risk communication strategy.[22]
Risk communication should be specifically directed toward the target group. According to Wiedemann risk communication should be arranged as two-way communication. Trust is important for effective risk management.[23]

Hazard Risk Communication Model

In the communication process different factors interact: the message, message characteristics, receiver characteristics, receiver´s perception of the message, confirmation with social networks and behavior response of the receiver. Risk perception and behavior are influenced by: (1) receiving the warning over different channels (electronic/print media, brochure, etc.), (2) characteristics of the message (accurateness, distinctness, consistency, etc.), (3) characteristics of the receiver (experience with a disaster, social interaction, distance from the hazard, etc.), (4) degree of personal perception of risk/vulnerability, (5) response (mitigation and preparedness measures).[24]

Risk communication that leads to the desired results cannot run a straight line or be one-directional because risk assessment can vary greatly. Risk communication should be flexible and adaptable in order to cater to the needs, the knowledge and the interests of many people. A uniform risk communication strategy for the entire affected population is hardly promising of success.[25]

[20] cf. Brauerhoch, F.O.; Ewen, Ch.; Sinemus, K.: Formen und Folgen behördlicher Risikokommunikation, Epp, A.; Hertel, R.; Böl, G.F. (eds.), Berlin 2008, p. 29-31
[21] cf. Smith, C.F.; Kain, D.J.: Making Sense of Hurricanes: Public Discourse and perceived risk of extreme weather, in: Critical Approaches to Discourse Analysis across Disciplines, Vol. 4, 2, 2010, p. 180-196, here: p. 182
[22] cf. Plapp, T.; Werner, U.: Understanding risk perception from natural hazards: examples from Germany, in: Amman, Dannenmann, Vulliet (eds): RISK 21 – Coping with risks due to Natural Hazards in the 21st Century, 2006, p. 101-108
[23] cf. Covello, V., McCallum, D., and Pavlova, M.: Principles and Guidelines for Improving Risk Communication, in: Covello, V., McCallum, D.; Pavlova, M. (eds.): Effective Risk Communication: The Role and Responsibility of Government and Nongovernment Organizations. New York, 1989; Johnson, B.: Qualitative Risk Assessment: Experiences and Lessons, in: V. Covello, V.; McCallum, D.; Pavlova, M.
[24] cf. Blanchard-Boehm, R.D.; Cook, M.J.: Risk Communication and Public Education in Edmonton, Alberta, Canada on the 10th Anniversary of the Black Friday Tornado, in: International Research in Geographical and Environmental Education, Vol. 13, No. 1, 2004, p. 38-54, here: p. 45; Mileti, D.S.; Fitzpatrick, C.: The Great Earthquake Experiment: Risk Communication and Public Action, Boulder 1993; Mileti, D.S.; Sorensen, J.S.: Communication of Emergency Public Warnings: A social Science Perspective and State of the Art Assessment, ORNL 6609, Oak Ridge 1990; Mileti, D.S.; Fitzpatrick, C.; Farhar, B.: Risk Communication and Public Response to the Parkfield Earthquake Prediction Experiment: Final Report to the National Science Foundation, Fort Collins. 1990
[25] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 274-275

The risk message has to be designed for the specific audience. It is important to have knowledge concerning the characteristics of the audience (also information concerning their perception, behavior, needs, concerns, knowledge of the subject, attitudes, etc.).[26]

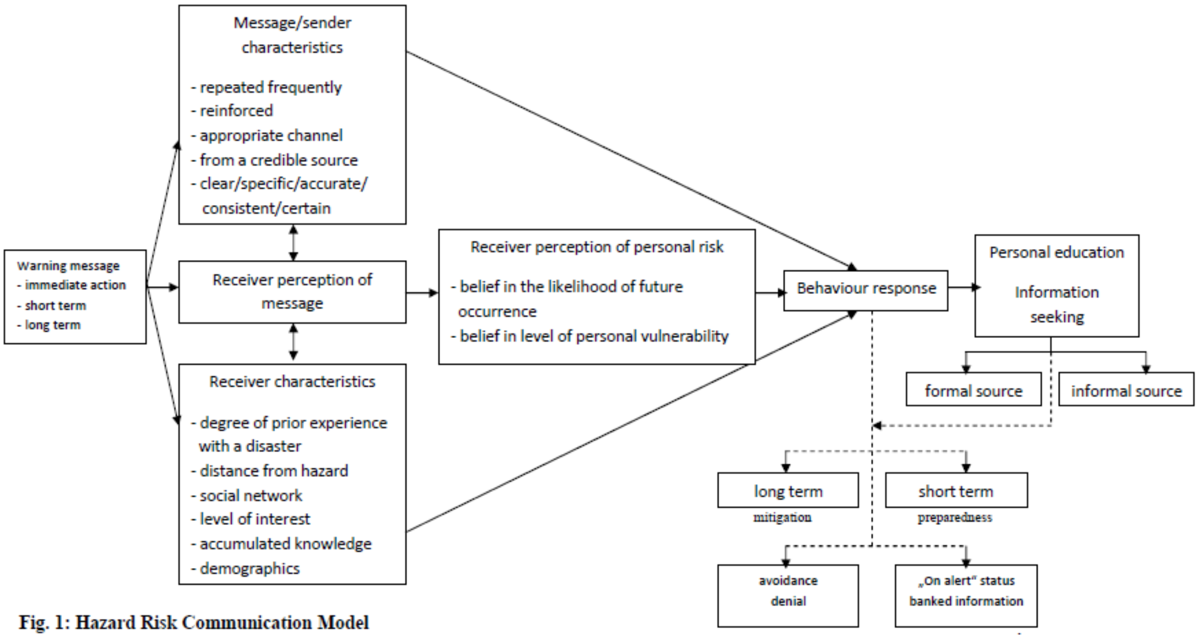

Figure 55: Hazard Risk Communication Model[27]

Important factors concerning a message

- use simple language: authoritative interpreters of e.g. technically sophisticated statements are important
- consistency of the information: people get information by different media and different sources. It is important that the information is credible.
- concerning the message – presented to the public – three critical issues have to be considered:
  - description of potential losses: the description of disasters is important, as well as pictures, computer based loss estimation maps, etc. Awareness has to be created concerning the hazard risk.
  - discussion of the potential timeline: people have to understand that the hazard might happen to them within the next 10 years, 20 years etc..
  - Explanation how to diminish losses: People have to be shown mitigation measures (e.g. video for homeowners concerning the strengthening of the disaster resistance of homes, support by a neighborhood emergency response team, evacuation guidelines, etc.).[28]
- Specification who is at risk (education and planning).

[26] cf. Covello, V.T.; McCallum, D.B.; Pavlova, M.: Principles and Guidelines for improving risk communication, in: Covello, V.T.; McCallum, D.B.; Pavlova, M.T.: Effective Risk Communication. The role and responsibility of government and nongovernment organizations, New York, 1989, p. 3-16

[27] Blanchard-Boehm, R.D.; Cook, M.J.: Risk Communication and Public Education in Edmonton, Alberta, Canada on the 10th Anniversary of the "Black Friday" Tornado, in: International Research in Geographical and Environmental Education, Vol. 13, Nr. 1, 2004, p. 38-54, here: p. 44

[28] cf. Mileti, D.S.; Peek, L.A.: Understanding Individual and Social Characteristics in the Promotion of Household Disaster Preparedness, in: New Tools for Environmental Protection: Education, Information and Voluntary Measures, 2002, p. 132

The process

Campaigns have to be comprehensible, the information reliable and it has to reach the audience. Important factors are:

- Several reliable resources of information: people obey information just if they trust the people giving the information. According to age, education, etc. people trust diverse sources. Various sources of information are necessary to inform all people.
- Adjust the information to the needs of the different groups: Information material should be created e.g. for old people.
- Dependent on the audience that should be reached different media should be used (Internet, community organizations, etc.).
- Information should be easily accessible.
- Interactive approach: the audience should be involved e.g. by discussion.[29]

Important aspects of a message for hazard education of the public:

- “accessible information
- consistent information
- media-ready packaging
- clear explanation of critical issues
- specification of whom is most at risk
- clarity surrounding the level of certainty of the message”[30]

Sources of information

The mass media are a part of public risk communication. The media influence the perception of danger as well as the assessment of risks.[31]

In the context of computer-assisted information systems, comprehensive information is offered that can be called up by every user in cases of need.[32] Additional possibilities for information must be offered as not all residents have access to the internet. Print media (e.g. community publications, local newspapers, etc.) play a role. This type of information should be made available a certain period in advance of times that – according to experience – are especially endangered by floods. Print media are more enduring than audio-visual media because the addressee defines the speed of reception by himself. Print media also reach people without internet access. To reach many addressees, different media should be used simultaneously.[33]

According to a study of Wagner (2007) the people with better hazard knowledge are those who make use of diverse sources of information or have hazard experiences.[34]

Risk communication activities of the responsible government offices and the media reporting influence the citizens' consciousness of risk. Creating such a consciousness is a goal of risk communication. The population has to be aware of possible risks in order to be able to set preventative measures.[35]

A governmental communication strategy (extensive information from the public authorities) is generally supported with information from additional sources. Information concerning
flood risk is acquired, for example, through[36]:

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[29] cf. Nathe, S.; Gori, P.; Greene, M.; Lemersal, E.; Mileti, D.: Public education for earthquake hazards, in: Natural Hazards Informer, 2, 1999

[30] Mileti, D.S.; Peek, L.A.: Understanding Individual and Social Characteristics in the Promotion of Household Disaster Preparedness, in: New Tools for Environmental Protection: Education, Information and Voluntary Measures, 2002, p. 130-131

[31] cf. Obermeier, O.P.: Die Kunst der Risikokommunikation, 1999, p. 92 und 75

[32] cf. Lundgren, R.; McMakin, A.: Risk Communication. A handbook for communicating environmental, safety and health risks, Columbia 1998, p. 138

[33] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 281-283

[34] cf. Wagner, K.: Mental Models of Flash Floods and Landslides, in: Risk Analysis, Vol. 27, No. 3, 2007, p. 671-682

[35] cf. Schuchardt, B.; Schirmer, M.; Lange, H.; Wittig, S.; Ronthaler, M.; Sprado, J.: Integriertes Hochwasserrisikomanagement in einer individualisierten Gesellschaft, Teilprojekt 5: Integration und Informationsplattform, 2008, p. 80-87

- Classic media: radio and television
- Processes of citizen participation (community assemblies, discussion rounds, work groups, workshops, forums, round table discussions, community inspection tours, etc.)
- Print media (journals, newspapers, flyers, brochures, information leaflets, etc.)
- Internet (e.g. Websites)
- Picture series (e.g. slides, posters, etc.)
- Official announcements
- Informative meetings, etc.
- Personal conversations
- Etc.

Guidelines for the design of warning messages/risk communication aspects propose the 27/9/3 template: limitation of a warning message/flyer to 27 words, 9 seconds, 3 messages.37 "Apparently under low stress the brain processes information in linear order, at average grade level, and can hold 7 messages at a time. Under high stress, however, it processes information based on primacy and recency, processes information at average grade level minus 4 and can only hold on average 3 messages. Therefore, it is important to choose a few messages with the highest potential impact."38

Internet

Comprehensive information concerning hazard characteristics, prevention measures as well as behavior during/after an emergency plays an important role. The internet as information tool for disaster preparedness is an important factor in risk communication.

Risk communication on the basis of the World Wide Web shows advantages:

- constant and fast update of the information,
- place a bookmark on a particular hazard information,
- quick access to the information.

Technological features (concerning the message) and psychological characteristics (concerning the receiver) contribute to the efficiency of risk communication.

For the assessment of the significance of a website for hazard preparedness the following points are important: [39]

- Content evaluation
- Process evaluation
- Outcome evaluation

Evaluation criteria for web-based information contain:

- "Regarding content evaluation (recipients´ perspective): completeness of the information (regarding the residents´ problem), comprehensibility, congruence between message and residents´ information needs/requests, potential to capture and maintain attention, appraisal of presentation style (pictures, colours, examples), and perceived feasibility of proposed actions.

[36] cf. Schuchardt, B.; Schirmer, M.; Lange, H.; Wittig, S.; Ronthaler, M.; Sprado, J.: Integriertes Hochwasserrisikomanagement in einer individualisierten Gesellschaft, Teilprojekt 5: Integration und Informationsplattform, 2008, p. 66-68
[37] Cf. Covello; cf. Morrow, B.H.: Risk behavior and risk communication: synthesis and expert interviews. Final report of the Noaa Costal services center, p. 29
[38] Morrow, B.H.: Risk behavior and risk communication: synthesis and expert interviews. Final report of the Noaa Costal services center, p. 29
[39] cf. Rohrmann, B.: The relevance of the internet for enhancing disaster preparedness of residents, in: 11th annual TIEMS conference – The international Emergency Management Society, 2004, p.3-4

- Regarding process evaluation (for information presentation or education process): facilitation of the learning process, opportunity for questions and discussion of problems, information confirmation activities of recipients, perceived ease of making contact with the authority (or feedback possibilities), satisfaction with presentation process.
- Regarding outcome evaluation (knowledge, intentions, behaviour): Provided materials discussed in household, materials (e.g. plans, checklists) utilized for preparedness, acceptance of hazard messages a/o suggested actions, internet websites ´bookmarked`, change of beliefs (mental models) regarding preparedness, advanced problem awareness (perceived risk/vulnerability of people/property), preventive measures conducted/realized (house, property, family planning), dependency on external help reduced (increased self-reliance), confidence in information source, participants´ satisfaction with outcomes of the information process as a whole."[40]

Criteria for the evaluation of risk communication[41]

- Needs appraisal: Appraisal of the needs of the bearers of risk and how they can be fulfilled.
- Complexity of risk as well as social pluralism: Risk is multidimensional. Characteristics of risks (e.g. level of familiarity, voluntariness, etc.) have an impact on peoples´ responses to risk. Moreover different cultural groups specify risks diversely.
- Risk in context: Comparison of risk reduction measures, comparison with other relevant risks, etc.
- Timelines: Risk communication should be early so that mitigation measures can be implemented.
- Empowerment: Empowerment of people at risk to take self-protection measures
- Credibility: Confidence in the source of information.
- Resilience: The anticipation of failure should cause resiliency in the communication process (blockages in information channels, etc.).

Four forms of risk communication

Hazard can be a potential future event, whereupon the risk message intends to prepare the message receiver for that event or it can be an actual occurring event. The understanding of the seriousness of the event by the message receiver is important as well as the action taken in series. Outrage refers to the emotions and behaviors of the message receivers.
According to Sandman (2003) four forms of risk communication can be differentiated:[42]

- **high hazard/low outrage (serious hazard, apathetic audience)**

Less upset people have to be warned about serious risks (watch out).
It is a challenge for the communicator to encourage the audience to take favored actions. Short messages intend to heighten the outrage of the audience with the aim to cause action and assure attention. The uninterested public is often addressed by heavy use of mass media.
An example of the high hazard/ low outrage scenario is the crisis communication before the Hurricane Katrina. Many residents followed the recommendation to evacuate, but some chose to stay (too low outrage level to move).

[40] Rohrmann, B.: The relevance of the internet for enhancing disaster preparedness of residents, in: 11th annual TIEMS conference – The international Emergency Management Society, 2004, p.3-4
[41] cf. Kasperson, R.E.; Palmlund, I.: Evaluating Risk Communication, in: Covello, V., McCallum, D.; Pavlova, M. (eds.): Effective Risk Communication: The Role and Responsibility of Government and Nongovernment Organizations. New York, 1989, p. 143-158, here: p. 154-157
[42] Sandman, P.M.: Four kinds of risk communication. The Synergist, 26-27, in: http://www.petersandman.com/col/4kind-1.htm.; cf. Ferrante, P.: Risk & Crisis Communication. Essential skills for today´s SH&E professional, in Professional Safety, 2010, p. 38-45; Sandman, P.M.: Meeting management: where does risk communication fit in public participation?, in: Risk = Hazard + Outrage 2008

- **medium hazard/medium outrage**

A dialogue with an interested audience concerning risks. Public participation resembles this type of risk communication.
The audience is interested (not too upset or too apathetic to listen) – issues should be discussed openly. The risk/crisis communicator should promote an open dialogue declaring the situation and give the audience the possibility of response (often a long process of dialogue between risk/ crisis communicator and the stakeholder).

- **low hazard/high outrage**

Calm down extremely upset people about small risks (calm down).
The most difficult scenario is the low hazard/high outrage scenario. There is often a high distrust of messages by the audience and often activists, exaggerating the situation, influence the audience. The task of the communicator is to decrease the outrage (listen) in order to achieve a more realistic view in the audience concerning the severity of the hazard. The communicator has the attention of the audience and based on good skills in risk and crisis communication, changes can be achieved. An example of a low hazard/high outrage situation was a much smaller oil spill of a BP tanker near the Californian Coast right after the disaster of Exxon Valdez (1989). In response to the information not immediately being made public by Exxon, BP made timely information about the disaster available. Although the BP spill was much smaller, the emotional reaction of the citizens of California started as high outrage that must have related back to happenings in connection with Exxon Valdez.

- **high hazard/ high outrage**

Help upset people to handle severe risks (crisis communication).
In this case the audience is anxious and frightened. Good communication skills are necessary to avoid outrage from mutating into terror or depression. These responses are counterproductive when encouraging people to take favored actions. The communicator must show good leadership skills. It is important to communicate the severity of a disaster and the importance of quick reaction, whereby empathy for the citizens is shown.

Instruments of Communication

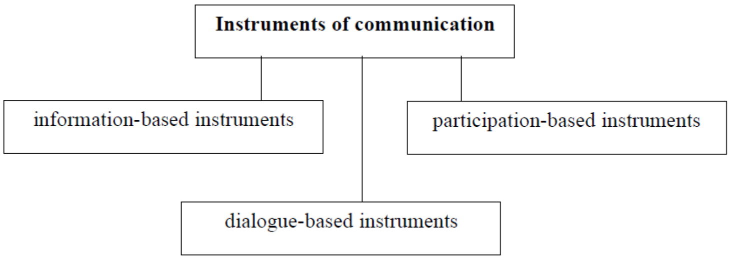

Figure 56: Instruments of communication[43]

One-way communication:
Information-based instruments: Transmission of information to the addressee (without feedback or two-way communication). This type of communication is used primarily when many people should be reached (exclusively information is conveyed: e.g. newspapers, brochures, TV, internet, radio).

[43] Source: Renn, O.; Carius, R.; Kastenholz, H.; Schulze, M.: ERiK- Entwicklung eines mehrstufigen Verfahrens der Risikokommunikation, (eds.): Hertel, R.F.; Henseler, G., Berlin, 2005, p. 20

Two-way communication:
Dialogue-based instruments include the addressees in the communication without directly involving them in the shaping or implementation of decisions or measures (question/answer, statement of opinion, etc.). It is characteristic to include the wishes of the recipients when making decisions (e.g. presentations, podium discussions, internet with feedback, etc.)
Counting among participation-based instruments are orientation instruments, commitment instruments or decision-making instruments.
According to Slovic, a two-way process of risk communication should be realized (experts and the public).44

Education as an important factor of risk communication

Education is an important element of risk communication – it increases the risk awareness of people and encourages them to take self-protection measures. Education and training are part of non-structural flood protection measures.[45] For example, the educational department in China has implemented disaster reduction measures (floods, etc.) into the curriculum of middle and primary schools (creating awareness of natural disaster reduction). Institutions of higher education also educate people in disaster reduction measures.[46]
"…to actively engage risk information, people need to feel the capacity to acquire and understand whatever information is necessary to (1) deal cognitively with a risk, (2) manage an emotional response to it, or (3) meet normative expectations about what they should know about the risk. This perceived (self-reported) capacity is associated positively with formal education and with knowledge the individual already possesses about the risk. Thus, risk communicators may need to make special efforts to make risk information accessible and understandable... These initiatives might include public education programs designed to improve the capacity various audiences have to get and evaluate risk information. Presumably, people who become frustrated when trying to obtain useful risk information may abandon the effort."[47]

Educational handling of flood topics - Floods in kindergarten and schools

A fundamental aspect in connection with flood risks is the primary prevention. Children and youth should be aware of flood risks and learn about protective measures. The importance self- and neighborly help as components of disaster control should be conveyed as early as kindergarten because children at this age show a special ability for learning. Children should act as disseminators in communicating what they have learned on to their families.
The topic of flood risk should also be anchored in the curriculum of schools (confrontation with local events). Changes in the surrounding in the past, present and future should be perceived and sense of responsibility developed. The topic of self-help should be anchored in the curricula and talks by external experts should be offered in schools and educational institutions to sensitize students to preventative measures.[48]

[44] cf. Slovic, P.: Perception of risk, in: Slovic, P. (ed.): The Perception of risk, London 2000, p. 220-231, here: p. 231
[45] Bruen, M.; Gebre, F.A.: Worldwide public perception of flood risk in urban areas and it´s consequences for hydrological design in Ireland, National Hydrology Seminar 2011, p. 10; cf. UN, International Strategy for disaster reduction: Living with risk: A global review of disaster reduction initiatives, New York/ Geneva 2004
[46] cf. Asian Disaster Relief Centre, 1999
[47] Griffin, R.J.; Yang, Z.; ter Huurne, E.; Boerner, F.; Ortiz, S.: After the flood: Anger, attribution and the seeking of information, in: Science Communication, 2008, 29, p. 285-315, here: p. 308
[48] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 283-286

Flood nature trails as an educational medium

Flood nature trails could make information about causes and effects of flood as well as protective measures available to interested people. Events could be organized (hikes) to learn about the flood nature trail. In addition, a flood nature trail could be appreciated by tourists.

- e.g. a river and its floodplain in their pristine condition
- regulation of a river
- causes of floods in general and a preview of future developments (e.g. climate change)
- history of a community with attention to different floods
- the situation following the operational launch e.g. of a barrage
- help of the local authorities
- help of the emergency rescue organizations
- self-help: simple measures (securing documents, emergency supplies, etc.)
- self-help: construction measures
- neighborly help and solidarity[49]

Especially in flood-endangered areas, an active information policy regarding risks is important.[50] Information is necessary to increase the willingness of individuals to take precautionary measures. It is important to communicate possibilities of self-protection measures so that people are knowledgeable about reducing individual risk.

Risk awareness and risk perception are among others influenced by

- the level of media focus on an issue,
- the degree of uncertainty,
- risk-benefit analysis,
- trust in the source of information as well as
- trust in the information, etc.[51]

Promotion of self-protective measures

Prevention as well as the setting of measure for self-protection should be promoted. Material incentives are identified as motivation factors in the setting of self-protection measures, such as financial assistance for private investments (e.g. flood-resistant building renovation). Voluntary approaches are preferred, as they promote the intrinsic motivation and a longer effectiveness can be secured.[52] The communication regarding flood risks is a fundamental precondition for increasing individual precautions.

[49] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 286-287

[50] cf. Plapp, T.: Wahrnehmung von Risiken aus Naturkatastrophen. Eine empirische Untersuchung in sechs gefährdeten Gebieten Süd- und Westdeutschlands, Karlsruhe 2004, p. 279-281

[51] cf. Paton, D.: Preparing for natural hazards: the role of community trust, in: Disaster Prevention and Management, 16, 3, 2007, p. 370-379; Masuda, J.R.; Garvin, T.: Place, culture and the social amplification of risk, in: Risk Analysis, 26, 2, 2006, p. 437-454; Ropeik, D.; Slovic, P.: Risk communication: A neglected tool in protecting public health, in: Risk in Perspective, 11, 2, 2003, p. 1-4; Baron, J.; Hershey, J.C.; Kunreuther, H.: Determinants of priority for risk reductions: The role of worry, in: Risk Analysis, 20, 4, 2000, p. 413-427; Rosati, S.; Saba, A.: The perception of risks associated with food-related hazards and the perceived reliability of sources of information, in: International Journal of Food Science and Technology, 39, 2004, p. 491-500; Grabill, J.T.; Simmons, W.M.: Toward a critical rhetoric of risk communication: Producing citizens and the role of technical communicators, in: Technical Communication Quarterly, 7, 4, 1998, p. 415-441; Smith, C.F.; Kain, D.J.: Making Sense of Hurricanes: Public Discourse and perceived risk of extreme weather, in: Critical Approaches to Discourse Analysis across Disciplines, Vol. 4, 2, 2010, p. 180-196

[52] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 291

Precautionary measures to reduce damage are:

- property precautions
- building precautions
- behavioral precautions[53]

Risk communication and participatory management of natural dangers in flood precautions[54]

To increase the perception of risk among endangered citizens, conveying the flood danger in a credible way plays a central role. Studies in flood areas along the Rhine have shown that flood experience is an important factor in regard to precautions against damage. Only few of the households or companies that had not already been affected by floods took measures for prevention. Comprehensive options for self-protection should be pointed out. Another important factor-along with conveying the risk of flood and presenting options for private damage precautions – is the cooperation of public officials, insurance companies, endangered households as well as companies. (Increase of the perceived responsibility to individually protect one's self → causes of private damage precaution).[55]
The perception of risk forms the basis for reactions to risks (individual preventative measures). Adequate communication strategies must take the aspect of risk perception into consideration.[56] The perception (personal vulnerability in regard to future events, etc.) is a fundamental component in explaining why people take precautionary measures or fail to do so.[57]

Sales of insurance policies rise only some months after the effects of a hazard.[58] Insurance is often contracted directly after floods but canceled quite quickly. When no floods occur within a certain period of time, the probability of floods is assessed lower and the willingness to contract insurance decreases. According to the findings of a study of Lave and Lave (1991) there is a connection between the knowledge of people concerning floods as well as the willingness to contract flood insurances and the employment status, educational attainment and the degree of reading newspapers/books. Residents having experienced floods personally know more about floods and show higher concern about floods.[59]

The findings of a study of Kenji Takao show a significant correlation between fear of floods and flood preparedness. Home ownership has been identified as important factor determining flood preparedness.[60] According to Turner (1983) homeowners at risk of earthquake hazards want more information concerning the potential for disaster and mitigation measures. A higher level of information pushes a homeowners´ sense of efficacy in coping with hazards; moreover it contributes to a more rational behavior.[61] Mulilis et.

[53] DKKV (eds.): Hochwasservorsorge in Deutschland. Lernen aus der Katastrophe 2002 im Elbegebiet, Schriftenreihe des DKKV 29, Lessons Learned, Bonn, 2004, p. 16-20

[54] cf. Grothmann, T.; Reusswig, F.; Linneweber, V.: Risikokommunikation und partizipatives Naturgefahrenmanagement in der Hochwasservorsorge, in: DKKV (eds.): Hochwasservorsorge in Deutschland. Lernen aus der Katastrophe 2002 im Elbegebiet, Schriftenreihe des DKKV 29, Lessons Learned, Bonn, 2004, p. 49

[55] cf. Grothmann, T.; Reusswig, F.; Linneweber, V.: Risikokommunikation und partizipatives Naturgefahrenmanagement in der Hochwasservorsorge, in: DKKV (eds.): Hochwasservorsorge in Deutschland. Lernen aus der Katastrophe 2002 im Elbegebiet, Schriftenreihe des DKKV 29, Lessons Learned, Bonn, 2004, p. 49

[56] cf. Plapp, T.; Werner, U.: Understanding risk perception from natural hazards: examples from Germany, in: Amman, Dannenmann, Vulliet (eds): RISK 21 – Coping with risks due to Natural Hazards in the 21st Century, 2006

[57] Palm, R.I.: Earthquake insurance: A Longitudinal Study of California Homeowners, 1995, p. 83

[58] cf. Baumann, D.D.; Sims, J.H.: Flood insurance: Some determinants of adoption, in: Economic Geography, 54, 1978, p. 189-196; Kunreuther, H.: Disaster insurance protection, Public policy lessons, New York 1978

[59] cf. Lave; T.R.; Lave, L.B.: Public perception of the risks of floods: implications for communication, in: Risk Analysis, Vol. 11, No. 2, 1991, p. 255-267

[60] cf. Kenji Takao: Factors determining resident´s preparedness for flood in modern megalopolises: the case of the Tokai Flood Disaster in Japan

[61] cf. Shirley Bradway Laska: Involving Homeowners in flood mitigation, APA Journal, 1986, p. 452-466, here: p. 462; cf. White, G.F.: Human responses to natural hazards, in: Perspectives on Benefit Risk Decision Making, Washington 1972; cf. Turner, R.H.: Waiting for disaster: Changing reactions to earthquake forecasts in southern California, International Journal of Mass Emergencies and Disasters, 1, 1983, p. 307-334

al. (2000) showed in a study concerning tornado preparedness of students, nonstudent renters and nonstudent owners that homeowners had a higher tornado preparedness than renters, who again showed a better preparation than students. Moreover the appraisal of preparedness resources has been higher than the perceived threat (concerning a tornado) by homeowners; moreover homeowners showed a higher responsibility for tornado preparation compared to renters. Renters again showed a higher appraisal of preparedness resources than the perceived threat - moreover they showed a higher responsibility for tornado preparation than students.[62] A correlation has been identified between disaster preparedness and socioeconomic characteristics e.g. education, household income, age, gender as well as ethnicity. Moreover proximity to the disaster area and preparedness correlate positively. Further important variables concerning person and event are probability of occurrence, severity of disaster, attitudes and norms of the person, the perceived effectiveness of the preparation process as well as self-efficacy.[63]

To improve risk communication it is important to involve people in potentially exposed regions in the communication and decision-making processes. Thereby, the population should be encouraged to deal more intensively with risks and to set comprehensive precautionary measures.[64]

According to Lindell/Perry (2000)[65], awareness of risk is promoted and the selection of potential precautionary measures is supported by the mass media or official information. Factors that influence the selection of precautionary measures include: estimation concerning the precautionary measure (easily implemented, etc.), the ability or readiness to set the precautionary measure as well as the personal threat due to natural dangers.

Risk communication informs about risks to enhance the coping capabilities.

Reasons for taking precautionary action

A model developed by Grothmann/Reusswig (2006) based on Protection Motivation Theory (PMT) declares the precautionary damage prevention of residents by their perception of prior experience with floods, risk of prospective floods, efficacy/cost of self-protection behavior, residents´ perceived ability to take protection actions as well as non-protective response.

[62] Cf. Mulilis, J.P.; Duval, T.S.; Bovalino, K.: Tornado Preparedness of Students, Nonstudent Renters and Nonstudent Owners: Issues of PrE Theory, Journal of Applied Social Psychology, 2000, 30, 6, pp. 1310-1329

[63] Cf. Edwards, M.L.: Social location and self-protective behavior: Implications for earthquake preparedness, International Journal of Mass Emergencies and Disasters, 1993, 11, p. 293-304; Mileti, D.S.; O´Brian, P.W.: Warnings during disaster: Normalizing communicated risk, Social problems, 1992, 39, p. 40-57; Kaniasty, K.Z.; Norris, F.H.: A test of the social-support deterioration model in the context of natural disaster, Journal of Personality and Social Psychology, 1993, 64, p. 395-408; Mulilis, J.P.; Lippa, R.A.: Behavioral change in earthquake preparedness due to negative threat appeals: A test of protection motivation theory, Journal of Applied Social Psychology, 1990, 20, p. 619-638; Mulilis, J.P.; Duval, T.S.; Bovalino, K.: Tornado Preparedness of Students, Nonstudent Renters and Nonstudent Owners: Issues of PrE Theory, Journal of Applied Social Psychology, 2000, 30, 6, pp. 1310-1329

[64] cf. Lorenzen, D.: Risikokommunikation über Naturkatastrophen, Göttingen 2009, p. 274-275

[65] cf. Lindell, M.; Perry, R.: Household adjustments to earthquake hazard: A review of research, in: Environment and Behavior 32, 2000, p. 461-501.

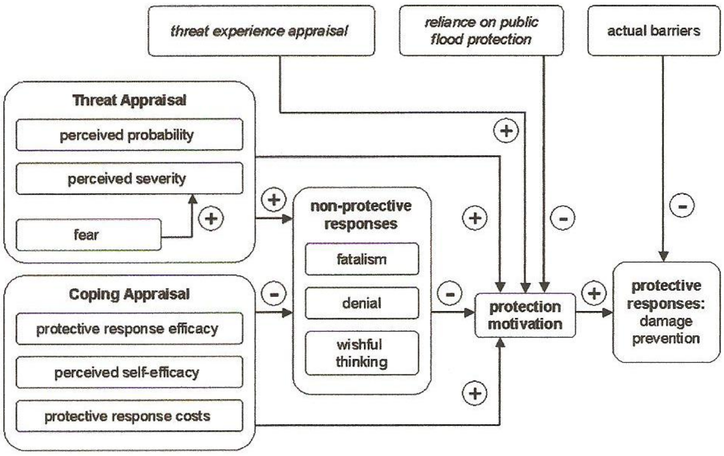

Figure 57: Precautionary damage prevention by residents in flood prone areas[66]

Two perceptual processes can be differentiated:

- the threat appraisal and
- the coping appraisal.

The threat appraisal (risk perception) concerns a persons´ assessment of the probability and the damage potential of a threat (no behavior change). Concerning the coping appraisal: evaluation of a persons´ ability to cope with the threat and to avoid harm because of the threat (including costs of coping).

Three components of threat appraisal are

- Perceived probability (perceived exposure to the threat)
- Perceived severity
- Fear (has an effect on the perceived severity of the danger)

After the threat appraisal process the coping appraisal process takes place (after passing a certain threshold of threat appraisal). Considering peoples´ estimation of their options/capability of response to a threat as well as their effectiveness and costs you can understand peoples´ response behavior to a theat.

The three components of coping appraisal are

- Protective response efficacy
- Perceived self-efficacy
- Protective response costs

Protective response efficacy: faith in the efficacy of protective actions (protect yourself respectively others from harm caused by the threat)
Perceived self-efficacy: perceived ability of a person to implement protective responses
Perceived protective response costs: costs of taking the preventative response (money, time, etc.)
A persons´ response to the threat rests upon the processes of threat appraisal and coping appraisal. Protective responses and non-protective responses can be differentiated. Protective responses (high threat appraisal and coping appraisal) cause the prevention of damage (monetary, physical) in case of the real occurrence of an event. Non-protective responses (denial of the threat, wishful thinking, etc.) contribute to the prevention of negative emotional effects of the perceived risk such as fear (no prevention of monetary and physical damage). The protection motivation describes the intention of action taking. Protection motivation does not implicate actual behavior because there can be actual barriers (e.g. lack of resources, knowledge, time, money, etc.) that have not been expected when the intention has been designed (differentiation between intention and actual behavior). Grothmann/Reusswig (2006) expand the

[66] Grothmann, T.; Reusswig, F.: People at risk of flooding: Why some residents take precautionary action while others do not, in: Natural Hazards, 2006, 38. P. 101-120, here: p. 105

scheme of Protection Motivation Theory and involve variables significant to proactive prevention of flood damage. Threat experience appraisal evaluates the severity of a past threat experience (no uncertainty). Threat experience appraisal should push peoples´ motivation to take pro-active measures.

These are important aspects for risk communication. For the motivation of people to a preventative behavior the influence of their risk perception may be too little. Issues of practical actions as well as barriers to self-protection behavior should be outlined. Besides the risk and potential negatives effects of floods the possibility, costs as well as effectiveness of personal pro-active actions should be communicated. According to Grothmann/Reusswig (2006) non-protective response (e.g. denial, etc.) seems to be an important factor in ´de-motivating´ proactive behavior. Another important factor is the reliance on public flood protection. The private precautionary measures taken by residents might be less in case of residents relying on the efficacy of measures of public flood protection. Communication has to create awareness that public flood protection has to be extended by private precautionary measures.[67]

Precautionary behavior and protection measures

According to Mileti und Fitzpatrick (1993) influencing factors on precautionary behavior are:

1. "The kind of information people received about the risk and what to do
2. Their own personal characteristics
3. The perceptions people held
4. Their information seeking behavior about the risk and what to do"[68]

Information-seeking is influenced by the factors 1-3, perception is influenced by the factors 1 and 2.[69] According to Mileti/Darlington (1997)[70] factors that may push the taking of protection measures are:

- Previous disaster experience
- Middle age
- Higher education level
- Family members living in the surrounding area

Good information should motivate people to deal with the environment and to look for more information.[71] A study of Mileti et. al (1990) in Parkfield/California concerning the effectiveness of a pamphlet in raising earthquake awareness shows important factors:[72]

1. Explanation of a complicated phenomenon in non-technical terms
2. Credible information resources
3. Repetition of consistent information in varying media
4. TV and radio are effective communication channels, but a written handout is liked by people
5. Information of the people concerning actions before, during and after a disaster
6. Discussion with peers supports the credibility of the information and to follow the information.

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[67] Grothmann, T.; Reusswig, F.: People at risk of flooding: Why some residents take precautionary action while others do not, in: Natural Hazards, 2006, 38. p. 101-120

[68] Mileti, D.S.; Fitzpatrick, C.: The great earthquake experiment: Risk communication and public action, Boulder 1993, p. 117

[69] cf. Wagner, K.: Naturgefahrenbewusstsein und –kommunikation am Beispiel von Sturzfluten und Rutschungen in vier Gemeinden des Bayerischen Alpenraums

[70] cf. Mileti, D.S.; Darlington, J.D.: The role of searching in shaping reactions to earthquake risk information, in: Social problems, 1997, p. 89-103

[71] cf. Mileti, D.S.; Peek, L.A.: Understanding Individual and Social Characteristics in the Promotion of Household Disaster Preparedness, in: New Tools for Environmental Protection: Education, Information and Voluntary Measures, 2002, P. 126

[72] cf. Mileti, D.S.; Peek, L.A.: Understanding Individual and Social Characteristics in the Promotion of Household Disaster Preparedness, in: New Tools for Environmental Protection: Education, Information and Voluntary Measures, 2002, p. 128

Mitelti et. al. (1993) showed in a study concerning a publication of earthquake probabilities in Bay Area (booklet distributed to the residents) that clear information about risks leads to comprehension of the basics and people can bear the read in mind. If people know that they can take measures of reducing vulnerability, they are more in favour of acting than those not knowing safety measures. It was also shown that people search information for the validation of the heard. Several people take measures after the insert has been read not only because they became aware of specific actions to be taken but also aspects heard anywhere before have been affirmed.[73]

Community based Disaster Management

Risk communication is important to promote the participation of people in disaster management. Community-based disaster management is essential - local people know the vulnerabilities of their surroundings quite well. Participation and empowerment of local people is of importance.
Community-based disaster management aims at improving resilience of a community. For example, citizens in Taiwan have studied how to analyze vulnerabilities, develop solutions and implement disaster management by means of a participatory process.

Important assumptions concerning community-based disaster management are:

- persuading people of the importance of a community-based disaster management
- developing a neighborhood inventory (people and facilities)
- establishing emergency plans, e.g. different scenarios for the neighborhood, role of people in the neighborhood according to their abilities (before, during and after the disaster)
- training programs for keeping up preparedness among stakeholders[74]

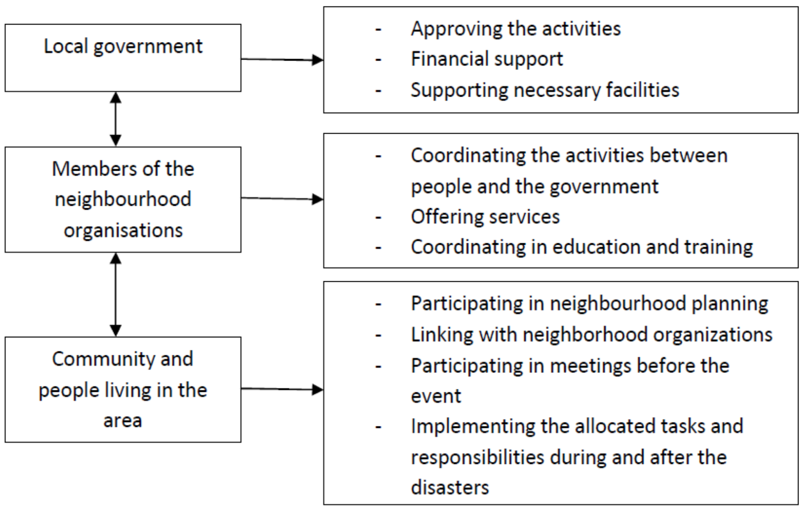

Figure 58: Groups in local government and neighborhood + roles[75]

[73] Mileti, D.S.; Peek, L.A.: Understanding Individual and Social Characteristics in the Promotion of Household Disaster Preparedness, in: New Tools for Environmental Protection: Education, Information and Voluntary Measures, 2002, p. 130-131
[74] cf. Izadkhah, Y.O.; Hosseini, M.: Sustainable neighborhood earthquake emergency planning in megacities, in: Disaster Prevention and Management, Vol. 19, No. 3, 2010, p. 345-357

[75] Izadkhah, Y.O.; Hosseini, M.: Sustainable neighborhood earthquake emergency planning in megacities, in: Disaster Prevention and Management, Vol. 19, No. 3, 2010, p. 353

5.4.2 Questionnaire

A questionnaire has been developed in four languages, with a detailed guidance how to apply and analyse the opinion poll. The opinion poll has been conducted in all five case study areas to figure out people`s behaviour and requirements, also regarding the nationalities.

The standardised questionnaire consists of 69 questions and an additional comments box at the end of the questionnaire, in which the respondents can enter any other issues. It is divided into six sections:

- Natural hazards and flooding in general
- Consequences of flood incidents
- Communication and information
- Self-protection and individual provisions
- Financial consequences of flooding
- Questions about you

The complete questionnaire is attached in appendix 4.

5.4.3 Applied fields – opinion poll

Survey areas and random sampling

For a better interpretation of the further results of the opinion poll the socio-economic characteristics of the case studies have been collected. The main characteristics are listed in Table 23.

Table 23: Socio-economic characteristics of the case studies

Survey area	Average Age	Gender ratio	Types of households
Arenys de Mar / Munt	0-15 years: 16.0% 15-64 years: 67.6% >65 years: 16.5%	Male: 49.2% Female: 50.9%	Single: 20.3% More persons: 79.8 %
Benaguasil	40 years	Male: 51.7% Female: 48.4%	Single: - More persons: -
Dresden[76]	42.5 years	0.9375	Single: 48% More persons: 52%
Graz / Andritz	39.8 years	Male: 47.5% Female: 52.5%	Single: 14.2 % More persons: 85.8%
Lodi	-	Male: 47.2% Female: 52.8%	Single: 27.9% More persons: 72.1%

As already mentioned, an important issue of the SUFRI questionnaire is to compile an international comparison of the data collected. It was for this reason that the questionnaire was distributed in several European cities. The selected survey areas are Arenys de Mar / Munt (Spain), Benaguasil (Spain), Dresden (Germany), Graz / Andritz (Austria) and Lodi (Italy), which are affected by an acute risk of flooding and which have already had to endure massive flooding in the past. Following a demographic analysis of the survey areas, the physical measurement parameter of a 100-year flood was used for the random sampling (see Figure 59). This means that all the households taken into consideration for the random sampling are situated in the respective area of a 100-year flood. Random samples were gathered in relation to the numerical differences in the population.

76 The stated date are the mean values of the Weißeritz catchment area and the Weißeritz catchment area in Dresden

The following table provides information on how the random samples were gathered in the individual survey areas:

Table 24: Radom sampling

Survey area	**Residents** in the area of the 100 year flood	**Households** in the area of the 100 year flood	**Random sampling** households to interview
Arenys de Mar / Munt	2282	570	every 2nd household
Benaguasil	800	200	every household
Dresden	4700	1175	every 4th household
Graz / Andritz	-	1321	every 4th household
Lodi	3000	750	every 3rd household

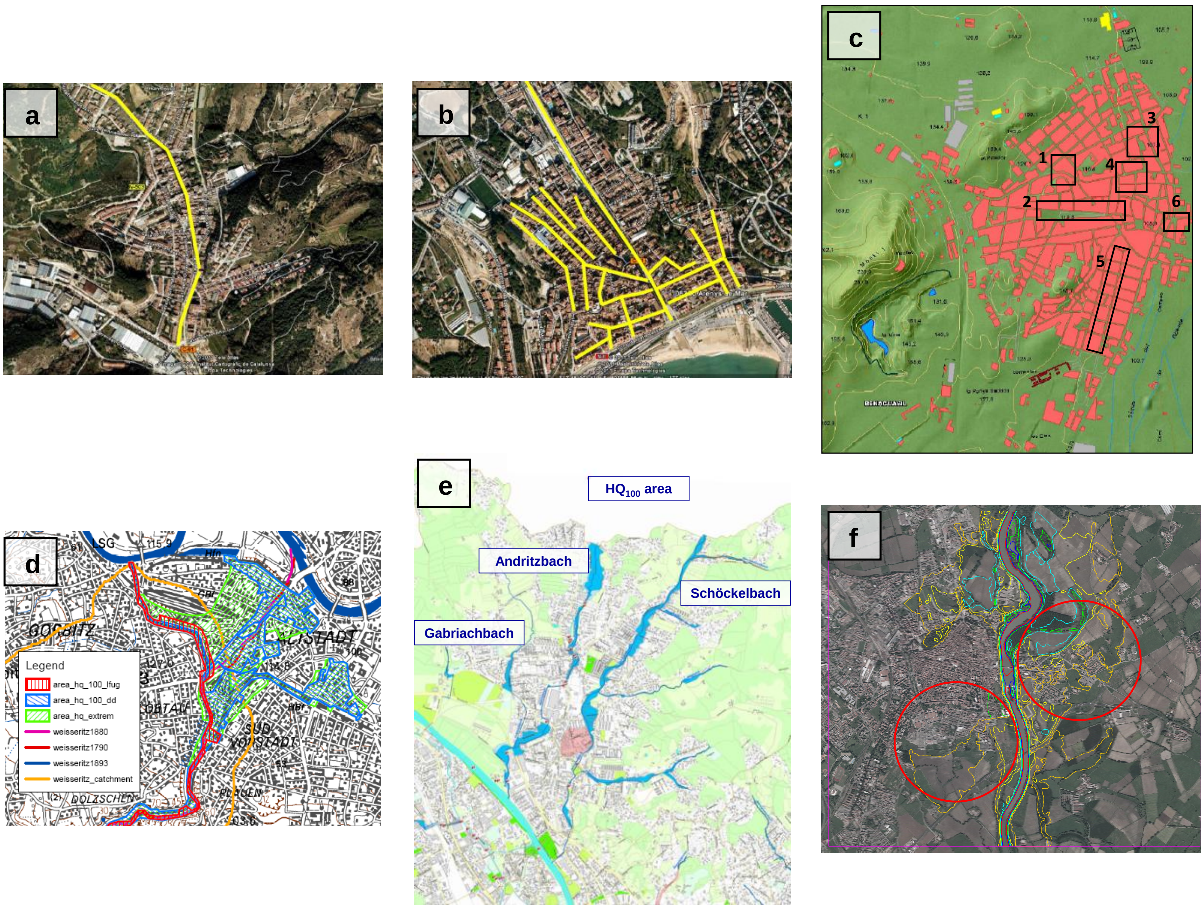

Figure 59: Investigation areas, a-b: Arenys de Mar / Munt, c: Benaguasil, d: Dresden, e: Graz, f: Lodi

Distribution, procedure of the opinion poll and return rate

In Arenys de Mar / Munt, Benaguasil, Dresden and Lodi the questionnaires were taken directly to the households by the persons commissioned to do so. In Graz / Andritz the questionnaires were also handed over to the appropriate household by commissioned persons in franked envelopes, however with the difference that the respondents were requested to send the pre-stamped and pre-addressed envelope with the completed questionnaire by mail to the Institute for Sociology at the Karl Franzens University in

Graz.[77] In Dresden due to the suggestions of the interviewed persons the opinion polls were also returned by mail and fax messages. In the other survey areas, the completed questionnaires were personally collected by commissioned persons at three different appointed times. Table 25 gives an overview of the survey period and the distribution respectively the kind of return.

Table 25: Survey period and distribution

	Survey period	Distribution	Return
Arenys de Mar / Munt	Oct. / Nov. 2010	personally	personally
Benaguasil	June 2010	personally	personally
Dresden	Oct. 2010	personally	personally, by mail, by fax message
Graz / Andritz	Sept. / Oct. 2010	personally	by mail
Lodi	Oct. / Nov. 2010	personally	personally

The return rates following the collection of all questionnaires are shown in Table 26.

Table 26: Return rate

Survey area	Households to interview[78]	Interviewed households[79]	Filled out questionaires	Return rate
Arenys de Mar / Munt	285	3026[80]	122	4%
Benaguasil	201	104	33	32%
Dresden	294	666	238	36%
Graz / Andritz	330	286	72	25%
Lodi	250	296	188	64%

The return rates range between 25 and 64 per cent and are thus to be recorded as exceptional in each survey area from a social scientific perspective. Only the return rate in Arenys de Mar / Munt is with 4% quite low.

During the realization of the opinion poll different experiences have been gained.

1. It's absolute necessary to adapt the modality of the investigation to the local circumstances in the case study area. Depending on the attitude and atmosphere regarding the authorities sometimes it could be useful to have them as partner, sometimes not.
2. It is advantageous if the interviewer speaks the same dialect/language as the interviewed persons (e.g. Catalan in Spain).

Table 27 and Table 28 give an overview of the special adaptation to the local circumstances respectively the reasons for refusal.

[77] This different method was chosen in Graz because it was recommended by experts there.

[78] In every of the selected households a questionnaire was distributed which was to be answered from a person. Thus a household stands for an asked person.

[79] The number those which can be asked and actually asked households are not usually ident: In Graz / Andritz and Benaguasil a certain number of questionnaires could not be brought to the appropriate households. Reasons for this were: House not inhabited; Inhabitants reject the acceptance of the asking sheets; Inhabitants were not to be found after the third contact yet. The project partners Dresden, Lodi asked more households than the sample planned.

[80] Due to the absence of hydraulic calculations and floodplain delimitations it has been decided to investigate 10% of the inhabitants in the basin of the Arenys river (22800 person). Due to a high percentage of rejection to fill-out the poll 28% of the existing householders of Arenys de Mar / Munt have been investigated.

Table 27: Special adaption to the local circumstances

Survey area	Special adaption to the local circumstances
Arenys de Mar / Munt	▪ 4 students conducted the opinion poll
Benaguasil	▪ Cooperation with the local authority of Benaguasil ▪ Information letter to inhabitants ▪ Interviewers (2 person) got official identification card of the authority Benaguasil ▪ Partly filled-out the opinion poll together with the interviewed people
Dresden	▪ Put questionnaires also into mailbox if people were unavailable ▪ Different way of return method (collected by interviewer, via mail, fax message)
Graz / Andritz	▪ Dissemination of questionnaire with stamped envelope (suggested by local experts) - Cooperation with the local citizens' initiative
Lodi	▪ Cooperation with Lodi`s civil protection office ▪ The mayor of Lodi wrote an information letter to the people concerned ▪ Cooperation with the committee of the flooded people in 2002 ▪ The Public Relation Office, together with the major of Lodi Town, has developed a press communicate to inform the population about the opinion poll, and they published it on the local press in the week 11-15 October 2010. ▪ Six researchers form university (PhD students, professor assistants and professors) conducted the opinion poll accompanied by a civil protection volunteer. ▪ Interviews during the weekend in order to be sure to find them in non-working hours. ▪ Identity cards for the interviewer

Table 28: Reasons for refusal

Survey area	Reasons for refusal
Arenys de Mar / Munt	▪ Interviewers have been from South America and spoke with an accent. In Arenys de Mar the people are very proud being a Catalan, which leads to communication difficulties.
Benaguasil	▪ Flood risk is not a threat for me and there is no need to complete the questionnaire ▪ I do not have knowledge in these topics. ▪ I did not suffer any problem in the past. ▪ I am busy. ▪ I am not interested in taking part in it.
Dresden	▪ Last significant flood event occurred more than 8 years ago (it was stated on basis of empirical studies that after 7 years flood awareness is about as low as before the flood) ▪ Many door to door sale or other (e. g. members of Jehovah's Witness) ▪ Questions too scientific, people don't understand what they have to do (question 26) ▪ Questionnaire too long
Graz / Andritz	No information
Lodi	No information

Results of the opinion poll - Descriptive Analysis

Each question of the opinion poll has been analyzed and the results of all case studies are presented in one figure to make them comparable. This also allows a quick interpretation of the results at a glance.

For the interpretation of the results it's very important to consider the number of those who have answered the question. If the number was lower than 25% of all interviewed persons in the corresponding case study, no analysis has been conducted. This means there could be a low percentage of respondents, which have to be taken into account when interpreting the results.
For the illustration of the figures integer have been used, thus small deviations from 100% can occur due to the fact that values have been rounded up or down.

Here general statements respectively trends or tendencies about the results for all case studies are summarized. A specification with values and percentages has been set aside deliberately to point out the main results for most of the cases. Thus, the detailed analysis will be published in a separate ERA-Net CRUE research report.

Q67 - Age:
In Dresden, Graz and Lodi the percentage of old people (> 60 years) who took part in this questionnaire is quite high.

In Dresden, Graz and Lodi more than 60% of the persons are older than 50 years. In Arenys de Mar / Munt and Benaguasil the biggest group (> 50%) of the persons is between 30 and 50 years old.

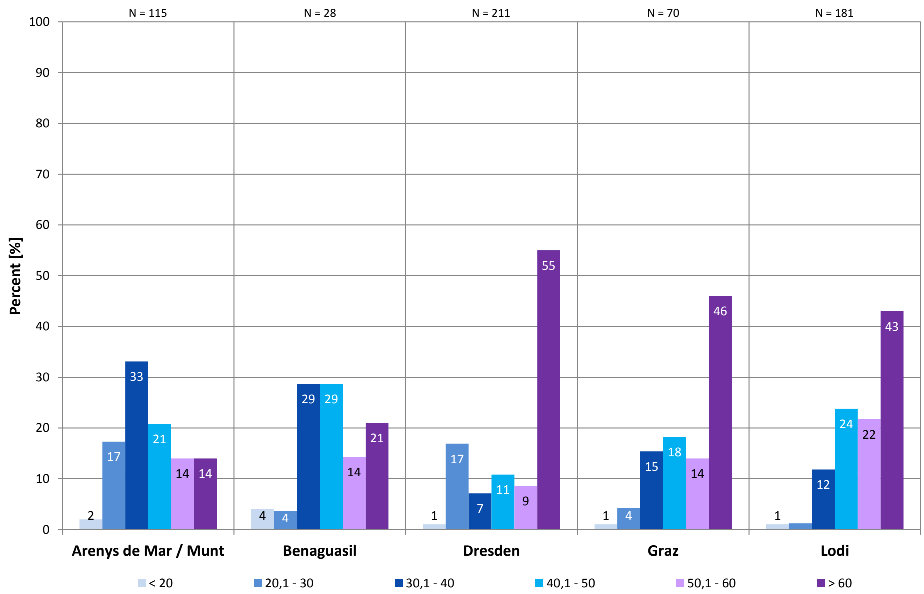

Figure 60: Q67 – How old are you?

Q1 - Satisfaction:
In all case studies the satisfaction with the current living situation is relatively high.

In all case studies more than 50% of persons are mostly or very satisfied with their current living situation, whereas the highest satisfaction can be registered in Graz with 44% persons who are very satisfied. The highest number of dissatisfaction arises in Lodi with 6% who are not satisfied.

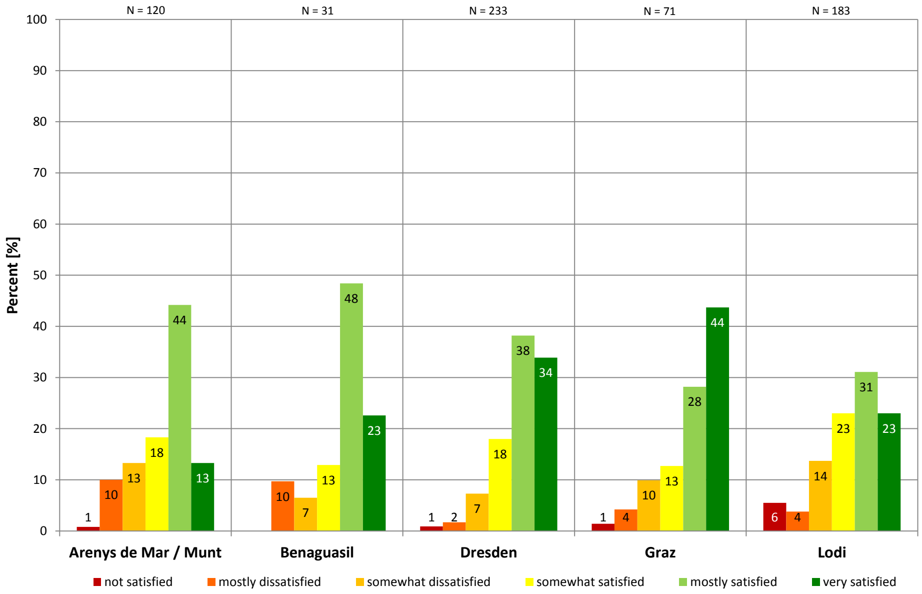

Figure 61:Q1 – How satisfied are you with your current living situation?

Q3 - Threatened by floods:
In Graz and Lodi people feel more threatened by floods than respondents in Arenys de Mar / Munt, Benaguasil or Dresden.

The results show, that the feeling of threat concerning floods is extraordinarily high in Lodi (45% feel threatened very much), followed by Graz (31%). Surprisingly only 5% of the people in Arenys de Mar / Munt feel threatened by floods. In Benaguasil and Dresden the quota of people who feel threatened and who not is relatively balanced. However the number of citizens who feel threatened very much is quite low (6% and 1%).

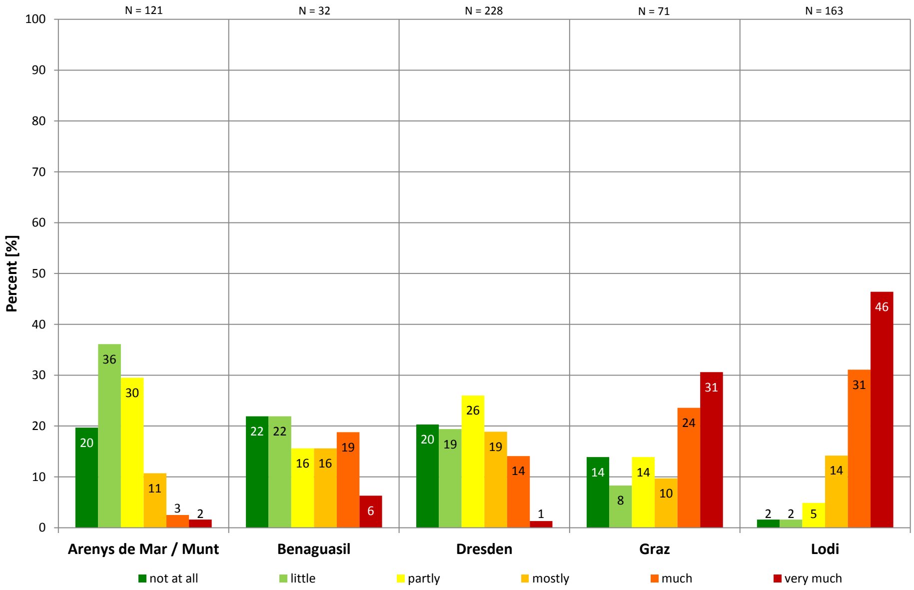

Figure 62: Q3 – To what extent do you feel threatened by **floods**?

Q6 - Cause for flood events

In Spain climate change, high building density, soil sealing and non-natural interferences as cause for flood events are rated much lower than in the other case studies.

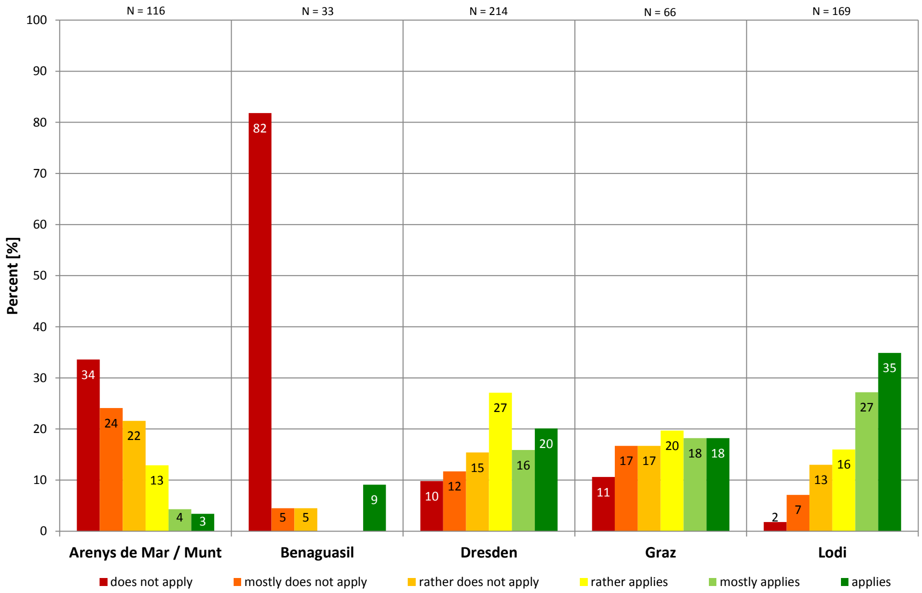

Figure 63: Q6 – What would you suppose are the causes of flood events – climate change?

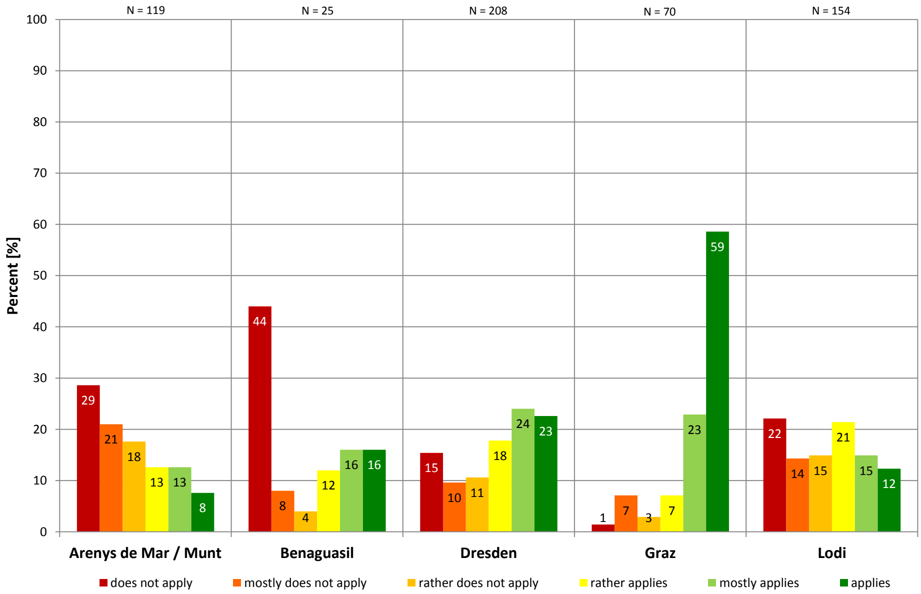

Figure 64: Q6 – What would you suppose are the causes of flood events – high building density?

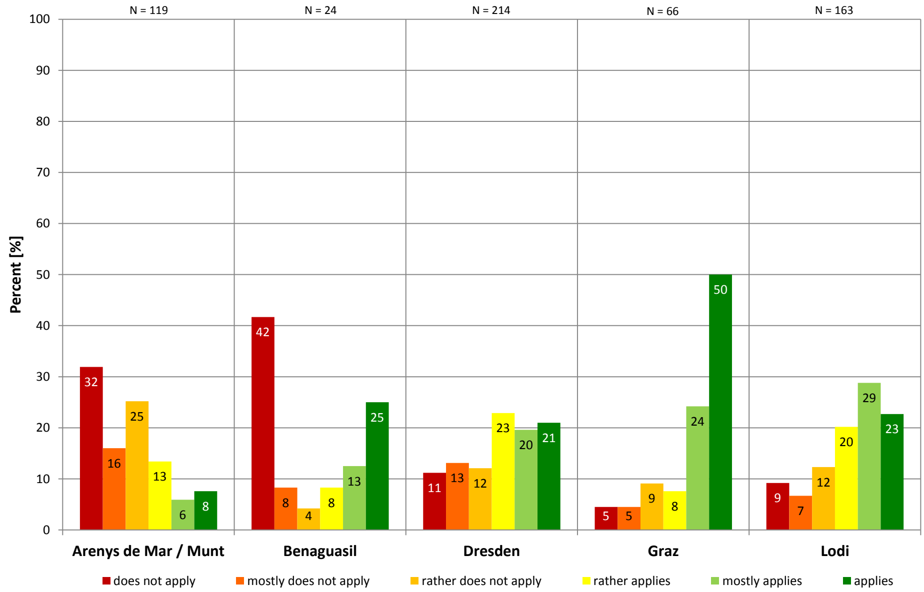

Figure 65: Q6 – What would you suppose are the causes of flood events – soil sealing?

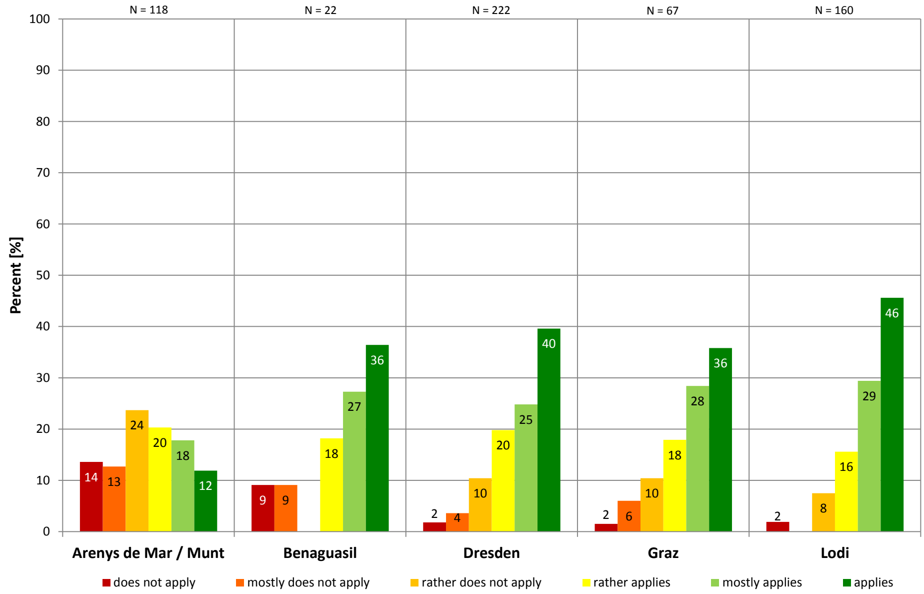

Figure 66: Q6 – What would you suppose are the causes of flood events – extreme weather conditions?

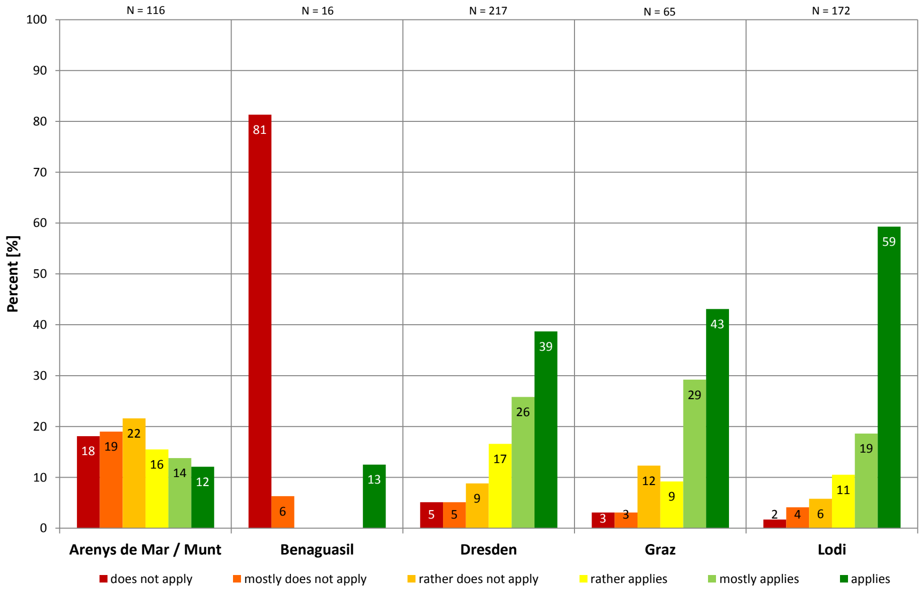

Figure 67: Q6 – What would you suppose are the causes of flood events – non-natural interferences?

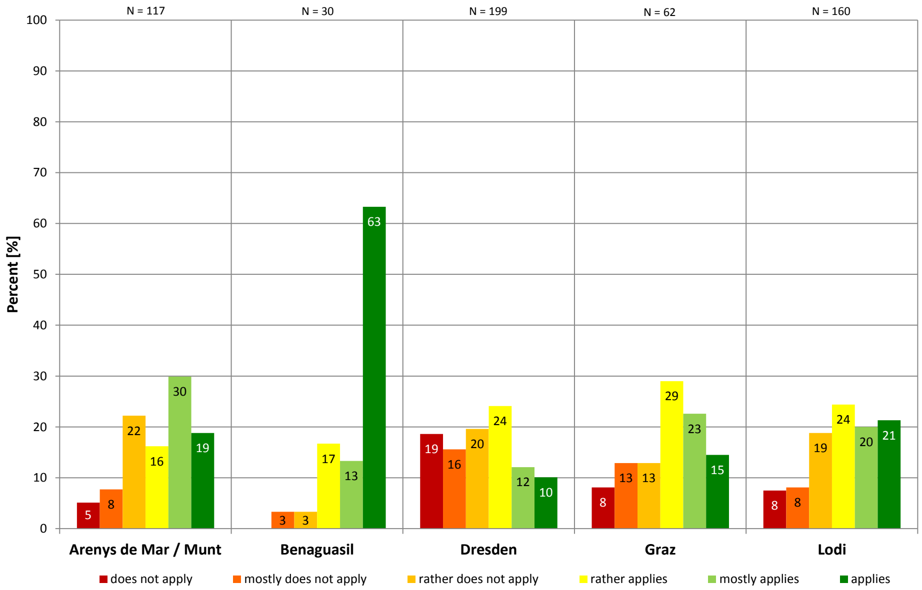

Figure 68: Q6 – What would you suppose are the causes of flood events – sewer construction?

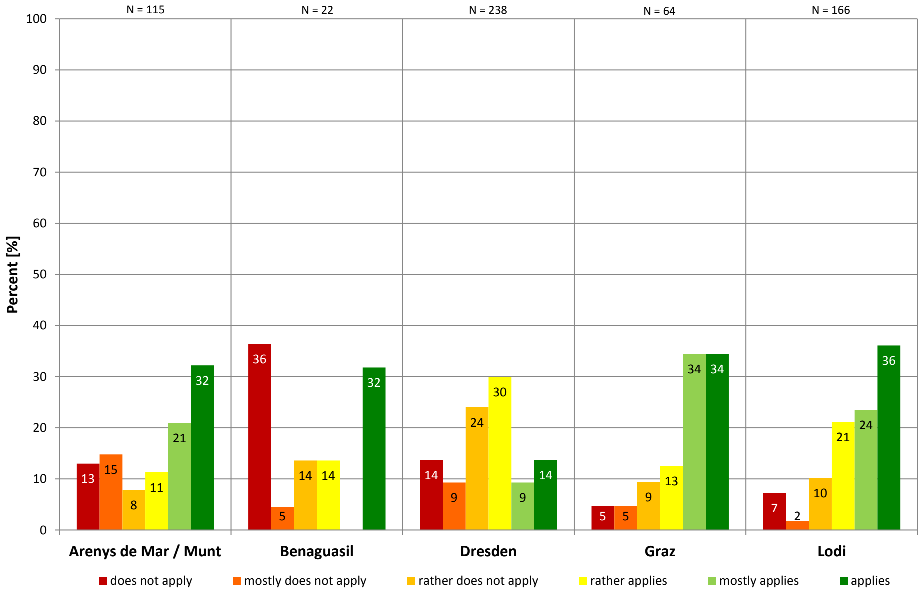

Figure 69: Q6 – What would you suppose are the causes of flood events – spatial planning?

Q7, Q21 - Evaluation of general statements:
In the case studies the evaluation of the general statements listed below have shown the same clear tendency.

- Man cannot control nature entirely: tendency applies[81]
- One can protect oneself from floods completely: tendency does not apply[82]
- There remains always a residual risk with natural hazards: tendency applies[83]
- When I moved to this area I was aware of the flood risk: tendency does not apply
- I have coped psychologically with the previous flood events very well: tendency applies
- During heavy rain I remember previously flood events: tendency applies
- Because of the financial burden I can barely afford a holiday: tendency does not apply

The results show, that most of the people are aware of the fact that there is always a residual risk. Additionally it shows the importance of awareness training regarding the flood risk in the residential area.

Q10: Affected by floods:
It's remarkable that in Arenys de Mar / Munt only 7% of the interviewed people have been affected by floods in the last 10 years. These percentage is much higher (> 60%) in the other case studies.

Q11: Frequency of affectedness:
In Dresden and Lodi the majority of the people have been affected once in the last 10 years. In Graz and Benaguasil flood events have happened more often. For Arenys de Mar / Munt an analysis was not possible due to the too low number of affected people.

[81] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.
[82] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.
[83] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.

Q13, Q15: Health problems:
The percentage of those who suffered from health problems after the last flood events is very low for Dresden and Graz. In Benaguasil none of the respondents had any health problems. The highest percentage can be registered for Lodi. The most indicated types of health problems in all case studies are panic attacks/anxiety states, insomnia, irritability/anger and restlessness. This also applies for physical impairments; with the exception that in Graz the highest percentage was achieved. For Arenys de Mar / Munt an analysis was not possible due to the too low number of affected people.

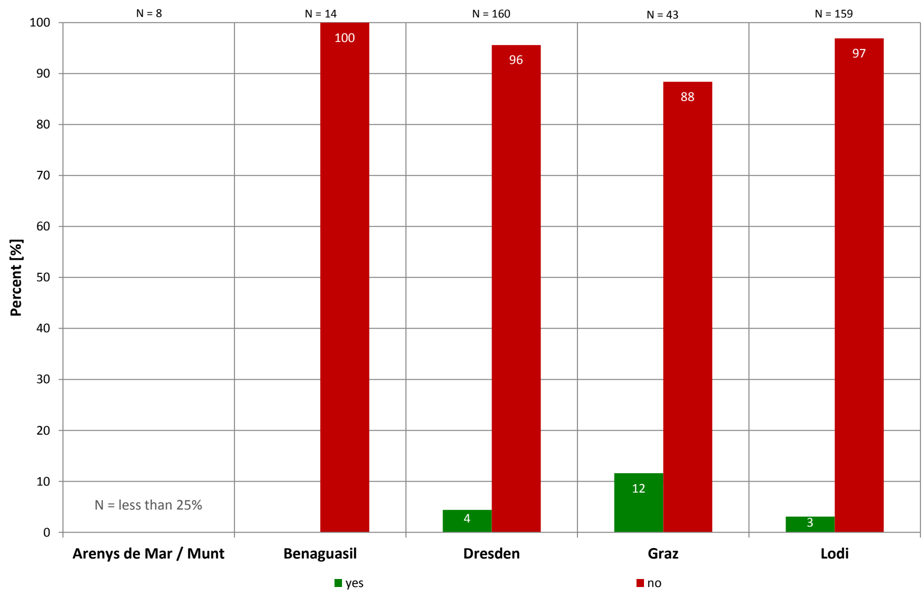

Figure 70: Q15 – Have you suffered from any physical impairments due to the flood event (bone fracture, etc.)?

Q24: Preferred source of information in case of emergency:
In all case studies, except Lodi, people like to be informed by the media. Further, in all case studies, except Benaguasil, people like to be informed by emergency services. The majority of the interviewed persons don't like to obtain information in case of emergency by internet, by on-site information centers or by friends / relatives.

Q26: Information about flood issues on a regular basis:
Regarding this topic the results show, that information by the media is preferred in all case studies.

Q28: Level of information during the last flood event:
The results show clearly that the majority of the people felt informed very badly during the last flood event. The percentage is especially high in Lodi with 85%, followed by Benaguasil with 68%, Graz 53% and Dresden 52%. Due to a too low number of affected people an analysis was not possible for Arenys de Mar / Munt.

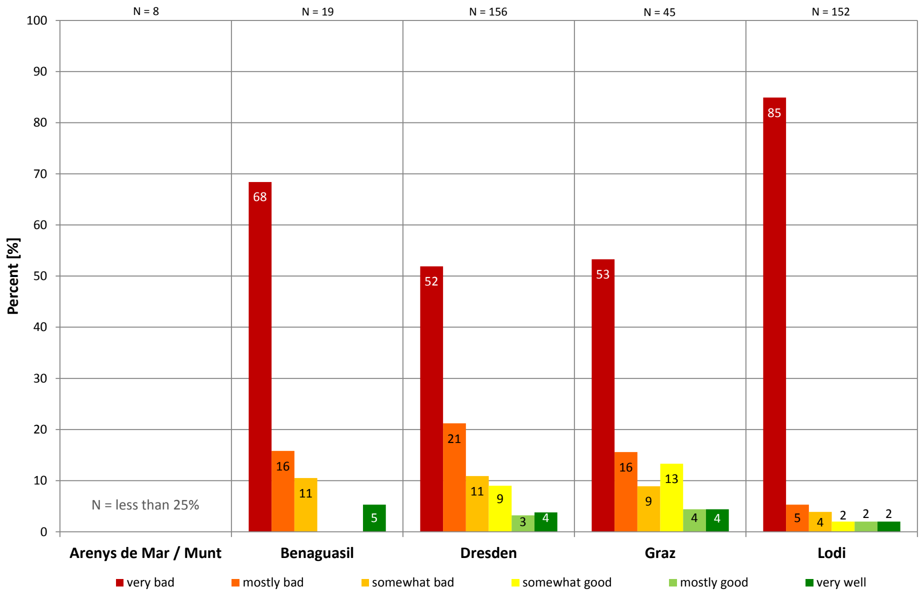

Figure 71: Q28 – How well informed have you felt during the last flood event?

Q29: **Time between first warning and onset of the flood:**
In the case studies Dresden, Graz and Lodi the people stated that the time between the first warning to the onset of the flood was quite short (up to 0,5 hours or from 0,5 to 2 hours).

In Lodi and in Graz more than 50% of the interview people stated that the time span between the first warning and the onset of the flood were less than 0,5 hours. In Dresden this applies for 33% and for 28% 0,5 to 2 hours have been available. Due to a too low number of affected people in Arenys de Mar / Munt and due to a too low number answers in Benaguasil an analysis was not possible.

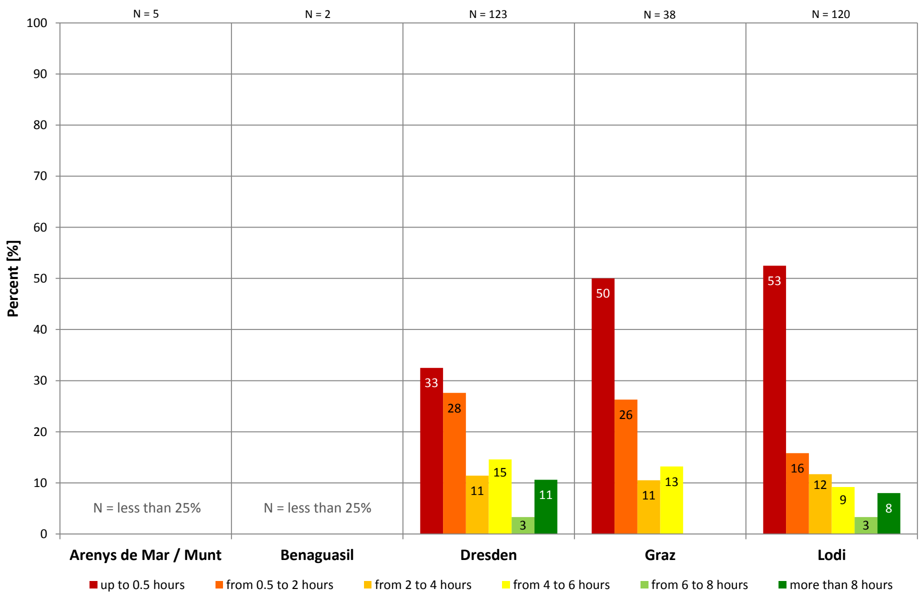

Figure 72: Q29 – How much time has passed between the first warning to the onset of the flood?

Q30: Assessment of available time span:

The available time span was far too short for most of the interviewed persons (Dresden 63%, Graz 56%, Lodi 82%). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt. Due to a too low number answers an analysis was not possible for Benaguasil.

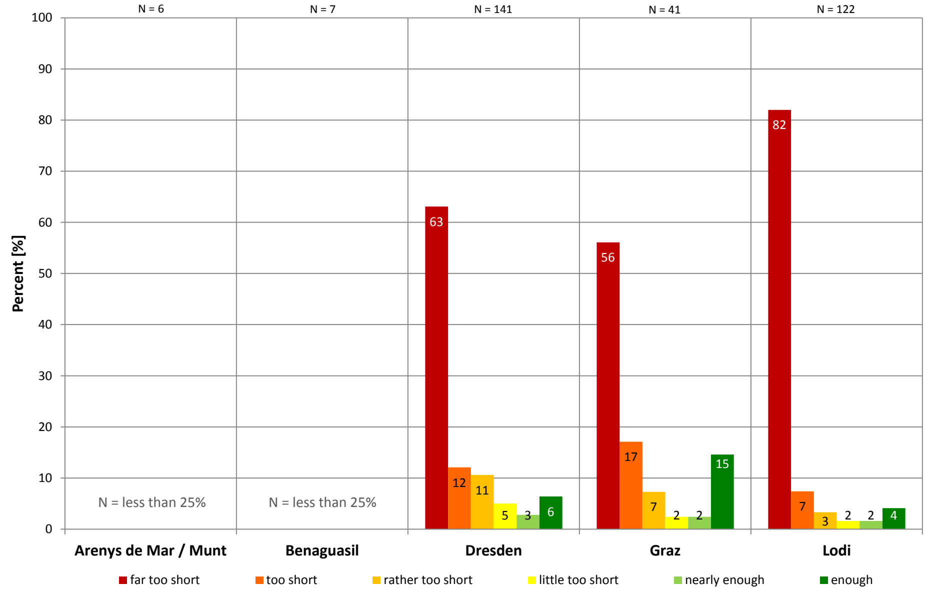

Figure 73: Q30 – This time span was …?

Q36: Knowledge about self-protection measures:

The majority of the interviewed people in Benaguasil (73%) and Graz (67%) have indicated to know measures for self-protection. In Arenys de Mar / Munt 71%, in Dresden 67% and in Lodi 62% don't know about this measures.

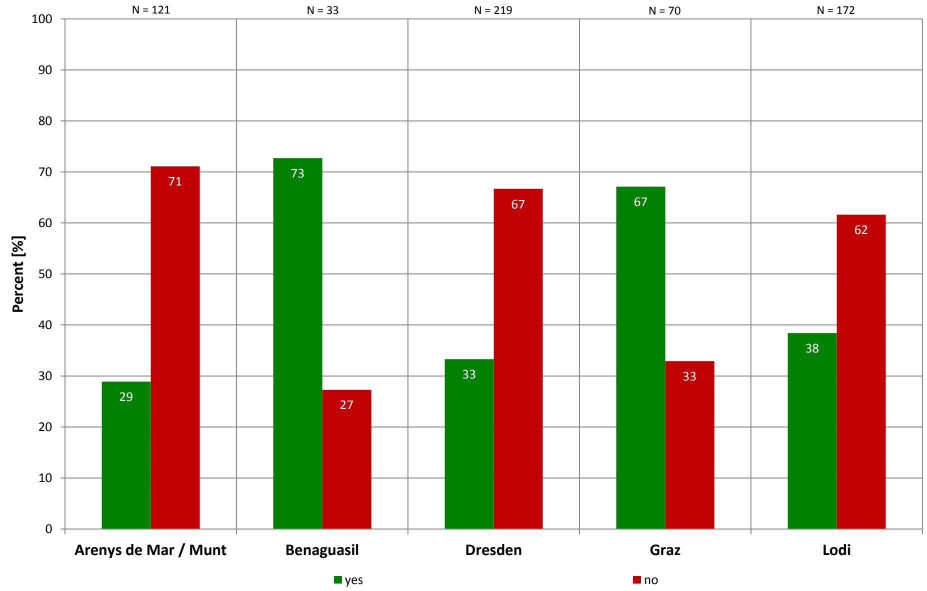

Figure 74: Q36 – Do you know concrete measures to protect yourself in case of flood?

Q40: Self-protection measures during the last flood:
The majority of the interviewed persons in all case studies did not take any self-protection measures.

Q45: Protective measures in the future:
In all case studies, except in Benaguasil, the majority of the people will take protective measures in the future.

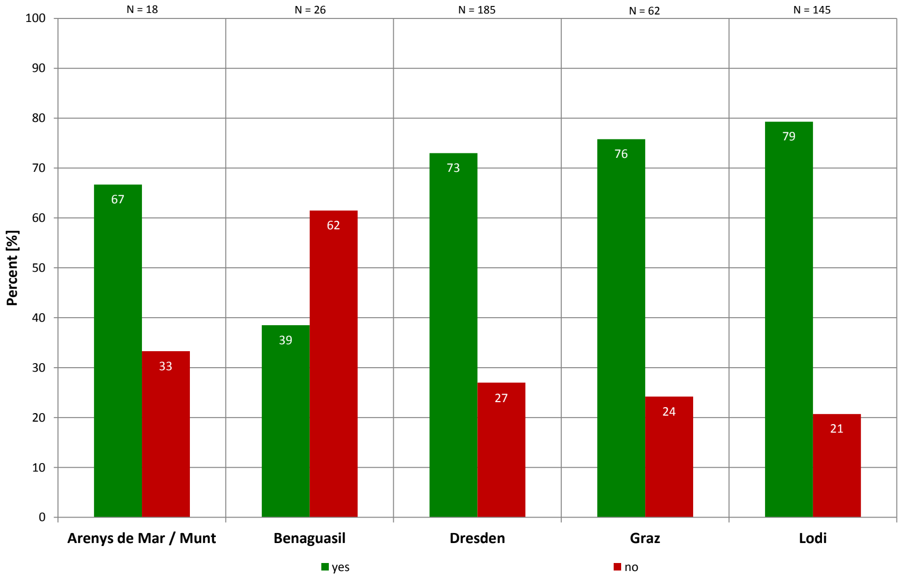

Figure 75: Q45 – Will you take protective measures in the future (again)?

Q46: Assessment of solidarity efforts in the neighborhood:
There is a clear tendency in all case studies, except Benaguasil, to assess the solidarity efforts in the neighborhood positive. In Benaguasil the opinions concerning this topic differ wider than in the other case studies, although 27% evaluated the solidarity efforts in the neighborhood as very good.

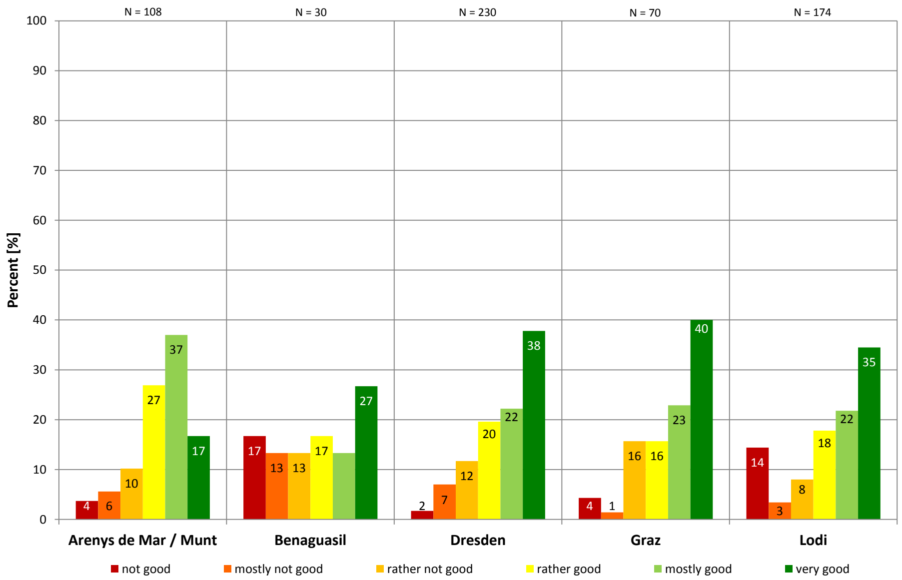

Figure 76: Q46 – How would you evaluate the solidarity efforts in your neighborhood

Q47: Importance of neighborly help:
There is a clear tendency in all case studies to assess neighborly help as important.

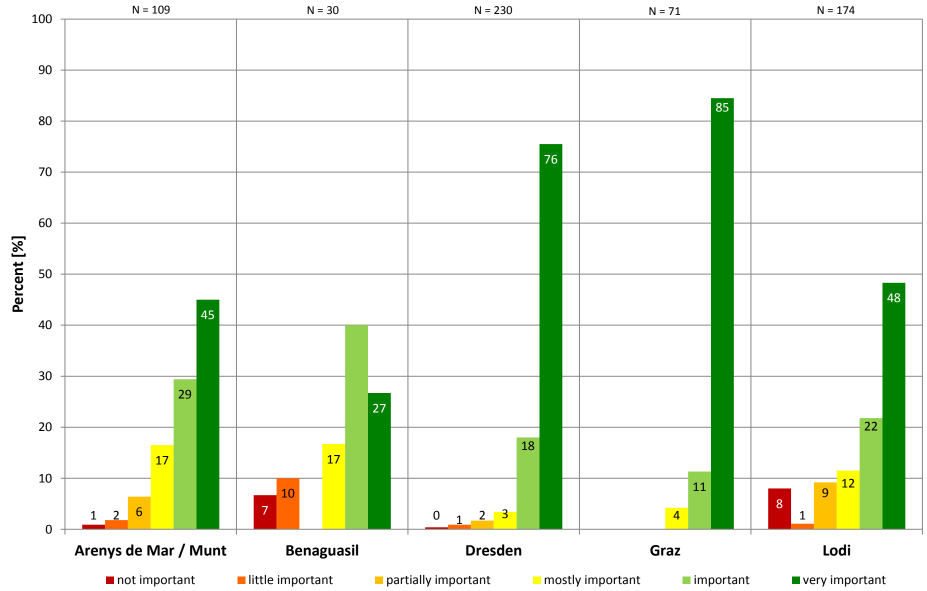

Figure 77: Q47 – Neighborly help is to me in case of a flood event ...?

Q50: Importance of the provided neighborly help:
There is a clear visible tendency towards the assessment of neighborly help as important or very important in Dresden (84%), Graz (89%) and Lodi (63%). In Arenys de Mar / Munt 77% of the people believe that it's partly important or mostly important.

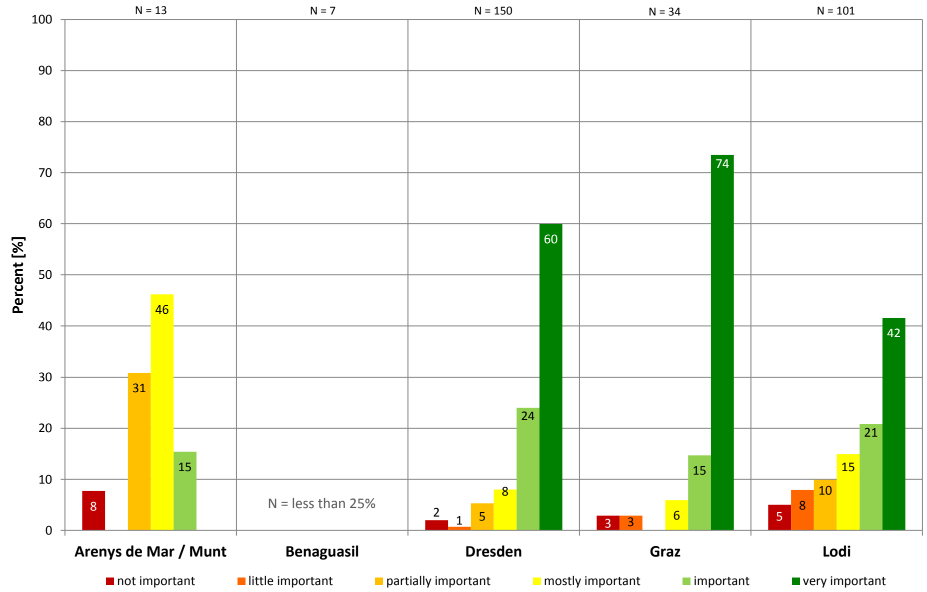

Figure 78: Q50 – How important was this provided help?

Q51: Labor slack due to the last flood event:
In all case studies a high percentage has experienced a labor slack due to the last flood event (>61%), whereas this percentage is especially high in Arenys de Mar / Munt (94%) and Graz (96%).

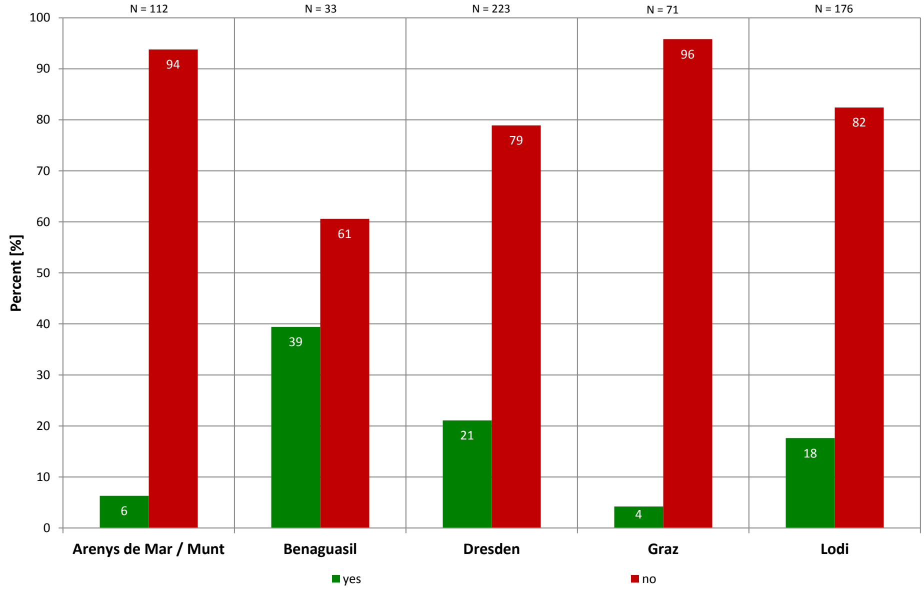

Figure 79: Q51 – Did you or a member of your household experience a labor slack due to the last flood?

Case study Lodi
Despite the fact that the last flood event in Lodi happened in 2002, people in Lodi seem to have experienced this events very intensely. In comparison to other case studies difference in the answers are conspicuous. They

- feel most threatened by floods
- rated the flood risk for them personally, inhabitants of their house and of their neighborhood highest
- rated their personal damage regarding material and financial causalities highest
- rated their personal damage regarding health problems highest
- rated the statement “I have coped psychologically with the previous flood events very well” with 46% rather applies and 32% applies. A clear difference to the other case studies, which answered with >60% with “applies” is noticeable.
- stated to need the longest time to prepare sufficiently for a flood.
- don’t like to be informed by the media as single case study
- stated with the highest percentage (86%) to feel uncomfortable because of missing information
- show the highest percentage regarding a very bad level of information during the last flood event

Results of the opinion poll – Hypothesis / correlation

Alongside a descriptive analysis, supposed correlations have been statistically checked. Therefore the Chi² test and the Spearman correlation coefficient have been used.[84]
29 hypotheses have been tested for each case study:

HYPOTHESIS 1: The more knowledge people have about floods, the higher is the awareness about the residual risk and the willingness to take self-protective measures in future.

HYPOTHESIS 2: The higher the risk-awareness of a person is the more probable is it, that the person knows about self-protective measures and that s/he has taken such also prior to the last flood.

HYPOTHESIS 3: The higher the educational level is, the higher is the awareness in regard to a residual risk.

HYPOTHESIS 4: Dependent on the gender the residual risk awareness differs.

HYPOTHESIS 5: How distinct the residual risk awareness is, depends on the information access.

HYPOTHESIS 6: The estimated meaningfulness of self-protective measures and the willingness to take self-protective measures in future depend on the information access.

HYPOTHESIS 7: The more persons felt threatened by floods, the more they have taken self-protective measures prior to the last flood and the likelier they will be taking self-protective measures in future.

HYPOTHESIS 8: The higher the educational level of a person is, the more the know about measures of self-protection and the likelier they took self-protective measures prior to the last flood.

HYPOTHESIS 9: Dependent on the gender the knowledge about measures of self-protection differs, and relatively rather frequent they have taken self-protective measures prior to the last flood.

HYPOTHESIS 10: The longer persons live in their present household, the more improbable is a migration and the likelier the persons are willing to take self-protective measures in future.

HYPOTHESIS 11: The more frequently persons have been affected by floods, the more useful they regard measures of self-protection and have also taken such.

HYPOTHESIS 12: House owners and persons who live on the ground floor are likelier willing to take measures of self-protection.

HYPOTHESIS 13: The more distinct the understanding is, that the residential area can be protected sufficiently with structural measures, the inferior is the knowledge about measures of self-protection.

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[84] The Chi² test tests the null hypothesis that no coherence exists between line and column variables.
The Spearman correlation coefficient (ordinal scaled variables) provides information on the strength of the coherences between line and column variables.

HYPOTHESIS 14: The greater the damage caused by floods had been, which had to be born with individual resources, the likelier people are willing to take measures of self-protection in future.

HYPOTHESIS 15: When measures of self-protection had been taken, the damages suffered due to floods had been lighter.

HYPOTHESIS 16: The more physical and psychological symptoms appeared due to flood events, the higher is the willingness to take self-protective measures in future.

HYPOTHESIS 17: In case of flood elderly persons accepted support more frequently than younger persons.

HYPOTHESIS 18: Depending on the experienced degree of threat the need for information in case of floods differs, especially the wish for information from the media, an on-site information center, task forces (emergency services), as well as communities/ authorities (local council).

HYPOTHESIS 19: Dependent on the level of education differs the need for information in case of floods, especially the wish of information from the media, an on-site information center, task forces (emergency services), as well as from communities/ authorities (local council).

HYPOTHESIS 20: Dependent on the gender the need for information in case of floods differs.

HYPOTHESIS 21: Affected differ from not-affected in the need of information in case of floods.

HYPOTHESIS 22: Subjectively people felt more informed in case of floods, when they obtained the information via media (television/ radio), task forces (emergency services) as well as communities/ authorities (local council) and not from the internet.

HYPOTHESIS 23: Persons, who feel threatened by natural disasters, differ from such with a subjective minor threat estimation, that the means of communication, which are preferred by them, in order to inform themselves on a regular basis about flood concerns, is first and foremost an on-site information center, followed by assemblies, advertisements (announcements, reports) in the media, a platform (sites) in the internet, and flyers (leaflets, pamphlets).

HYPOTHESIS 24: Persons affected from floods differ to those less affected through their preference in the means of communication to keep themselves informed on a regular basis about flood concerns, first and foremost the on-site information center, followed by assemblies, advertisements (announcements, reports) in the media, a platform (sites) in the internet, and flyers (leaflets, pamphlets).

HYPOTHESIS 25: The younger the persons are, the more they would like to retrieve (obtain) information from the internet.

HYPOTHESIS 26: The greater the knowledge of a person is in regard to floods, the shorter is the necessary time span in order to be prepared sufficiently for floods.

HYPOTHESIS 27: Dependent on the level of education the willingness to effect an insurance against catastrophes in future differs.

HYPOTHESIS 28: Affected differ from not-affected in the willingness to insure themselves against damages of catastrophes in future.

HYPOTHESIS 29: The higher the monthly income is, the more persons are willing to insure against catastrophes in future.

All in all it can be summarized that for none of the tested hypothesis there is a significant relation or correlation in all case studies. Only for some of the hypothesis for single case studies a relation respectively a correlation could be noticed (21 cases out of 150 possible). For the majority of the hypothesis for which significance tests could have been conducted, showed no correlation or relation (58 cases out of 150 possible). For all those tested hypothesis where a significance test was not possible because of different reasons (e.g. multiple answers, problematic cell composition, and so on) as far as it was possible tendencies have been indicated. It has to be noted that an analysis of the hypothesis for Arenys de Mar / Munt respectively Benaguasil was not possible in majority of cases due to too less answers or due to a problematic cell composition.

Table 30 gives an overview of the results of the carried out statistical tests. It shows if there is a correlation respectively relation in regard to the corresponding hypothesis. Five different results can be distinguished:

Table 29: Legend to the Table 30

---	No significance test was possible, no further analysis was possible
YES	No significance test was possible, but a tendency could be observed
YES	A significance test was possible, a significant relation could be observed
NO	No significance test was possible, but no tendency could be observed
NO	A significance test was possible, no significant relation could be observed

Table 30: Overview Results Test Hypothesis, each case study

Hypothesis	Arenys de Mar / Munt	Benaguasil	Dresden	Graz	Lodi
H1 a	---	---	YES	YES	YES
H1 b	---	YES	YES	YES	NO
H2 a	YES	YES	YES	NO	NO
H2 b	NO	NO	NO	YES	NO
H3	NO	---	NO	NO	NO
H4	NO	---	NO	YES	NO
H5	NO	---	NO	NO	NO
H6 a	---	---	YES	YES	YES
H6 b	YES	---	YES	YES	YES
H7 a	---	---	YES	YES	YES
H7 b	---	YES	NO	YES	YES
H8 a	---	---	NO	NO	NO
H8 b	NO	---	NO	NO	NO
H9 a	NO	YES	NO	NO	NO
H9 b	NO	---	NO	NO	NO
H10 a	---	---	NO	YES	NO
H10 b	---	---	---	YES	NO
H11 a	---	---	NO	YES	YES
H11 b	---	---	NO	YES	---
H12 a	---	YES	NO	NO	NO
H12 b	---	YES	YES	NO	NO
H13	---	---	NO	NO	NO
H14	---	---	NO	---	NO
H15 a	---	---	NO	YES	YES
H15 b	---	---	NO	---	NO
H16	---	NO	NO	YES	NO
H17	NO	NO	NO	YES	NO
H18	NO	NO	NO	NO	NO
H19	NO	---	NO	NO	NO
H20	NO	---	NO	NO	NO
H21	NO	YES	YES	NO	YES
H22	---	---	YES	NO	YES
H23	YES	YES	YES	YES	YES
H24	YES	NO	YES	NO	YES
H25	---	---	YES	YES	YES
H26	---	---	NO	NO	NO
H27	---	---	YES	NO	NO
H28	---	---	YES	NO	NO
H29	---	---	---	YES	NO

A selection of the hypothesis are described in detail in the following tables.

HYPOTHESIS 2
The higher the risk-awareness of a person is the more probable is it, that the person knows about self-protective measures and that s/he has taken such also prior to the last flood.

Table 31: Hypothesis 2a - Knowledge about self-protective measures according to the residual risk awareness

ARENYS DE MAR / MUNT	There is a significant relation between the residual risk awareness and the knowledge about self-protective measures (Chi2 = 6.946, df = 1, N = 117, p = 0.008). Those who presume that a residual risk is always given have more knowledge about self-protecting measures.	**YES**
BENAGUASIL	None of the respondents have low risk awareness. Thus it can't be tested if the knowledge about self-protective measures differs according to the residual risk awareness. The data show the tendency that – within the group of respondents with high risk awareness – 85.7% of the respondents have knowledge on self-protective measures, 14.3% haven't.	**YES**
DRESDEN	There is a significant relation between knowledge about self-protective measures and the residual risk awareness of the interviewed people (Chi2 = 4.350, df = 1, N = 216, p = 0.037). The data shows that 36.6% of those people, who have high risk awareness, have knowledge on self-protective measures. (Again: only very small differences)	**YES**
GRAZ	There is no significant correlation between the residual risk awareness and the knowledge about self-protective measures (Chi2 = 0.091, df = 1, N = 68, p = 0.763).	**NO**
LODI	There is no relation between knowledge about self-protective measures and the residual risk awareness of the interviewed people (Chi2 = 1.955, df = 1, N = 163, p = 0.162). The data show that 62.9% of those people, who have high risk awareness, don't have knowledge on self-protective measures. (Again: only very small differences)	**NO**

Table 32: Hypothesis 2b - Measures taken at the last flood event according to residual risk awareness

ARENYS DE MAR / MUNT	There is no significant relation between the residual risk awareness and the conduct during previous environmental catastrophes. (Chi2 = 0.040, df = 1, N = 83, p = 0.841).	**NO**
BENAGUASIL	Again, none of the respondents have low risk awareness. Thus it can't be tested if the measures taken at the last flood differ according to the residual risk awareness. (This applies also all other hypothesis which aim to test something according to residual risk awareness). The data show the tendency that – within the group of respondents with high risk awareness – 57.1% of the respondents have taken self-protective measures during the last flood, 42.9% haven't.	**NO**
DRESDEN	There's no significant relation between measures taken at the last flood event and the residual risk awareness (Chi2 = 0.649, df = 1, N = 214, p = 0.420). The data show that only 15.8% of those with high risk awareness have taken self-protective measures during the last flood (only very small differences).	**NO**
GRAZ	There is a significant correlation between the residual risk awareness and the conduct during previous environmental catastrophes. Those, who presume that a residual risk is always given, have taken averagely more self-protection measures (Chi2 = 4.842, df = 1, N = 67, p = 0.028).	**YES**
LODI	There's no significant relation between measures taken at the last flood event and the residual risk awareness (Chi2 = 0.915, df = 1, N = 168, p = 0.339). The data shows that only 21.2% of those with high risk awareness have taken self-protective measures during the last flood (only very small differences).	**NO**

HYPOTHESIS 3
The higher the educational level is, the higher is the awareness in regard to a residual risk.

Table 33: Hypothesis 3

ARENYS DE MAR / MUNT	There is no significant relation between the educational level and the residual risk awareness (Chi2 = 6.800, df = 3, N = 86, p = 0.079). The figures shows that people who obtained professional training have low risk awareness; a lot of people who graduated from university (33.3%) have high risk awareness.	**NO**
BENAGUASIL	Not possible: All respondents have high risk awareness. It seems to be problematic that only a few people answered the question on the highest educational level (N=14) and the question on their risk awareness (N=7).	**---**
DRESDEN	There's no significant relation between education and the residual risk awareness (Chi2 = 3.167, df = 3, N = 218, p = 0.367). The only visible tendency is that 37.5% of the respondents with high risk awareness have obtained professional training, only 26.2% of those with low risk awareness. Only 12.5% of people with high risk awareness have graduated from upper secondary school	**NO**
GRAZ	There is no correlation between the educational level and the residual risk awareness (Chi2 = 0.232, df = 2, N = 68, p = 0.891).	**NO**
LODI	There's no significant relation between education and the residual risk awareness (Chi2 = 4.165, df = 4, N = 169, p = 0.384). The only visible tendency is that 54.9% of the respondents with low risk awareness have graduated upper secondary school (largest group).	**NO**

HYPOTHESIS 4
Dependent on the gender the residual risk awareness differs.

Table 34: Hypothesis 4

ARENYS DE MAR / MUNT	There's no significant relation between risk awareness and gender. (Chi2 = 0.235, df = 1, N = 113, p = 0.628). There are no differences between men and women visible.	**NO**
BENAGUASIL	Not possible: All respondents have high risk awareness.	**---**
DRESDEN	There's also no significant relation between gender and the residual risk awareness (Chi2 = 0.230, df = 1, N = 202, p = 0.632). There are no differences between men and women visible.	**NO**
GRAZ	Risk awareness bears a gender-based characteristic. Women tend to, rather than men, to establish a relation in case of natural catastrophes to residual risks (Chi2 = 4.842, df = 1, N = 68, p = 0.028).	**YES**
LODI	There's also no significant relation between gender and the residual risk awareness (Chi2 = 0.787, df = 1, N = 162, p = 0.375). 68% of the respondents with low risk awareness and 60.7% of the interviewed people with high risk awareness are male.	**NO**

HYPOTHESIS 5
How distinct the residual risk awareness is, depends on the information access.

Table 35: Hypothesis 5

ARENYS DE MAR / MUNT	There is no relation between the residual risk awareness and the preferred means of communication. Respondents prefer flyers advertisements and posters in public as means of communication. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
BENAGUASIL	All means of communication have been chosen only by 3 to 4 respondents – thus there are no meaningful results. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**---**
DRESDEN	Overall people with high and low risk awareness seem to prefer advertisements and posters in public. In addition information centres are liked. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
GRAZ	There is no correlation between the residual risk awareness and the preferred means of communication. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
LODI	Overall people with high and low risk awareness seem to prefer the same means of communication. In general, advertisements and posters in public are very popular. In addition information centres are liked. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**

HYPOTHESIS 6
The estimated meaningfulness of self-protective measures and the willingness to take self-protective measures in future depend on the information access.

Table 36: Hypothesis 6a - Preferred communication channels of those, who intend to take self-protective measures in future

ARENYS DE MAR / MUNT	Only 10 people, who intend to take self-protective measures in future have answered this question. Thus the differences visible in the figure below aren't meaningful. (Also, the aspects of relevance can't be tested because multiple answers were possible.)	**---**
BENAGUASIL	Again, it is problematic that only a few people (only 3) have answered this question.	**---**
DRESDEN	Respondents who intend to take self-protective measures in future prefer advertisements or posters in public. They also like information centres and internet.	**YES**
GRAZ	It is striking that the on-site information center has been attributed equal importance to as has been to advertisements and posters in public	**YES**
LODI	Respondents who intend to take self-protective measures in future prefer advertisements or posters in public. They also like information centres, internet and assemblies.	**YES**

Table 37: Hypothesis 6b - Preferred communication channels of those, who regard self-protective measures as effective

ARENYS DE MAR / MUNT	The data shows that advertisements and posters in public have been attributed equal importance to. Internet and assemblies are the least preferred communication channels.	**YES**
BENAGUASIL	Again, it is problematic that only a few people have answered this question.	**---**
DRESDEN	The data show that advertisements and posters in public are of most importance to respondents who regard self-protective measures as effective; furthermore information centers and internet are popular.	**YES**
GRAZ	It is striking that the on-site information center has been attributed equal importance to as has been to advertisements and posters in public.	**YES**
LODI	The data show that advertisements and posters in public are of most importance to respondents who regard self-protective measures as effective; furthermore information centers are popular.	**YES**

HYPOTHESIS 8
The higher the educational level of a person is, the more the know about measures of self-protection and the likelier they took self-protective measures prior to the last flood.

Table 38: Hypothesis 8a - Measures of self-protection corresponding to the level of education

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the problematic cell composition.	**---**
BENAGUASIL	Due to the problematic cell-occupations it can't be tested if the measures of self-protection correspond with the level of education. In addition only 14 people have answered this question – there are no meaningful results.	**---**
DRESDEN	There is no significant relation between the subjectively perceived threat of floods and self-protective measures in future (Chi2 = 3.264, df = 3, N = 208, p = 0.353). The share of people who graduated from upper secondary school in the group of respondents who have taken self-protective measures during the last flood is the smallest (6.5%).	**NO**
GRAZ	There appears to be no significant correlation, although tendencies are visible (Chi2 = 2.438, N = 67, df = 2, p = 0.295). Persons with a university degree have taken in comparison to other educational groups the least self-protective measures.	**NO**
LODI	There is no significant relation between the subjectively perceived threat of floods and self-protective measures in future (Chi2 = 1.359, df = 4, N = 174, p = 0.851). The differences between the educational groups are marginal; the share of people who obtained professional training in the group of respondents who have taken self-protective measures during the last flood is the smallest (15.4%).	**NO**

Table 39: Hypothesis 8b - Knowledge about measures of self-protection in respect of level of education

ARENYS DE MAR / MUNT	There's no significant relation (Chi2 = 3.936, N = 67, df = 3, p = 0.268). The knowledge about measures of self-protection seems to be evenly distributed among the layers of the population. Only people who graduated upper secondary school seem to know less about protective measures.	**NO**
BENAGUASIL	Due to the problematic cell-occupations it can't be tested if the measures of self-protection correspond with the level of education. In addition only 14 people have answered this question – there are no meaningful results.	**---**
DRESDEN	There is no significant relation between knowledge about measures and the level of education (Chi2 = 1.200, df = 3, N = 209, p = 0.753). Only 20% of the respondents with compulsory school have knowledge about measures of self-protection.	**NO**
GRAZ	The findings are unmistakable. The knowledge about measures of self-protection is evenly distributed among the layers of population (Chi2 = 0.515, N = 67, df = 2, p = 0.773).	**NO**
LODI	There is no significant relation between knowledge about measures and the level of education (Chi2 = 2.576, df = 4, N = 172, p = 0.631	**NO**

HYPOTHESIS 13
The more distinct the understanding is, that the residential area can be protected sufficiently with structural measures, the inferior is the knowledge about measures of self-protection.

Table 40: Hypothesis 13

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the different cell composition.	**---**
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested. In addition only 7 people have answered this question – thus, there are no meaningful results.	**---**
DRESDEN	There appear no significant relations between the estimation of effectiveness of protective measures and awareness about self-protective measures (Chi2 = 1.724, df = 3, N = 205, p = 0.632). However, the data show the following tendency: approximately 54% of the respondents, who do (rather) not think that protective measures aren't effective, have knowledge about self-protective measures, so do approximately 75% of the respondents who think that protective measures are effective.	**NO**
GRAZ	There is no conclusive correlation (Chi2 = 5.693, df = 4, N = 70, p = 0.223).	**NO**
LODI	There appear no significant relations between the estimation of effectiveness of protective measures and awareness about self-protective measures (Chi2 = 5.954, df = 3, N = 163, p = 0.114). However, the data show the following tendency: approximately 30% of the respondents, who do not or do think that protective measures are effective, have knowledge about self-protective measures.	**NO**

HYPOTHESIS 18
Depending on the experienced degree of threat the need for information in case of floods differs, especially the wish for information from the media, an on-site information center, task forces (emergency services), as well as communities/ authorities (local council).

Table 41: Hypothesis 18

ARENYS DE MAR / MUNT	People who experienced threat prefer information from the media, emergency services and communities (local council). These three types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. Therefore it cannot be tested in terms of significance.)	**NO**
BENAGUASIL	People who experienced threat prefer information from the media, internet and community/local council. These three types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
DRESDEN	People who experienced threat prefer information from media, emergency services and community/local council. Those two types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
GRAZ	There are no significant differences respective to the degree of threat (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
LODI	People who experienced threat prefer information from emergency services and community/local council. Those two types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**

HYPOTHESIS 26
The greater the knowledge of a person is in regard to floods, the shorter is the necessary time span in order to be prepared sufficiently for floods.

Table 42: Hypothesis 26

ARENYS DE MAR / MUNT	Due to the problematic cell composition the hypothesis can't be tested.	**---**
BENAGUASIL	Due to the small number of cases and the problematic cell composition the hypothesis can't be tested.	**---**
DRESDEN	There's no significant relation between the knowledge of a person in regard to flood and the necessary time span in order to be prepared sufficiently for floods (Chi2 = 0.527, df = 3, N = 221, p = 0.913). There are also no differences between the groups that are worth mentioning.	**NO**
GRAZ	There are no significant differences. (Chi2 = 2.17, df = 3, N = 71, p = 0.538=).	**NO**
LODI	There's no significant relation between the knowledge of a person in regard to flood and the necessary time span in order to be prepared sufficiently for floods (Chi2 = 1.100, df = 3, N = 181, p = 0.777). There's no conclusive tendency.	**NO**

Further, five hypotheses have been tested for all case studies together:

HYPOTHESIS 1: Being personally affected by a flood incident leads the feeling of being at risk from a flood to increase.

HYPOTHESIS 2: Being personally affected has an effect on knowledge about flooding and its causes.

HYPOTHESIS 3: There is a correlation between sex and the indicated level of knowledge regarding flooding and its causes.

HYPOTHESIS 4: People with a higher level of education evaluate their level of knowledge regarding flooding and its causes as greater than people with a lower level of education.

HYPOTHESIS 5: People with a higher level of education have more knowledge of self-protection measures during a flood incident.

Two examples are shown below:

HYPOTHESIS 1 – all case studies
Being personally affected by a flood incident leads the feeling of being at risk from a flood to increase.

Table 43: Hypothesis 1, all case studies (n = 620)

			affected by a flood in the last 10 years		
			yes	no	
threatened by floods in own neighbourhood	low		73	116	189
		%	19.3%	47.9%	30.5%
	middle		115	93	208
		%	30.4%	38.4%	33.5%
	high		190	33	223
		%	50.3%	13.6%	36.0%
			378	242	620
		%	100.0%	100.0%	100.0%

It is to be deduced from the contingency table that the threat of a flood in the respondents' own areas of the city is perceived as greater if the respondents have been personally affected by at least one flood incident in the last ten years. Pearson's chi-square value is very significant ($p<0.001$) and Spearman's correlation coefficient has a value of -0.393 and is very significant ($p<0.001$). It can thus be assumed that there exists a slightly stronger negative correlation between the variables of being personally affected and threat from a flood. Being personally affected by a flood affects, in an increasing way, the subjective perception of a threat from a flood in the respondent's own area of the city.

HYPOTHESIS 2 – all case studies
Being personally affected has an effect on knowledge about flooding and its causes.

Table 44: Hypothesis 2, all case studies (n = 625)

			affected by a flood in the last 10 years		
			yes	no	
personal knowledge	low		53	54	107
		%	13.7%	22.7%	17.1%
	middle		181	120	301
		%	46.8%	50.4%	48.2%
	high		153	64	217
		%	39.5%	26.9%	34.7%
			387	238	625
		%	100.0%	100.0%	100.0%

Of those affected, 13.7% and 39.5% indicate that they have a low and a high level of knowledge regarding floods respectively. The middle category was chosen the most frequently both by people affected (46.8%) and those not affected (50.4%). Pearson's chi-square value is significant ($p=0.001$) and Spearman's correlation coefficient has a value of -0.15 and is very significant ($p<0.001$). In this respect, being personally affected by a flood is associated with an increased estimation of knowledge of flooding and its causes. The correlation is, however, very weak and is no longer convincing.

5.4.4 Applied fields – information campaigns

Work package 4 of the project SUFRI aims for the development of best strategies for risk communication. Therefore public opinion polls have been carried out in every case study area, to detect possible differences in the perception of the population.
In this context it is essential not only to investigate how people feel and think about floods or what they have experienced during flood situations. It is important to analyze why people think or behave this way.
One approach to filter this out is to look back in the history of carried out information campaigns in the case study areas. This helps, on the one hand, to get to know how people got sensitized, and on the other hand, to get the information which tools have been yet used and how successful they have been.

Therefore the following working tasks have been conducted in the case studies Benaguasil and Graz:

1. Identification of all responsible entities, which are carrying out information campaigns
2. Collection of all information/material of carried out information campaigns, this includes “When?, How?, What?, Where?, Print run?, Reached persons?, Experience, Feedback, Availability of the medium”
3. Analysis of the carried out information campaigns by filtering out the advantages and disadvantages

The following subchapters only present the main results of the case studies Benaguasil and Graz; the detailed analysis will be published in a separate ERA-Net CRUE research report.

Main results / excerpt of the case study Benaguasil

It has not yet been developed a flood communication strategy in Benaguasil. Measures carried out regarding flood protection and prevention have been mainly based on response to past flood events.
However, in the last years some actions have been developed to act more sustainable in this matter. As an example, the City of Benaguasil is currently involved in two European projects: Aquaval and SUFRI. Both projects are in the field of flood risk reduction and the development of sustainable strategies against floods.
Some actions have been already finished such as the construction of a new permeable parking (SuDS).
Nowadays, new structural measures are under development to reduce flood risk in Benaguasil. Additionally, results of the SUFRI project will enable to establish nonstructural measures to reduce flood consequences. The City of Benaguasil is aware of the importance of public participation on these matters. Therefore, collaboration of the municipality during the opinion poll has been completely satisfactory to involve the affected population in the process.

Different groups are involved in the communication process in the Valencian Autonomous Region. Specially, in the case of Benaguasil, the following institutions are involved:

- Regional Government– Department of Civil Protection
- Police and Fire Corps
- City of Benaguasil – Mayor's office
- City of Benaguasil – Department of Urban Planning

Main results / excerpt of the case study Graz

In Graz no strategic flood communication strategy is in use. The carried out measures regarding flood information were and are mainly based on reaction due to an occurred flood event.
However, in the last years some actions and campaigns have been developed to act more sustainable in this matter.
Main activities of the City of Graz are in the field of web-applications, which are not yet fully-developed, but should lead to a comprehensive website, where the interested citizen can get all information he/she wants. Nowadays a presence in the web is essential, particularly to get in touch with younger people. But this approach needs to be accompanied by diverse other campaigns. Further the effort for maintenance of the web-applications is quite high and has to be taken into consideration. By reducing the amount of web applications, and only focusing on some important issues, the effort for maintenance decreases and, thus, it's easier for the people to get along.
The approach "public participation", which means to involve the affected population in the planning process, has been used in some campaigns, e.g. the action day.

Different groups are involved in the communication process in Graz, like

- Government of Styria – Department of Water Protective Economy and Groundwater Resources
- City of Graz – Mayor's office
- City of Graz – Department of Green Space and Water Bodies
- City of Graz – Department of Civil Protection and Fire Brigade Graz
- District Andritz – Political parties, like ÖVP, SPÖ, BZÖ
- Citizens' initiative

As the excerpts of corresponding journals of the City of Graz (BIG) and those of the political parties (Echo Graz Nord and Zwölfer) show, there is no common communication strategy, how to make people more aware in the topic of floods.
There are some good approaches in establishing a communication strategy concerning floods in Graz. But it is essential that these actions are evaluated, regularly carried out or maintained and are impeded in a master-plan.

Comparison of information campaigns Benaguasil – Graz

In both case studies carried out measures regarding flood information were mainly based on reaction due to an occurred flood event. There exists no strategic flood risk communication. As a result of the growing pressure new structural measures are under development and some actions and campaigns have been developed to act more sustainable in this matter. According to the investigations there is a bigger focus on public participation in Graz than in Benaguasil. But it must be remarked, that also in Graz public participation is in the early stage of development. Table 45 illustrates in comparison the carried out information campaigns in Benaguasil and Graz, which are described in the previous chapters.

Table 45: Overview of the carried out information campaigns in Benaguasil and Graz

BENAGUASIL		GRAZ	
Information Campaign	**How often?**	**Information Campaign**	**How often?**
Web Applications			
www.112.cv.com	regularly	www.hochwasserschutz.graz.at	regularly
www.benaguasil.com	regularly	Facebook	sporadically
---	---	**Google maps** Construction progress Sandbag depots General agreement drawings History of flood-fighting operations	in process
---	---	**Flickr** City of Graz on Flickr Fire brigade Graz on Flickr	sporadically
Journals			
UFRIM conference proceedings	once	BIG – BürgerInnen Information Graz	sporadically
3IWRDD – Third International Forum on Risk Analysis, Dam Safety, Dam Security and Critical Infrastructure Management	once	Echo Graz Nord	sporadically
---	---	Zwölfer	sporadically
Events			
Workshop on Flood Risk Identification, Evaluation and Management	once	Action day for security – main focus floods	regularly
Third International Week on Risk Analysis, Dam Safety, Dam Security and Critical Infrastructure Management	every 3 years	Groundbreaking ceremony – retention basins Gabriachbach	once
Opening ceremony – Permeable Parking in Benaguasil	once	Opening ceremony – retention basin Gabriachbach	once
---	---	Press conference - presentation of the governmental crisis management	once
---	---	Press conference - presentation of the research project SUFRI	once
Other measures			
Non-structural measures: Waterstops	when necessary	Sandbag depots	regularly
Non-structural measures: Sustainable Urban Rain Water Management Plans	always	"Flood Bags" for district leaders	once
Structural measures: SuDS and drainage systems	always	Printed matters	once
---	**---**	SMS – Info about possible flood events	regularly
---	**---**	Preannouncement construction works	regularly
---	**---**	Construction site signs	regularly
---	**---**	Information for reporters	sporadically
---	**---**	Gathering flood-news in the City of Graz	sporadically

5.5 Optimization of Disaster Control Management

Specific Outcomes

- Survey of responsibilities of entities in case of flood management for Graz, Benaguasil and Arenys de Mar/Munt
- Recommendations for the development of an action plan focused on non-structural measures
- Evaluation criteria for non-structural measures
- Visualization of risk zones in maps

Lessons Learned

- There exist no tables of risk reduction coefficients for the different non-structural measures, even less for the combination of different NSM. Thus, there remains as future research work.

5.5.1 Lessons in disaster control management

Disaster Control Management is a discipline that has grown strongly during the last 30 years, as a result of the continuous emergencies that have occurred in floods, fires, hurricanes, tornadoes, terrorism, chemical hazards, landslides and earthquakes risks (Emmanuel M. Luna, 2009).
This topic has been established as a science, even reaching master programs in some universities based entirely on Disaster Control Management (DCM). In this discipline, the procedures, guidelines and methodologies for mitigation and management of emergencies are defined. It is important to emphasize that in the category of disasters natural and anthropogenic causes are included, such as floods or terrorism.
Four components are universally identified in Disaster Control Management (Ibarra Lopez M., 2009): prevention, preparedness, recovery and reaction (Figure 80).

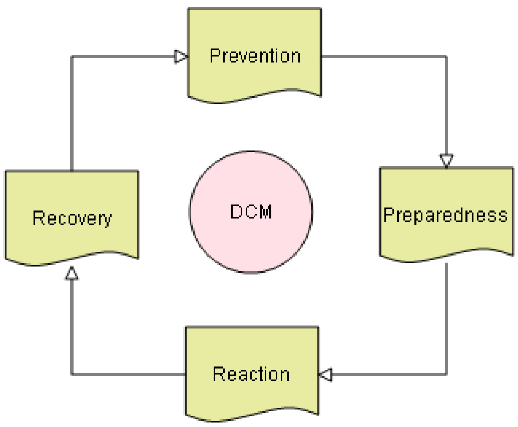

Figure 80: Disaster Control Management component scheme.

These four components are specified during the three main stages (or phases) of the Disaster Control Management (http://www.fema.gov/). These stages are identified as: **before**, **during** and **after**. The main issue of DCM is to take actions and implement the 4 components in these phases or stages, because these components are the summary of all plans, procedures, methodologies and actions to apply in case of emergency. In summary, these 4 components are a guide for entities to act in case of emergency (Ibarra Lopez M., 2009).The four components can be defined as:

Prevention:
The objective of the prevention phase is to foresee, warn and avert the disasters damages (as far as possible) (Emmanuel M. Luna, 2009). This is achieved by assessing all the vulnerability areas and subsequently, taking all the preventive actions and measures that could mitigate the risk. Prevention includes the implementation of mitigation strategies. Mitigative measures can be structural or non-structural measures (Consortium of Academic Libraries, 2004). Structural measures (in flood case) are those built to reduce risk (encroaching, channeling or flooded areas). Non-structural measures (NSM) include early warning systems, urban planning, increasing of resilience and improvement of the legislation to mitigate risk.

Preparedness:
Preparedness is a constant activity of organizing, assessing and planning activities to guarantee effective coordination between action forces (Ibarra Lopez M., 2009), which means to be prepared for disaster emergencies. During the preparedness phase measures are focused on action forces and population coordination. It differs from the previous activity because prevention aims at long term risk mitigation. The main activities for flood emergencies include disaster communication and evacuation plans (NSM).

Reaction:
Reaction is the quality of quickly and efficiently executing the actions to reduce risk. Evaluating the reaction capacity consists of assessing the ability of the action forces (firefighters, police etc.). Disaster exercises or drills have a very important role to improve this ability. This includes the mobilization capacity of all the necessary resources (material or human) to cope the emergency (Emmanuel M. Luna, 2009). Another relevant NSM in flood emergencies (to improve the reaction) is the coordination between entities.

Recovery:
In the recovery phase the main objectives are focused on return or comeback to the initial state before the natural or anthropogenic disaster had occurred. Increasing the capacity of “recovery” in the population and in the action forces, will increase the resiliency (due to their close correlation) and will mitigate the damage of disasters (Ibarra Lopez M., 2009). For flood emergencies the NSM of policies and national insurances becomes important.

5.5.2 Agencies in the field of Disaster Control Management

For several years, agencies responsible for disaster control management have been developed because of requirements due to effective flood management concerning natural disasters and other anthropogenic origin. With the aim of comparative experiences about disaster control management, specifically focused on flood emergencies, a brief searching about disaster control management entities was conducted.

A study of the existing agencies of disaster control management, their organization and their used methodologies has been conducted for the following countries:

- **International:** International Association of Emergency Managers
- **Argentina:** Civil Protection Department in the Ministry of Interior, supported by National Institute of Water (INA)

- **Australia:** Emergency Management of Australia (EMA); included in the Attorney Generals department which is in charge of the public security
- **Colombia:** National System for Disaster Response and Prevention (SNPAD) supported by Institute of Hydrology, Meteorology and Environmental Studies (IDEAM)
- **Chile:** National Emergency Office (ONEMI), included in the Interior Ministry of Chile, supported by General Direction of Waters (DGA)
- **Spain:** different autonomous regions, where each region develops and implements their own self-governing laws; **Catalonia:** Department of Interior in the CECAT (Centre de Coordinació Operativa de Catalunya)
- **Italy:** Civil Protection Department, grounded in the offices of the Presidency of the Council of Ministers since 1982.
- **United States:** Federal Emergency Management Agency(FEMA), which is included in the Homeland Security Department

Example United States

As a representative example of organization, disaster control management in the United States will be explained in more detail.

Available agencies for Disaster Control Management
The leading entity for disaster control management in the United States is the FEMA (Federal Emergency Management Agency) (http://www.fema.gov/). This agency is included in the Homeland Security Department. Different organizations brings collaborations to the FEMA agency for de DCM. The United States, as a decentralized country (federal), has several FEMA state agencies with diverse representation offices in each U.S.A. state.

Organization of the FEMA
The United States have a federal government, but at country level are organized some entities as the Homeland Security Department, which depends on the entity in charge of the disaster control management in the U.S.A.: the FEMA agency.
The FEMA agency has implemented several action lines in case of emergencies. In the particular case of flood emergencies there are available risk maps on their website http://www.fema.gov/. This is due to one of the main approaches adopted by the FEMA, which is to promote the purchase of safety insurances against flood damages (Figure 81). However, each state (In the United States) has a federal support, which is activated in the moment of the emergency declaration.

In the U.S.A. the emergencies are managed at the most-local possible level “utilizing mutual aid agreements with adjacent jurisdictions”. Due to the strong attacks occurred in recent years, the level of participation in case of a terrorist related incident or of “National Significance", the Secretary of Homeland Security will initiate the National Response Framework (NRF) (http://www.fema.gov/). In this way, a federal resources will be included to responds the emergency.
A citizen corps is included in the FEMA, which is an organization of volunteer service, (locally managed) and coordinated by DHS (Department of Homeland Security), whit the principal aim to prepare the inhabitants for emergency response and in this way mitigate the risk (http://www.fema.gov/).
The US Congress established the Center for Excellence in Disaster Management and Humanitarian Assistance (COE) as the principal agency to promote disaster preparedness and societal resiliency in the Asia-Pacific region (http://www.fema.gov/).

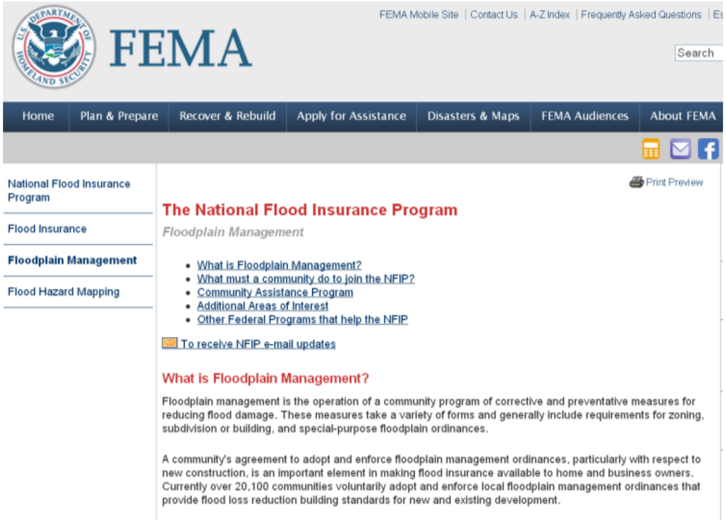

Figure 81: Official FEMA web page, and the national insurance program.

Study of the methodologies that the agencies use

FEMA agency has established actions to be undertaken by the population during the 3 stages of the Disaster Control Management (Before, During, After) in case of flood emergencies. These actions consist of a series of steps to assume in an emergency. For the particular case of flooding there are:

Activities to develop in flood emergencies defined by the FEMA agency (**Before a flood**).

To prepare for a flood, you should:

- Avoid building in a flood prone area unless you elevate and reinforce your home.
- Elevate the furnace, water heater, and electric panel if susceptible to flooding.
- Install "check valves" in sewer traps to prevent floodwater from backing up into the drains of your home.
- Contact community officials to find out if they are planning to construct barriers (levees, beams, floodwalls) to stop floodwater from entering the homes in your area.
- Seal the walls in your basement with waterproofing compounds to avoid seepage.

Activities to develop in flood emergencies defined by the FEMA agency (**During a flood**).

If a flood is likely in your area, you should:

- Be aware of streams, drainage channels, canyons, and other areas known to flood suddenly. Flash floods can occur in these areas with or without such typical warnings as rain clouds or heavy rain.
- Be aware that flash flooding can occur. If there is any possibility of a flash flood, move immediately to higher ground. Do not wait for instructions to move.
- Listen to the radio or television for information.

If you must prepare to evacuate, you should do the following:

- Secure your home. If you have time, bring in outdoor furniture. Move essential items to an upper floor.
- Turn off utilities at the main switches or valves if instructed to do so. Disconnect electrical appliances. Do not touch electrical equipment if you are wet or standing in water.

If you have to leave your home, remember these evacuation tips:

- Do not walk through moving water. Six inches of moving water can make you fall. If you have to walk in water, walk where the water is not moving. Use a stick to check the firmness of the ground in front of you.
- Do not drive into flooded areas. If floodwaters rise around your car, abandon the car and move to higher ground if you can do so safely. You and the vehicle can be quickly swept away.

Activities to develop in flood emergencies defined by the FEMA agency (**After a flood**).

The following are guidelines for the period following a flood:

- Listen for news reports to learn whether the community's water supply is safe to drink.
- Avoid floodwaters; water may be contaminated by oil, gasoline, or raw sewage. Water may also be electrically charged from underground or downed power lines.
- Avoid moving water.
- Be aware of areas where floodwaters have receded. Roads may have weakened and could collapse under the weight of a car.
- Stay away from downed power lines, and report them to the power company.
- Return home only when authorities indicate it is safe.
- Stay out of any building if it is surrounded by floodwaters.
- Use extreme caution when entering buildings; there may be hidden damage, particularly in foundations.
- Service damaged septic tanks, cesspools, pits, and leaching systems as soon as possible. Damaged sewage systems are serious health hazards.
- Clean and disinfect everything that got wet. Mud left from floodwater can contain sewage and chemicals.

The HAZUS software package developed by FEMA is central in the risk assessment process in the country (http://www.fema.gov/). The United States and its territories are covered by ten regions for FEMA's emergency management purposes. Tribal, state, county and local governments develop emergency management programs and operate hierarchically within each region (http://www.fema.gov/).

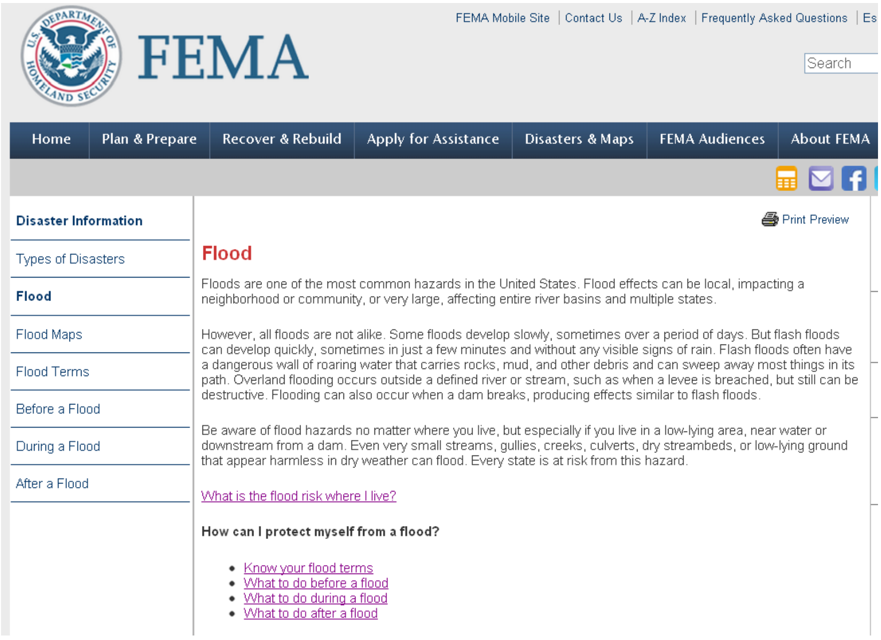

Figure 82: The DCM of FEMA in case of flood emergencies and the action to be undertaken.

5.5.3 Experiences and keynotes in Disaster Control Management

The components (prevention, preparedness, reaction and recovery) explained in chapter 5.5.1 define several mechanisms on which organizations should focus their efforts to make an "Adequate risk management in emergencies cases from natural or anthropogenic hazard"(Ibarra Lopez M., 2009).
About the different forms of government organization, it was observed that the departments (or emergency management agencies) depend or are modified according to the political distribution of the country. This helps the program implementation and operation for disaster control management plans in the municipalities. The most striking example can be found in Spain or Argentina, which are decentralized nations. These nations leave the risk management to the provincial governments, make up less unexpected to the inhabitants according to their government form (Http://www.proteccioncivil.gov.ar).
Another topic is the inscrutability of some disaster control management entities consulted. This fact produces that most of the information is unavailable in the web pages. It is very difficult to do a global comparison of the methods, tools and requirements that an agency must meet in flood emergencies.
In many countries it is known that there are flooding risk maps, but it is very difficult to find it to develop a transnational comparison (as in the Colombian case). This can occur due to different facts: for the case of Colombia it is due to the information acquiring cost. In other countries (like in Spain) (http://www.proteccioncivil.org/es/index.html), the philosophy is opposed to the previous case, since much of the information obtained from public resources (paid by taxpayers) is public and without cost. The efforts undertaken by governments should be focused on DCM components (Prevention, Preparedness, Reaction, Recovery).

Prevention phase includes risk awareness campaigns and trainings in the action forces (Ibarra Lopez M., 2009). (Contain the population awareness on the potential damages of flooding).

- Laws or regulations.
- Awareness campaign.
- Delineation of flood prone areas.
- Structural and nonstructural measures.
- Maintenance of the Channel, encroachments etc.. (clean up and restoration operations)
- Planning of actions and involved actors in emergency cases.
- Training (action forces).

In the **preparedness phase** the structural and non-structural measures can be divided into passive or active (Emmanuel M. Luna, 2009). The difference between them is that the active measures attempt to improve incentives for risk reduction.

- Laws or regulations.
- Training (action forces).
- Development of an Action Plan
- Establishment of the functions and responsibilities of the action forces.
- Establishment of the command chain.

In the **reaction phase** (of the action forces and the population), efforts should focus on the tools, capacities and procedures that the involving actors will need to have a flood emergency (Emmanuel M. Luna, 2009).

- Laws or regulations.
- Resources assignation (which should be easily accessible). This includes monetary, structural or human resources.
- Disaster exercises to improve the reaction capacity of the population and the action forces.

In the **recovery phase** the ability to return at the starting point before the disaster (called resilience capacity) is tested, which indirectly evaluates the efficiency of the government of a country (Consortium of Academic Libraries, 2004).

- Laws or regulations.

- National or local funds for emergency or disasters scenarios.
- Public entity organization and action forces regulation.
- Flood insurances
- Action plan review and evaluation of the measures adopted.

As have been evidenced in this report, the government and forms of risk management vary from country to country, but should try to follow certain guidelines established and adopted by different agencies in charge of the DCM (as FEMA). Finally it is also important to include the recommendation of international agencies (as IAEM) as well as fixed compromises (such as the Hyogo plan) acquired by different nations to reduce and mitigate the risk in emergency cases.

5.5.4 Emergency scenarios and worksheet for action forces Focused on optimized NSM implementation

The main scope of the SUFRI project was the implementation of non-structural measures to mitigate flood risk. This methodology seeks to establish guidelines for the WP5 goals development, more concisely for the Municipal Action Plan development (including worksheets for Action Forces) and bring the optimization of disaster control management.

This topic has been a research topic over the past years due to the fact that complete protection (through structural measures) against floods phenomena is not feasible. The set of non – structural measures coupled with risk assessment, risk mapping and risk management is known in Spain as Municipal Action Plan (MAP) and in the EU nomenclature as a Risk Management Plan (RMP). It pretends to follow the main ideas/imposed directives in the Flood Directive of 2008.

A RMP/MAP is a non-structural measure itself (NSM) that includes more NSM like insurances mechanisms, urban planning, evacuation plans etc.. Also reports in the SUFRI project have insisted on the residual risk estimation and mitigation complexity due to NSM. In the same way we have tried to develop tools and criteria to deal with evaluation of this measures as has been shown in the WP3 or the present WP5 methodology. Two sources of residual risk have been handled in the SUFRI project: the Urban Surface Runoff (also called Pluvial Flooding) events and River Flooding events.

Generally there are no guidelines or procedures for the action plans development. With the flood directive exception of 2008 there is very little information that can be found about it. Usually the implementation and development of these plans is left to each stakeholder`s criterion, because these plans depend on the characteristics of each place (country/region). Due to the above it is also important to clarify that the action plan development requires agreement and dialogue between the diverse entities involved in flood emergencies, this is why this work can become quite complex and expensive.

To develop an action plan for flood emergencies the following procedure must be followed:

Risk identification

In our case we work on flooding (flood risk) and more concisely the residual risk of flooding, which is defined as the risk remaining after the implementation of structural measures. In the WP3 methodology the urban surface runoff (also called pluvial flooding) and the river flooding risk events were analyzed. Generally, the idea and definition of the term “residual risk” itself is quite ambiguous, especially if one considers that there are several processes at hydrological, social and environmental level which in some way introduce uncertainty in the flood risk quantification.

The first work to be done is the risk identification and subsequently raising of some hypothesis to assess the risk. This is because a basin can be found in diverse risk levels combinations or states: i.e. one basin which was built in a flooding area. Obviously some part of the flood risk is mitigated by this measure but another part remains in the basin. If in this basin others structural or non-structural measures are applied, the risk will decrease, but it will certainly never become zero. These multiple combinations make that the identification of a single option for risk mitigation will not be feasible. In the WP3 some NSM were developed and exposed, which are applied to reduce human and material losses (estimated in Euros). The risk reduction is assessed by mitigation coefficients, but the deepest study of each reduction coefficients for every measure (in terms of NSM) escapes to the scope of this project, which is left as future works to be performed.

Summarizing this first part consists in identifying the residual risk, and visualizing what measures are likely to reduce risk and what measures can be implemented to mitigate risk. Risk identification consists in defining the risk problem delimitation and is an opportunity to impose the hazard and vulnerability hypothesis.

Risk assessment

SUFRI Methodology for pluvial and river flooding risk assessment in urban areas to inform decision-making

There are different forms to assess risk: quantitatively or qualitatively. In WP3 diverse ways of risk quantification have been extensively discussed and summarized.
With the aim of implementing NSM, risk assessment is necessary because it is the way how decision makers (in the action forces) can compare and evaluate if the implementation of a specific NSM can bring risk mitigation (or not). It means that inevitably risk assessment is needed because it justified the NSM resource investments (physical, human and environmental). Moreover, it helps to optimize the NSM implementation (how the entities need to apply the NSM).
The estimation of risk should include all the structural and non - structural measures to be implemented in the watershed. It is clear that the units of comparison are the societal risks (potential causalities) and the economic risk (potential loses in €) developed for each return period to be evaluated. It is also very important (and has been deeply recommended) to develop the ***risk maps*** because it is the way of making graphically the risk assessment. This helps to have a better spatial understanding of the phenomenon. On the other hand it is a good helping tool for those people who are not *"experts"* on the topic of risk, to identify vulnerable areas and their possible impacts. (S. Fuck et all, 2009)

Analysis of the structures of the emergency organization

It is important to recognize and analyze all the institutions and actors involved in flood emergency events, trying to identify the weak points in this organization and taking the advantages of all strengths. The analysis of the organization could bring ideas of what non– structural measures can be implemented and which measures are harder to perform (for institutional or organizational reasons). The analysis of the organization may also show deficiencies/disadvantages in the present organization, which can also focus on defects improvement.
Once again, in order to implement NSM it is necessary to know the laws, responsibilities, institutions and forces present that act in flood emergencies. In general, the implementation of a Municipal Action Plan (or Risk Management Plan) requires continuous interaction and cooperation between the diverse entities. This is because the different non-structural measures require intervention at different levels and degrees of all entities in flood emergency events. Reaching an understanding and cooperation between the different entities is a task that can lead to a great progress in the DCM. For this reason the analysis of the structures of the emergency organization is very important in the development of a MAP. Otherwise it is not possible to know who and how non-structural measures must be implemented.

Evaluation of existing NSM (and/or to implement)

Once you have made a first assessment of the residual risk, it is necessary to identify which non-structural measures can be applied in the watershed. For this work a recapitulation of non-structural measures has been done, which are outlined below:

1. **Urban planning and policies:** Municipal Action Plan, Flood Directive (EU), INUNCAT in Catalonia and PATRICOVA in Valencia.
2. **Flood forecasting:** Early Warning System (Nowcasting, Forecasting and Ensebles models)
3. **Communication:** Communications media (Fax, Internet etc..), between entities and entities – population.
4. **Mobilization:** Rescue corps, and material resources (medicines, food and sand bags.) need to cope with the emergency.
5. **Coordination and operating practices (disaster exercises):** Acting harmonization and training of the actors involved in emergencies scenarios (Entities and population)
6. **Insurance and aids mechanisms:** The insurance acquisitions have a vital importance for mitigation and economic recovery after a disaster. Insurances implementation, aids and resources coming from charity or national helps can reduce the damages that are not easily quantifiable, as for example, the cultural damage.

Summarizing, within the list of measures that have been identified in the SUFRI project and those that can be classified as NSM, we should choose which of them could be implemented in the basin. Note: not all NSM can be always applied, because they depends on the national/regional conditions and the available resources.

Assignment of actors who perform NSM

Once which NSM can be implemented has been evaluated, the next step is to identify who have to act in emergency cases (which of the actors, institutions and population). To achieve this, it is needed to develop agreements with the different entities involved about the NSM to implement. This can be found at two levels: Institutions and Population.

Establishment of restrictions regarding the implementation of NSM

Once the possible non-structural measures to implement are chosen, it is necessary to analyze which are the restrictions of these measures.
This is the result of the basin limitation, because many of these measures have a space or are a limited resource that can interfere with the time of execution. i.e. you can not contract infinite police mans to warn, evacuate or mobilize the population.
In summary, the assessment of the restrictions physically helps us to know which action in flood emergencies are the priorities.

Matrix of NSM vs Mitigation

Due to the resources constraints exposed in the previous point, we must build different combinations of NSM application. This means building different combinations of NSM implementation, trying to cover different possible applications and establishing the mitigation of each combination. In this part the

optimization is performed because different combinations of NSM can lead to different values of societal risk or economic risk mitigation and it is important to find the balance between these variables.
To carry out this work there is no procedure or methodology to follow and to assess the different NSM combination mitigation, so, the iterative application of Ipresas is necessary.
Unfortunately the risk reduction coefficients (mitigation) for different non-structural measures are not available. In the development of Ipresas, only the early warning system (EWS) implementation was considered. Obviously, the studies of these coefficients are left as a future research work because it escapes the scope of this study.
To realize an optimization in terms of non-structural measures, these coefficients should be taken into account. In this way, the values of risk mitigation (due to NSM) would be obtained. One form is constructing an objective function where the risk value (Societal or Economical risk) has to be minimum for the structural measures combination *"known as Optimal".*
The development of the risk mitigation factors is **beyond the scope** of this report and project. However, reduction coefficients were constructed for the Arenys de Mar/Munt case study, based on experience criteria. Obviously, the coefficient reduction implementation/development is left to the users.

If **no coefficients** are available, we propose to do the optimization with respect to the economic cost of implementing non-structural measures. That is, the optimal proposal is the one that has a lower associated cost.

Worksheet for the action force

Finally the last point for the development of the Action Plan is to choose the combination of non-structural measures to mitigate better the risk. This corresponds to summarize (for each entity) what to do (their responsibilities) in case of flood emergencies. These should be discretized in time.

5.5.5 Applied Fields – Emergency scenario and worksheet for action forces focused on NSM – case study Arenys de Mar/Munt

To cope and mitigate the residual risk (mainly by urban surface runoff) the worksheets for action forces that are included in the so called Action Plan (Risk Management Plan) and focused in non – structural measures (NSM) were done. The worksheet is also based in different emergencies scenarios (correlated with a return period) that are managed in the official entities in Catalonia.
The assessment of the urban surface runoff as a potential risk was chosen because the fact that a large part of the flood risk along the Arenys de Mar/Munt basin has been mitigated, as a consequence of the recent construction of a flooding area (that mitigates the risk) and the encroachment of the Arenys river in Arenys de Munt and Arenys de Mar. It consists in obtaining societal and economic risk values for different return periods. Likewise, the implementation of diverse NSM was proposed and also the societal and economic risk mitigation was established.
To implement new NSM, responsibilities and actors were assigned for all the new and present measures, which previously were analyzed in terms of the responsibility – actor scheme. The NSM implementation was optimized respect to the basin resources (called restrictions). Finally, uncertainty analysis was followed along the present report to observe and quantify the uncertainty in the data inputs (hydrology). This has proven to be a critical point that influences the results in the risk assessment.

Risk identification

Once the urban surface runoff risk has been identified as the main phenomenon, we start to define the components to estimate the residual risk in the basin as: Risk = Hazard x Vulnerability. (Note: Some authors include the Exposure in the Risk assessment)

Hazard
To quantify the hazard of the urban surface runoff events, it is necessary to impose some hypotheses that were followed along this case study. These are:

1. The roof of the buildings and houses in the basin are no connected to the sewer systems.

2. It is assumed that in case of heavy rainfalls the potential of flow dragging waste, scrubs and debris is very high. Consequently, the worst scenario is that were all the houses and streets gutters are filled.

3. It is supposed that the Rational Method is valid. It means that the evaporation, transpiration and infiltration are not significant in the calculus of the events.

4. The supposed flow regime developed along the streams and streets is equivalent to the uniform permanent regime. It means that the friction slope is equal to the basin slope and the losses could be estimated due to the manning equation.

Applying these hypotheses we can arrive to the following expressions for the hydraulic depth and velocity:

$$y = \left(\frac{I.A_b.n}{b.S^{1/2}} \right)^{3/5}$$

$$V = \frac{1}{n} \left(\frac{I.A_b.n}{b.S^{1/2}} \right)^{2/5} S^{1/2}$$

Where: V is the flow velocity, I is the rainfall intensity (mm/h), A_b is the contributive area, n is the Manning coefficient, y is the hydraulic depth, b is the width of the channel and S is the channel Slope.

Vulnerability

The susceptibility of the pedestrian to be affected by the surface runoff phenomenon (called vulnerability) can be produced by two facts: the pedestrian slide down and the overturning moment produced by the flow discharge forces over the pedestrians (Nania L., 1999). Obviously there are other variables that can affect the pedestrian stability crossing through a flooded street (age, experience, vision, strength, etc ...), but in order to fix the problem it was decided to only manage these two variables.

Stability criteria:

The stability criteria of a person crossing an urban flooding street according the drag force of the flow can be approximated by:

$$V^2.y \leq \frac{2.\mu.(W-\gamma.V_{ped})}{2.C_d.\rho.b} \leq \frac{2.\mu.W_{equiv}}{2.C_d.\rho.b} \leq 1.0 \;\; m^3/s^2$$

Similarly if we consider the overturning moment it can be obtain the following equation:

$$V^2.y^2 \leq \frac{W_{equiv}.b/4}{2.C_d.\rho.b} \leq 0.204\,(m^4/s^2)$$

Where: μ is the friction coefficient, W the weight in the foot of the pedestrian, the C_d is the drag coefficient, b_p is the width of the pedestrian foot and ρ is the water density.

Result:

The uncertainty analysis includes the assessment of the upper and lower interval of each statistical method used for the hydraulic variables (V, y), the results are summarized in the Table 46 and Table 47.

Table 46: Stability criteria's for different return period fitted by the Least Square method.

Stream Way	T=2 years		T=10 years		T=20 years		T=50 years		T=100 years		T=200 years		T=500 years	
	$V^2.y$	$V.y$	$V^2.y$	$V.y$	$V^2.y$	$V.y$	$V^2.y$	$V.y$	$V^2.y$	$V.y$	$V^2.y$	$V.y$	$V^2.y$	$V.y$
Panagall	3.8	0.65	7.67	1.07	9.34	1.23	11.6	1.44	13.4	1.6	15.3	1.75	17.9	1.96
Puig	0.68	0.2	1.37	0.32	1.67	0.37	2.07	0.44	2.4	0.48	2.73	0.53	3.19	0.59
Bellsolell	0.29	0.11	0.59	0.18	0.71	0.2	0.89	0.24	1.03	0.26	1.17	0.29	1.37	0.32
Calle Real de Pascual	0.34	0.12	0.68	0.2	0.83	0.23	1.03	0.26	1.19	0.29	1.36	0.32	1.58	0.36
Carretera de Torrentbo	0.12	0.05	0.24	0.08	0.29	0.1	0.36	0.11	0.42	0.13	0.47	0.14	0.55	0.16
Carrer de la Rasa	2.02	0.41	4.07	0.68	4.96	0.78	6.18	0.91	7.14	1.01	8.13	1.11	9.5	1.24
Carrer can Borrell	0.07	0.05	0.15	0.09	0.18	0.1	0.22	0.12	0.26	0.13	0.29	0.14	0.34	0.16
Carrer de la nou	0.02	0.02	0.04	0.04	0.04	0.05	0.06	0.05	0.06	0.06	0.07	0.07	0.09	0.07
Carrer Pau Casals	0.22	0.1	0.45	0.16	0.54	0.18	0.68	0.22	0.78	0.24	0.89	0.26	1.04	0.29
Carrer Lluis Companys	0.19	0.09	0.39	0.14	0.47	0.16	0.59	0.19	0.68	0.21	0.77	0.23	0.9	0.26

Table 47: Stability criteria's for different return period fitted by the Moments method.

Stream Way	T=2 years		T=10 years		T=20 years		T=50 years		T=100 years		T=200 years		T=500 years	
	V².y	V.y	V².y	V.y	V².y	V.y	V².y	V.y	V².y	V.y	V².y	V.y	V².y	V.y
Panagall	3.77	0.64	7.34	1.04	8.87	1.19	11	1.38	12.6	1.53	14.3	1.67	16.7	1.86
Puig	0.67	0.2	1.31	0.31	1.58	0.36	1.95	0.42	2.25	0.46	2.55	0.51	2.97	0.56
Bellsolell	0.29	0.11	0.56	0.17	0.68	0.19	0.84	0.23	0.96	0.25	1.09	0.27	1.27	0.31
Calle Real de Pascual	0.33	0.12	0.65	0.19	0.79	0.22	0.97	0.25	1.12	0.28	1.27	0.31	1.48	0.34
Carretera de Torrentbo	0.12	0.05	0.23	0.08	0.27	0.09	0.34	0.11	0.39	0.12	0.44	0.13	0.52	0.15
Carrer de la Rasa	2	0.41	3.9	0.66	4.71	0.75	5.82	0.88	6.7	0.97	7.6	1.06	8.85	1.18
Carrer can Borrell	0.07	0.05	0.14	0.08	0.17	0.1	0.21	0.11	0.24	0.12	0.28	0.13	0.32	0.15
Carrer de la nou	0.02	0.02	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.06	0.08	0.07
Carrer Pau Casals	0.22	0.1	0.43	0.16	0.52	0.18	0.64	0.21	0.73	0.23	0.83	0.25	0.97	0.28
Carrer Lluis Companys	0.19	0.09	0.37	0.14	0.45	0.16	0.55	0.18	0.64	0.2	0.72	0.22	0.84	0.25

Risk assessment

The "SUFRI Methodology for pluvial and river flooding risk assessment in urban areas to inform decision-making" was applied in the streets exposed previously (10 streets). Total risk in the basin is the result of all individual streets risk contributions. This hypothesis is based on the fact that the catchment area is small enough to assume that the events are simultaneous in all the Arenys de Munt streets. In fact from the beginning only one rainfall gauging station was available and with this unique information the hydrology was approximated. The societal risk is shown in Figure 83. This picture shows an intermediate case between the so called "worst case", with no measures (NSM) and the sewer system collapsed, and the case where an EWS has been implemented and tested with the sewer system working correctly (Q_{10}). It also shows that the EWS implementation would greatly reduce potential human losses in the basin.

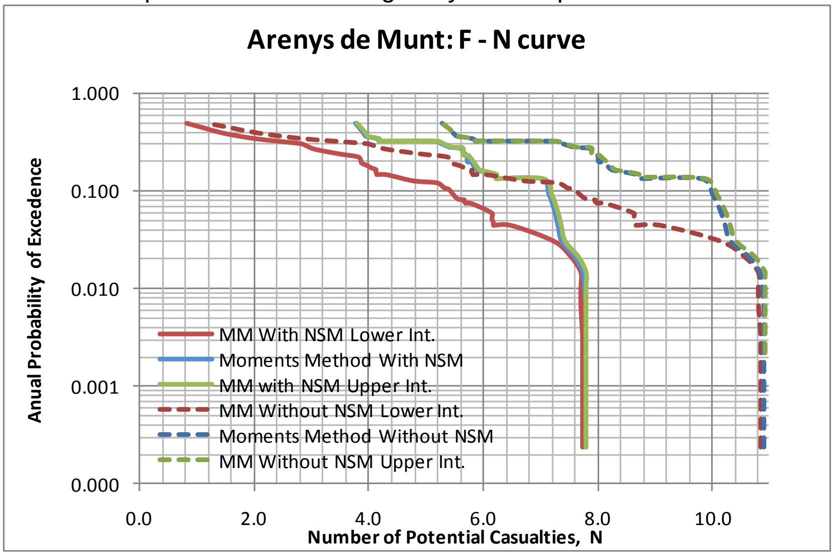

Figure 83: Societal Risk due to urban surface runoff (Rainfall by Moments Method).

It is important to denote from the past figure, that there are life loss values of very low return periods, because at the beginning of the “Risk” assessment, it was supposed that the sewer system (and the gutters) had collapsed, in order to have a maximum potential life loss value. Considering the drainage into the model, it is clear that the “social risk” values decreased significantly. Making that for low return periods, there are no losses of life. The second main conclusion that can be observed from the past figure is that the upper interval is very close to the statistical distribution mean value. This occurs because the vulnerability criteria, which is used in the form of flow severity intervals produces the same flow severity values for both upper and mean intervals. The last conclusion could stress a weak point in the flow severity ranges although it is important to emphasize that there do not exist other flow severity formulation. *"Whereupon you work with what you can"*

Figure 84 illustrates the “worst case”, the intermediate case (with the EWS) and the case with the EWS implementation and the sewer system working correctly. In the same picture, the upper and lower intervals of both statistical distribution were not superimposed because for the last case (EWS + sewer system) the interval overlapped with the mean value, as a result of subtracting the Q_{10} return period (sewer capacity) to the other 5 return period peak discharges (T= 20, 50, 100, 200 and 500 years).

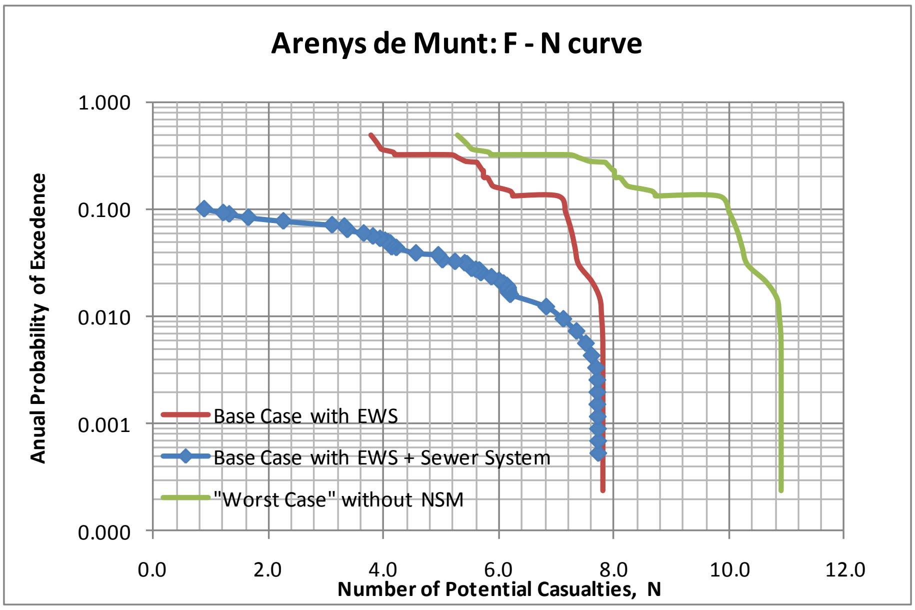

Figure 84: Societal Risk due to urban surface runoff (all cases).

From the previous figure it can be seen that for low return periods the risk is mitigated. The EWS reduce around 28% of the societal risk (although not constant), but in the combination of the EWS + sewer system case, this reduction is more significant.
Again in Figure 85 the economic risk (with confidence intervals) for the EWS implementation and the “worst case” without no measures is exposed. It is clear that the potential economic losses are reduced by the implementation of a EWS.

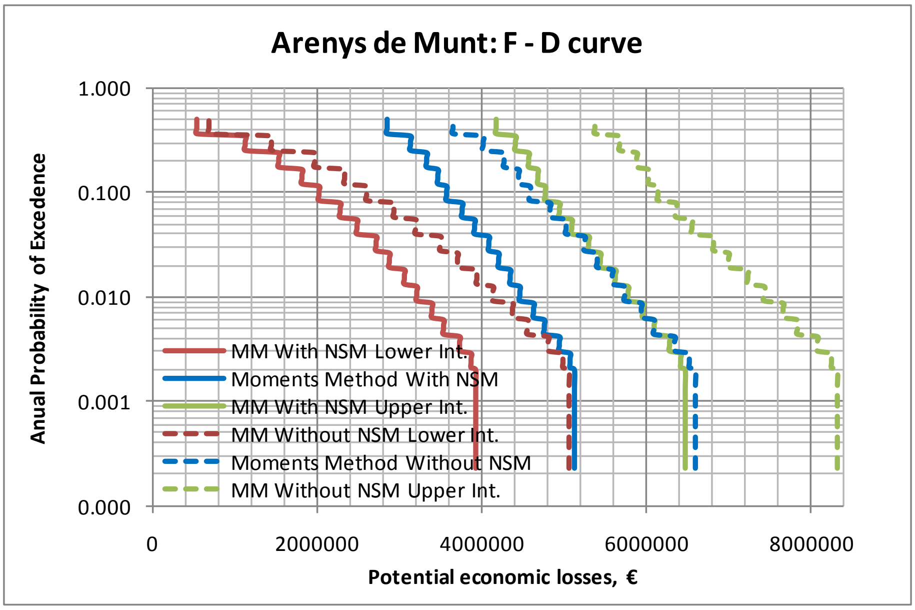

Figure 85: Societal Risk due to urban surface runoff (Rainfall by Moments Method).

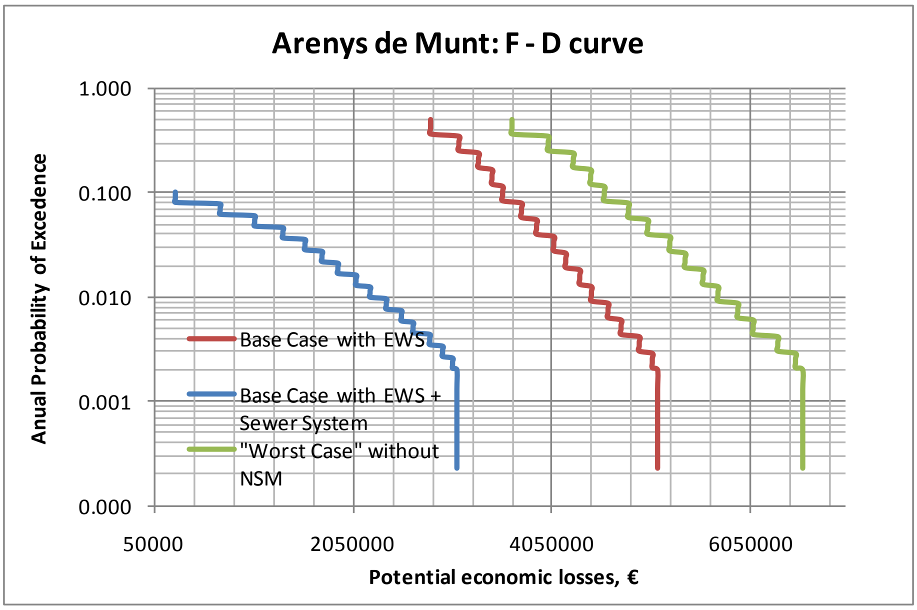

Figure 86: Economic Risk due to urban surface runoff (all cases).

It is very important to denote that the economic risk reduction by EWS implementation is more significant than in societal risk, because a few hours of lead time could represent significantly economic losses reduction. This reduction could even be up to 90 % of the initial value taking the EWS + sewer system (Figure 86).

Risk mapping (delimitation of unsafe zones)
In Table 48 the delimitation of the streets that do not satisfy the vulnerabilities criteria with the uncertainty analysis is shown. To do this (and combined) the tables of the uncertainty analysis were mixed (and combined) taking into account the criteria of the pedestrian stability. This is obtained assigning the red

color to those streets that in the risk analysis the vulnerability criteria for the upper and lower rainfall intervals fail. These streets are exposed as *"Dangerous zone"*. However if one event is not dangerous (with the upper or lower interval) and the other one is the opposite, it is assigned the yellow color and named as *"Risky zone"*. Finally, if in both cases (with upper and lower analysis), no events are detected, the green color is assigned and is classified as *"safe zone*".

Table 48: Affected streets under the uncertainty analysis by Least Square method.

	Return Period						
Street	T=2	T=10	T=20	T=50	T=100	T=200	T=500
Panagall							
Puig							
Bellsolell							
Calle Real de Pascual							
Carretera de Torrentbo							
Carrer de la Rasa							
Carrer can Borrell							
Carrer de la nou							
Carrer Pau Casals							
Carrer Lluis Companys							

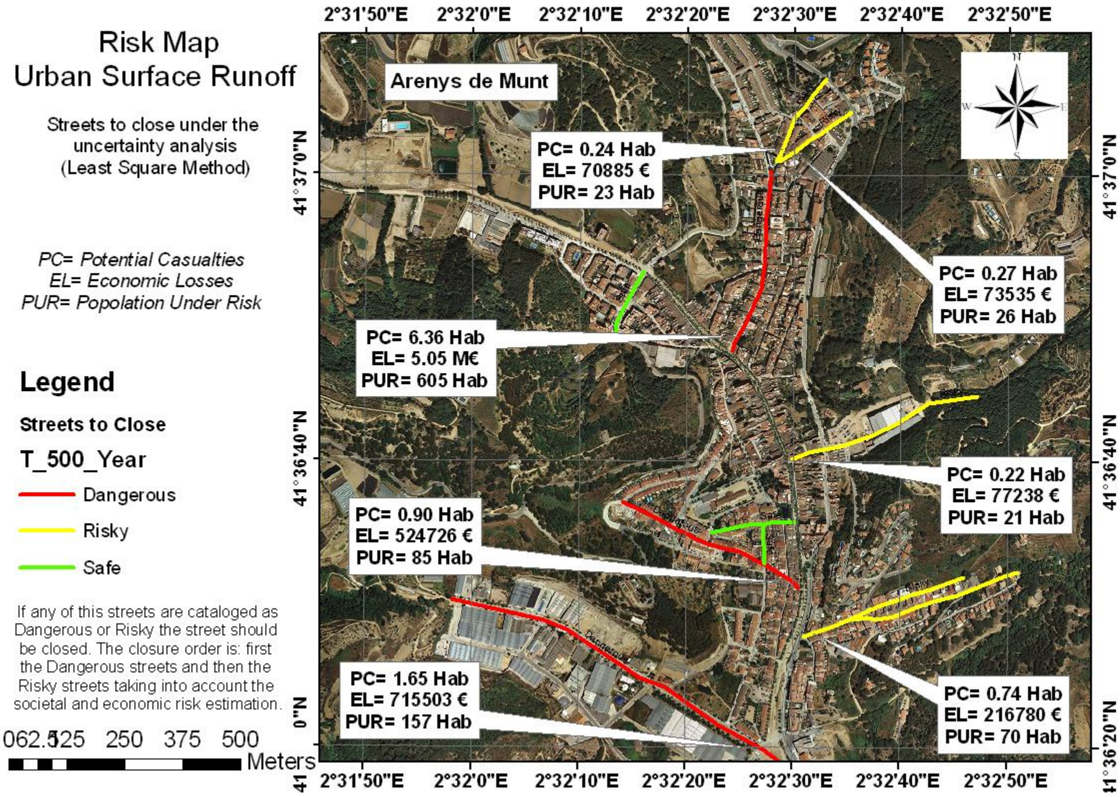

Figure 87. Risk flood map for urban surface runoff by Least Square Method.

Analysis of the structures of the emergency organization

As mentioned above the analysis of the organization could bring ideas of what non– structural measures can be implemented and which measures are harder to perform (for institutional or organizational reasons). Speccially, for the proposed NSM implementation, the entities listed in the Table 49 (with his responsibilities) are involved in the Arenys de Mar/Munt NSM implementation.

Table 49: Actors responsibilities (Arenys de Mar/Munt).

D4	Subdepartment of Coordination Operation Center of Civil Protection (CECAT)	D4.1	Launch flooding alarms
		D4.2	Using the advanced command center , follow and control the protocols established for the flooding scenarios
		D4.3	Inform the superior commands about condition and situation of the flooding emergency
D6	Police	D6.1	Notify (using their media) the potential danger of flooding. (as result of the predictions)
		D6.2	Grant the public and private property (delinquency etc)
		D6.3	Evacuation help (if is necessary)
		D6.4	Cooperate with other entities for the reduction of the flood risk in case of emergency.
D7	Firecorps	D7.1	To rescue the affected people
		D7.2	Evacuate the affected areas
		D7.3	Look for protected zones
		D7.4	Develop simulations and training in case of emergency
		D7.5	Communicate the danger to the associated task forces (city hall, CECAT etc) the state of flooding emergency, and transmit the information to the civil population

Evaluation of Existing NSM (and/or to implement)

From the organization analysis and the different meetings with the entities involved in flood emergencies the following NSM for Arenys de Munt basin were detected (Table 50).

Table 50: List of analyzed NSM for the Arenys de Munt basin.

Non - Structural Measure	Activity/Entity/Resource	Local Scale
Urban Planning and Policies:	Municipal Action Plan	INUNCAT in Catalonia and PATRICOVA in Valencia
	Flood Directive Implementation	
Flood Forecasting	Early Warning System by METEOCAT, and the SAIH of ACA	The EHIMI and SAHBE projects
Communication	CECAT and the command center	Arenys de Munt Municipality and the Police corps
Mobilization	Military or health care corps. Physical resources.	Asistance to the affected people, evacuation and construction of structures (sand bags, camping tents etc.).
Coordination and operating practices	CECAT	CECAT training in flood emergencies.
Insurances and aids mechanisms	No mechanism or aids were detected	All to do.

Implemented

The SUFRI project has tackled population experience and forms of risk communication in the basin. Basically the communication is developed at two levels: Between entities and from entities to population.

The warnings start and are controlled by CECAT, and CECOPAL (the command board) takes decisions to forward them at different levels and entities. Once the warning is received in the Municipality, the police is informed and is in charge of warning the population.

The second well established NSM is the mobilization of physical resources. Specifically, in Arenys de Munt are very experienced in the implementation of the wooden tables called *“Tajaderas”* that could be considered as physical resources. **The very fast reaction (of the Arenys de Munt inhabitants) to the flood emergencies make possible to clear the streets of cars in a few minutes!** (Figure 88).

Figure 88: Risk communication and evacuation of the Arenys stream in Arenys de Munt. (10 – 15 min.)

Finally, the last NSM found is the Arenys de Munt land planning, which was updated in 2003. In this plan the hydrological system (explained later) and the protection strips of the river are distinguished.

In current implementation

Currently, work on implementation remains, such as different measures as the delimitation of hazard zones, the risk assessment and the risk management planning due to the Flood Directive. In Catalonia INUNCAT forces the municipalities identified as "under risk" to develop the Municipal Action Plan (MAP), which includes the hazard delimitation, the risk assessment and the risk management plan. Evidently, due to the current economic crisis the process of the MAP has been delayed in various municipalities despite the directives are very clear with the deadline time (Figure 89).

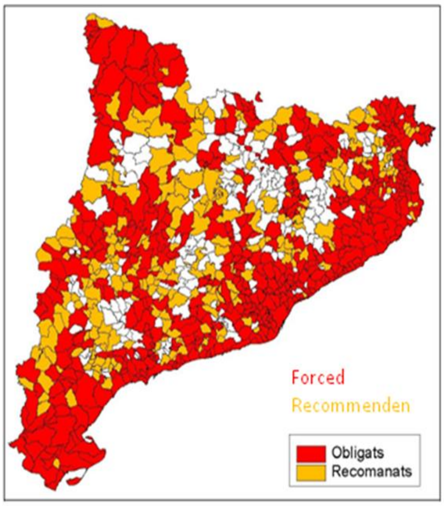

Figure 89: Municipalities Forced to develop a Municipal Action Plan. (INUNCAT, 2009)

The EHIMI (Hidrometeorologic development tool for Catalonia in Spanish) project and the Early Warning Systems for Catalonia are still in development. Concisely different project as the IMPRINTS or the COST 731 have been developed to improve and make feasible an accurate EWS of at least 6 hours lead time.

Finally CECAT develop risk exercises and training in flood emergencies. Most of these trainings are in charge at the CECAT staff. Sometimes the entities in the towns are informed. In Arenys de Munt, no risk exercises or training by CECAT were detected.

To implement

A short investigation in the insurances agencies was developed. The conclusion is that in Catalonia it does not exist a specific insurance for flood emergencies. The damages effects of flood events are included in general insurances that include fires, earthquakes and robberies.

Assignment of actors who preform NSM

A total of seven NSM have been analyzed (see Table 51). For each NSM it is needed to establish what entity will act in flood emergencies (Actors).

Table 51, shows the responsibilities-actor distribution. In this table it can be seen that the population appears as an actor for flood emergencies. It is specifically responsible for the installation of the *"Tajaderas"*.

For the forecasting non-structural measure, the combination of the local expert judgment (who is in the area) with this NSM can lead to a successful hydro meteorological forecasting.

Table 51: NSM-Actors assignation for Arenys de Munt Basin

N.	**NSM**	**Regionally**	**Locally**	**Observation:**
I	Land Uses Planning	Only a check by the Catalonia government, but are no involved	The Arenys de Munt municipality: Specifically the Urbanism director	Only the Arenys de Munt municipality has the responsibility. The land planning will be checked every 5 years.
II	The Flood Directive Implementation	Catalonia Government, ACA, METEOCAT, CECAT (Interior Minister	Arenys de Munt municipality	Until now an official decree was enacted on July 2010. Different deadlines were established for FHM, FRM and FRMP also called (MAP).
III	Flood Forecasting	ACA and CECAT	Expert judgment. (Antoni Sintes)	With only 6 lead time hours forecasting the potential damages and casualties could be mitigated.
IV	Communication	CECAT	Arenys Municipality and Police	The weak point of the risk communication has been the excessive warning advices. A check by a local expert can lead to a system improvement
V	Mobilization	Catalonia Government	Population, Police and Firefighters	The evacuation, streets closure and physical resources mobilization will be implemented during the flood scenarios.
VI	Disaster Exercises	CECAT	Municipality, Police and Firefighters	The Municipality acts only if a disaster control exercise is made in Arenys de Munt
VII	Insurances and Aids	Catalonia Government	Arenys de Munt Municipality	The Government has to legislate new insurance rules and the Arenys de Munt municipality to promote insurance acquisition.

*Also in the Maresme Concill have a hydro meteorological department experts

Establishment of restrictions regarding the implementation of NSM

From the previous subsection, 7 actors (or entities) were assigned to the non-structural measures. In many of them, more than one actor is involved, so there could exist interferences or "restrictions" between them because the actors resources are finite.
With the aim of making the application as simple as possible (focused in the NSM optimization) the following restrictions and acting protocols for each actor involved were established (Table 52, Table 53):

Table 52: Acting protocol for each entity (actor) identify in the Arenys de Munt basin.

Entity	Invlolved in:	Have to…:
CECAT	II, III, IV, VI	Due to own responsibilities, the CECAT will have to take care and improve the warnings in order to not get worse the risk communication (NSM) in Arenys de Munt. Also the CECAT needs to develop more drills in flood emergencies.
Catalonia Governemnt	I, II, V, VII	The Catalonia government through his management departments, will have to control the land uses planning and the implementation of the European Flood Directive and will also try to improve the flood insurance system.
ACA	I and III	The ACA efforts need to be focused in the improvement of the forecast systems (cooperating with METEOCAT and CECAT)
Arenys de Munt municipality	I, II, IV, VI, VII	It contributes almost in a big part of the NSM, so, the ACA needs to perform the coordination works between all the involved entities trying to dispose of help to as much people as possible.
Police	IV, V, VI	The police in addition of the vigilance works, will have to develop the risk communication and the streets closures.
Firefighters	V, VI	The firefighter will attend all the emergencies raised by flood emergencies and will have to execute the evacuation.
Population	V	The population has to put the "Tajaderas" and take care with the new information

The Arenys de Munt restrictions (as has been explained) are focused on the physical limitations that the NSM could have in the basin.

Table 53: Arenys de Munt non-structural measures restrictions.

Communication	<= to 4 person
Mobilization	<= to 6 person
EWS	< = of 10 000 € (per year)
MAP (include Land Planning)	<= 115000 € (each 5 years)

For our experimental basin an annual budget of 500 000 Euros was chosen to be distributed annually according to the different activities.
Note: The land use planning will be included in the MAP study with the aim of not paying two times studies that are closely correlated.

Matrix of NSM vs Mitigation

This is one of the last sections of the implementation and assessment of non-structural measures for flood risk mitigation. Once the NSM restrictions are known, multiple application combinations should be performed taking into account these restrictions, these NSM combinations should bring risk mitigation.

To evaluate this mitigation, as well as to perform the WP5 optimization respect to the NSM implemented, the Arenys de Munt basin should have risk mitigation factors (of economic and societal risk). The development of these factors is **beyond the scope** of this report and project, however reduction coefficients were constructed (Table 54 to Table 57) for the Arenys de Munt case study, based on experience criteria. Obviously the coefficient reduction implementation/development is left to all the users.

Table 54: The Communication NSM reduction/mitigation percentage in Arenys de Munt (%).

Number of Person	Lives	Euros
1	15	15
2	19	18
3	22	21
4	23	24

Table 55: Mobilization NSM reduction/mitigation percentage in Arenys de Munt (%).

Number of Person	Lives	Euros
2	15	18
3	19	22
4	23	26
5	27	30
6	31	34

Table 56: MAP NSM reduction/mitigation percentage in Arenys de Munt (%).

5 years inversion (€)	Lives	Euros
100000	22	30
105000	22.5	31
110000	23	32
115000	23.5	33

Table 57: EWS NSM reduction/mitigation percentage in Arenys de Munt (%).

5 years inversion (€)	Lives	Euros
5000	14.28	20
10000	28.57	22.25

Note: the reduction coefficients of Mobilization and Communication (NSM) are in terms of numbers of persons working for the specific measures, in opposite way, the MAP and EWS are in terms of the annual investment of this NSM.
For coordination and operative practices (disaster exercises) and insurances no reduction coefficients were established. Consequently, they will not vary the NSM optimization.

Table 58: Non-structural measures combination for Arenys de Munt. (Comb=1).

NSM	Fireman	Police man	EWS (Expert & Maintenance)	Comunnication press person	Other	Global Cost	Annual Cost
Municipal Action Plan	0	0	0	0	1	100000	6000
Early Warning System	0	0	1	0	0	10000	10000
Communication Improvement	0	2	0	1	0	110000	110000
Mobilization	4	0	0	0	0	160000	160000
Coordination and Excercises disasters	0	0	0	0	1	40000	40000
Inusrrances and aids	0	0	0	0	1	174000	174000
Total							500000

Potential fatality mitigation = 65.52%
Potential economic loss mitigation = 66.97%
Note: the total mitigation is the product of the reduction coefficients for each NSM. This also could be questionable, because when different NSM are implemented, the mitigation coefficients behavior do not necessary have to be the same as if only one NSM has been implemented.

Table 59: Non-structural measures combination for Arenys de Munt. (Comb=2).

NSM	Fireman	Police man	EWS (Expert & Maintenance)	Comunnication press person	Other	Global Cost	Annual Cost
Municipal Action Plan	0	0	0	0	1.1	110000	22000
Early Warning System	0	0	2	0	0	10000	10000
Communication Improvement	0	1	0	1	0	70000	70000
Mobilization	5	0	0	0	0	200000	200000
Coordination and Excercises disasters	0	0	0	0	1	40000	40000
Inusrrances and aids	0	0	0	0	1	158000	158000
Total							500000

Potential fatality mitigation = 66.05%
Potential economic loss mitigation = 68.5%

The previous combinations show that a large mitigation was obtained due to a NSM implementation. Perhaps this happens because the proposed mitigation coefficients are lineal and do not consider the decrease of the mitigation values as more non-structural measures are implemented (the coefficients lose the capacity to reduce risk when more NSM are implemented).

Finally, in the Arenys de Munt case study there has been built an objective function in excel sheet which includes the restrictions set in the NSM and looks for the highest value of risk mitigation.

Applying the objective function respect to both variables (economic losses and societal risk) and taking into account that it is not feasible to contract 5.1676 persons (but 5 or 6 persons could), the best solution is shown in Table 60:

Table 60: Non-structural measures combination for Arenys de Munt. (Comb=5).

NSM	Fireman	Police man	EWS (Expert & Maintenance)	Comunnication press person	Other	Global Cost	Annual Cost
Municipal Action Plan	0	0	0	0	1	115000	23000
Early Warning System	0	0	1	0	0	10000	10000
Communication Improvement	0	2	0	1	0	110000	110000
Mobilization	6	0	0	0	0	240000	240000
Coordination and Excercises disasters	0	0	0	0	1	40000	40000
Inusrrances and aids	0	0	0	0	1	77000	77000
Total							500000

Optimal (by two variables) Potential fatality mitigation = 69.69%
Optimal (by two variables) Potential economic loss mitigation = 71.8%

The combination exposed in Table 60 also leave more monetary reserves (77 000 €). The final Societal and Economic Risk having taking into account the 7 NSM is shown in the Figure 90 and Figure 91.

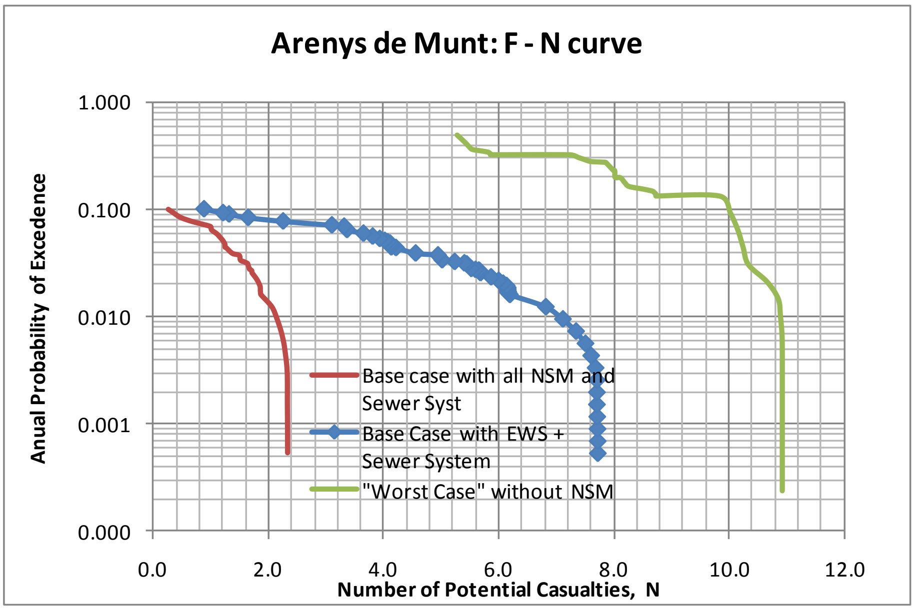

Figure 90. Societal Risk by different conditions of NSM implementations. (Arenys de Munt Torwn)

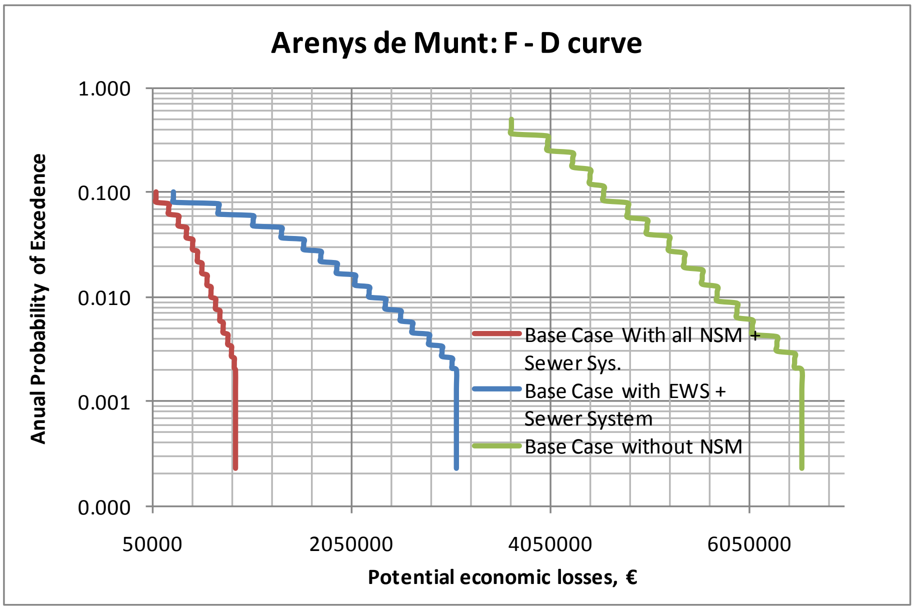

Figure 91. Societal Risk by different conditions of NSM implementations. (Arenys de Munt Town)

Worksheet for the action force

Finally a very simple and understandable worksheet for the action forces and population are exposed in the Table 61, according to the 5 warning levels of the CECAT agency:

Table 61: Worksheet for the action forces and population for flood emergencies (urban surface runoff).

Entity	Pre-Advice	Pre-Alert	Alert	Emergency Type 1	Emergency Type 1
CECAT	Warnings emission	Warnings emission	- Warnings emission - CECOPAL conformation	- Warnings emission - CECOPAL conformation. - Ask for Regional aids	- Warnings emission - CECOPAL conformation. - Ask for National aids.
Catalonia Governemnt	-	-	- Watch the established protocols	- Watch the established protocols - Aids Management	- Watch the established protocols - Aids Management -Follow the emergency and physical resources
ACA	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission
Arenys de Munt municipality	- Follow the Advice	- Mayor and Police warn implication	- Mannage the warning to the population. -Specific Orders to the police	- Provide all the resources availables for the people affected. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia	- Provide all the resources availables for the people affected. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia.
Police	-	-	- Follow the situation - Warn the population	- Warn the population. - Streets Clousre (for Pedestrian)	- Warn the population. - Streets Clousre. -Help in the evacuation
Firefighters	-	-	- Follow the situation -Attend emergencies	-Attend Emergencies -Start evacuation	- Evacuate affected people -Help the injured persons
Population	-	-	-	- Tajaderas Implementation	- Tajaderas Implementation -Sand bags implementation

5.6 National comparison of the investigation results

Specific Outcomes

Experiences in different European cities (Graz, Dresden, Lodi, Benaguasil, Arenys de Mar/Munt), e.g.:

- A comparison of the needed time for sufficient preparation of flood and the time the test persons had during the last flood event, the characteristic shows a widely homogenous trend. Except for Lodi, where people need more than 6 hours for preparation, the majority tends towards a time span of 2-4 hours or less. Resultant, a resolvable problem can be identified in Benaguasil, Dresden, Graz and Arenys de Mar / Munt due to the needed and the possible existing time span.
- A further trend points out that the knowledge of measures comes along with the setting of self-precaution measures.
- The distribution of responsibilities before a flood or in case of flooding differs from cast study to case study.

Lessons Learned

- Because of a positive tendency in taking self-precaution measures, information campaigns regarding this topic shall be promoted.
- A high number of people felt uninformed during last flood events. That's why the attention shall be turned on this matter.
- Media and emergency services are most welcome by the population as methods to get information. Depending on the city, people also have confidence in their community and local council.

5.6.1 General

The previous surveys captured the existing warning systems, the population`s view about protection measures, information management and necessities as well as the organisation structures and responsibilities of crisis management in five different cities in four European countries (Graz (AUT), Dresden (GER), Lodi (I), Benaguasil (E), Arenys de Mar/Munt (E)). Work package 6 provides a comparison of the results to give an overview of the different national approaches, e.g. the different responsibilities in case of flooding.

Most of the results have already been discussed in the previous chapters. The aim of this work package is to provide a quick and compact overview of the main results.

Therefore a criteria catalogue (see Figure 92 for an excerpt) has been developed to filter out the main differences in the case studies. The catalogue is provided in appendix 5 and comprises 5 sections:

Section A – Characteristics of the case study areas

- River characteristics
- Characteristics of the population and way of living

Section B – Warning Systems

- Weather forecast
- Warning system – inhabitants

Section C – Risk Analysis

- Flood protection measures
- Flood risk analysis
- Risk estimation (River flooding)
- Risk estimation (Pluvial flooding)

Section D – Communication

- Information about the participants
- Natural hazards and floods in general
- Consequences of flood events
- Communication and information
- Information campaigns by stakeholder

Section E – Disaster Control Management

- Activities and responsibilities of entities before a flood event
- Activities and responsibilities of entities during a flood event
- Activities and responsibilities of entities after a flood event
- Action Plan (Risk Management Planning)
- Other

If a criterion applies, it is either marked with the symbol ‘X’ or ‘yes’ respectively ‘no’. Sometimes further information is given by a verbal description. If there are no data available or the criterion does not apply these fields are marked with the symbol ‘-‘.

				Analysis Case Study					
Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
B	Warning Systems								
B 1	*Weather forecast*								
B 1. 1	Are rainfall-runoff-models in use?	B1 1.1		no	no	-	yes	no	No, in the Arenys basin but the ACA,
B 1. 2	Are forecast models in use?	B1 2.1		no	expert knowledge	-	yes	yes	Yes, is managed by the METEOCAT
B 1. 3	Measurements of	B1 3.1	precipitation (yes / no)	yes	yes	-	yes	yes	yes
		B1 3.2	precipitation (if yes, number of stations)	13 rainfall gauges	8	-	3	1	yes, 1 official rainfall station and 1 station managed by Antoni Sintes
		B1 3.3	river discharge (yes / no)	yes	yes	-	yey	no	no
		B1 3.4	river discharge (if yes, number of stations)	2	11	-	4	-	-
B 1. 4	First installation of	B1 4.1	river gauge	2010	1913	-	1922	-	1990
		B1 4.2	precipitation gauge	1938	-	-	1988	1992	Is posible to found information from earlers 1916. The official station was installed in 1990
B 1. 5	Measurement data will be	B1 5.1	collected	yes	yes	-	yes	yes	yes
		B1 5.2	analysed	probably yes	yes	-	It is already analysed in the Emergency Action Plan of Loriguilla Dam	yes	yes
B 2	*Warning system - inhabitants*								
B 2. 2	Warning message distribution	B2 2.1	TV, radio	yes	yes	-	yes	yes	yes
		B2 2.2	Internet (websites)	yes	yes	-	yes	yes	yes
		B2 2.3	SMS	yes	yes	-	no	no	yes
		B2 2.4	E-Mail	no	yes	-	-	-	yes
		B2 2.5	Diaphones	no	yes	-	-	-	no
		B2 2.6	Megaphones	yes	-	-	yes	yes	yes
		B2 2.7	Insurances	yes	-	-	-	-	no
		B2 2.8	Others	text messages from professional fire brigades of Graz to registered people	-	-	-	-	Warning Bell

Figure 92: Excerpt of the criteria catalogue. Graz, Dresden, Lodi, Benaguasil, Arenys de Mar/Munt.

In the section **‘A – Characteristics’** it’s obviously that all case studies have a different data background, e.g. regarding records about flood events in the past or about the availability of annularity of flood events.

Section **‘B – Warning Systems”** provides a short overview of the available weather forecast and warning systems.

Section **'C – Risk Analysis'** gives some background information about the used data for the risk analysis in a certain case study.

In section **'D – Communication'** main results of the public opinion poll are presented with percentage. Detailed results are given in chapter 5.4, Risk Communication, p. 88 and the corresponding appendix 4.

However, some main results are highlighted in this chapter in a different context.

The radar diagrams in Figure 93 show an extract of the diversion of the knowledge about flood protection measures and the effectively application of them as well as the exposure to economic loss regarding insurances and disaster funds (valid percentage of received questionnaires). The left diagram poses that the knowledge of self-precaution is very well in Graz and Benaguasil in comparison with Lodi, Dresden and Arenys de Mar / Munt, however the willingness of setting self-protection measures was clearly lower. The future trend gravitates into the usage of more self-protection measures in the Austrian, Italian and German case study area. The Spanish respondents tend to keep their attitude.

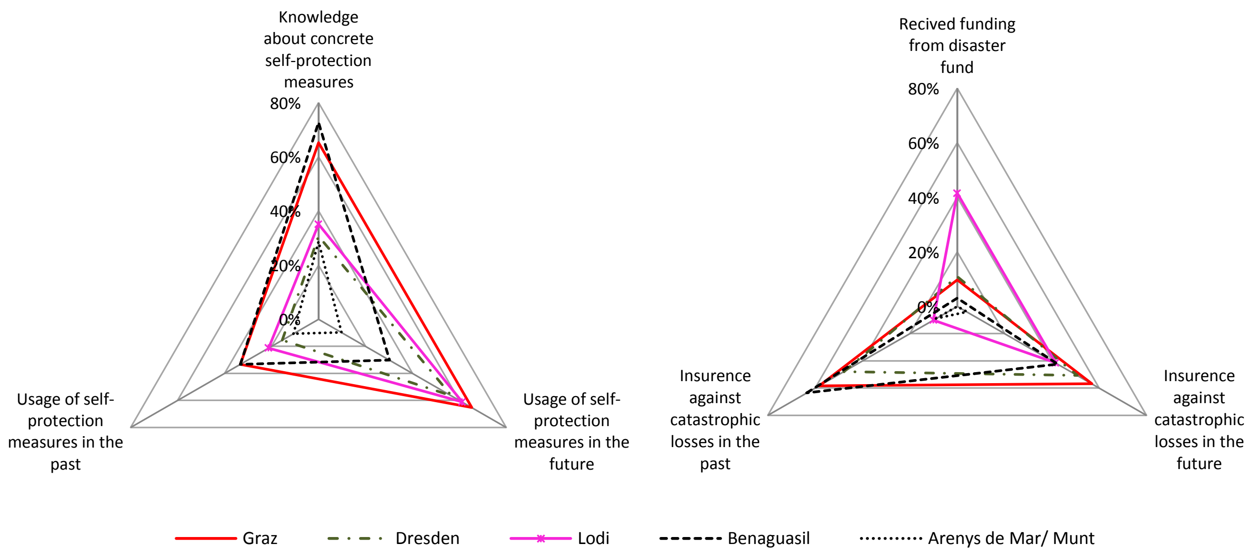

Figure 93: Excerpt of the results of the public opinion poll

The right diagram shows the willingness to insure own property which is situated in the middle field and will still keep the same in the future, with exception of Lodi and Arenys de Mar / Munt. In Lodi, nearly half of the economic loss was covered by the disaster fund contrary to the other investigation areas, which seems to increase the willingness to insure their selves. In the other examples there can be pointed a combination between missing state assistance and readiness to take out an insurance.
A comparison of the test person`s view regarding their needed time for sufficient preparation against flood and the time the test persons had during the last flood event the characteristic shows a widely homogenous trend (Figure 94, left). Except for Lodi, where people need more than 6 hours for preparation, the majority tends towards a time span of 2-4 hours or less. Resultant, a resolvable problem can be identified in Benaguasil, Dresden, Graz and Arenys de Mar / Munt due to the needed and the possible existing time span.

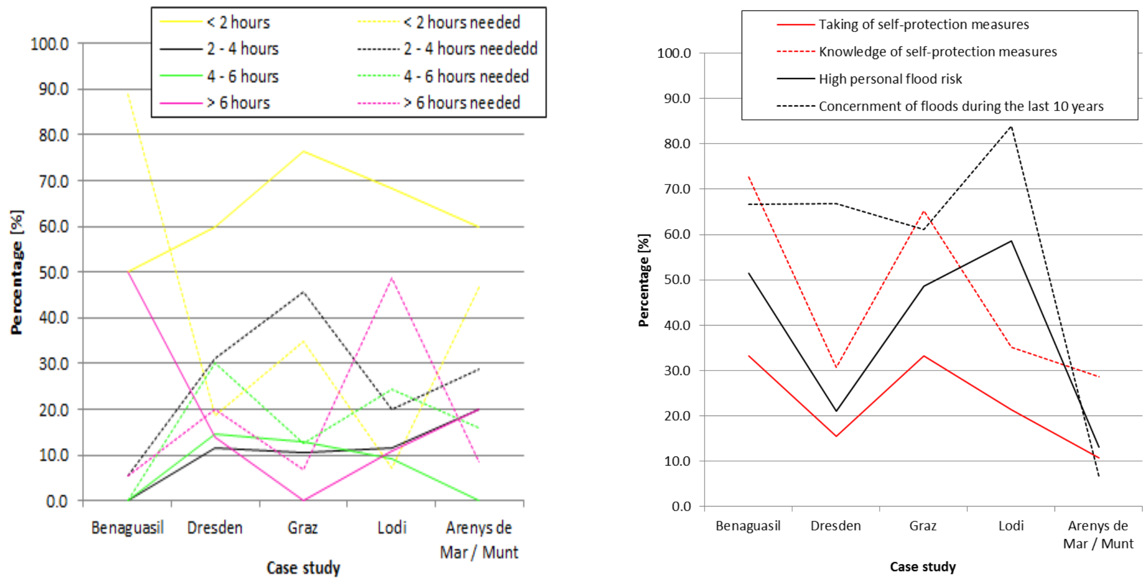

Figure 94: Excerpt of the results of the public opinion poll – comparison of the needed and existing time span for taking self-precaution measures (left) and the knowledge and willingness of taking measures versus personal flood risk (right)

Continuative, this leads to pose a question about the knowledge and willingness for taking self-precaution measures to give the inhabitants a tool for self-help (Figure 94, right). The trend points out that the setting of self-precaution measures comes along with the knowledge of measures, whereas the knowledge is attended by the estimation of the personal flood risk.

Section **'E – Disaster Control Management'** provides, amongst others, a clear picture about the distribution of responsibilities in the case studies. Representative these results have been worked out graphically, in Figure 95 and Figure 96.

Figure 95 shows the responsibilities before a flood event for each case study regarding

- Simulations and training
- Organization of the disaster management
- Development of risk maps
- Guidelines and action plans

for predefined entities

- National authority
- Regional authoritiy
- Police
- Fire corps
- Military
- Dam owners
- Community boards – population
- Community boards – population and stakeholder
- Others

The results show that there is a wider distribution of the tasks in the case studies Valencia and Benaguasil. In Dresden all responsibilities are focused on three entities, the regional authority, police and fire corps. None of the community boards in no case study are involved in the above mentioned tasks.

Figure 96 shows the responsibilities during a flood event.
In this case the following tasks have been analyzed for the predefined entities:

- On-site assistance for population regarding information
- Who is responsible and carries out flood protection measures (sand bags, etc.)?
- Who is responsible for hydrological monitoring?
- Who is responsible for dam management?
- Who is responsible for medical service?
- Who guards the public and private property?
- Who informs the public?
- Which entities are informed?

Here it is again notable, that the responsibility is widely distributed to all mentioned entities in the case studies Valencia and Benaguasil. All entities are at least responsible for two tasks. In Dresden in in Arenys de Mar / Munt the task are concentrated on a smaller number of entities.

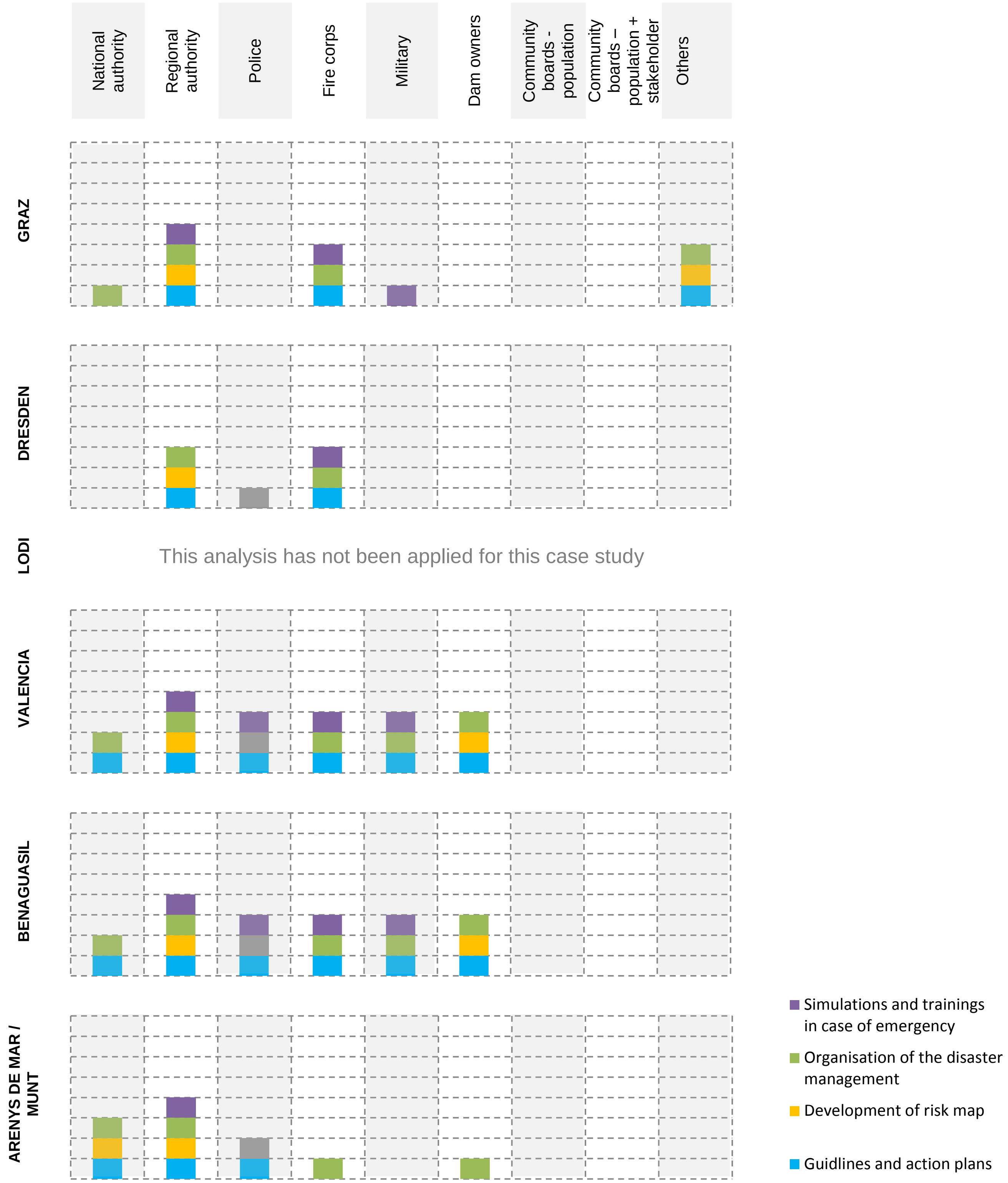

Figure 95: Responsibilities before a flood event

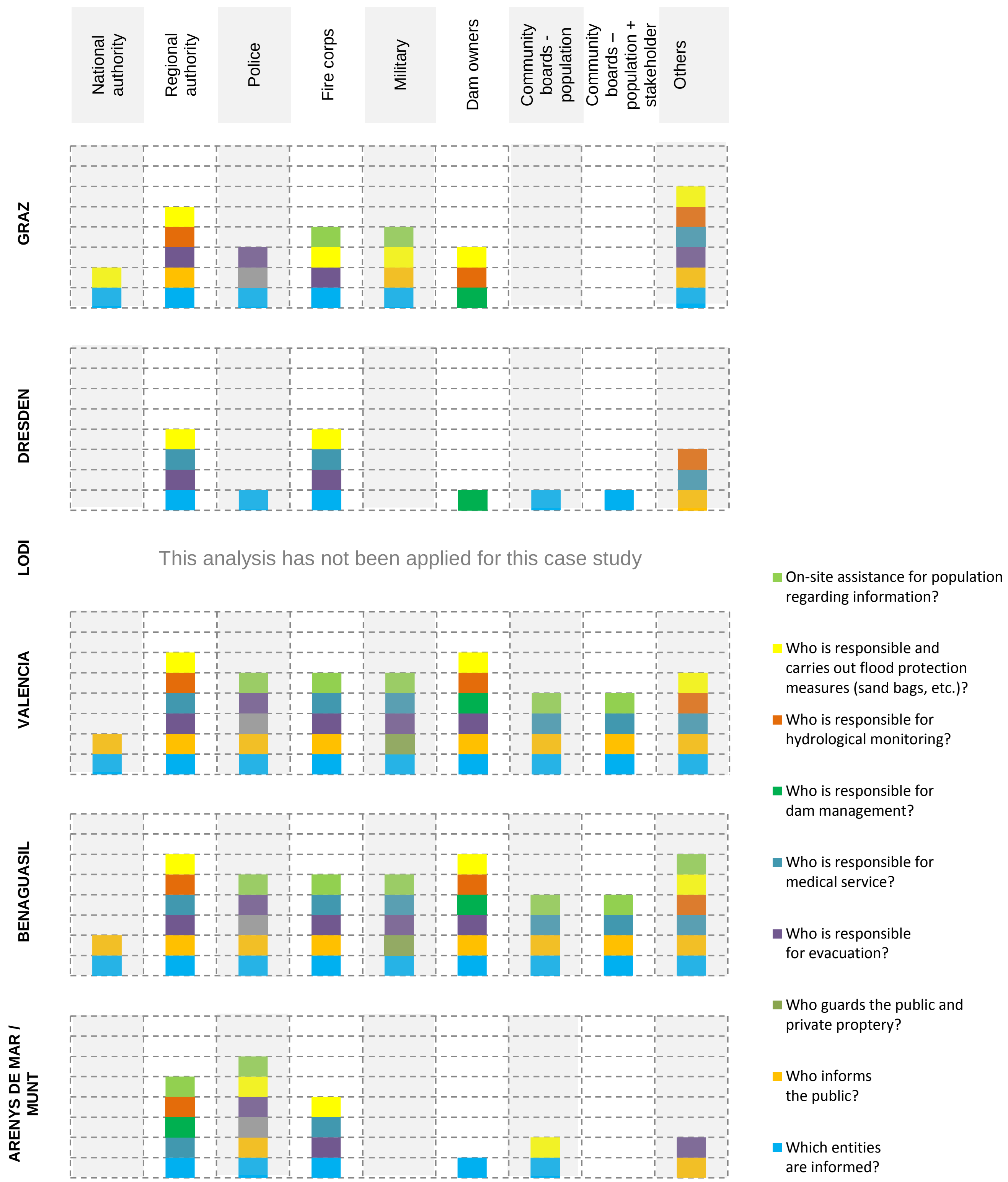

Figure 96: Responsibilities during a flood event

6 Contribution of the project to the overarching topics of the call

This chapter refers to the overarching questions of the 2nd call of ERA-Net CRUE initiative. The connection of the project with the flood directive as well as the comprehension of the flood affected parties is explained. Further, the chapter includes explanations of the harmonisation of flood risk management within the EU and in-depth analysis of case studies. Restrictions of the generalisation of the results and project`s contribution to resilience close the project`s ideas / inputs to the overarching questions.

6.1 Connection to the Floods Directive

According to the flood directive flood risk management plans (chapter IV, article 7)

- "… shall address all aspects of flood risk management focusing on **prevention, protection**, **preparedness**, including **flood forecasts and early warning systems** and taking into account the characteristics of the particular river basin or sub-basin." (Directive, 2007)
- "… shall take into account relevant aspects such as **costs and benefits**, …" (Directive, 2007)

The main goal of SUFRI is the improvement of flood risk management plans with non-structural measures, especially for smaller mountainous and/or urban catchment areas.
Regarding these aspects the project contributes to advanced warning systems, risk communication, and crisis management as well as to risk analysis.

Based on the different demands of five representative case studies the general approaches have been provided.
The total process for implementing flood risk assessment, flood hazard maps as well as flood risk management plans includes the quantification of flood risk and how the effect of non-structural measures can be included in the progress of flood risk analysis, trans-national strategies of risk communication, a survey of an actor-responsibility in case of flood emergencies and the obtainment of knowledge regarding flood warning dissemination in urban areas.

The project developed an approach for pluvial and river flooding risk assessment in urban areas and it proposes the use of F-N graphs as a comprehensive tool for evaluating flood risk. This method can be applied by a wide range of people such as technical personnel of municipalities, stakeholders, researchers, etc. This detailed analysis assists the decision maker by implementing flood risk maps as part of the methodology to providing full risk characterization of any area subjected to potential flooding and consistent management plans. Further, the assessment of the public attitude benefits the flood risk management plans.

The main objective of the SUFRI approach for crisis management planning focused on non-structural measures was the identification of entities involved in flood emergencies (action forces and population), their responsibilities and the evaluation/implementation of non-structural measures. This implementation was developed for the case study Arenys de Mar/Munt, taking into account the local restriction of non-structural measures.

6.2 Participation

Each project partner integrated affected parties in their case study area. In most cases policy maker take an active part in the realization of the aims of our project, on one hand as consultant and on the other hand as informant regarding the specific circumstances of the investigation area.
This collaboration impact on the standardized questionnaire regarding specific questions about action forces, wishes of the population and other themes the policy maker and action forces are interested in. Further, the recording of responsibilities and management plans was only possible with the intensive cooperation of the different parties.
On a national level meetings with stakeholder and authorities have been held to review and discuss current situations (tasks, problems, …) and to obtain data of the project area. In Benaguasil, e.g., the interviewer of the opinion poll got an identity card of the municipality, along with a letter of the City Council explaining the purpose of the opinion poll, as support, and, in Graz a periodical working group has been established. The public has been integrated with the opinion poll, a meeting to present the results will be held in most investigation areas. In Graz, the citizens' initiative of Andritz (district of Graz) has been involved in the development and realization of the public opinion poll to avoid bad attitudes because of special circumstances and differences between them and the authorities.
In Arenys de Mar/Munt, entities have been involved in the development of the SUFRI Approach for crisis management planning focused on non-structural measures, especially their experiences have accounted a lot.
For Lodi case there was a strong cooperation with Lodi's Civil Protection Office, the committee of the flooded people in 2002 and the Public Relation Office, together with the city council of Lodi Town. A conference will be organized for inhabitants and public administration to show the results of the opinion poll.

Case study surveys with meetings of policy makers and agencies (e.g. persons in charge of managing warnings or of the water management) have been undertaken on a transboundary level (with representatives of all SUFRI project partner).

The project has contributed to the subsequent listed questions as follows:

How has your project contributed to

a) strengthen public participation in the establishment of future flood risk management plans,
b) valuable lessons for public authorities/institution and
c) good governance?

Ad a)
The opinion poll survey is a useful tool for public participation. Good governance can be achieved only if interests of citizens are considered and decisions take into account all possible consequences of an action (benefits and costs, in this particular case, regarding flood risk). The willingness of the public for participation is intimately connected with taking their requirements seriously. Therefore, one project output, the standardized questionnaire (available in 4 languages), is an ideal tool to strengthen public participation for integrating their requirements in future flood risk management plans.

Ad b)
The outcome of the developed public opinion poll can give the public authorities an instrument for understanding the population`s needs and satisfaction with them. E.g., the official fire brigade of Graz was very interested in the population`s satisfaction with their work wherefore this topic has been included into the questionnaire (question 35). Further, the action forces can get valuable information of the analysis about their crisis management. The recommendations achieved in WP2 provide a good knowledge basis for analysing and reviewing of the public flood warning systems. The output of WP5 leads to detailed worksheets for the action forces and population (Figure 97).

Entity	Pre-	Pre-Alert	Alert	Emergency Type 1	Emergency Type 1
CECAT	Warnings emission	Warnings emission	- Warnings emission - CECOPAL conformation	- Warnings emission - CECOPAL conformation. - Ask for Regional aids	- Warnings emission - CECOPAL conformation. - Ask for National aids.
Catalonia Governemnt	-	-	- Watch the established protocols	- Watch the established protocols - Aids Management	- Watch the established protocols - Aids Management -Follow the emergency and physical resources
ACA	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission	- Warnings emission
Arenys de Munt municipality	- Follow the Advice	- Mayor and Police warn implication	- Manage the warning to the population. -Specific Orders to the police	- Provide all the available resources for the affected people. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia	- Provide all the available resources for the affected people. -Inform the disaster consequences to CECAT and Gouvernemtn of Catalonia.
Police	-	-	- Follow the situation - Warn the population	- Warn the population. - Streets Clousre (for Pedestrian)	- Warn the population. - Streets Clousre. -Help in the evacuation
Firefighters	-	-	- Follow the situation -Attend emergencies	-Attend Emergencies -Start evacuation	- Evacuate affected people -Help the injured persons
Population	-	-	-	- Tajaderas Implementation	- Tajaderas Implementation -Sand bags implementation

Figure 97: Worksheet for action forces and population for flood emergencies. Arenys de Munt. (Polytechnical University of Catalonia)

Ad c)
The outcome of the risk estimation (F-D and F-N curves) can support the authorities and governance in decision-making processes. The results show the benefit of different protection measures (structural and mainly non-structural) including prioritization based on the efficiency in risk reduction.

6.3 Harmonisation

Case studies in four different countries (Austria, Germany, Italy and Spain) can point out national differences and similarities in national flood risk management strategies (national proceedings, infrastructure, the efforts of rehabilitation, the public's risk perception, as well as the competence of authorities). Thus, efficient local strategies can be helpful for other countries to improve their tailor-made solutions as well as to find trans-national strategies for interacting management plans.

Special requirements as well as financial support are needed on a regional scale to implement new approaches on a local scale. E.g. the public opinion poll can have a positive impact on flood event management regarding the comprehension of the public`s need.

6.4 Restrictions

The methodology for pluvial and river flooding risk assessment in urban areas is developed on a general base to implement it in different areas which are affected by pluvial or river flooding. This method is not restricted to any kind of social, political or economic characteristics. Uncertainties depend on the quality of necessary data and their availability.

The method for risk awareness of the population can be applied independent of the flood type and social as well as economic characteristics. Political characteristics of the local parties can influence the willingness of the public to cooperate with, respectively the type of procedure (collection by personal contact, mail, …). The opinion poll consists of a standardized questionnaire and procedure to reach a generalization of the results.

Moreover, the compilation of existing flood warning systems offers a generalized collection to show up the applicability and uncertainties of the systems.

The SUFRI approach for crisis management planning focused on non-structural measures attempts to address the implementation of non-structural measures to reduce the residual risk. However, the implementation of non-structural measures sometimes is limited because of limited resources (monetary, human or time). This fact shall be taken into account in the approach of crisis management planning.

6.5 Enhancement of Resilience

Aspects as resistance, recovery and adaptive capacity are strongly related to the human behaviour. If people have a good knowledge about natural threats in their surroundings, their own residual risk, possible protection measures (especially self-precaution measures) and information about warning systems they can act targeted to resist floods more effective and recover easier.
Another contributed aspect of our project is the knowledge what kinds of measures are more efficient to resist floods.

There are two aspects considering the resilience of communities: on one hand people`s attitude and knowledge of residual risk in their environment as well as their cooperativeness after a flood event impact the resilience directly, on the other hand the setting of non-structural measures and the risk reduction involved affect the vulnerability of an area and, as a consequence, the resilience of its inhabitants and community.
Therefore, the method for risk awareness of the population (public opinion poll) advances the public participation and the cooperation of the public and the authorities. The authorities and action forces get a clear picture of the human behaviour as well as their needs can be collected and lead to a successful risk communication strategy for an improvement of resilience.
The methodology for pluvial and river flooding risk assessment in urban areas leads to a clear visualization of the consequences of setting different non-structural measures. Furthermore, it captures the current resilience and quantifies the potential for enhancement of such resilience.

7 Implications for stakeholders

The methodology for pluvial and river flooding risk assessment in urban areas has been developed as an instrument for decision-maker. It supports practitioners and policy makers in their decision-making process with well-conditioned curves that show the effects of several protection measures and provide a good basis for planning and managing flood risk.

Further, the analysis of the public opinion poll can provide policy makers with a clear picture of the population`s needs and perception to act in a problem orientated manner.

In all investigation areas the authorities respectively the policy makers of the cities get the results of the public opinion poll as a reflection of their work and recommendations for public participation and communication strategies. The compilation of advanced warning systems can be served as reference work.

8 Policy recommendations (National/European level) and further research needs

8.1 Data Related Issues

River flooding risk assessment in the case study area Graz
In Graz the situation regarding political and social issues, as well as civil engineering reasons is partially a bit stressed. The implementation of structural measures is in process, but the available flood-lines and geometry of the Schoeckelbach was based on the realized measures before October 2008. Since 2008 other planned measures have been realized, partially as in the design, partially differing because of adapted design. Information about water depths, velocities and width as well as 30-year and 100-year flood planes were only available regarding the stage of October 2008.
Concerning the implementation of structural measures it is also a political issue depending on the implementation time and achievable degree of protection. The social and public acceptance is low since the flood events of the last years.
Therefore, in trade-off with the customer, the Government of Styria, the preliminary results of the risk estimation will not be published in this report. Elements of the elaboration would be changed respectively upgraded, based on new data. This improved risk analysis of Andritz regarding the brook Schoeckelbach is no part of the SUFRI project and may be published in a later stage.

Pluvial flooding risk assessment in the case study area Benaguasil
In Benaguasil, the City Council is currently carrying out several measures to reduce flood risk in this urban area. New structural and non-structural measures are now being implemented, such as the construction of a permeable parking and changes on the drainage system.
Due to frequent flood events, the City Council is concerned on the importance of non-structural measures regarding public education, participation and communication to reduce potential flood consequences.
Therefore, results of the developed analysis will be published and used to elaborate the Municipal Action Plan of Benaguasil in collaboration with the Civil Protection Department of the region.

River flooding risk assessment in the case study area Dresden
Since the last extreme flood event in 2002 several flood protection measures have been in planning stage or under construction which affects the result of today risk assessment (possible inundation area, number of affected people, possible damages). In addition new river gauges were installed. A continuous review of input data as well as analysis of flood management after future flood events will enable the authorities to meet the needs if the population.

Public opinion poll in the case study Lodi
A system of levees to protect the lower areas is being almost utilized. The results of the opinion poll will help the government of the city Lodi to get a clear picture of the public feeling about the future structural measures.

8.2 Policy maker issues

The research work of SUFRI causes the following recommendation for policy makers:

- The tool for risk estimation can assist in the decision making process. It provides a clear overview of the social and economic flood risk and evaluates the effects of several structural and non-structural measures. F-N and F-D curves describe the quantitative results of the analysis of social and economic loss regarding the probability in an understandable and easy way.
- An analysis of the public opinion poll can point out a clear picture which kind of measures, information or assistance is needed in the population`s view. This kind of information can assist in the decision making process for setting tasks and measures respective the flood management process.
- The compilation of advanced flood warning systems delivers a reference work for authorities and policy maker. It covers the state-of the art of flood warning and their advantages as well as disadvantages.

8.3 Scientific Issues

Advanced warning systems
Automatic warning message dissemination is not common in flood warning systems. The warning chain is often discontinuous in order to check the measurement results of river discharge gauges or to validate the results of rainfall-runoff-models. Automatic flood warning systems are today research topics or in planning stage. Here linking between the forecasted rainfall and the flood induced damage is very complex.

Flood risk assessment
The SUFRI methodology for river and pluvial flood risk assessment in urban areas (developed in WP3) will be used to provide a more complete tool for flood risk evaluation and assessment in order to achieve an integrated flood risk management, including all type of hazards such as seismic, hydrologic, and antrophic threats (including impact of climate change).

Critical Infrastructure Management
Characterization of the system response, as it has been described in the SUFRI methodology for river and pluvial flood risk assessment in urban areas, should include all critical infrastructures, not only flood defence infrastructures, thus researching on the overlapping of Directive 2007/60/EC on the assessment and management of flood risks and 2008/114/EC on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection.

Consequence estimation
Consequence estimation should be able to better capture environmental issues. Also improvements in life loss estimation are achievable by researching on simulation models.

Mitigation coefficients of non-structural measures
To evaluate the risk mitigation with non-structural measures as well as the optimization of non-structural measures, reduction coefficients (mitigation coefficients) have been developed based on the case study Arenys de Mar/Munt as well as on expertise criteria. The development of these reduction coefficients on a general level, not only based on a specific case study, were beyond the scope of this project, thus this topic is left as a future work.

8.4 Practitioner Issues

Advanced warning systems
The review of warning systems and documentation of operation experiences was often only triggered by extreme flood events. As intended by EU Flood directive and due to the great number of flood events all over in Europe this improvement process has become more continuous in the last two decades. Therefore, authorities shall force the improvement of documentation not only of extreme floods in large catchment areas, but also of small floods in small catchment areas. This gathered information can be used to improve the hydrodynamic calculations, risk estimation and disaster control management.

SUFRI Method for risk awareness of the population (Figure 98)

- Comparative studies in further districts of Graz or other cities: e.g. St. Peter / Graz, Steyr
- Questionnaire for stakeholder – needs, structures, problems
- Connection of the needs of all parties

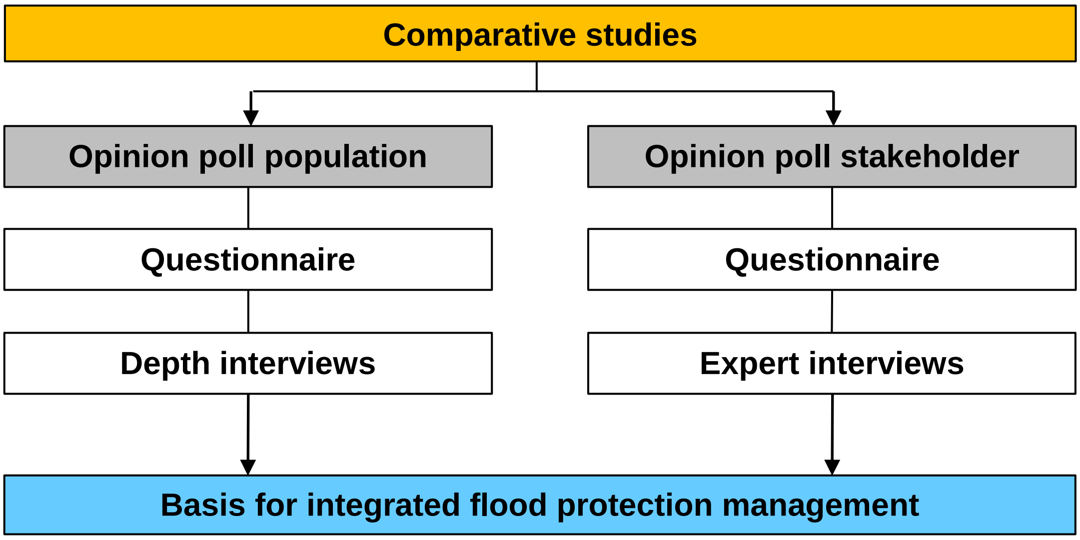

Figure 98: Practitioner issues – SUFRI Method for risk awareness of the population

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Appendix 1

Terms and Definitions
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Terms and Definitions

Notes to report editor:

This section provides definitions of terms used in the respective research projects.

Term	Definition
Case study	City or group of population, taking into account the total area or a particular zone. It should include all areas with potential flood damage in case of flooding. In general, the whole urban site is considered.
Structural measure	Flood defense system or infrastructure that acts on flood mechanisms and propagation, modifying their characteristics.
Non-structural measure	Flood management system or policy that modifies the vulnerability of an area or population in case of flooding.
Base-case	It represents the current situation of the case study, including current structural and non-structural defenses. The analysis of the Base-case provides flood risk results for the urban area in the present moment.
Coastal flooding	Coastal flooding is often connected to offshore low-pressure systems driving sea water inland but it also includes flooding due to a tsunami wave. Areas which lie below sea level are more endangered.
F-D curve	The F-D curve presents values in both axes (cumulative annual exceedance probability and estimated economic consequences).
F-N curve	The F-N curve presents values in both axes (cumulative annual exceedance probability and estimated loss of life) and the area under this curve is the total societal risk.
Flash floods	Flash floods are characterised by a fast increasing discharge in small or intermittent brooks and rivers and is caused by heavy rainfall events. These rivers are often characterised by steep longitudinal slope. Therefore the water propagates very fast which led to additional damage due to erosion processes. It is also possible that the water reaches areas where no or little rainfall occurred before. This is very common in mountainous areas and Mediterranean countries.
Flood risk analysis	Flood risk analysis is a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could involve a potential threat or harm to people, property, livelihoods and the environment on which they depend.
Maritime flood	Sea can inundate urban coastal areas as a result of natural events as hurricanes, cyclones and typhoons. Furthermore, in the case of urban areas below the sea level, if the structures that protect them are not able to contain the sea water, the flood consequences can be very important.
Pluvial flooding	The term “pluvial flooding” refers only to a flood which was caused by rainfall and includes both urban flooding and flash flooding.
Rainfall	High-intensity runoff may produce flooding in urban areas. This kind of flood will be more hazardous when the drainage system of the city is not capable to drain all the water effectively.
Risk	Risk = Hazards x Vulnerability Its units are the ones used for measuring the vulnerability divided per time, for instance a monetary unit or number of victims per year, because the hazard probability usually has units of time-1. When risk consequences are computed in number of victims, resulting risk is usually called societal risk, which is defined as the relationship between frequency and the number of victims in a given population from the realization of specified hazards. Societal risk includes

vulnerability, not only hazard characteristics.

River flood ◄ Rivers can burst their banks and inundate urban areas. Although river floods are usually associated with storms, it must be analyzed as a different source of flood risk, because storms many kilometers upstream the urban area can produce flooding, independently of urban rainfall. Furthermore, other natural processes like snow melt can also produce important river floods. River flooding is connected with a high or flood water level in a river. Areas which are situated near the river banks could be flooded if the ground level is beneath the flood water level. Rainfall, snow melting or dam failures can cause high river water levels.

Study scenario ◄ For a defined urban area, study scenarios are determined by the number of non-structural measures or alternatives that are considered to compare the effect of non-structural measures with the current situation of the case study.

Glossary of Acronyms and Abbreviations

a	Year
AE	Catchment area
AEP	Annual Probability of Exceedance
Af	Potential flooded area (km²). In pluvial flooding, two values are estimated: Af (flood depths < 0.15 m) and Af1 (flood depths > 0.15 m)
Af'	Flooded areas without households (used for estimating economic damages)
A_{ff}	Affected area, used as potential flooded area for calculations (km²)
A_F	Total flooded area (km²)
A_T	Total area of the case study (km²)
b	width of the main waterpath (street)
b	Width of the channel (m)
BMLFUW	Federal Ministry of Agriculture, Forestry, Environment and Water Management of Austria
C	Category for the case study to obtain reference fatality rates (RFR) in river flooding
C_p	Category for the case study to obtain fatality rates (FR_p) in pluvial flooding
C_d	Drag coefficient
CD	Direct costs (€)
CECAT	Centre de Coordinació Operativa de Catalunya
CI	Indirect costs (€)
CR	Reference cost, established for each land use category (€/m²)
CRUE	Coordination of the research financed in the European Union on flood management
CT	Total costs: sum of direct and indirect costs (€)
CU	Land use category
d	Density of population at the study area (inhabitants/km^2)
d_C	Density of population to estimate population at risk, from density reduction based on building typology (inhabitants/km^2)
D	Damage
DCM	Disaster Control Management
DGA	General Direction of Waters - Chile
DV	Parameter for the definition of flood severity levels in river flooding (m²/s)
EMA	Emergency Management of Australia
EWS	Early warning system
f	Annual probability of exceedance (years^{-1})
F	Cumulative annual probability of exceedance (years^{-1})
FEMA	Federal Emergency Management Agency
f_c	Factor. Ratio of indirect to direct costs (%)
F_f	Friction Force (N)
FR	Fatality rate in river flooding
FR_p	Fatality rate in pluvial flooding
FRM	Flood risk management
FWS	Flood warning system
h	Height (m)
H	Water depth in river flooding

IDEAM	◀	Institute of Hydrology, Meteorology and Environmental Studies - Colombia
INA	◀	National Institute of Water - Argentinia
MAP	◀	Municipal Action Plan - Spain
MICINN	◀	Ministry of Science and Innovation of Spain
N	◀	Number of potential fatalities
NaDiNe	◀	Natural Disasters Networking Platform
NSM	◀	Non-structural measures
Q	◀	Question
Q_f	◀	Flow discharge
$Q_{2.33}$	◀	Mean annual river discharge
ONEMI	◀	Oficina Nacional de Emergencias – Ministerio Nacional - Chile
ρ	◀	Density of the water (kg/m^3)
P_o	◀	Runoff threshold
P_d	◀	Daily rainfall rate
PD	◀	Percentage of damage
PR	◀	Population at risk
R	◀	Reference cost, established for each land use category (€/m^2)
RMP	◀	Risk management plan
S	◀	Flood severity in pluvial flooding
S_v	◀	Flood severity in river flooding
SNPAD	◀	National System for Disaster Response and Prevention - Colombia
SUFRI	◀	Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk
T	◀	Return period
T(x)	◀	Return period (Years)
TC	◀	Time category
TW	◀	Warning time
V	◀	Flow Velocity (m/s)
V_{ped}	◀	Pedestrian foot volume (m^3)
W	◀	Weight in the foot of the pedestrian (Kg)
W_{equiv}	◀	Equivalent weight (Kg)
W_{df}	◀	Maximum width of the flood area (m)
WLV	◀	Torrent and avalanche control, Austria
y	◀	Water depth in pluvial flooding
y	◀	Hydraulic depth (m)
γ	◀	Specific weigth of water (N/m^3)
µf	◀	Friction coefficient (Adim)

Table of project information

Joint project title	**SUFRI - Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk**
CRUE Project No.:	
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Objectives	Flood forecasting and warning are widely in use for large river catchment areas, but for small catchment areas respectively urban areas are still research topic. Further, experiences of practical applications are still seldom. Besides forecasting and warning, adequate risk communication strategies are important for flood management issues. Therefore, information about people`s conduct and needs should be taken into account, but currently limited empirical data are available. In recent years risk estimation has become of more research interest too, because of the recognition that an absolute flood protection is not feasible. Therefore, there is the intention to develop a simple tool for supporting flood risk evaluation in urban areas, as a resource in decision-making processes. An interdisciplinary approach that combines societal and technical visions, as advanced warning, risk estimation and public participation, can lead to an improvement of the crisis management planning.
Background	In the recent past, flood events occurred ever more frequently, and with snowballing effects for the landscape and its habitants. As a result of the current situations in many European cities that relate to flooding the demand of the population for absolute safety becomes top priority. In terms of the implementation of the Floods Directive in 2007 a broad basis of knowledge and tools, as well as the development of improved strategies for flood risk management are required. Particularly in regard to urban areas flood protection and retention are more problematical than in

	rural areas due to limited space in combination with a high density of population. Flood analyses have shown that structural measures of flood protection are limited applicable and that absolute protection is not feasible. The residual flood protection has to be achieved with non-structural measures such as forecast models, risk communication, and disaster control. Improving the risk awareness and increasing, thus, the public participation, respectively, is essential for coping with the effects in order to achieve an effective flood management.
Research ◄	The research topics of the project SUFRI range from advanced forecast models, flood warning and tools for flood risk estimation in urban areas to adequate strategies for risk communication on the basis of an opinion poll. The research work involves literature survey regarding models for forecast and flood warning, their advantages and disadvantages as well as experiences with their application. Further literature survey contains different methods for risk estimation. The specific tools have been analysed in order to develop a method for estimating consequences in case of river and pluvial flooding on the basis of the state-of-the-art of risk analysis, in reference to dam and levee safety. The actual state of the science of risk communication leads to the development of communication strategies and a questionnaire for improvement of the public awareness and participation.
Findings ◄	• Compilation of advanced warning systems • Compilation of risk communication strategies • SUFRI Methodology for pluvial and river flooding risk assessment in urban areas • SUFRI Method for risk awareness of the population • SUFRI Approach for crisis management planning • Examples of use in Austria, Germany, Italy and Spain and their trans-national comparison • International symposium UFRIM for communicating the research results
Implications (Outcome) ◄	Within the SUFRI project many different approaches and compilations have been developed in order to improve the flood risk management process with non-structural measures. This interdisciplinary approach intent to a combination of flood forecast and warning systems, risk estimation and public participation. The results of each methodology as well as compilation can assist the policy maker, stakeholder and authorities in their decision-making process and give them recommendations for setting adequate non-structural measures.
Publications related to the project ◄	Escuder-Bueno I., Castillo-Rodríguez J.T., Petaccia G., Perales-Momparler S. (2011) “Application of a complete and quantitative tool for flood risk analysis in urban areas”. Proceedings of 3rd International Week on Risk Analysis, Dam Safety, Dam Security, and Critical Infrastructure Management (3IWRDD) Forciniti E., Ghilardi P., Petaccia G. (2011) “Application of SUFRI Methodology for the reduction of Flood Risk in Lodi Town (Italy)”, Proceedings of UFRIM conference, Graz, Austria Bornschein A., Pohl R. (2011). Early Flood Warning Systems for Urban Areas. UFRIM Conference, Graz, Austria

Escuder Bueno I., et al (2011). UFRIM – Urban Flood Risk Management International Symposium, Conference: A complete and quantitative tool for flood risk analysis in urban areas: river and pluvial flooding, Graz (Austria).

Ortner S., Jöbstl C., Knoblauch H. (2011). „SUFRI – Sustainable strategies of urban flood risk management with non-structural measures to cope with the residual risk". UFRIM – Urban Flood Risk Management International Symposium, Graz (Austria).

Morales-Torres A., et al (2010). "Metodologías de estimación de consecuencias de inundación en zonas urbanas y estudio de su reducción a través de medidas no estructurales". Spanish National Committee on Large Dams (SPANCOLD), IX Spanish Symposium on Dams, Valladolid (Spain)

Escuder-Bueno I., Morales-Torres A., Perales-Momparler S. (2010). RLHE - Red de Laboratorios Hidráulicos de España, Seminar, Conference: Herramientas para la estimación del riesgo de inundación y estudio de su reducción a través de medidas no estructurales, Valencia (Spain).

Knoblauch H., et al (2010). "SUFRI". Working group F Thematic workshop 'Flash floods and pluvial flooding', Poster, Cagliari (Italy).

Zenz G., et al (2010). „Sustainable Strategies of Urban Flood Risk Management with non-structural Measures to cope with the Residual Risk". Proceedings of 11th Aprilsymposium ‚Brandschutz im neuen Jahrtausend', Brandschutzforum Austria, Graz (Austria).

Knoblauch H., et al (2010). "SUFRI". Conference Dresdner Wasserbaukolloquium 2010, Poster, Dresden (Germany).

Hornich R. (2010). "Transposition and translation of the directive to Austria, presentation of SUFRI project". Conference on challenges and opportunities of the directive on the assessment and flood risk management, Barcelona (Spain).

Escuder-Bueno I., Morales-Torres A., Perales-Momparler S. (2010). "Urban flood risk characterization as a tool for planning and managing". USACE Workshop Alexandria: Exploration of Tolerable Risk Guidelines for Levee Systems, Washington (USA).

Hornich R., Jöbstl C., Ortner S., Knoblauch H., Grossmann G., Kulmhofer A., Berger T. (2010). „SUFRI Nachhaltige Strategien für das Hochwasserschutzmanagement in Städten zur Beherrschung des Restrisikos mit nicht-technischen Maßnahmen". Wasserland Steiermark, Styria (Austria).

Jöbstl C., Knoblauch H., Ortner S., Grossmann G., Kulmhofer A., Berger T., Hornich R. (2009). „SUFRI - Sustainable Strategies of Urban Flood Risk Management with non-structural Measures to cope with the Residual Risk". Proceedings of the Final conference of the COST action C22 urban flood management in cooperation with UNECSO-HIP, 'Roadmap towards a flood resilient urban environment', 26th - 27th November 2009, Paris

(France).

Díaz M. A., Bateman A., Medina V. (2009). Mitigation of the residual risk of flooding by non-structural measures and early warning system in the Arenys de Mar basin. Conference poster on Radar in Meteorology and Hydrology, Sibiu (Romania).

Jöbstl C., Knoblauch H., Ortner S. (2009). „Nachhaltige Strategien für das urbane Hochwasserschutzmanagement mit nicht-strukturellen Maßnahmen“. 11. Treffen junger WissenschafterInnen an Wasserbauinstituten, conference proceedings pages 75-80, Lausanne (Switzerland).

Appendix 2

Flood warning systems for urban areas - overview flood maps

Although the EU Flood directive established flood hazard maps and flood risk maps in Europe many other terms or meanings of such kind of maps are older and common in European countries. The following tables try to summarize the different terms which are used considering flood maps and its specific content and purpose for which they have been created.

Table 1: Overview flood maps: flood event maps

term	reference	content/commentary
hazard map	Guidelines for flood hazard maps Ministry of environment and nature protection, agriculture and consumer protection in Nordrhein-Westfalen, Düsseldorf, Germany	A flood hazard map can include information about design flood events, historical flood events or statistical flood events with different reoccurrence periods.
flood hazard map (Hochwasser-gefahrenkarte)	Spanknebel 2009	Flood hazard maps are maps, which contains the following information: … - the extent of a historical or extreme event.”

Table 2: Overview flood maps: flood hazard maps

term	reference	content/commentary
Hazard note map as a preliminary version of a hazard map	Bavarian Agency for Environment, Augsburg, Germany 2005*	Preliminary version until a hazard map is available, scale between 1:10.000 and 1:50.000, includes information about local hazard, but without intensity and reoccurrence period, the map is based on an scientific approach but the hazard was not analysed in detail

*http://www.lfu.bayern.de/geologie/fachinformationen/hangbewegungen/was_sind_gefahren/doc/gefahrenkarte.pdf

Flood maps published by the Environmental Agency, UK include two different marked areas (Table 3). They can be described as follows: Dark blue shows the area that could be affected by flooding, either from rivers or the sea, if there were no flood defences. This area could be flooded: from the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year or from a river by a flood that has a 1% (1 in 100) or greater chance of happening each year. Light blue shows the additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with a 0.1% (1 in 1000) or greater chance of occurring each year. These two colours show the extent of the natural floodplain if there were no flood defences or certain other manmade structures and channel improvements. A purple line shows some of the flood defences built to protect against river floods with a 1% (1 in 100) chance of happening each year, or floods from the sea with a 0.5% (1 in 200) chance of happening each year, together with some, but not all, older defences and defences which protect against smaller floods. Flood defences that are not yet shown will be gradually added. Hatched areas benefit from flood defences, in the event of a river flood with a 1% (1 in 100) chance of happening each year, or a flood from the sea with a 0.5% (1 in 200) chance of happening each year. If the defences were not there, these areas would be flooded.

Table 3: Overview flood maps: flood intensity maps

term	reference	content/commentary
flood plain maps (Überschwemmungs-gebietskarten)	Ministry of Agriculture, Environment and rural areas, Kiel, Germany*	inundation area of 10-years, 50-years, 200-years and 200-years-flood, within the inundation area of a 100-years-flood flow depth is marked with different colours, scale 1:5.000
hazard map	Cologne, Germany**	inundation area and flow depth according to different flood water levels of the river gauge Köln with and with-out the consideration of planned structural flood defence measures, considered flood water levels: 10,70 m, 11,30 m = 100-years-flood, 11,90 m = 200-years-flood und 12,50 m = extreme flood event
flood map	Environment Agency, UK***	1. Floodplain without flood defence (dark blue = affected by flooding, either from rivers (1 in 100 years) or the sea (1 in 200 years); Light blue = extreme flood event from rivers or the sea (1 in 1000 years). 2. Floodplain with Flood Defences (purple line) 3. Significant, Moderate or Low Likelihood of Flooding
hazard map	Guidelines for flood hazard maps Ministry of environment and nature protection, agriculture and consumer protection in Nordrhein-Westfalen, Düsseldorf, Germany	A flood hazard map can include information about design flood events, historical flood events or statistical flood events with different reoccurrence periods.
flood plain maps	District Office (Landratsamt) Löbau-Zittau Saxony, Germany	inundation area due to a 100-year-flood, (scale 1: 2 000)
hazard map	Leipzig, Germany****	flood extent due to flood events which can occur with probability of 95 % once in 25, 50, 150 und 200 years
flood risk map	England, Wales, UK*****	news.bbc.co.uk "… homeowners in England and Wales … Areas are given low, moderate or significant risk ratings according to location, predicted water levels, and type and condition of flood defences. "
flood hazard map	Spanknebel 2009	hazard due to a flood event as a combination of reoccurrence period and degree of flooding
flood risk map for England and Wales	IH Report 130 Morris & lavin 1996	Maps of England and Wales showing an estimate of the areas that would be inundated by floods of the 100-year return period level from non-tidal rivers, in the absence of flood defences..
ZÜRS	German insurance and reinsurance companies******	areas of three different hazard levels consi-dering flood reoccurrence < 1 in 50 years; > 1 in 50 years but < 1 in 10 years; > 1 in 10 years
spezial hazard map (Sondergefahrenkarte)	Saxony, Germany	flooded area and flood development due to a (hypothetical) dam failure

*http://www.schleswig-holstein.de/UmweltLandwirtschaft/DE/WasserMeer/05__Hochwasserschutz/03 __GeneralplanBHWS/07
** http://www.hochwasser.de/index.php/service/gefahrenkarten-koeln
***http://www.environment-agency.gov.uk/homeandleisure/floods/31664.aspx
****http://www.leipzig.de/de/buerger/service/dienste/umwelt/hochwasser/07104.shtml
*****http://www.mortgagearrangers.co.uk/flood_risk_map.htm
******http://dkkv.step-gmbh.de/index.php?id=191

It is mentioned there that flood defences do not completely remove the chance of flooding, however, and can be overtopped or fail in extreme weather conditions. An assessment of the likelihood of flooding from rivers and the sea at any location in UK is based on the presence and effect of all flood defences, predicted flood levels, and ground levels and was conducted by the Environmental Agency. Three levels of risk of flooding (Significant, Moderate or Low Likelihood of Flooding) are assigned to each location.

ZÜRS (Zonierungssystem für Überschwemmung, Rückstau und Starkregen) is a system to distinguish between different zones characterized by the risk of flooding in Germany. It is maintained by insurance companies in Germany. Owners of houses which are situated within an area of hazard level 3 (> 1 in 10 years) generally can't get an insurance police.

EU FLOOD DIRECTIVE

The EU Floods Directive aims in minimizing flood risk in European countries. In chapter III, article 6 the content of flood hazard maps and flood risk maps are explained as follow:

1. Member States shall, at the level of the river basin district, or unit of management referred to in Article 3(2)(b), prepare flood hazard maps and flood risk maps, at the most appropriate scale for the areas identified under Article 5(1).

2. Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:

a) floods with a low probability or extreme event scenarios;

b) floods with a medium probability (likely return period ≥ 100 years);

c) floods with a high probability, where appropriate.

3. For each scenario referred to in paragraph 3 the following elements shall be shown:

a) the flood extent;

b) water depths or water level, as appropriate;

c) where appropriate, the flow velocity or the relevant water flow.

4. Flood risk maps shall show the potential adverse consequences associated with flood scenarios referred to in paragraph 3 and expressed in terms of the following:

a) the indicative number of inhabitants potentially affected;

b) type of economic activity of the area potentially affected;

c) installations as referred to in Annex I to Council Directive 96/61/EC of 24 September1996 concerning integrated pollution prevention and control [9] which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC;

d) other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

5. Member States may decide that, for coastal areas where an adequate level of protection is in place, the preparation of flood hazard maps shall be limited to the scenario referred to in paragraph 3(a).

6. Member States may decide that, for areas where flooding is from groundwater sources, the preparation of flood hazard maps shall be limited to the scenario referred to in paragraph 3(a).

7.. … flood hazard maps and flood risk maps are completed by 22 December 2013.

Table 4: Overview flood maps: flood hazard map

term	reference	content/commentary
flood hazard maps	EU floods directive*	see above
flood hazard maps	Canton Bern, Switzerland**	Maps which shows in detail all kind of hazards due to snow, rock and landslides as well as flood events and depressions (Dolinen), different colours mark different degrees of hazard: red (high), blue (medium), yellow (low), yellow-white (residual)
flood hazard maps	Bavarian Agency for Environment, Augsburg, Germany ***	Cause of hazard, extent of affected area, degree of hazard, reoccurrence probability, scale: 1:2,000 to 1:10,000
flood hazard maps (Carte des zones inondables) for Luxemburg and Rheinland-Pfalz, Germany	Ministry of environment, forests and consumer protection, Rheinland-Pfalz, Germany and Ministère de l'Intérieur et de l'Aménagement du Territoire Administration de la Gestion de l'Eau, Luxembourg (Project TIMIS Flood, Oktober 2008)	areas along river reaches which can be flooded, different colours represent different degrees of hazard, scale 1:5000
Hazard areas map (Gefahrenzonenkar-ten)	Grafe 2009	
Flood hazard areas map (Hochwasser-gefahrenzonenkar-ten)	Spanknebel 2009	areas with different degree of hazard depending of intensity and occurrence probability
Gefahrenzonenplan (definition is not very specific)	Bavarian Agency for Environment, Augsburg, Germany***	Provides obligatory guidelines for planning, , based on empirical data and depending on editors knowledge and has to be approved by responsible administration
flood hazard maps	Ministry of agriculture, environment and rural areas, Kiel, Germany****	The map shows the hazard due to a flood event as a combination of reoccurrence period and degree of flooding, the degree of flooding is represented by flow depth

* DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks, L 288/30 EN Official Journal of the European Union 6.11.2007
**http://www.bve.be.ch/site/bve_geo_karte_gk5
*** http://www.lfu.bayern.de/geologie/fachinformationen/hangbewegungen/was_sind_gefahren/doc/ gefahrenkarte.pdf
**** http://www.schleswig-holstein.de /UmweltLandwirtschaft /DE/Wasser Meer/05_ _Hochwasserschutz/03__GeneralplanBHWS/07

Table 5: Overview flood maps: flood risk map

term	reference	content/commentary
flood risk map	EU floods directive*	see above
risk map	FEMA, USA**	The vision for Risk MAP is to deliver quality data that increases public awareness and leads to action that reduces risk to life and property. Risk MAP builds on flood hazard data and maps produced during the Flood Map Modernization (Map Mod) program.
risk map (Risikokarte)	Bavarian Agency for Environment, Augsburg, Germany ***	based on flood hazard map, considering of availability and value of potential objects (e. g. buildings) at risk in addition

* DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks, L 288/30 EN Official Journal of the European Union 6.11.2007
** http://www.fema.gov/plan/prevent/fhm/rm_main.shtm
*** http://www.lfu.bayern.de/geologie/fachinformtio-nen/hangbewegungen/was_sind_gefahren/doc/gefahrenkarte.pdf

Table 6: Overview flood maps: flood risk management

term	reference	content/commentary
flood risk management plan	EU floods directive*	(14) Flood risk management plans should focus on prevention, protection and preparedness. With a view to giving rivers more space, they should consider where possible the maintenance and/or restoration of flood-plains, as well as measures to prevent and reduce damage to human health, the environment, cultural heritage and economic activity. The elements of flood risk management plans should be periodically reviewed and if necessary updated, taking into account the likely impacts of climate change on the occurrence of floods. Member States shall ensure that flood risk management plans are completed and published by 22 December 2015.
flood risk assessment	Environment Agency, UK**	Flood risk assessments are our way of compiling information about the hazards and types of risk a flood presents, and their likely social, environmental and economic impacts. They help us establish the nature and scale of the existing risk, and how this may change over time or as a result of any flood risk management measures we put in place. As well as historical data from past floods, we continually monitor present water levels. We develop models from this data to predict the course and severity of future floods. All this information goes into our Flood risk assessments, which particularly focus on: - Source of a flood, e.g. river, waterway, or tidal or coastal water. - Paths that the water will take during floods, and how the severity of a flood affects its path. - Impact on the people, land and property affected by flooding. This includes physical, emotional, social or economic harm.

* DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks, L 288/30 EN Official Journal of the European Union 6.11.2007
**http://www.environment-agency.gov.uk/homeandleisure/floods/31664.aspx

Appendix 3

SUFRI Methodology for pluvial and river flooding risk assessment in urban areas to inform decision-making

Contents

1 Scheme of input data for consequences in case of river flooding

Chapter 1 includes the overall scheme to assist SUFRI methodology to obtain input data for the risk model within the analysis of flood risk in case of river flooding. This chapter contains three additional sheets:
1A – Flow chart
1B – Tables and definition of additional parameters
1C – Notes

A.1.1. DEFINITION OF THE CASE STUDY CATEGORY TO DETERMINE REFERENCE FATALITY RATES (RFR)

(Sources: [22])

TABLE A.1.1. REFERENCE FATALITY RATES FOR EACH CASE STUDY CATEGORY.

Category for the case study (C)		Warning time TW (h)	Flood severity (Sv) High (3)	Medium (2)	Low (1)	
C1	- There is no public education on flood risk. - No warning systems, no EAP. - There is no coordination between emergency agencies and authorities. - No communication mechanisms to the public.	0	0.9	0.3	0.02	Natural flow regime
		0.25	0.9	0.3	0.02	
		0.625	0.7	0.08	0.015	
		1	-	0.06	0.0006	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C2	- There is no public education on flood risk. - There is no EAP, but there are other warning systems. - There is no coordination between emergency agencies and authorities. - No communication mechanisms to the public.	0	0.9	0.3	0.02	
		0.25	0.9	0.3	0.02	
		0.625	0.675	0.075	0.014	
		1	-	0.065	0.00065	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C3	- There is no public education on flood risk - There is EAP, but it has not been applied yet. - Some coordination between emergency agencies and authorities (but protocols are not established). - No communication mechanisms to the public.	0	0.9	0.3	0.02	
		0.25	0.85	0.2	0.015	
		0.625	0.6	0.07	0.012	
		1	-	0.05	0.0005	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C4	- There is no public education on flood risk. - EAP is already applied. - Coordination between emergency agencies and authorities (there are protocols). - No communication mechanisms to the public.	0	0.9	0.3	0.02	EAP No public education
		0.25	0.75	0.15	0.01	
		0.625	0.5	0.04	0.007	
		1	-	0.03	0.0003	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C5	- There is no public education on flood risk - EAP is already applied. - Coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public (not checked yet).	0	0.9	0.3	0.02	
		0.25	0.75	0.15	0.01	
		0.625	0.5	0.0375	0.0065	
		1	-	0.0275	0.000275	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C6	- There is no public education on flood risk - EAP is already applied. - Coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public.	0	0.9	0.3	0.02	
		0.25	0.75	0.15	0.01	
		0.625	0.475	0.035	0.006	
		1	-	0.025	0.00025	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C7*	- Public education. - EAP is already applied. - Coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public.	0	0.9	0.3	0.02	Dam break No hydrologic scen.
		0.25	0.65	0.1	0.0075	
		0.625	0.4	0.02	0.002	
		1	-	0.01	0.0002	
		1.5	-	0.0002	0.0002	
		24	-	0.0002	0.0001	
C8	- Public education - EAP is already applied. It has been proved or used previously. - Coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public.	0	0.9	0.3	0.02	
		0.25	0.55	0.08	0.006	
		0.625	0.35	0.01	0.0015	
		1	-	0.005	0.00015	
		1.5	-	0.0002	0.00015	
		24	-	0.0002	0.0001	
C9	- Public education. - EAP is already applied. It has been proved or used previously. - High coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public.	0	0.9	0.3	0.02	
		0.25	0.55	0.08	0.006	
		0.625	0.35	0.008	0.0015	
		1	-	0.004	0.000125	
		1.5	-	0.0002	0.0001	
		24	-	0.0002	0.0001	
C10	- Regular activities and plans for public education. - EAP is already applied. It has been proved or used previously. - High coordination between emergency agencies and authorities (there are protocols). - Communication mechanisms to the public.	0	0.9	0.3	0.02	Best scenario
		0.25	0.5	0.03	0.006	
		0.625	0.3	0.005	0.001	
		1	-	0.002	0.0001	
		1.5	-	0.0002	0.0001	
		24	-	0.0002	0.0001	

Validation between categories depending on non-structural measures

*(C7 is used for categories 'C8','C9' and 'C10' if the analysis of a flood defence failure in case of non-hydrologic scenario is considered

A.1.2. REDUCTION ON THE VALUE OF DENSITY OF POPULATION IN AREAS WITH A HIGH PERCENTAGE OF MULTI-STORY BUILDINGS TO OBTAIN POPULATION AT RISK (PR)

Data requirements:
- Density of population for the study area (d) or total number of citizens within the urban area.
- Average height of buildings (hm) or mean value of number of floors (np).
- Water depths due to the flood (H).

This part is considered in urban areas where np >2 or hm>6.6m (urban areas with a high percentage of multi-story buildings).

TABLE A.1.2. Density population for risk calculations (dC)

	Case	dC
Mean value of the number of floors (np)	H < h1p*	dC = d / np
	h1p < H < h2p	dC = d x 2 / np
	H > h2p	dC = d x (H/hm*) / np
Average building heigth (hm)	H < h1p	dC = d x h1p / hm
	h1p < H < h2p	dC = d x h2p / hm
	H > h2p	dC = d x H / hm

*h1p= 3.3m, h2p= 6.6m and hm = height between floors.

(Source: SUFRI)

NOTE: If there are several urban areas in the case study (several villages, towns, etc. of minor importance or low population), it is recommended to obtain 'np' or 'hm' of three units or cities of differente population (entity) and consider the results as a reference number (p.e. if population=x: x<10,000; 10,000<x<100,000 y x>100,000).

A.1.3. DEFINITION OF FLOOD SEVERITY (Sv)

In general, flood severity of each flood scenario is established from the DV parameter.

$$DV = \frac{Qaf - Q_{2.33}}{w}$$

Data requirements:
- Peak discharge at the study site (Qaf).
- Mean annual discharge of the river at the study site ($Q_{2.33}$).
- Maximum width reached by the flood at the study site (w).

If previous information is not available, then the flood severity category can be determined using flood water depths (H).

TABLE A.1.3. FLOOD SEVERITY (Sv)

		DV	H
Severity for each flood scenario (Sv)	Low (1)	< 4.6 m²/s	< 3.3 m
	Medium (2)	> 4.6 m²/s	> 3.3 m
	High (3)	Areas located downstream the dam**	

(Source: [22])

**DSO-99-06 procedure does not include recommendations on how to establish the diference between medium and high severity. Therefore, except for specific cases, high flood severity is established in urban areas located close to the dam, where shelter or evacuation are not feasible and total destruction of the area would occur in case of dam break.

Sources:
[9] Risk Based Profiling System (USBR, 2001)
[12] PATRICOVA (2002)
[22] DSO-99-06 Procedure (Graham, 1999)

A.1.4. INDICATIONS TO OBTAIN WARNING TIME (TW) FOR EACH FLOOD SCENARIO, DEPENDING ON THE ARRIVAL WAVE TIME AND OTHER FACTORS RELATED TO BREACH DEVELOPMENT, FAILURE MODE AND THE EXISTANCE OF AN EMERGENCY ACTION PLAN.

– WARNING TIME FOR RISK MODELS OF THE NATURAL FLOW REGIME OF THE RIVER (RN) AND STRUCTURAL MEASURES (EXCEPT FOR DAMS)

TW = TD = tQ2 - tQ1

where TD is the diference between the time of the first notice peak discharge at the study site (Q1) and the time of first damages in buildings or households (Q2)

Day: TW = TD = tQ2 - tQ1
Night: TW (h) = TD (h) - 0.25 (TW at night is defined as a time which is 15 minutes lower than TW during the day)

– WARNING TIMES FOR RISK MODELS WITH DAM UPSTREAM THE STUDY AREA

Breach Development Speed (TBR)

Breach Development	TBR (h)	TBR (min)
Fast	0.25	15
Moderate	0.75	45
Slow	1.25	75

Failure Mode Factor (FMF)

	Average value		Day		Night	
Failure mode	FMF (h)	FMF (min)	FMF (h)	FMF (min)	FMF (h)	FMF (min)
Seismic	0.375	15-30	0.25	15	0.5	30
Internal erosion	0.375	15-30	0.25	15	0.5	30
Hydrologic	0.125	0-30	0	0	0.25	30

(Source: [9])

Warting time (TW)*
TW = Wave arrival time (Twv) + Breach Development Speed (TBR) - Failure Mode Factor (FMF) - FPE

*For cases with no dam-break, the warning time is considered as the diference between the peak flow that reaches the first buildings and the first notice flow. This time is denoted by TD

If there is no Emergency Action Plan, a factor FPE equal to 30min should be considered.

p.e. TBR=0.25h y FPE=0.5h. All time values in hours.

	LOAD SCENARIO		Day	Night
NO EMERGENCY ACTION PLAN	Seismic		TW= Twv - 0.5	TW= Twv -0.75
	Internal erosion		"	"
	Hydrologic	No dam-break**	TW= TD	TW= TD - 0.25
		Dam-break	TW= Twv -0.25	TW= Twv -0.5

Warting time (TW)*
TW = Wave arrival time (Twv) + Breach Development Speed (TBR) - Failure Mode Factor (FMF)

**In case of no dam-break, the warning time will be equal to the diference between the first notice peak discharge and the peak flow that reaches the first constructions. This time is denoted by TD.

p.e. TBR=0.25h. All time values in hours.

	LOAD SCENARIO		Day	Night
EMERGENCY ACTION PLAN	Seismic		TW= Twv	TW= Twv - 0.25
	Internal erosion		"	"
	Hydrologic	No dam-break**	TW= TD + 0.5	TW= TD + 0.25
		Dam-break	TW= Twv + 0.25	TW= Twv

(Source: SUFRI)

TABLES TO DETERMINE INPUT DATA FOR THE RISK MODEL
-RIVER FLOODING-

SHEET A.1B. TABLES

Table 7: 1A – Flow chart, 1B – Tables and definition of additional parameters

CODE	NOTE
N.1.	Analysis of the case study, including residential areas, industrial areas and other units with potential victims in case of flood. Data requirements: demography, land uses, type of buildings, maps, statistics, historical records and information of past events, economic rates, etc.
N.2.	Study of population variability: moment of the day, day of the week, season, special events, etc. i.e. Work conditions, studies, other residence, etc. To reduce the amount of calculations in case studies with a high number of population units, consequences for two time categories can be obtained and then a factor is applied to estimate results for other categories (i.e.Nj=Ni x PRj/PRi)
N.3.	A risk model for the base-case should be implented, including the current structural measures. However, if possible, the risk model to study the natural flow regime of the river should be performed for comparison purposes. Once this base-case is performed, other alternatives can be applied for studying the effect of structural or non-structural measures (MS or MNS).
N.4.	Hydraulic modeling will provide data for each flood scenario. The model should represent the characteristics of the river. It should be hydraulic, complete and dynamic, enable to obtain results in sub-critical and supercritical flow. Uni-dimensional models are maybe more appropiate than bi-dimensional (the first require less amount of data). The model should be capable of modelling unsteady flow regimes in case of structural failure. Some examples are: MIKE 11(DHI), SOBEK (Deltares) o HEC-RAS (USACE).
N.5.	Q, first notice flow, is the peak discharge at the study site that reaches the capacity of the river bank and it is estabilshed as a threshold: population is aware of a potential flood event. First-damage flow, Q2, is the peak discharge at the study site that reaches the first buildings or households.
N.6.	Input data for the risk model, related to consequences is divided into two parts: loss of life and economic losses.
N.7.	Category of the case study (C) to obtain reference fatality rates (RFR) is defined taking into account: (Table A.1.1.) - Public education. - Communication. - Coordination between emergency agents and authorities. - Existence of Emergency Action Plans (dams).
N.8.	Once the category is defined, there are 15 reference fatality rates for different flood severity levels and warning times, where: - Severity (Sv): High, medium or low. - Warning time (TW): 0 h, 0.25 h, 0.625 h, 1 h, 1.5 h and 24 h.
N.9.	Warning times (TW) vary depending on the base-case (dams, leeves, dikes, ponds, etc.), also if non-structural measures are applied. If there is a dam upstream the location, warning times depend on breach development, existence of EAP, etc. Warning times are defined differently in 'day' or 'night' time categories. (Table A.1.4.)
N.10.	For each flood scenario, fatality rates (FR) are obtained by interpolating the reference values from warning times obtained from flood characteristics (flood severity and time category). (Table A.1.3.)
N.11.	The number of potencial fatalities (N) is obtained for each flood scenario, time category (TC) and land use category (CU) as the product of the fatality rate (FR) and population at risk (PR): N = PR x FR. In general, results of potential loss of life lower than 1 are rounded up to N=1.
N.12.	For risk models of the natural flow regime, input data includes relations Qmax-N, where Qmax is the peak discharge associated with each return period and N is the number of potential fatalities.
N.13.	Economic losses of each flood scenario (direct and indirect costs) are obtained from the estimation of a reference cost (CR) for each land use category (CU). Economic costs will depend on the percentage of damages (PD) in each flooded area (depth-damage curves).
N.14.	Indirect costs can be estimated as a percentage of direct costs. A factor, fC, is defined for each case study and it will depend on the population, infrastructures, economic relevance of the city, etc. i.e. it will range from 0% to 55% [5].
N.15.	If dam failure is considered in case of non-hydrological scenario (no rainfall event), then values of the Failure Mode Factor for seismic scenario are used to estimate warning times (FMF, Table A.1.4.).
N.16.	The effect of non-structural measures can be included as a reduction of the potential economic losses of the flood. If the estimation of this reduction can be established, then the percentage of reduction will be estimated from 'warning time-damage reduction' curves ([42]), in flood scenarios in which water depths are lower than 1.2 m (low severity levels).
N.17.	The risk model will use input data for estimation of consequences and risk calculation from the list of values Q-N obtained from the steps described in the given flow chart, where Q is the flow that identifies each flood scenario (natural flow regime, flood routing or dam-break) and N is the potential loss of life or number of fatalities for that flood case.

Sources: [9] Risk Based Profiling System (USBR, 2001)
[12] PATRICOVA (2002)
[22] DSO-99-06 Procedure (Graham, 1999)
[42] Parker et al (2005)

NOTES TO OBTAIN INPUT DATA FOR THE RISK MODEL -RIVER FLOODING-

Sheet A.1C. | NOTES

Table 8: 1C – Notes

2 Scheme of input data for consequences in case of pluvial flooding

Chapter 2 includes the overall scheme of SUFRI methodology to obtain input data for the risk model in case of pluvial flooding. This chapter contains two additional sheets:
2A – Flow chart
2B – Tables, definition of additional parameters and notes

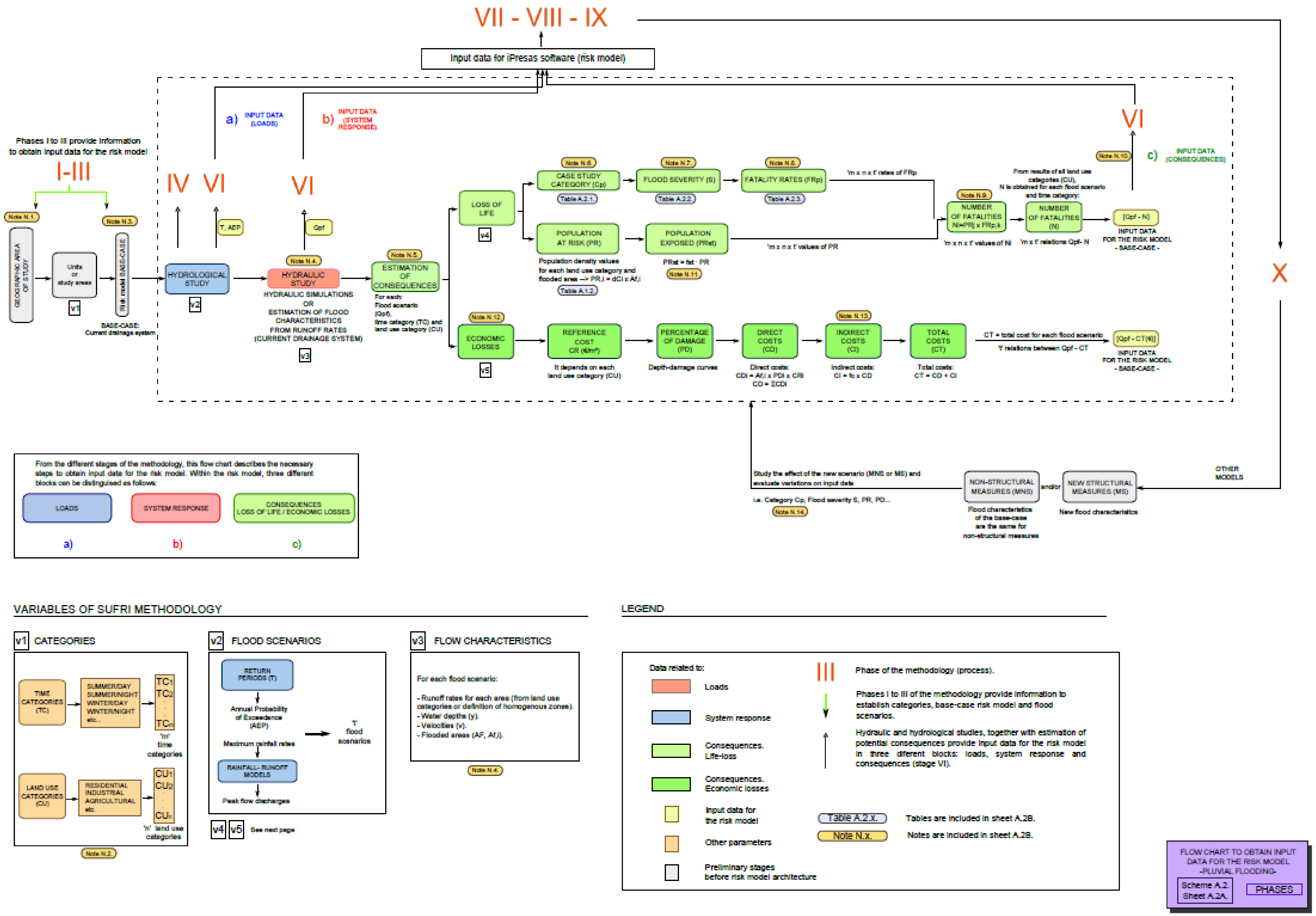

Figure 1: 2A – Flow chart

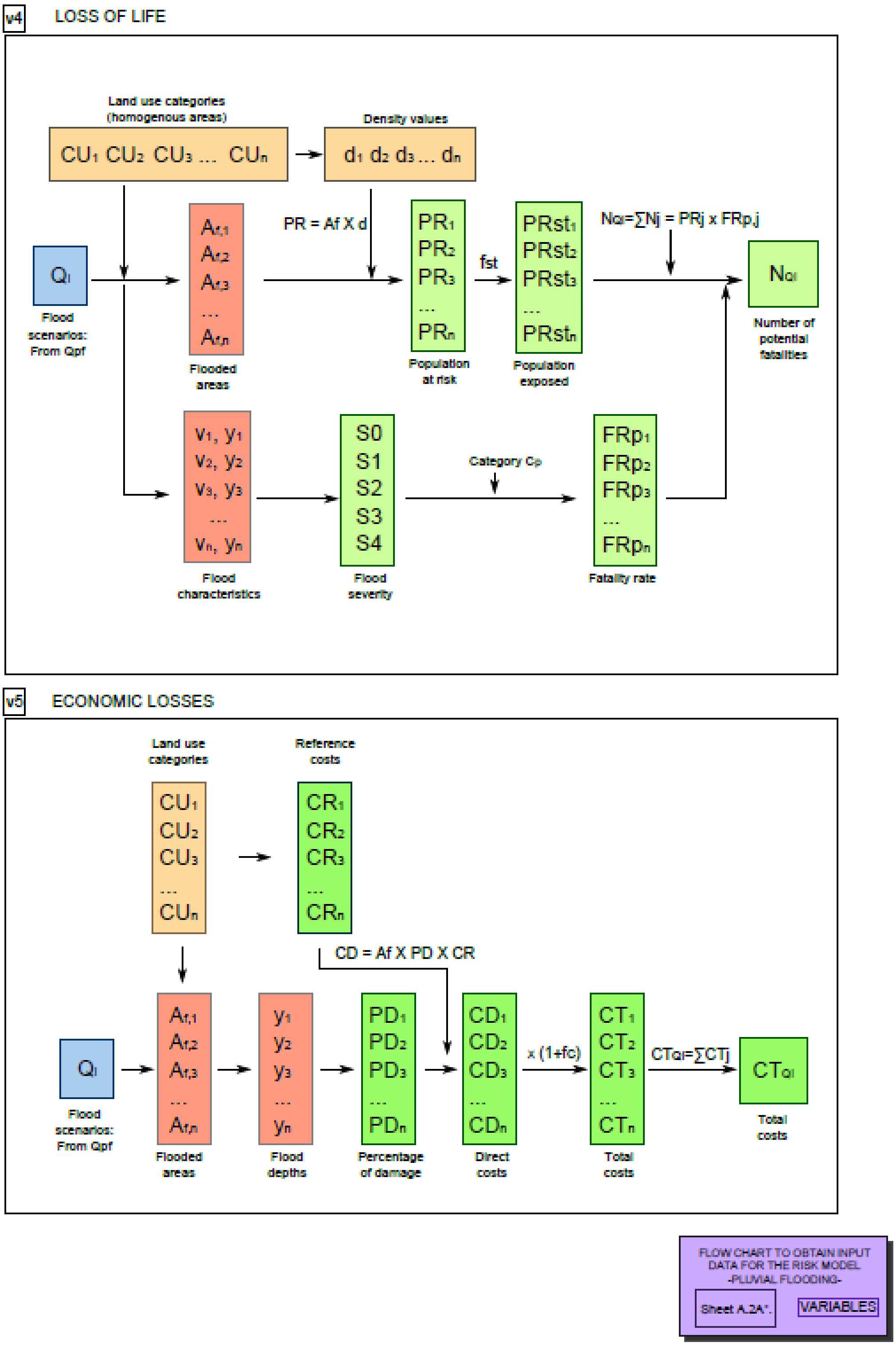

Figure 2: 2A – Flow chart

TABLE A.2.1. CATEGORY Cp FOR THE CASE STUDY TO OBTAIN FATALITY RATES IN PLUVIAL FLOODING (Source: SUFRI)

Category C_p	Definition
C_{p1}	No warning systems
C_{p2}	Existence of warning systems, but not used or protocols are unknown
C_{p3}	Warning systems completely established and proved (drills)

TABLE A.2.2. FLOOD SEVERITY LEVELS (S) (Source: SUFRI and criteria Appendix 3)

Flood severity (S)		Depth y(m)	Velocity v (m/s)	Dragging parameter v·y (m²/s)	Sliding parameter v²·y (m³/s²)
S0	No fatalities are expected. People expected to survive.	<0.45	<1.50	<0.50	<1.23
S1	*Low severity* People may suffer loss of stability. People in danger.	<0.80	<1.60	<1.00	<1.23
S2	*Medium severity* Significant loss of stability. Cars can lose roadholding. Floating.	<1.00	<1.88	<1.00	<1.23
S3	*High severity* High risk for people outside. Low risk for buildings	>1.00	>1.88	>1.00	>1.23
S4	*Extreme severity* Structural damages on buildings	>1.00	>1.88	>3.00	>1.23

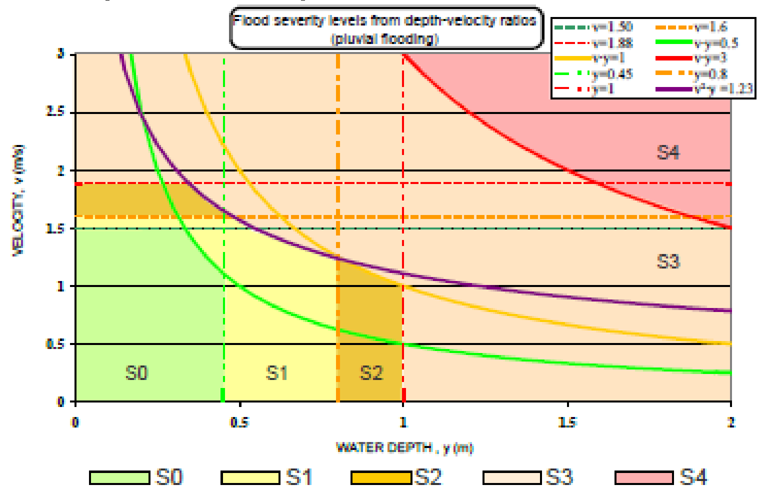

TABLE A.2.3. FATALITY RATES FOR EACH CATEGORY (Cp) AND FLOOD SEVERITY (S). (Source: [36],[45])

Category C_p	Flood severity S	Fatality rate, FRp	Range of values for FRp
C_{p1}	S0	0.0003	0.0000 - 0.0009
	S1	0.0021	0.0010 - 0.0030
	S2	0.0038	0.0015 - 0.0045
	S3	0.0105	0.0060 - 0.0400
	S4	0.0448	0.0100 - 0.1100
C_{p2}	S0	0.0003	0.0000 - 0.0008
	S1	0.0018	0.0012 - 0.0024
	S2	0.0033	0.0014 - 0.0037
	S3	0.0090	0.0050 - 0.0350
	S4	0.0384	0.0100 - 0.0950
C_{p3}	S0	0.0002	0.0000 - 0.0007
	S1	0.0015	0.0010 - 0.0020
	S2	0.0027	0.0010 - 0.0030
	S3	0.0075	0.0040 - 0.0280
	S4	0.0320	0.0090 - 0.0800

CODE	NOTE
N.1.	Analysis of the case study, including residential areas, industrial areas and other units with potential fatalities in case of flood. Data requirements: demography, land uses, type of buildings, maps, statistics, historical records and information of past events, economic rates, etc.
N.2.	Study of population variability: moment of the day, day of the week, season, special events, etc. I.e. Work conditions, studies, other residence, etc. To reduce the amount of calculations in case studies with a high number of population units, consequences for two time categories can be obtained and then a factor is applied to estimate results for other categories (i.e.Nj=Ni x PRj/PRi)
N.3.	A risk model for the base-case should be developed, including the current drainage system. Once this base-case is performed, other alternatives can be applied for studying the effect of structural or non-structural measures (MS or MNS).
N.4.	Hydraulic modelling or other calculations will provide data for each flood scenario, defined by a return period. The model/process should represent the characteristics of the current drainage system.
N.5.	Input data for the risk model, related to consequences is divided into two parts: loss of life and economic losses.
N.6.	The category (Cp) that determines fatality rates (FRp) in case of pluvial flooding, depends on existence of warning systems (Table A.2.1.).
N.7.	Flood severity in pluvial flooding is based on a classification of five levels, from the characteristics of the flood: water depth (y) and velocity (v). These five levels range from S0 to S4.
N.8.	Once the category is established (Cp), fatality rates (FRp) depend on the flood severity level of each flood scenario (S).
N.9.	The number of potencial fatalities (N) is obtained for each flood scenario, time category (TC) and land use category (CU) as the product of the fatality rate (FRp) and population at risk (PR): N = PR x FRp. In general, results of potential loss of life lower than 1 are rounded up to N=1.
N.10.	The risk model uses input data for risk calculation from the list of values Qpf-N obtained from the steps described in the given flow chart, where T is the return period (flood scenario) and N is the potential loss of life or number of fatalities for that flood case.
N.11.	People exposed to the flood (PRst) can be estimated as a percentage (fsi) of the population at risk (PR): number of people within the flooded area.
N.12.	Economic losses of each flood scenario (direct and indirect costs) are obtained from the estimation of a reference cost (CR) for each land use category (CU). Economic costs depend on the percentage of damages (PD) in each flooded area (depth-damage curves).
N.13.	Indirect costs can be estimated as a percentage of direct costs. A factor, fc, is defined for each case study and it depends on population, infrastructures, economic relevance of the city, etc. I.e. it can range from 0% to 55% [13].
N.14.	The effect of non-structural measures can be included, for example, as a reduction of the potential economic losses of the flood. A percentage of damage reduction can be estimated from 'warning time-damage reduction' curves ([44]), in flood scenarios with water depths lower than 1.2 m.

Sources:
[13] PATRICOVA (2002)
[36] Defra (UK)
[44] Parker et al (2005)
[45] Penning-Rowsell et al (2005)

TABLES TO OBTAIN INPUT DATA FOR THE RISK MODEL -PLUVIAL FLOODING-
Sheet A.2B. | TABLES and NOTES

Figure 3: 2B – Tables, definition of additional parameters and notes

3 Vulnerability criteria in pluvial flooding

In this chapter, all vulnerability criteria used for the definition of flood severity levels in pluvial flooding are included. They are classified in terms of the main parameter of each criterion:

Criteria regarding maximum flood depth (ymax)

Denver
A flood water depth of 0.45 m is defined as a threshold level. Above this level, it is considered that water floods buildings and households.

Mendoza
This criterion establishes the previous threshold for a flood depth of 0.30 m.

Témez
A threshold of a flood depth of 1 m is considered to establish risk zones. Flooded zones with water depths below this level are established as non-risk areas.

Criteria regarding maximum velocity (Vmax)

Témez (1992)
A maximum velocity of 1 m/s is established as a threshold value for the definition of risk areas. Flooded zones with velocities below this value are established as non-risk areas.

Gómez and Russo (2009)
In 2009, Gómez and Russo (Gómez and Russo, 2009) performed an experimental study of a scale model to obtain risk criteria in urban areas. From the analysis and conclusion of their tests, three thresholds were defined from the velocity characteristics:

- Low risk3 (1.51 m/s < v < 1.56 m/s): People have problems to stand in floodwater with these characteristics.
- Medium risk (1.56 m/s < v < 1.88 m/s): High loss of stability and manoeuvrability.
- High risk (v > 1.88 m/s): People are unable to stand with these characteristics and they are swept away.

Table 9 includes the velocity ranges for these three categories.

Table 9: Velocity ranges from Gómez and Russo, 2009 (Gómez and Russo, 2009).

Category	v (m/s)
Non-risk area	v < 1.51
Low risk	1.51 < v < 1.56
Medium risk	1.56 < v < 1.88
High risk	v > 1.88

Criteria regarding dragging parameter (V·Ymax)

Témez (1992)
A maximum value of the parameter v·y equals to 0.50 m^2/s is considered. Above this threshold, flood characteristics are considered within the risk zone.

FEMA (1979)
A maximum rate of 0.56 m^2/s is considered as a threshold value for analysing loss of stability of an adult being exposed to a flood.

Reiter (2001)
This criteria provides a classification on flood severity levels from the v·y parameter of the flood. Five categories are defined:

Table 10: Flood severity levels from Reiter, 2001

Category	v·y (m^2/s)
Low severity. People expected to survive	0-0.5
High severity. People in danger, cars floating	0.5-1
Low severity for buildings. High risk for people outside in floodwater	1.0-3.0
Medium severity for buildings (damages)	3.0-7.0
High severity for buildings (destruction)	>7.0

Criteria regarding SLIDING stability (V^2·Ymax)

Nanía (2002)
This study evaluates the capability of an adult to stand in floodwater before being swept away due to sliding. This theoretical analysis defines a reference value of v·y equals to 1.23 m^3/s^2 (Nanía , 2002). This value is established for an adult of 60 kg. This value is affected by the weight and height of the considered person.

Other criteria

DGOHCA (Ministry of Environment, Spain) (From Oleagordia et al)
Three categories are established for the classification of the river flood plane on risk zones:

- Low risk area: areas with flood depths lower than 0.40m for return periods of 500 years.
- Medium risk area: areas with flood characteristics between low and high risks.
- High risk area: areas with flood depths higher than 0.40m for return periods of 50 years.

PATRICOVA (2002, Spain)
This Plan for Flood Risk Prevention in the Valencian Region (PATRICOVA, 2002) classifies the magnitude of the flood event in terms of the flood depth (with a threshold value of 0.80 m) and their frequency in terms of annual probability of occurrence. This Plan provides six levels of flood characterization (from 1, High, to 6, Low):

Table 11: Risk categories from PATRICOVA, 2002.

Flood depth	Low frequency T=100 - 500 years	Medium frequency T=25 - 100 years	High frequency T<25 years
Low (<0.80m)	6 (LOW)	4 (MEDIUM)	3 (MEDIUM)
High (>0.80m)	5 (LOW)	2 (HIGH)	1 (HIGH)

4 Estimation of fatality rates in pluvial flooding

Introduction

For the estimation of fatality rates in pluvial flooding, the methodology described in Penning-Rowsell et al, 2005, has been used. This method is based on defining zones of different flood hazard and estimating the total number of people located in the flooded zones, the proportion that are likely to be exposed and who are likely to be injured or killed.
Fatality rates for pluvial flooding are obtained from the combination of SUFRI methodology with the aforementioned method. This appendix presents an outline of the process, including the main factors and parameters.
Thus, for each level of flood severity (S0 to S4), fatality rates are obtained from the abovementioned framework by Penning-Rowsell et al, 2005.

Procedure

The method evaluates the number of deaths/injuries from the following parameters:

- Flood depth: y
- Velocity of the floodwater: v
- Hazard rating, HR: HR=y·(v+1.5)
- Area vulnerability, AV: AV=FW+SO+NA

where FW denotes flood warning, SO represents the speed of onset and NA is used to identify the nature of the area (building typology).

- Exposure, X (percentage of people exposed to risk): X(%)=AV·HR
- Population at the flooded area: N(Z)
- People exposed: N(ZE)=X·N(Z)
- P1 factor (people older than 75 years): P1
- P2 factor (disabled and long-term sick): P2
- People vulnerability, Y: Y(%)=P1+P2
- Number of injuries: N(ZE)·Y
- Number of deaths: 2·HR·N(ZE)·Y

From the given parameters, the estimation of fatality rates for SUFRI methodology in case of pluvial flooding is based on the following assumptions:

- Area vulnerability

Mean values for the characterization of speed of onset (SO=2) and building typology (NA=2) are established. The existence of flood warning is considered from the three described categories in SUFRI methodology. The FW parameter is defined from FW=1 (category Cp3, warning systems) to FW=3 (category Cp1, no warning systems are available). Consequently, three different values of area vulnerability (AV) are studied to develop three categories of fatality rates (one for each category Cp1 to Cp3).

- People vulnerability

  Mean values are used for Y (Y=0.50), regarding the presence of very old people and those who are at risk due to disabilities or sickness. If other characteristics of the population are considered, then Y can be modified and fatality rates should be corrected.

The resultant number of fatalities is estimated by:

$$\text{Fatalities} = 2 \cdot HR \cdot N(ZE) \cdot Y = 2 \cdot HR \cdot [N(Z) \cdot AV \cdot HR] \cdot Y$$

If Y=0.50 is considered and the fatality rate (FR) is defined as the ratio between the number of fatalities and the population at risk, N(Z):

$$FR = 2 \cdot HR^2 \cdot AV \cdot Y = 2 \cdot (y \cdot (v+1.5))^2 \cdot AV \cdot 0.5 \cdot 10\text{-}4 = (y \cdot (v+1.5))^2 \cdot AV \cdot 10\text{-}4$$

The procedure includes two parameters that should be considered as a percentage (2·HR and N(ZE)), consequently, a factor 10-4 should be used to obtain fatality rates if flood depth (y) and (v) are expressed in m and m/s. As it was described above, AV ranges from 5 to 7 (depending on the category of the case study, Cp).

Once the previous expression is defined, fatality rates are obtained for mean values of flood depth and velocity (Table 12) for each flood severity level established in SUFRI methodology (S0 to S4).

Table 12: Mean values of flood characteristics for each flood severity level.

	y(m)	v (m/s)	y·v (m2/s)
S0	0.3	0.8	0.24
S1	0.65	1.15	0.75
S2	0.9	1.1	0.99
S3	1.25	1.6	2
S4	2	2.5	5

Minimum and maximum values of the fatality rates for each category of flood severity are obtained from the given situations:

- Maximum flood depth for each flood severity category, with a velocity of the flood water of 1 m/s.
- Maximum velocity for each flood severity category, with a flood depth of 0.45 m.

Table 13 shows the associated values of flood characteristics for each flood severity category to analyze the effect of their variation on the results.

Table 13: Flood characteristics for estimating maximum and minimum fatality rates.

Severity	y(m)	v (m/s)	y·v (m^2/s)	Severity	y(m)	v (m/s)	y·v (m^2/s)
S0	0.44	1	0.44	S0	0.45	1	0.45
S1	0.79	1	0.79	S1	0.45	1.59	0.72
S2	0.99	1	0.99	S2	0.45	1.87	0.84

S3	2.99	1	2.99	S3	0.45	5	2.25
S4	5	1	5	S4	0.45	8	3.6

After applying the flood characteristics presented in Tables Table 12 and Table 13 to the previous expression and analysing the results, the following fatality rates are established for each Cp category (depending on the existent warning system):

Table 14: Fatality rates established in SUFRI methodology.

Category	Flood severity	Fatality rate, FR (Proposed value)	Fatality rate, FR (Range)
C_{p1}	S0	0.0003	0 - 0.0009
	S1	0.0021	0.001 - 0.003
	S2	0.0038	0.0015 - 0.0045
	S3	0.0105	0.006 - 0.04
	S4	0.0448	0.01 - 0.11
C_{p2}	S0	0.0003	0 - 0.0008
	S1	0.0018	0.0012 - 0.0024
	S2	0.0033	0.0014 - 0.0037
	S3	0.0090	0.005 - 0.035
	S4	0.0384	0.01 - 0.095
C_{p3}	S0	0.0002	0 - 0.00065
	S1	0.0015	0.001 - 0.002
	S2	0.0027	0.001 - 0.003
	S3	0.0075	0.004 - 0.028
	S4	0.0320	0.009 - 0.08

5 Reference costs and Depth-damage curves for estimation of economic losses

REFERENCE COST

The definition of the reference cost for each land use category can be based on national statistics, insurances, aids, economic studies and market prices, etc.
In this appendix two examples are included as a reference for estimating reference cost. On one hand, Table 15 shows values for different land uses from a regional Plan in Spain, PATRICOVA, 2002, (Action Plan on Flood Risk of the Valencian Region). On the other hand, rates from International Commission for the protection of the Rhine (IKSR 2001, from HR Wallington Ltd., 2006) are shown in Table 16.
These values should be adapted to each case study, depending on the area of study.

Table 15: Reference costs from PATRICOVA, 2002.

Code	Land use	Rate (€/m²)	
		High	Low
00	Residential	68.7	22.9
01	Residential. Low density.	68.7	22.9
02	Residential. Medium density.	56.3	18.8
03	Residential. Medium-high density.	75.0	25.0
04	Residential. High density.	100.0	33.3
05	Campsites, caravans, etc.	68.7	22.9
00 a 04	Commercial uses in residential areas	51.8	17.3
06	Industrial use.	16.9	5.6
07	Industrial use. Low density.	16.9	5.6
08	Industrial use. High density.	23.7	7.9
09	Equipments, infrastructures, etc.	51.8	17.3
10	Tertiary sector	51.8	17.3
11	Combined	51.8	17.3
12	Others. Undefined.	0	0
20	Agricultural use. Fruits.	0.89	
21	Agricultural use. Cereal.	0.34	
22	Agricultural use. Rice.	0.34	
23	Agricultural use. Fruits.	0.56	
24	Agricultural use Citrus fruits.	0.86	
25	Others	0.34	
36-40	Dry lands. Herbaceous.	0.34	
	Dry lands (vineyards, olives, etc.)	0.56	
Others		0	

Table 16: Reference costs from IKSR 2001 (HR Wallington Ltd. Guidelines for socio-economic flood damage evaluation, 2006).

Land use category	Real state and fix (€/m^2)	Mobile goods (€/m^2)	Total (€/m^2)
Residential areas	231	59	289
Industrial areas	231	80	311
Urban infrastructures	263	2	265
Agricultural areas	-	-	9
Forest areas	-	-	1

DEPTH-DAMAGE CURVES

Depth-damage curves or functions are distributions that represent flood depth and the percentage of damage in assets, from the land use of the flooded area, building typology and/or their content. In this section several depth-damage curves found in the literature are described.

General depth-damage curves

This type of depth-damage curves do not distinguish between land uses or building typologies. For example, depth-damage curves from PATRICOVA, 2002, do not consider structural damages or destruction of their content. Rates are defined for a generic land use. Land use distinctions are included in the definition of the reference cost.
Table 17 includes the depth-damage relationships proposed in PATRICOVA, 2002, and Figure 4 shows the depth-damage curve.

Table 17: Rates of damage from different flood depth conditions (PATRICOVA, 2002)

Flood depth (m)	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
Damage (%)	1%	2.5%	5%	14%	40%	60%	67%	71%	75%	77%

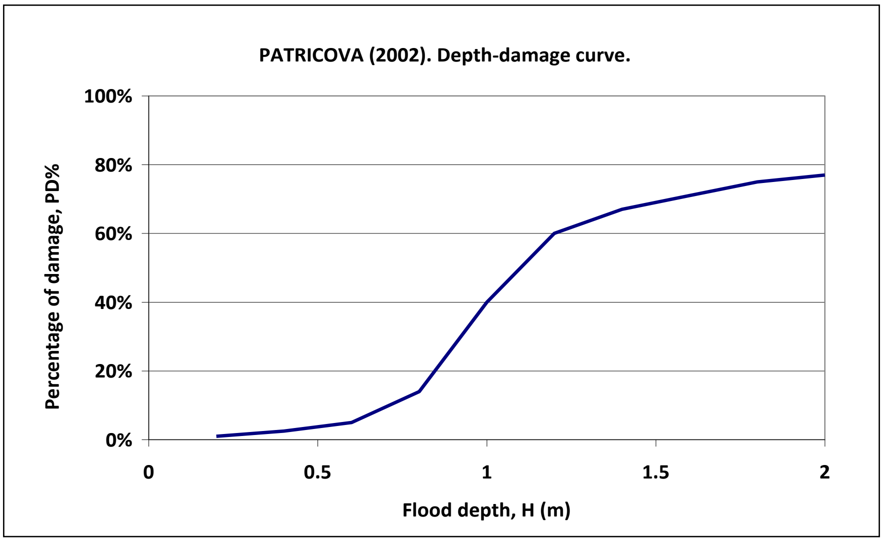

Figure 4: Depth-damage curve. PATRICOVA, 2002

Depth-damage curves for buildings

There are several depth-damage curves proposed by USACE (Ashley et al, 2008) (Dawson, 2003) that define the percentage of damage in case of flooding from the following concepts:

- Structure value. Preliminary data for estimating the value of the content.
- Depth-damage function. Damage of the structure or building as a percentage of the structure value. It depends on the number of floors (one-story or multi-story buildings) and the existence of basement.
- Content-damage relationships. As a function of content valuations (estimation of the economic value of the content). A structure occupancy type is assigned.
- Content depth-damage relationships. The content depth-damage relationship provides the estimate of content flood damage as a percentage of content value.

Depth-damage curves from USACE (Dawson , 2003) consider the first floor (ground floor) as a reference level for the definition of flood water depth.
Table 18 shows depth-damage relationships in case of buildings without basement, where SD denotes standard deviation from the mean value of the percentage of damage. Figure A.5.2 shows the depth-damage curves from the given values in Table 18.

Table 18: Depth-damage relationships. No basement. USACE (2000) (Dawson, 2003).

		No basement							
		Structure				Content			
		One story		Two or more stories		One story		Two or more stories	
Depth (ft)	Depth (m)	Damage Mean (%)	SD	Damage Mean (%)	SD	Damage Mean (%)	SD	Damage Mean (%)	SD
-2	-0.7	0%	0.00%	0%	0.00%	0%	0.00%	0%	0.00%
-1	-0.3	2.50%	2.70%	3.00%	4.10%	2.40%	2.10%	1.00%	3.50%
0	0.0	13.40%	2.00%	9.30%	3.40%	8.10%	1.50%	5.00%	2.90%
1	0.3	23.30%	1.60%	15.20%	3.00%	13.30%	1.20%	8.70%	2.60%
2	0.7	32.10%	1.60%	20.90%	2.80%	17.90%	1.20%	12.20%	2.50%
3	1.0	40.10%	1.80%	26.30%	2.90%	22.00%	1.40%	15.50%	2.50%
4	1.3	47.10%	1.90%	31.40%	3.20%	25.70%	1.50%	18.50%	2.70%
5	1.7	53.20%	2.00%	36.20%	3.40%	28.80%	1.60%	21.30%	3.00%
6	2.0	58.60%	2.10%	40.70%	3.70%	31.50%	1.60%	23.90%	3.20%
7	2.3	63.20%	2.20%	44.90%	3.90%	33.80%	1.70%	26.30%	3.30%
8	2.6	67.20%	2.30%	48.80%	4.00%	35.70%	1.80%	28.40%	3.40%
9	3.0	70.50%	2.40%	52.40%	4.10%	37.20%	1.90%	30.30%	3.50%
10	3.3	73.20%	2.70%	55.70%	4.20%	38.40%	2.10%	32.00%	3.50%
11	3.6	75.40%	3.00%	58.70%	4.20%	39.20%	2.30%	33.40%	3.50%
12	4.0	77.20%	3.30%	61.40%	4.20%	39.70%	2.60%	34.70%	3.50%
13	4.3	78.50%	3.70%	63.80%	4.20%	40.00%	2.90%	35.60%	3.50%
14	4.6	79.50%	4.10%	65.90%	4.30%	40.00%	3.20%	36.40%	3.60%
15	5.0	80.20%	4.50%	67.70%	4.60%	40.00%	3.50%	36.90%	3.80%
16	5.3	80.70%	4.90%	69.20%	5.00%	40.00%	3.80%	37.20%	4.20%

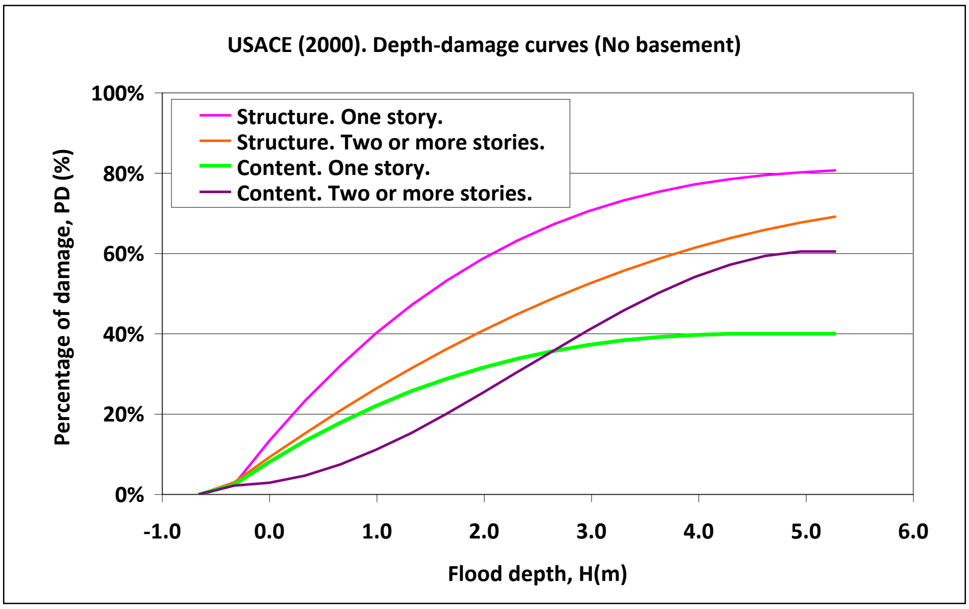

Figure 5: Depth-damage curves. No basement. USACE (2000) (Dawson, 2003).

Table 19 and Figure 6 include depth-damage relationships for buildings with basement.

Table 19: Depth-damage relationships. Basement. USACE (2003) (Dawson, 2003).

		Basement							
		Structure				Content			
		One story		Two or more stories		One story		Two or more stories	
Depth (ft)	Depth (m)	Damage Mean (%)	SD	Damage Mean (%)	SD	Damage Mean (%)	SD	Damage Mean (%)	SD
-8	-2.6	0%	0.00	2%	2.70	0%	1.60	0%	0.00
-7	-2.3	0.70%	1.34	1.70%	2.70	0.80%	1.16	1.00%	2.27
-6	-2.0	0.80%	1.06	1.90%	2.11	2.10%	0.92	2.30%	1.76
-5	-1.7	2.40%	0.94	2.90%	1.80	3.70%	0.81	3.70%	1.49
-4	-1.3	5.20%	0.91	4.70%	1.66	5.70%	0.78	5.20%	1.37
-3	-1.0	9.00%	0.88	7.20%	1.56	8.00%	0.76	6.80%	1.29
-2	-0.7	13.80%	0.85	10.20%	1.47	10.50%	0.74	8.40%	1.21
-1	-0.3	19.40%	0.83	13.90%	1.37	13.20%	0.72	10.10%	1.13
0	0.0	25.50%	0.85	17.90%	1.32	16.00%	0.74	11.90%	1.09
1	0.3	32.00%	0.96	22.30%	1.35	18.90%	0.83	13.80%	1.11
2	0.7	38.70%	1.14	27.00%	1.50	21.80%	0.98	15.70%	1.23
3	1.0	45.50%	1.37	31.90%	1.75	24.70%	1.17	17.70%	1.43
4	1.3	52.20%	1.63	36.90%	2.04	27.40%	1.39	19.80%	1.67
5	1.7	58.60%	1.89	41.90%	2.34	30.00%	1.60	22.00%	1.92
6	2.0	64.50%	2.14	46.90%	2.63	32.40%	1.81	24.30%	2.15
7	2.3	69.80%	2.35	51.80%	2.89	34.50%	1.99	26.70%	2.36
8	2.6	74.20%	2.52	56.40%	3.13	36.30%	2.13	29.10%	2.56
9	3.0	77.70%	2.66	60.80%	3.38	37.70%	2.25	31.70%	2.76
10	3.3	80.10%	2.77	64.80%	3.71	38.60%	2.35	34.40%	3.04
11	3.6	81.10%	2.88	68.40%	4.22	39.10%	2.45	37.20%	3.46
12	4.0	81.10%	2.88	71.40%	5.02	39.10%	2.45	40.00%	4.12
13	4.3	81.10%	2.88	73.70%	6.19	39.10%	2.45	43.00%	5.08
14	4.6	81.10%	2.88	75.40%	7.79	39.10%	2.45	46.10%	6.39
15	5.0	81.10%	2.88	76.40%	9.84	39.10%	2.45	49.30%	8.08
16	5.3	81.10%	2.88	76.40%	12.36	39.10%	2.45	52.60%	10.15

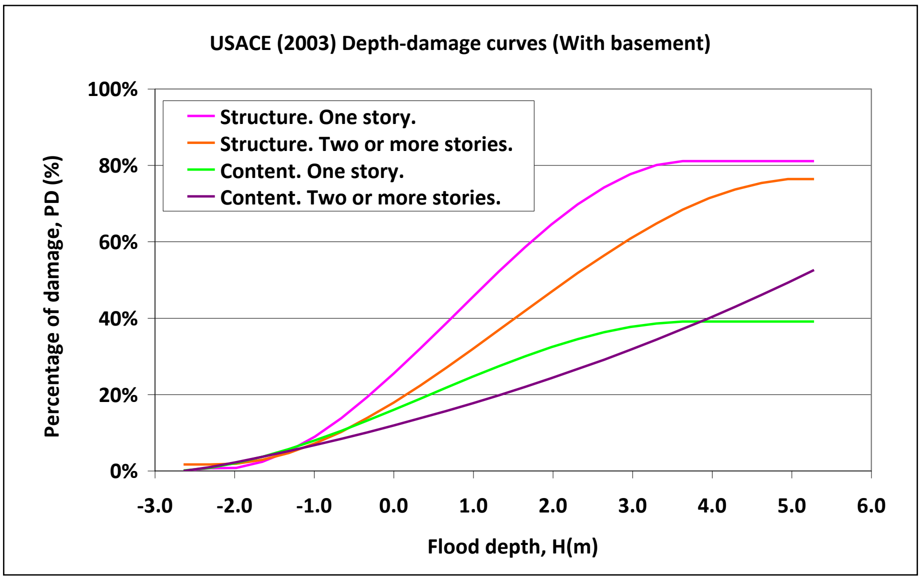

Figure 6: Depth-damage curves. Basement. USACE (2003) (Dawson, 2003).

Depth-damage curves for multiple categories

Several depth-damage relationships can be found in the literature for the estimation of economic losses due to a flood event. In this section, an example of depth-damage curves for different land use categories and assets is shown in Figure 7 (Elsner et al, 2003, based on Klaus and Schmitdke, 1990).

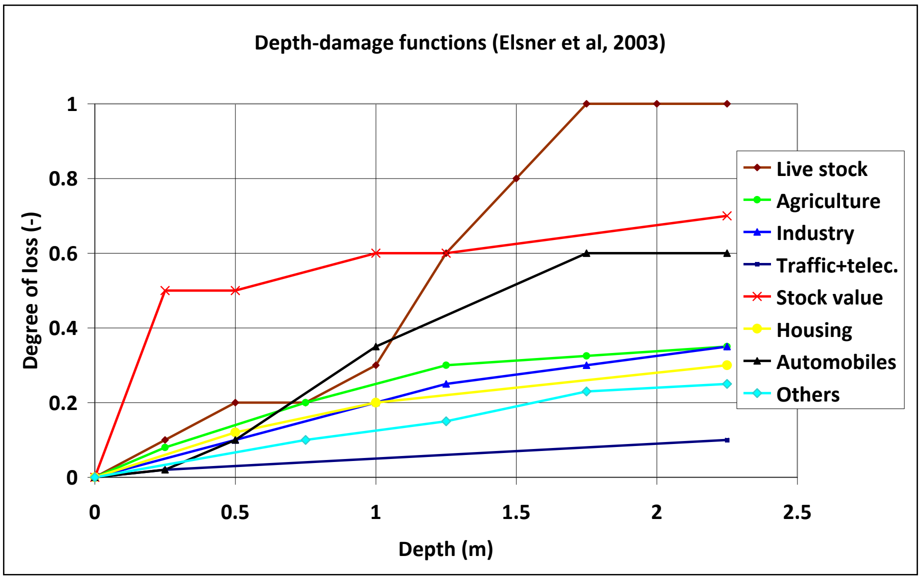

Figure 7: Depth-damage curves for multiple land uses. Elsner et al (2003).

Depth-damage curves for road networks

If damage estimation of road networks is considered, a reference flood depth can be established as a threshold. Streets with flood depths above this reference level are considered as damage areas, obtaining the total length of affected roads. This threshold is often determined at a level of 0.30 m of flood depth in the literature (INUNCAT, 2009 (ACA, 2009)).

Depth-damage curves for vehicles

There are also depth-damage criteria for the estimate of economic costs from damages on vehicles (Scawthorn et al, 2006). Figure 8 shows an example of depth-damage functions for three categories of vehicles: cars, light trucks and heavy trucks.

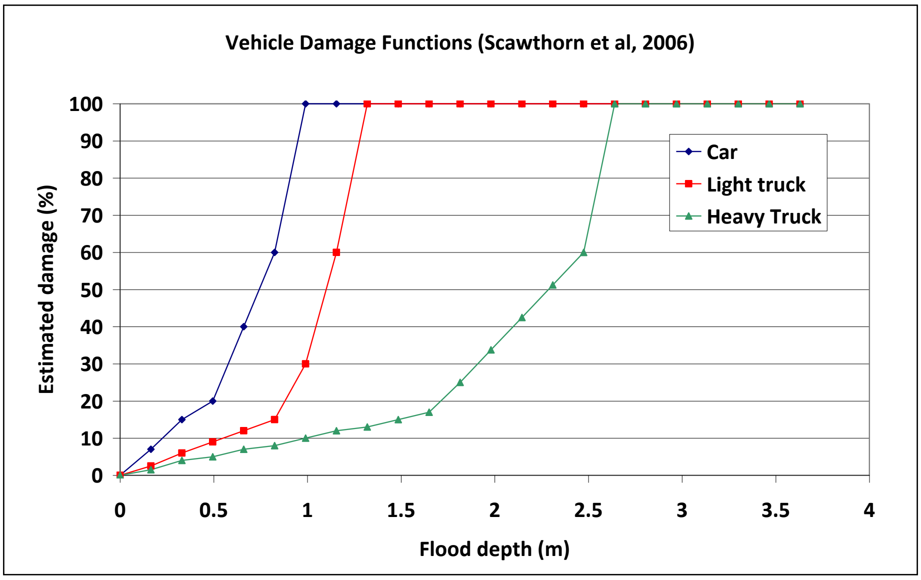

Figure 8: Depth-damage curves for vehicles. Scawthorn et al, 2006.

6 Risk model schemes

As it has been described in SUFRI methodology, the risk model scheme can be generally divided into three blocks of nodes: loads, system response and consequences.
The risk model scheme depends on the characteristics of each case study and the existing structural measures. Their architecture requires a more complex scheme if several infrastructures should be analyzed (i.e. large dams, levees, detention basins, embankments, etc.)
In this appendix, several schemes of different risk models are presented as an example for the risk model architecture.

Natural flow regime. River flooding

This section includes the example of a risk model for the analysis of the natural flow regime of a river. Figure 9 shows the sequence of nodes for the construction of the risk model from iPresas software (Serrano-Lombillo, 2010).

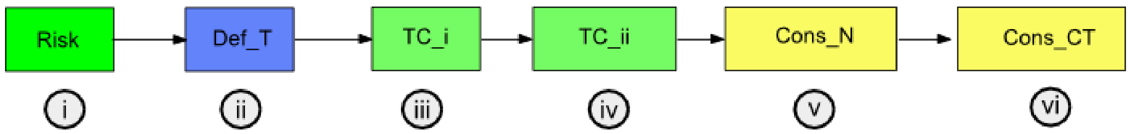

Figure 9: Generic scheme for the study of the natural flow regime of the river.

Each node corresponds with the following information:

i. Risk. This fist node is included for the estimate of total risk. It requires the definition of a variable with one option or category (i.e. variable='risk'), which probability is 1 (probability of being in this category is 100%).

ii. Def_T. This node includes the established return periods for the definition of flood scenarios and their annual probabilities of exceedance. Each return period is related to a maximum peak discharge of the hydrograph.

iii. TC_i. This node is related to information on seasonal variability of the population in the study area (i.e. probabilities of being during summer, winter, special events, etc.).

iv. TC_ii. This node includes information concerning daily variability of the population in the study area (i.e. probabilities of being during the day or at night).

v. Cons_N. This node is associated with files that contain data from the estimation of consequences in terms of life-loss (T-N relationships: number of potential fatalities, denoted by N or 'lives', for each flood scenario).

vi. Cons_CT. This node includes input data from the estimation of consequences in terms of economic losses (T-CT relationships: level of economic losses, denoted by CT or 'costs', for each flood scenario).

Structural measures (dam). River flooding

In this section, the risk model scheme for a base-case with a dam located upstream the urban area is studied.
Figure 10 shows the overall scheme of a risk model that includes the existence of a dam upstream the urban area. This scheme represents a dam with two failure modes in hydrologic scenario (Serrano-Lombillo, 2010).

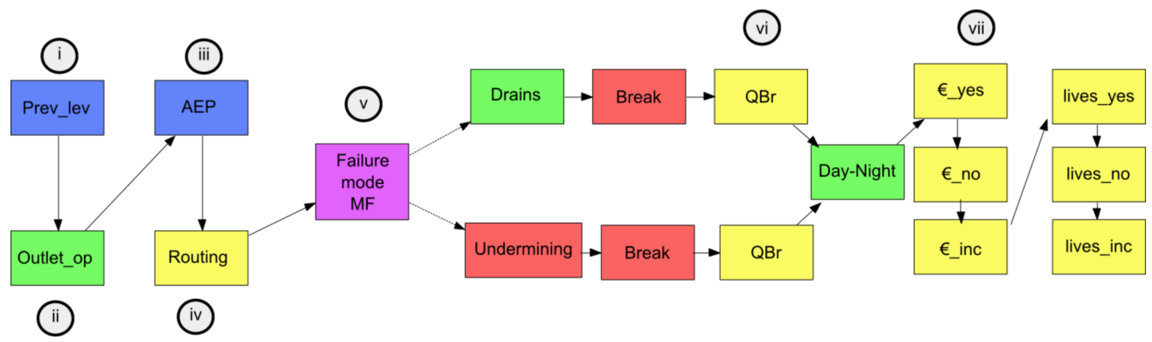

Figure 10: Risk model scheme of a dam with two failure modes.

Information related to these nodes is summarised as follows:

i. Prev_Lev. This node includes the probability of exceedance of a certain water pool level, that is, the probability of being in a certain level when the flood occurs.

ii. Outlet_op. In this node, functionality of outlet works (spillway) is described.

iii. AEP. This node is used to generate several branches with the probability of a certain flood event occurring.

iv. Routing. This node includes the results of the flood routing process, and provides maximum water pool levels, flow discharges and overtopping characteristics.

v. MF. This is an artificial node which introduces the failure modes of the dam. Two failure modes are considered in this scheme.

vi. Qbr. This node represents the dam break peak discharge associated to each failure mode.

vii. €_yes, €_no and E_inc. These nodes include data from potential consequences in terms of economic losses in three different cases: costs due to floods from dam break, costs due to floods from flood routing and incremental costs. If loss of life is analysed, then nodes denoted by 'lives_yes, lives_no and lives_inc' include data from potential consequences in terms of loss of life in the same previous cases: life-loss due to dam break, flood routing and incremental values.

Non-structural measures. River flooding

In this point, differences on the risk model are described from the study of non-structural measures. If the effect of non-structural measures should be analyzed, the risk-model for the base-case is used as a reference scheme.

Figure 11 shows the base-case scheme of the previous section and indicates which nodes should be modified (with new input data) for risk evaluation with non-structural measures (these nodes are shown in Figure 11 within a box, related to point ‘vii’).

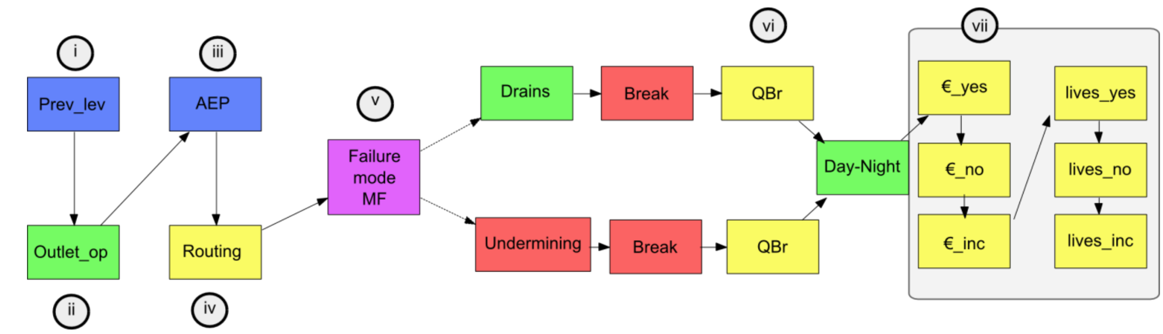

Figure 11: Risk model scheme for non-structural measures.

The effect of non-structural measures includes variations on potential consequences of the established flood scenarios. Consequently, new input data is required for nodes related to the third block of the risk model scheme, identified by a grey area in Figure 11 and described above in paragraph ‘vii’.

Pluvial flooding

In this case, the risk model scheme is similar to the previous example for the study of the natural flow regime of a river. The risk model requires the definition of nodes that include information on flood scenarios, system response and potential consequences.
Figure 12 shows the overall risk model scheme for pluvial flooding.

Figure 12: Risk model scheme for pluvial flooding.

Despite the similarities between both risk model schemes (Figure 9 and Figure 12), differences rely on the content of each node.

i. PF. This node is set at the beginning of the risk model for the estimate of total risk. It requires the definition of a variable (i.e. ‘risk’) and just one option with probability equal to 1.

ii. TC_i. This node includes information on seasonal variability of the population in the study area (i.e. probabilities of being during summer, winter, special events, etc.).

iii. TC_ii. This node includes information concerning daily variability of the population in the study area (i.e. probabilities of being during the day or at night).

iv. Flood. This node includes the established flood scenarios for the analysis. Each flood scenario is defined by a return period.

v. Runoff. This node relates each flood scenario to a reference runoff rate (Q_{pf}). This reference value is used to associate each flood scenario with potential consequences.

vi. Cons_N. This node contains data from the estimation of consequences in terms of loss of life (Q_{pf} -N relationships: number of potential fatalities, denoted by N or 'lives', for each flood scenario).

vii. Cons_CT. This node includes input data from the estimation of consequences in terms of economic losses (Q_{pf} -CT relationships: level of economic losses, denoted by CT or 'costs', for each flood scenario).

F-N curve

Finally, representation of F-N curves is described in this point, from results of the risk model developed by means of iPresas software (Serrano-Lombillo, 2010).
Once the risk model is ready for the analysis (all input data is linked to the corresponding node) and results are obtained, then the following command should be applied:

File → Export F-N…

From these commands, a dialogue box gives two options: societal or economic risk (identified by the name established in nodes Cons_N and Cons_CT for the variable of consequences: N or lives and CT or costs).
As a result, the iPresas software creates a .txt file that contains two columns of data: level of consequences (in terms of expected number of fatalities or economic costs) and annual probability of exceedance (AEP).
The F-N curve is obtained from the representation of the cumulative annual probability of exceedance (F, years-1) of a certain number of fatalities (N) or economic costs (€).

Figure 13 shows an example of a F-N curve, where both axes are generally displayed in logarithmic scale.

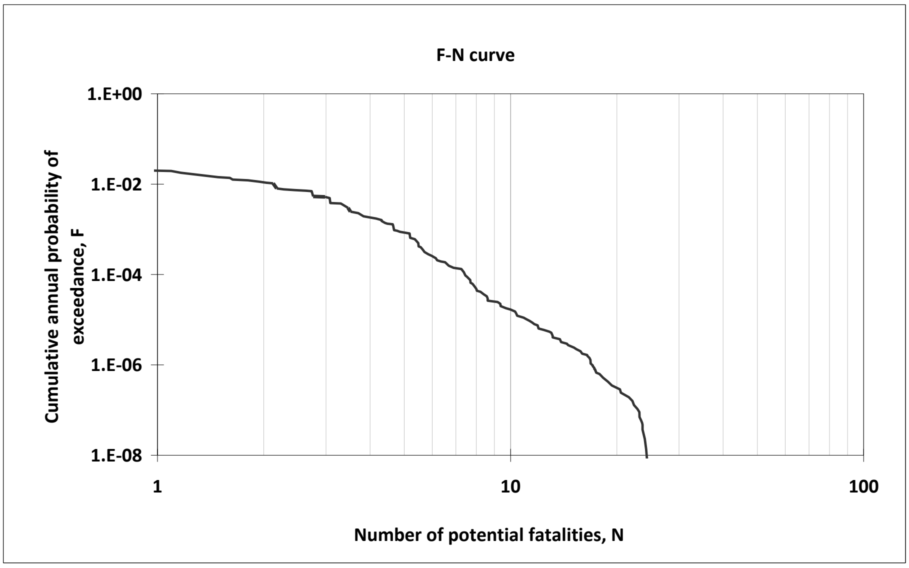

Figure 13: F-N curve. Generic example.

7 Existing tolerability criteria for flood risk

Tolerability criteria for flood risk are the basis for a proper risk management, with the aim of improving the decision process for implementation of measures for risk mitigation. Therefore, the concept of tolerable risk is fundamental to risk-informed decision making (Munger, 2009). These tolerability criteria must be mainly referred to human loss of life, as it is the main consequence of flood, but also based on economic consequences.

Figure 14 shows the three general ranges for risk tolerability. The first range is the unacceptable region, where risk can only be justified in extraordinary circumstances. The second region is the range of tolerability, where the risk is under the tolerability risk limit. In this region the analysis of risk is crucial because this risk is accepted by the society if it cannot be lowered in an economically efficient way. The third region is the broadly acceptable region, where risk can be defined as insignificant and can be controlled adequately.

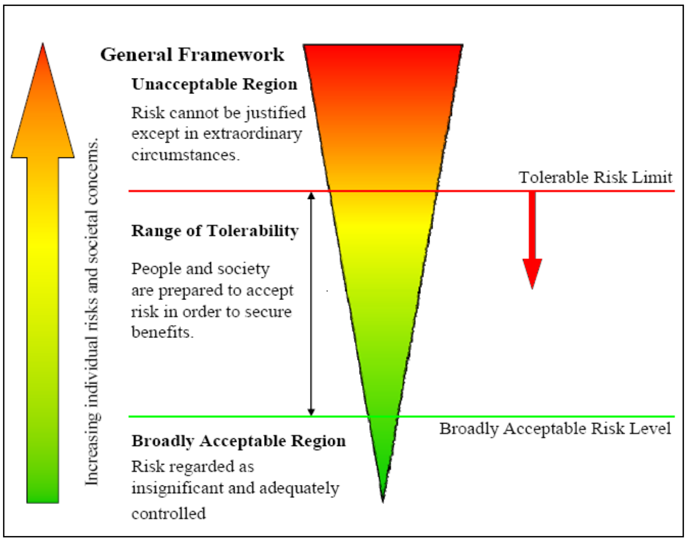

Figure 14: Generalized tolerability of risk framework (HSE, 2001).

In general, in the range of tolerability, the ALARP principle (As Low As Reasonably Practicable) must be followed. This concept considers that risks lower than the tolerable risk limit are only tolerable if further risk reduction is impracticable or the cost is grossly disproportional to risk reduction.
Risk tolerability criteria cannot be only decided by legislators or technicians, since risk tolerability must be known and shared with all the affected population.

In most countries, flood risk tolerability criteria have not been developed yet, as the inexistence of completely developed tools for societal flood risk quantification restricts such development, these criteria must be developed to ensure a proper management of flood risks measures. The current acceptability criteria for risk can be classified in two groups: tolerability guidelines for individual risk and for societal risk.

Tolerability criteria for individual risk

Individual risk is based on the probability part of the risk and, in the case of flood risk, it includes two components: the probability of inundation and the probability of death of an exposed person to the flood. Therefore, individual risk depends on the characteristics of the inundation, hazard, and not on the vulnerability. Their units are number of fatalities per unit of time, as a consequence of the combination of these two probabilities.

The most relevant tolerability criteria with legal importance for acceptability of general individual risk have been developed by the Dutch Ministry of Housing, Urban Planning and Environment (VROM), which limits individual risk in urban areas to 10-6. In addition, limitation of individual risk proposed by the Dutch Technical Committee for Advising in Defence Constructions (TAW) is (Vrijling, 2001):

$$IR < \beta \cdot 10^{-4}$$

Where β is the policy factor, which varies accordingly to the degree to which participation in the activity is voluntary and with the perceived benefit. Proposed values for this factor are between 0.01 for involuntary activities and 10 for voluntary activity for personal benefit. Typical values of this factor are shown in Figure 15 In the case of dikes that protect from flooding urban areas, the β factor usually used is between 1 and 0.1.

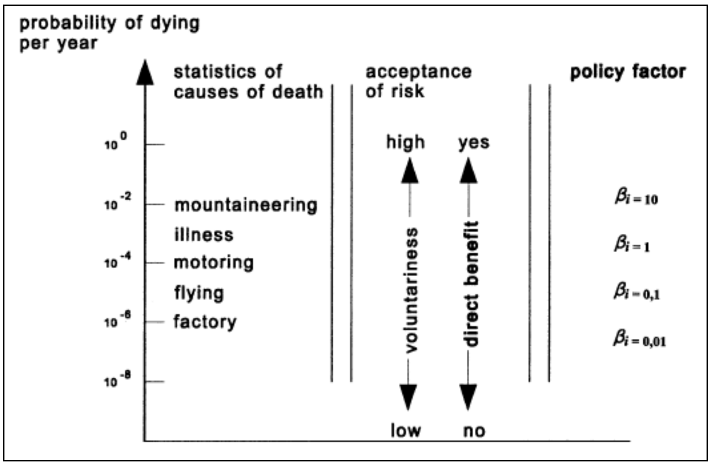

Figure 15: Personal risks in western countries, deduced from the statistics of causes of death and the number of participants per activity (Vrijling, 2001).

The most common acceptability criteria for flood risk are based on the limitations of the probability of occurrence of a flood in a certain urban area. This limit is also a measure of the hazard flood component, like the individual risk, although this probability does not include the probability of loss of lives. In general, limits for individual risks are important to avoid high risks related with damage to one person, they must be accompanied with societal risk limits (Jonkman, 2007).

Tolerability criteria for societal risk

It is generally accepted that individual risk criteria must be accompanied with societal risk limits (Jonkman, 2007).
Societal risk is the relationship between frequency and the number of victims in a given population from the realization of specified hazards, consequently it is more complete than individual risk because it includes vulnerability, not only hazard characteristics.

This risk is normally evaluated with F-N curves that represent the relation between the probability of occurrence of the hazard and the number of victims produced by the hazard. The area under a F-N curve is the total societal risk. These curves are limited by different lines, expressing the acceptability risk criteria. These criteria have not been developed for flood risk, although there are different standards for hazardous industries, as it is shown in Figure 16.

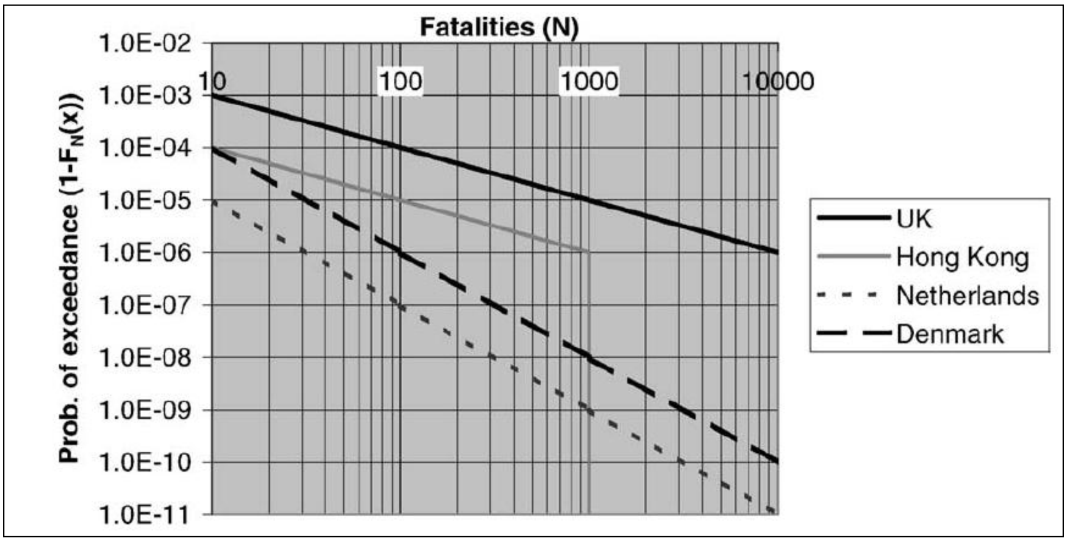

Figure 16: Some international standards for hazardous industry in F-N format (Jonkman, 2003).

The best known criterion for evaluating societal risk has been formulated in terms of F-N curves by Vrijling (Vrijling, 2001), establishing the tolerable risk by means of the following equation:

$$1 - F_N(n) < C_N / n^{\alpha}$$

Where FN is the flood probability of occurrence, CN is a constant that determine the vertical position of the F-N limit line, n is the number of fatalities and α is the risk aversion coefficient that determines the steepness of the F-N limit curve (more usual value is 2).
The coefficient α reflects risk aversion toward large accidents. A standard value of α=1 is called risk neutral. For instance, if α=2, then larger accidents with many fatalities are accepted with a relatively smaller probability than smaller accidents.

The value of CN can be derived from the following formula, proposed by Vrijling et al, 2001:

$$C_N = \left(\frac{\beta \cdot 100}{k} \right)^2$$

where k=3 (proposed value in Vrijling, 2001) and β is the aforementioned policy factor, ranging from 0.01 (for involuntary activities) to 10 (voluntary activity for personal benefit). The policy factor, β, is used for the limit of the individual risk and the population at risk.

This criterion can be applied for single installations, not only for a national scale. In that case, CN is denoted by CI.
The results of the application of these limits for the societal flood risk in the province of South Holland with different values of Ci are shown in Figure 17.

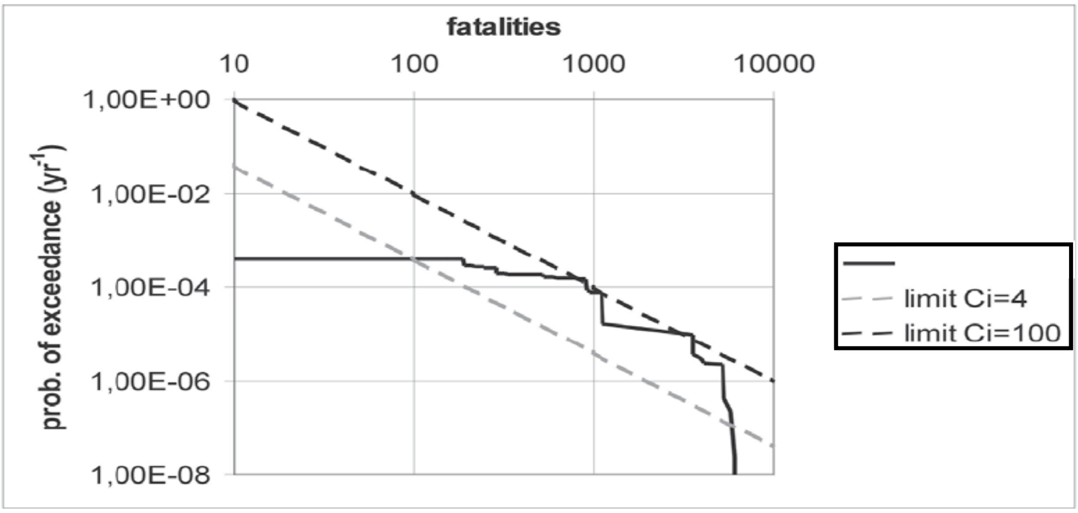

Figure 17: F-N curve for dike ring South Holland and two limit lines for different values of C_i

Furthermore, some tolerability criteria of flood risk have been developed for incremental societal flood risk produced by the existence of large dams. These criteria are also usually drawn in F-N curves, as the criteria proposed by ANCOLD, 2003. These criteria have been developed for incremental risk, thus they cannot be used to evaluate the total societal flood risk as the criterion proposed by Vrijling, 2001.

In conclusion, F-N curves can be a useful tool to evaluate societal flood risk, although different criteria for each country must be developed and accepted by the society. In addition, economical tolerability criteria for floods of a higher probability of occurrence could be developed in cases of high economic consequences but low loss of life.

Appendix 4

Results of the opinion poll

Opinion poll in English

Contents

1 Preface

Each question of the opinion poll has been analyzed and the results of all case studies are presented in one figure to make them comparable. This also allows a quick interpretation of the results at a glance.
Further 29 hypotheses have been tested for each case study and 5 hypothesis for all case studies.

2 Results of the opinion poll - Descriptive Analysis

In this chapter, first noticeable results will be briefly described.
Afterwards the detailed analysis of each question follows (exception: open questions). At the beginning general information about the case study respectively the interviewed persons are given. Afterwards the remaining five sections of the opinion poll “natural hazards and flooding in general, consequences of flood incidents, communication and information, self-protection and individual provisions, financial consequences of flooding” are analyzed.

For the interpretation of the results it’s very important to consider the number of those who have answered the question. If the number was lower than 25% of all interviewed persons in the corresponding case study, no analysis has been conducted. This means there could be a low percentage of respondents, which have to be taken into account when interpreting the results.
For the illustration of the figures integer have been used, thus small deviations from 100% can occur due to the fact that values have been rounded up or down.

2.1 Noticeable results and summary

Here general statements respectively trends or tendencies about the results for all case studies are summarized. A specification with values and percentages has been set aside deliberately to point out the main results for most of the cases. Thus, the detailed analysis in the chapter □, p. 6 should be considered for a better and proper understanding.

Q67 - Age: In Dresden, Graz and Lodi the percentage of old people (> 60 years) who took part in this questionnaire is quite high.

Q1 - Satisfaction: In all case studies the satisfaction with the current living situation is relatively high.

Q3 - Threatened by floods: In Graz and Lodi people feel more threatened by floods than respondents in Arenys de Mar / Munt, Benaguasil or Dresden.

Q6 - Cause for flood events: In Spain climate change, high building density, soil sealing and non-natural interferences as cause for flood events are rated much lower than in the other case studies.

Q7, Q21 - Evaluation of general statements: In the case studies the evaluation of the general statements listed below have shown the same clear tendency.

- Man cannot control nature entirely: *tendency applies*[1]
- One can protect oneself from floods completely: *tendency does not apply*[2]
- There remains always a residual risk with natural hazards: *tendency applies*[3]
- When I moved to this area I was aware of the flood risk: *tendency does not apply*
- I have coped psychologically with the previous flood events very well: *tendency applies*
- During heavy rain I remember previously flood events: *tendency applies*
- Because of the financial burden I can barely afford a holiday: *tendency does not apply*

The results show, that most of the people are aware of the fact that there is always a residual risk. Additionally it shows the importance of awareness training regarding the flood risk in the residential area.

Q10: Affected by floods: It's remarkable that in Arenys de Mar / Munt only 7% of the interviewed people have been affected by floods in the last 10 years. These percentage is much higher (> 60%) in the other case studies.

Q11: Frequency of affectedness: In Dresden and Lodi the majority of the people have been affected once in the last 10 years. In Graz and Benaguasil flood events have happened more often. For Arenys de Mar / Munt an analysis was not possible due to the too low number of affected people.

Q13, Q15: Health problems: The percentage of those who suffered from health problems after the last flood events is very low for Dresden and Graz. In Benagusail none of the respondents had any health problems. The highest percentage can be registered for Lodi. The most indicated types of health problems in all case studies are panic attacks/axiety states, insomnia, irritability/anger and restlessness. This also applies for physical impairments; with the exception that here in Graz the highest percentage was achieved. For Arenys de Mar / Munt an analysis was not possible due to the too low number of affected people.

Q24: Preferred source of information in case of emergency: In all case studies, except Lodi, people like to be informed by the media. In all case studies, except Benaguasil, people like to be informed by emergency services. The majority of the interviewed persons don't like to obtain information in case of emergency by internet, by on-site information centers or by friends / relatives.

Q26: Information about flood issues on a regular basis: Regarding this topic the results show, that information by the media is preferred in all case studies.

Q28: Level of information during the last flood event: The results show clearly that the majority of the people in all case studies felt informed very badly during the last flood event. For Arenys de Mar / Munt an analysis was not possible due to the too low number of affected people.

Q29: **Time between first warning and onset of the flood:** In the case studies Dresden, Graz and Lodi the people stated that the time between the first warning to the onset of the flood was quite short (up to 0,5 hours or from 0,5 to 2 hours).

[1] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.
[2] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.
[3] The Spanish case studies could not be considered for this question, due to a modification of the assessment scale during the translation.

Q30: Assessment of available time span: The results show clearly that the available time between the first warning and the onset of the flood was too short.

Q36: Knowledge about self-protection measures: In Benaguasil and in Graz the majority of the people know concrete measures to protect themselves in case of flood. In Arenys de Mar / Munt, Dresden and in Lodi, the majority does not know about them.

Q40: Self-protection measures during the last flood: The majority of the interviewed persons in all case studies did not take any self-protection measures.

Q45: Protective measures in the future: In all case studies, except in Benaguasil, the majority of the people will take protective measures in the future.

Q46: Assessment of solidarity efforts in the neighborhood: There is a clear tendency in all case studies, except Benaguasil, to assess the solidarity efforts in the neighborhood positive.

Q47: Importance of neighborly help: There is a clear tendency in all case studies to assess neighborly help as important.

Q50: Importance of the provided neighborly help: There is a clear tendency towards the assessment of neighborly help as important or very important in Dresden, Graz and Lodi. In Arenys de Mar / Munt people have assessed the help mostly as partially important or mostly important.

Q51: Labor slack due to the last flood event: In all case studies a high percentage have experienced a labor slack due to the last flood event.

Case study Lodi

Despite the fact that the last flood event in Lodi happened in 2002, people in Lodi seem to have experienced this events very intensely. In comparison to other case studies difference in the answers are conspicuous. They

- feel most threatened by floods
- rated the flood risk for them personally, inhabitants of their house and of their neighborhood highest
- rated their personal damage regarding material and financial causalities highest
- rated their personal damage regarding health problems highest
- rated the statement "I have coped psychologically with the previous flood events very well" with 46% rather applies and 32% applies. A clear difference to the other case studies, which answered with >60% with "applies" is noticeable.
- stated to need the longest time to prepare sufficiently for a flood.
- don't like to be informed by the media as solely case study
- stated with the highest percentage (86%) to feel uncomfortable because of missing information
- show the highest percentage regarding a very bad level of information during the last flood event

2.2 General

Q67: Age

In Dresden, Graz and Lodi more than 60% of the persons are older than 50 years. In Arenys de Mar / Munt and Benaguasil the biggest group (> 50%) of the persons is between 30 and 50 years old.

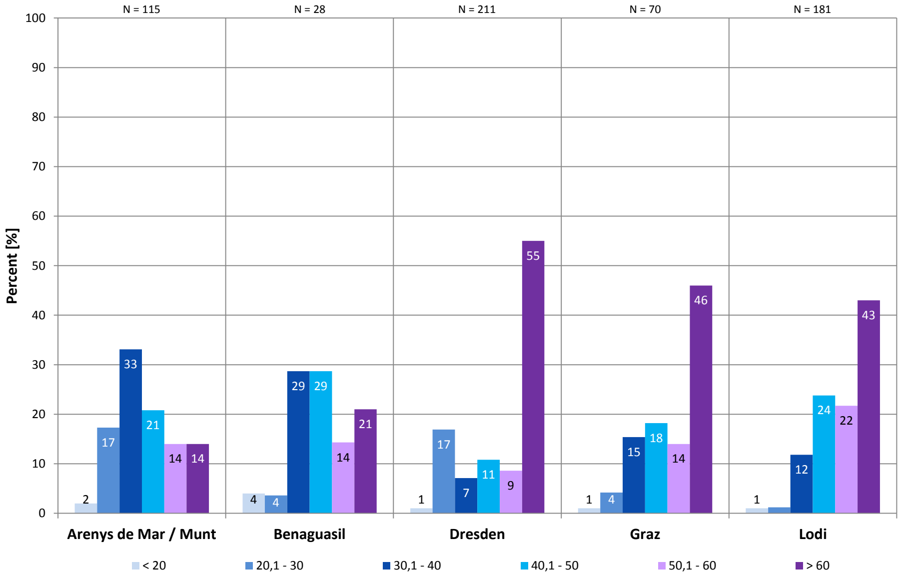

Figure 2-1: Q67 – How old are you?

Q66: Gender

In the Spanish case studies more women than man took part in the poll. Extraordinary high is the difference in Benaguasil where 64% women, in opposite 36% men filled out the poll. In the remaining case studies the proportion is the other way round. Here Lodi is worth do mention, with a percentage of 62% men.

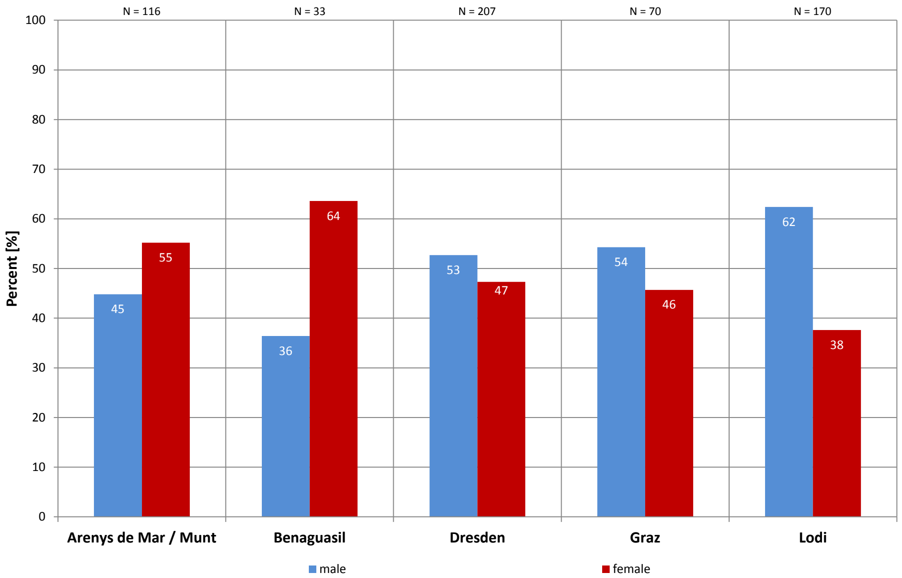

Figure 2-2: Q66 – Please state your gender

Q68: Highest educational achievement

In Dresden und Graz a high number of university alumnis is evident (> 45%). In Lodi and Arenys de Mar / Munt the upper secondary school has been the most frequently answer, whereas in Benaguasil these answer was compulsory education.

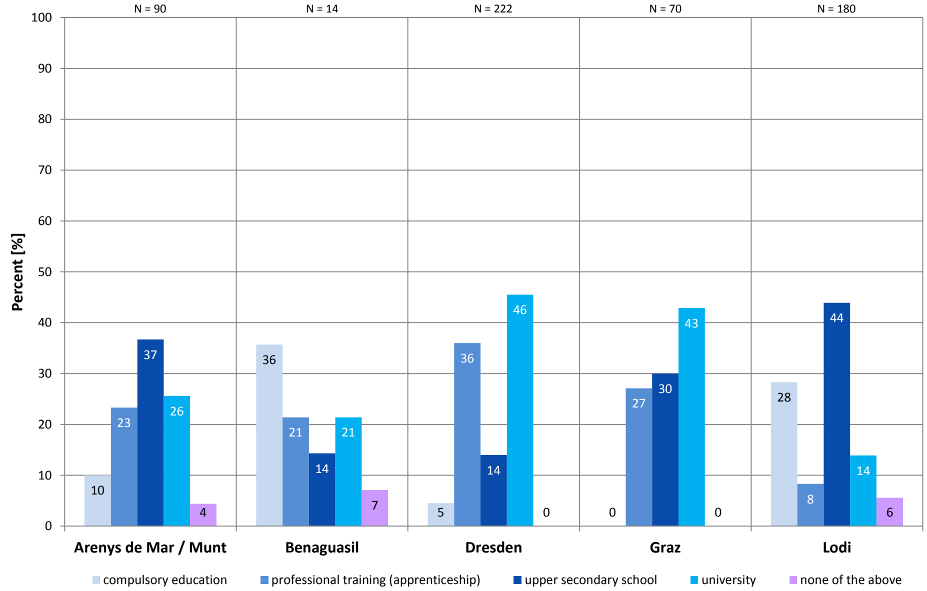

Figure 2-3: Q68 – What is your highest educational achievement?

Q69: Income

The highest income can be documented in Graz, where 58.4% have a monthly household net income of more than 2,001€, followed by Lodi with 43.1%. In Arenys de Mar / Munt and Dresden most of the people (76,2% and 81,8%) have an income until 2,000€. In Dresden the number of people who live with less than 1,000€ is with 33% quite high.

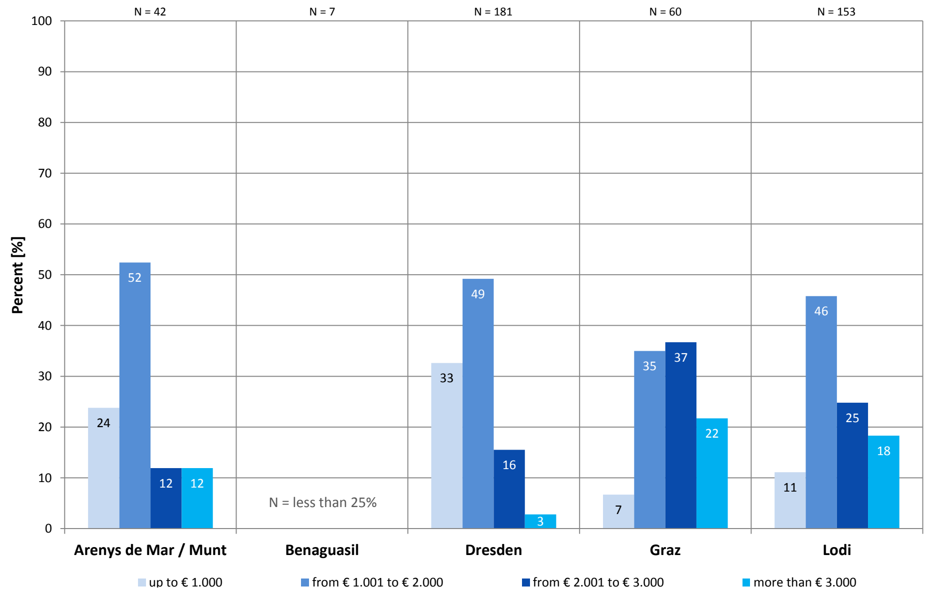

Figure 2-4: Q69 – How high is your monthly household (net) income?

Q62: Persons per household

The highest number of single-households is in Dresden with 30%, the lowest number in Arenys de Mar / Munt with 6%. Interesting is also the result, that in Dresden 56% and in Graz 45% of the persons live in a household with 2 persons. In Arenys de Mar / Munt and Lodi more than 50% live in households with 3 or more persons.

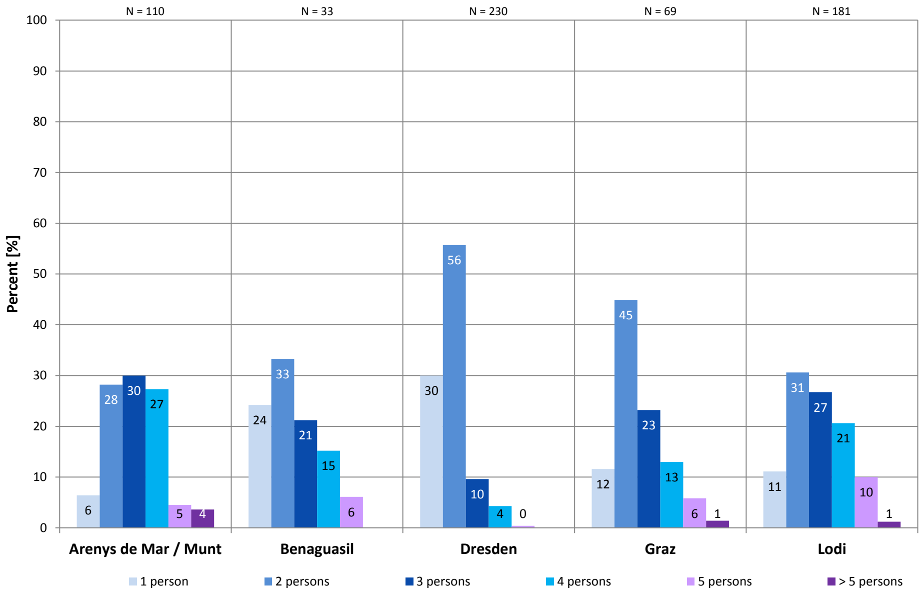

Figure 2-5: Q62 – How many persons live in your household?

Q60: Time in present household

More than 40% of people in all case studies lived more than 20 years in the present household. The only exception is Arenys de Mar / Munt, where 29% have stated to do so. It is noticeable, that in Lodi 83% of the persons lived more than 20 years in the present household.

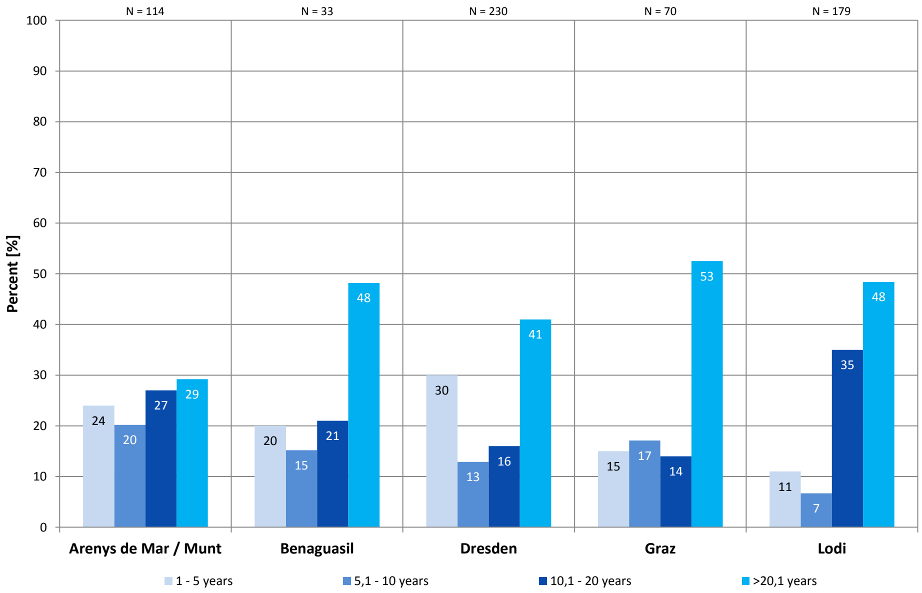

Figure 2-6: Q60 – How long have you lived in your present household

Q64: Floor
In Benaguasil, Graz and Lodi more than 60% of the persons live on the ground floor. In Dresden, which is a big city, most of the people (59%) have indicated to live on the second floor or higher.

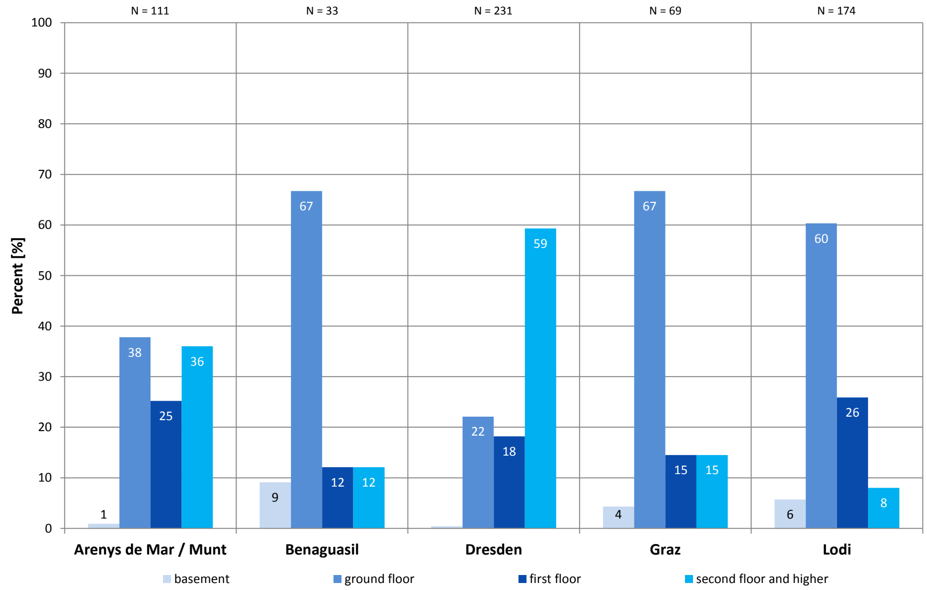

Figure 2-7: Q64 – On which floor do you live?

Q65: Cellar compartment or basement garage
In Dresden and Graz the numbers of the use of a cellar compartment or a basement garage are exceptionally high with more than 90%. In all other case studies more than half of the interviewed people don't use them, whereas the number in Arenys de Mar / Munt with 19% is the lowest.

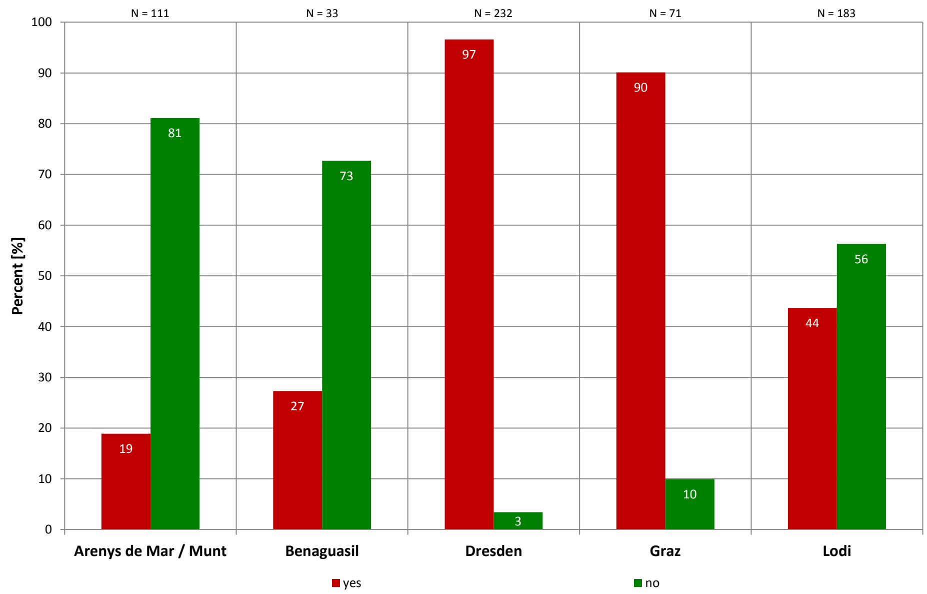

Figure 2-8: Q65 – Do you use a cellar compartment or a basement garage?

Q1: Satisfaction with current living situation

In all case studies more than 50% of persons are mostly or very satisfied with their current living situation, whereas the highest satisfaction can be registered in Graz with 44% persons who are very satisfied. The highest number of dissatisfaction arises in Lodi with 6% who are not satisfied.

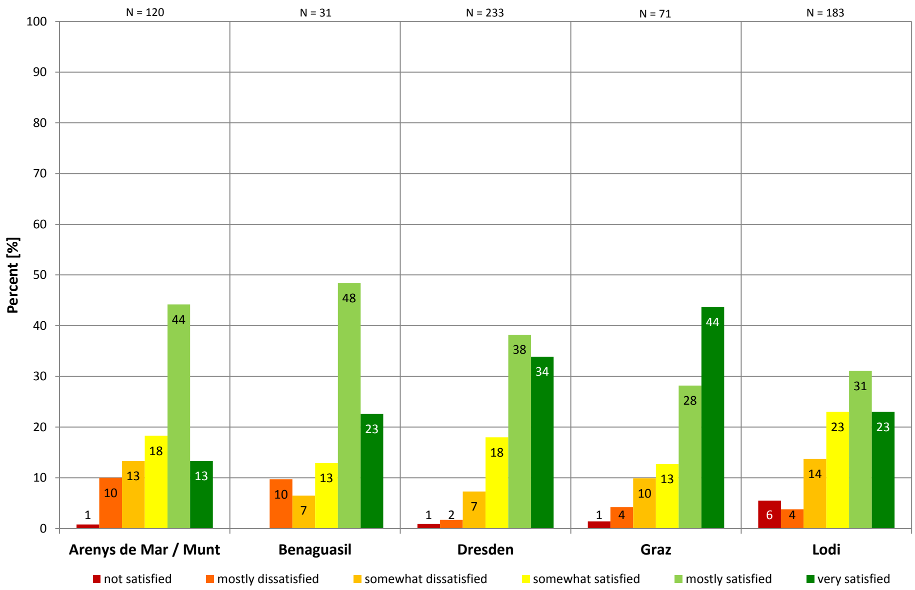

Figure 2-9: Q1 – How satisfied are you with your current living situation?

Q2: Type of current living situation

Due to the fact, that Dresden is a big city, most of the people live in an apartment in an apartment house (55%) respectively in a multi-family house (43%). Non of them live in a one-family house. The number of people who live in an apartment in an apartment house also applies for Arenys de Mar / Munt (35%). In all case studies except Dresden, more than 39% of the persons live in one-family houses. In Benaguasil 33% of the people have another living situation.

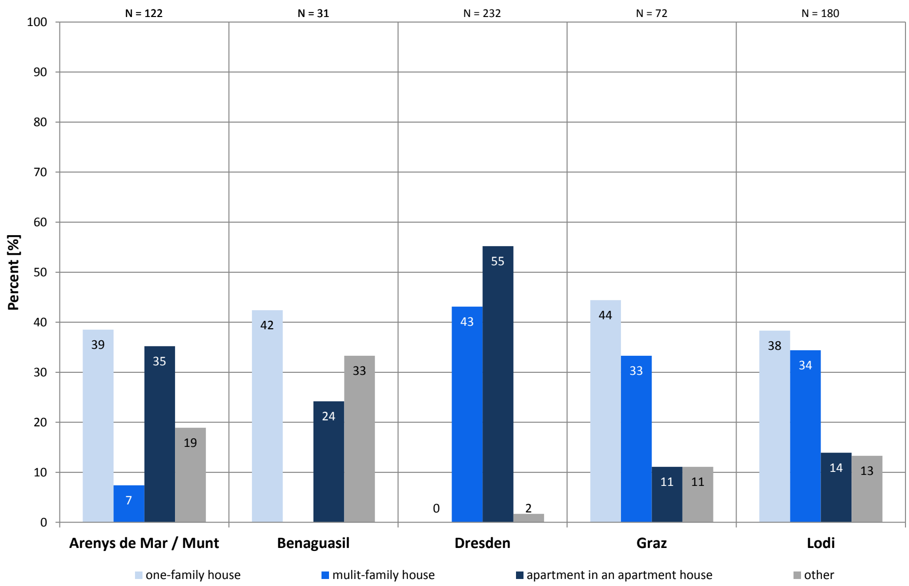

Figure 2-10: Q2 – Which of the following options applies to your current living situation?

2.3 Natural hazards and flooding in general

Q3: Threat by heavy storms

The results show, that the feeling of threat regarding heavy storms for all case studies is relatively low (not at all, little > 37%) or middle (partly or mostly > 37%). In Benaguasil the citizen feel most threated by storm. Here 22 % indicated to be threatened much or very much.

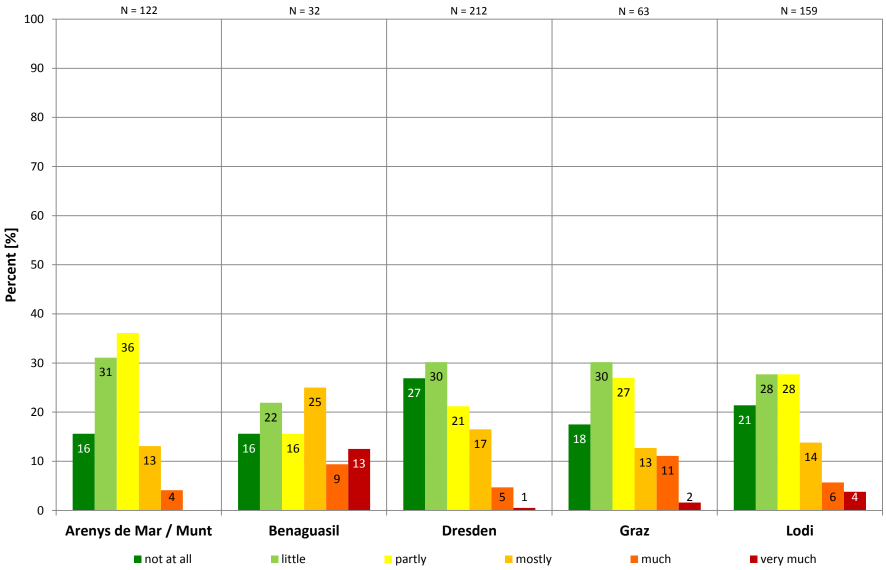

Figure 2-11: Q3 – To what extent do you feel threatened by heavy **storms**?

Q3: Threat by floods

The results show, that the feeling of threat concerning floods is extraordinarily high in Lodi (45% feel threatened very much), followed by Graz (31%). Surprisingly only 5% of the people in Arenys de Mar / Munt feel threatened by floods. In Benaguasil and Dresden the quota of people who feel threatened and who not is relatively balanced. However the number of citizens who feel threatened very much is quite low (6% and 1%).

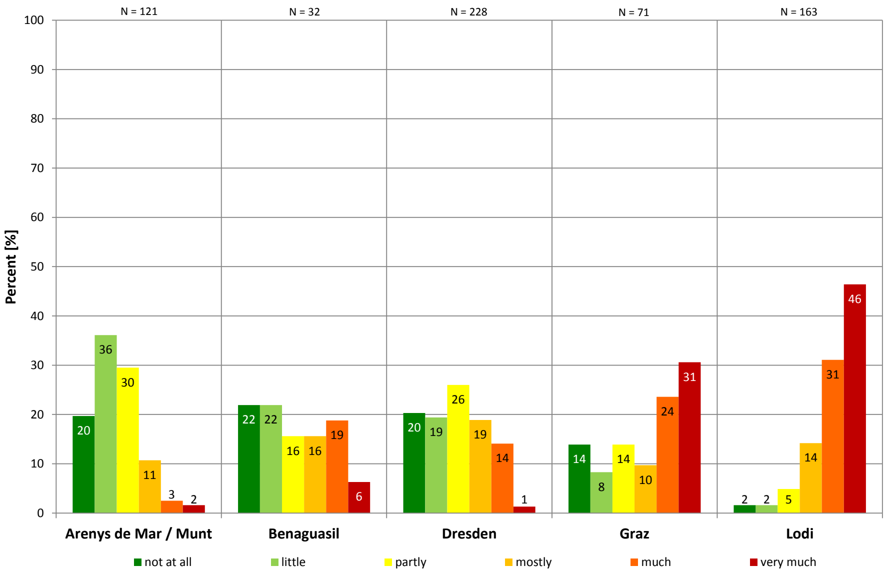

Figure 2-12: Q3 – To what extent do you feel threatened by **floods**?

Q3: Threat by hail
The results show that hail is hardly a topic in Spain. Most worried about hail are the people in Italy, followed by Austria. Dresden lies in the middle of all case studies.

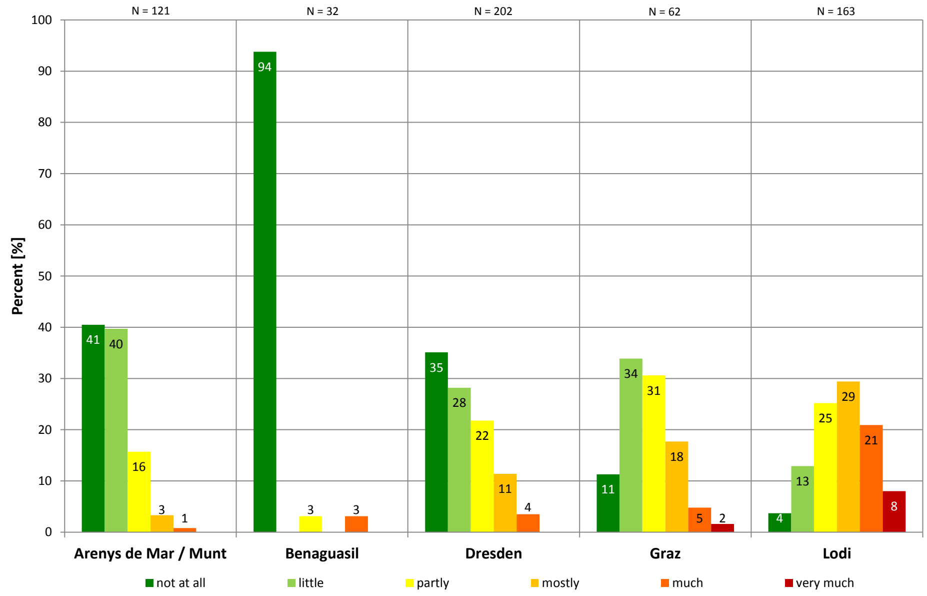

Figure 2-13: Q3 – To what extent do you feel threatened by **hail**?

Q3: Threat by land slides
The results show that most of the people in all case studies are not or little afraid of land slides.

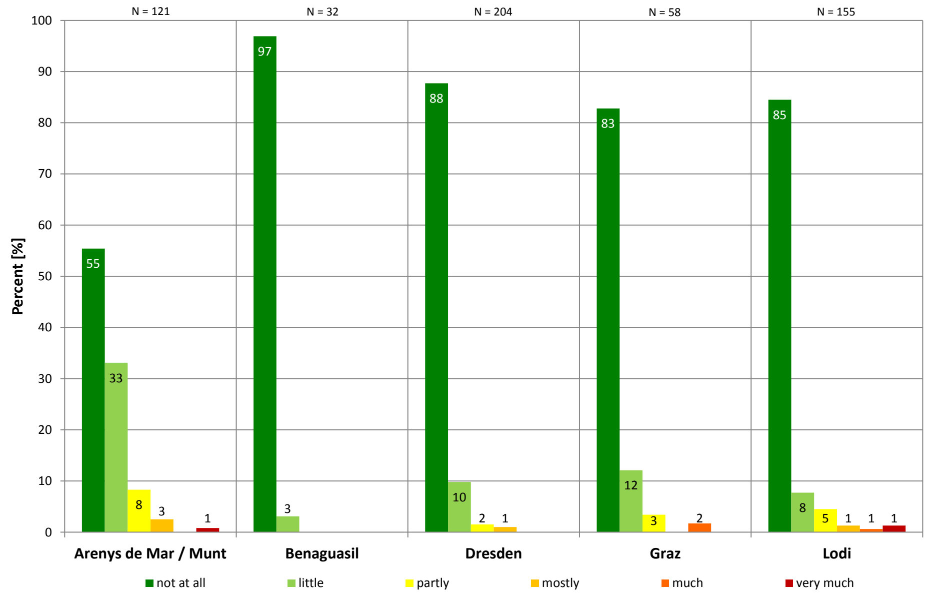

Figure 2-14: Q3 – To what extent do you feel threatened by **land slides**?

Q3: Threat by earthquakes

The results show that most of the people in all case studies are not or little afraid of earthquakes. The only exception is Lodi, where 7% are very much, 8% are much and 21% feel mostly threatened by earthquakes.

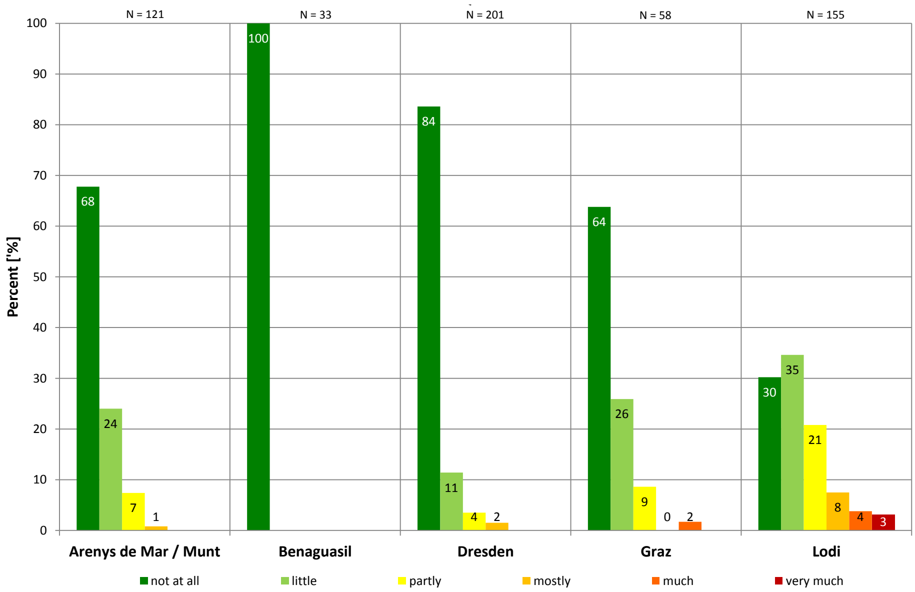

Figure 2-15: Q3 – To what extend do you feel threatened by **earthquakes**?

Q4: Flood risk - personally

The results show that the people in Benaguasil (44%), Graz (45%) and Lodi (54%) think that the flood risk for them personally is much or great. Especially in Lodi 37% stated that the flood risk is great. It has to be noticed that the percentage of people in Benaguasil (41%) and Graz (40%) who think that the flood risk is little or rather small is nearly the same as the percentage who think the risk is much or great. In Dresden 61% think that the risk is little or rather small, and only 11% that it's much or great. For 71% of the people in Arenys de Mar / Munt the risk is little or rather small.

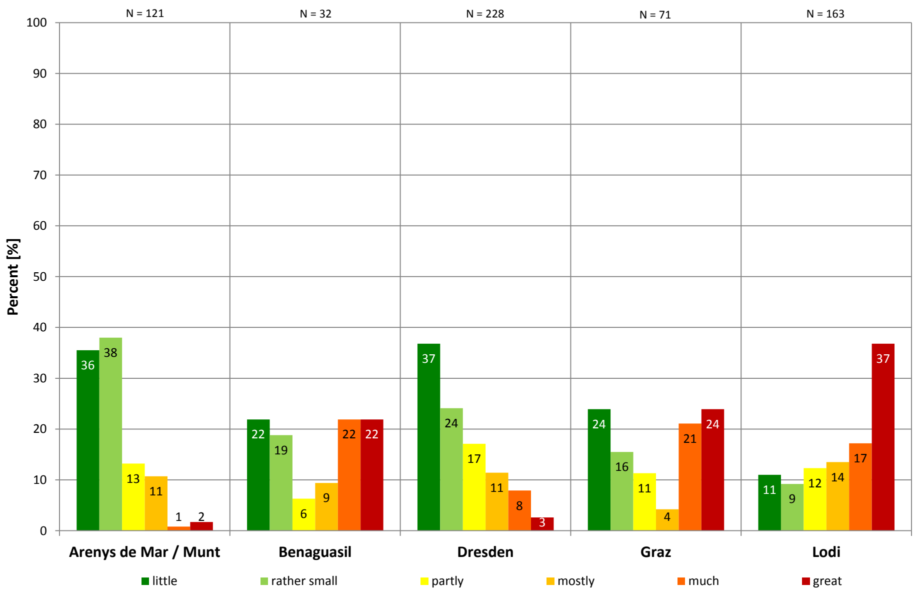

Figure 2-16: Q4 – How would you rate the flood risk **personally**?

Q4: Flood risk – inhabitants of the house

The results show similar results as for the personally flood risk.

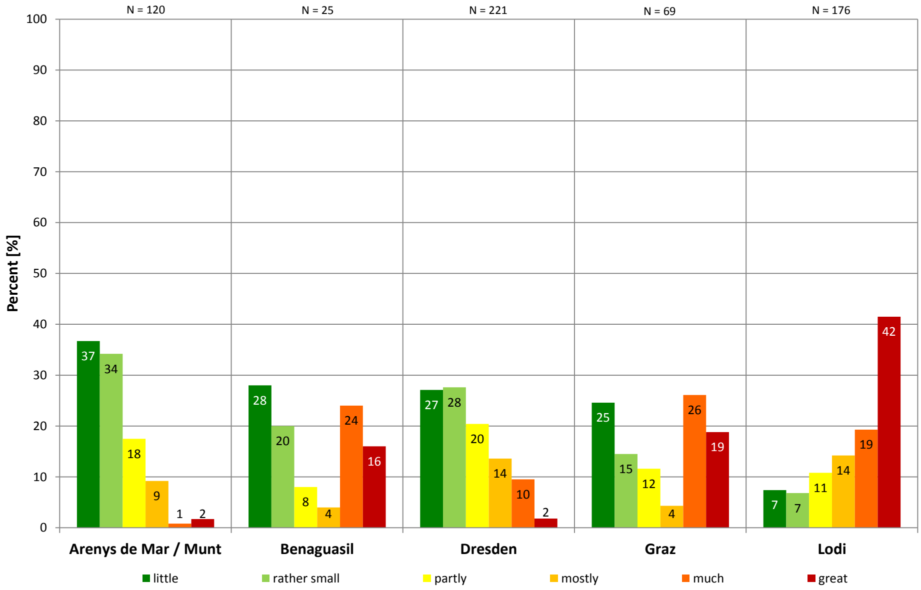

Figure 2-17: Q4 – How would you rate the flood risk for inhabitants of **your house**?

Q4: Flood risk – inhabitants of neighborhood

The results show for all case studies that the flood risk is higher assessed than the personal risk respectively the risk of inhabitants of the same house. Only in Lodi this risk is evaluated a little bit lower.

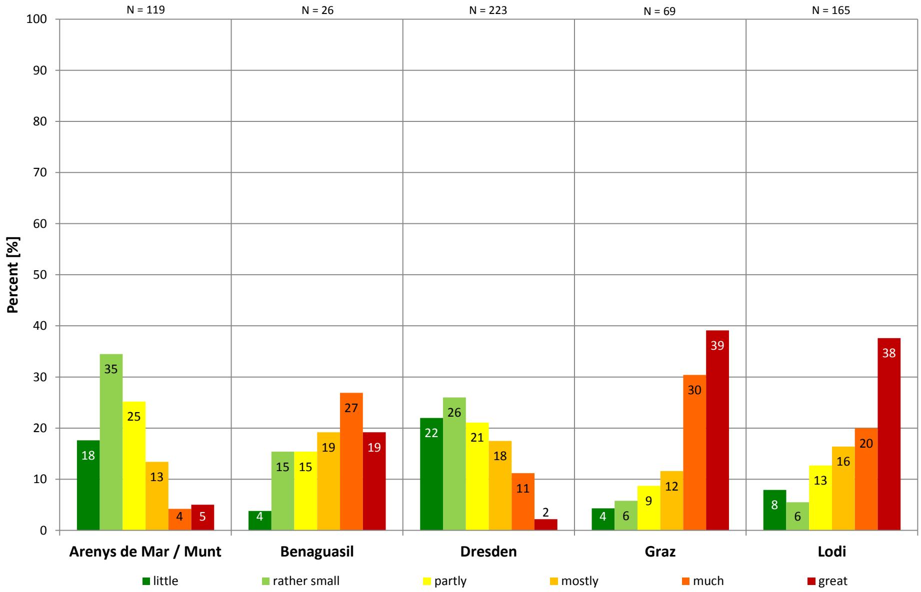

Figure 2-18: Q4 – How would you rate the flood risk for inhabitants of **your neighborhood**?

Q4: Flood risk – whole city

The results show for all case studies that the flooding risk for the whole city is rated more as middle high. Here also the tendency remains that in Lodi people rate the flood risk higher.

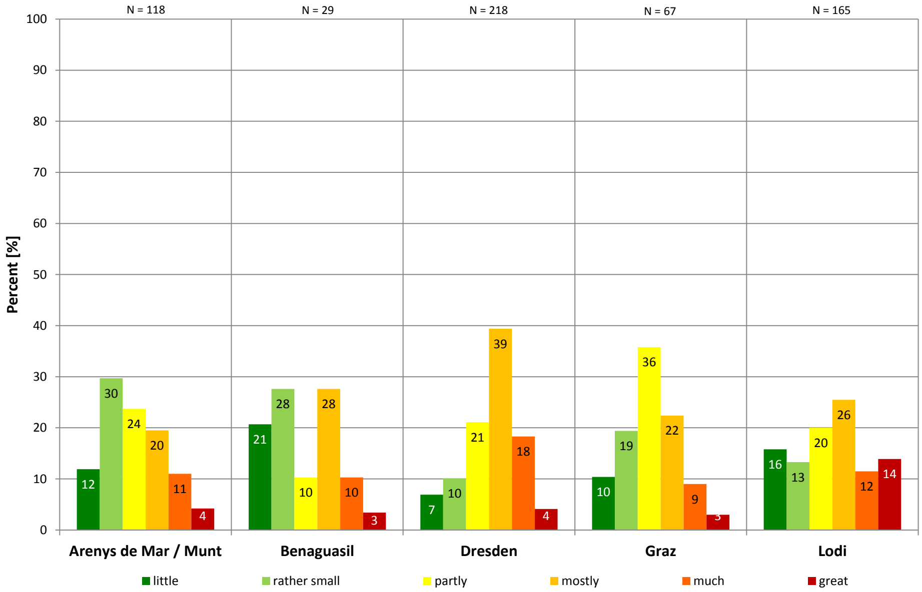

Figure 2-19: Q4 – How would you rate the flood risk for inhabitants of the **whole city**?

Q5: Personal knowledge about floods

The results show that especially people in Arenys de Mar / Munt think their knowledge about floods is very bad (5%), mostly bad (32%) respectively somewhat bad (44%). In all other case studies a weight of the graphs to the right side can be observed, which means they have a better knowledge. Even if it must be remarked, that in Benaguasil and Lodi around 10% think their knowledge is very bad. In Graz 59% stated a mostly good or very good knowledge.

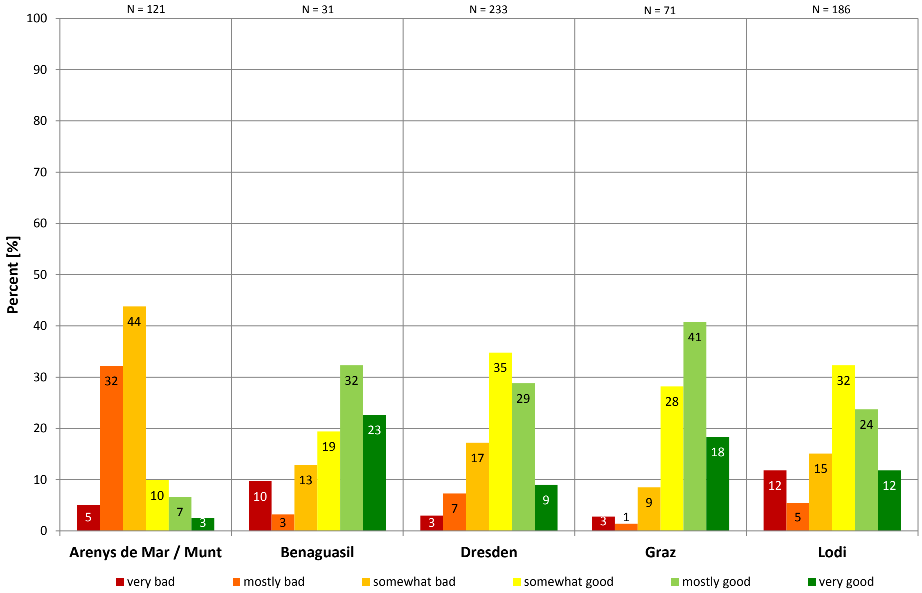

Figure 2-20: Q5 – How would you rate your personal knowledge about floods and their causes?

Q6: Causes of flood events – climate change

For people in Benaguasil climate change is with 82% not the reason for the floodings in their city. Also the people in Arenys de Mar / Munt attribute not so much attention to this topic (34% does not apply, 24% mostly does not apply). In Dresden a slightly tendency torwards climate change as reason for flooding can be observed. In Graz the opinion between those who think there is a relation and those who don't think so is relatively balanced. In Lodi most of the people (35% applies, 22% mostly applies) think that the flooding in their area are influenced by climate change.

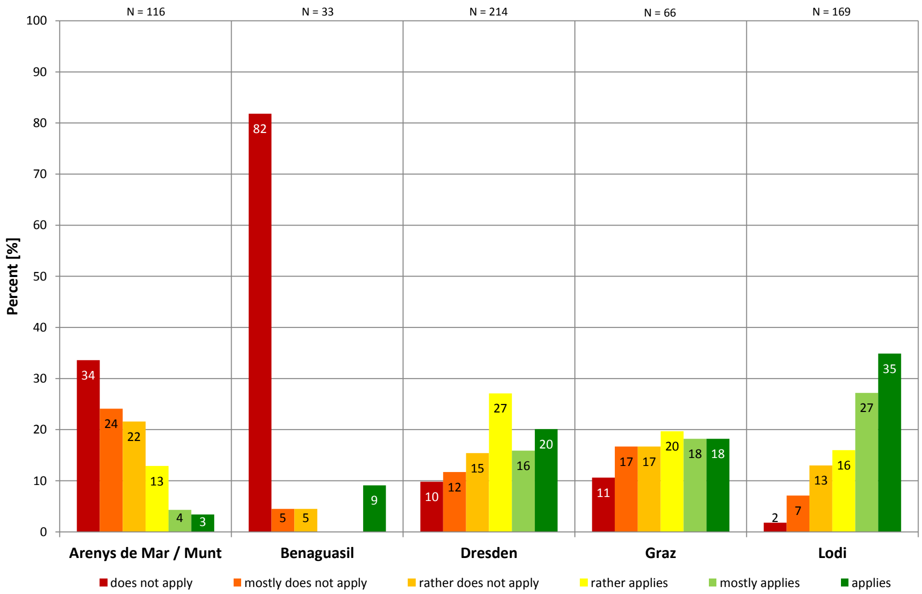

Figure 2-21: Q6 – What would you suppose are the causes of flood events – climate change?

Q6: Causes of flood events – high building density

It is obviously that people in Graz think this is one of the most important reasons for the flood events in Graz (59% applies, 23% mostly applies), followed by Dresden (23% applies, 24% mostly applies). But in Dresden also 25% state that this does not respectively mostly does not apply. In Lodi the ratio between those pro and against this reason is quite balanced with a small benefit of those who don't agree. This ratio is in Arenys de Mar / Munt much stronger. Here 29% indicated that the high building density does not apply respectively 21% mostly does not apply. In Benaguasil 44% of the citizen are of the opinion that this does not apply, 26% that it applies, respectively 16% that it mostly applies.

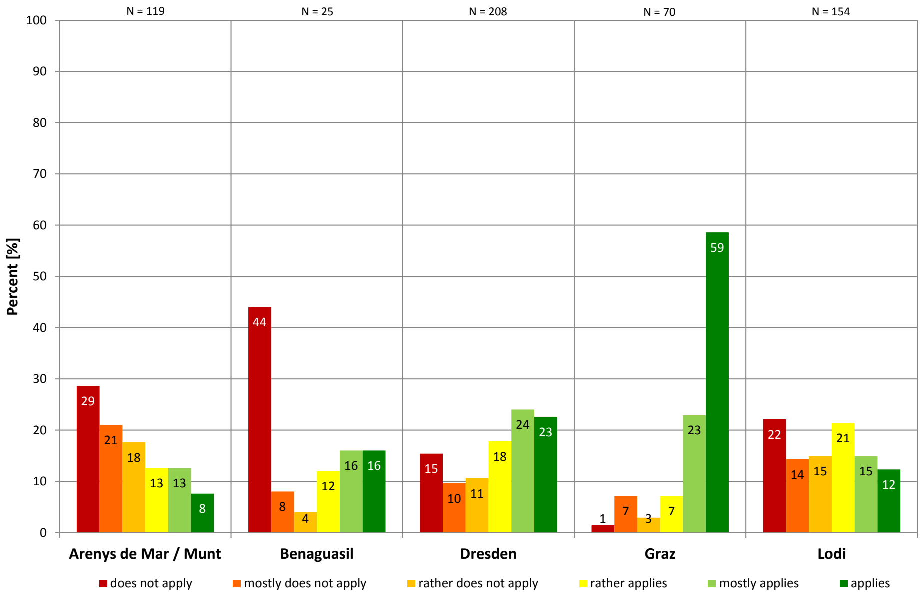

Figure 2-22: Q6 – What would you suppose are the causes of flood events – high building density?

Q6: Causes of flood events – soil sealing

In Arenys de Mar / Munt 48% of the people believe that soil sealing is not or mostly not responsible for the flood events. Also in Benaguasil the number of those who think that it's not the cause is with 42% quite high. Although 25% stated that soil sealing is the cause of flooding. In all other case studies soil sealing is more assumed to be the cause, wheras in Graz more than 74% of the people think that this applies or mostly applies.

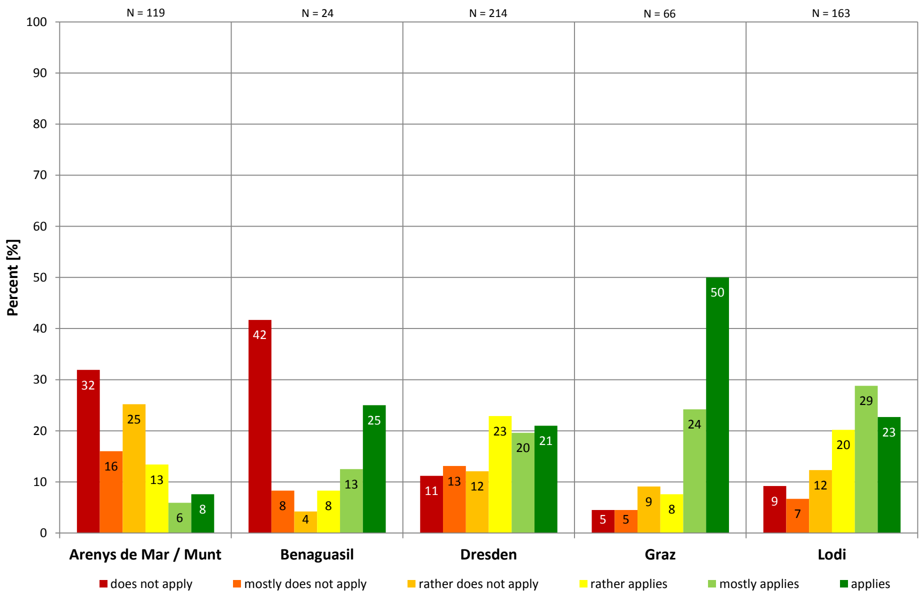

Figure 2-23: Q6 – What would you suppose are the causes of flood events – soil sealing?

Q6: Causes of flood events – extreme weather conditions

In all case studies, with exception of Arenys de Mar / Munt, the majority of the respondents believe that extreme weather conditions are the cause of flood events.

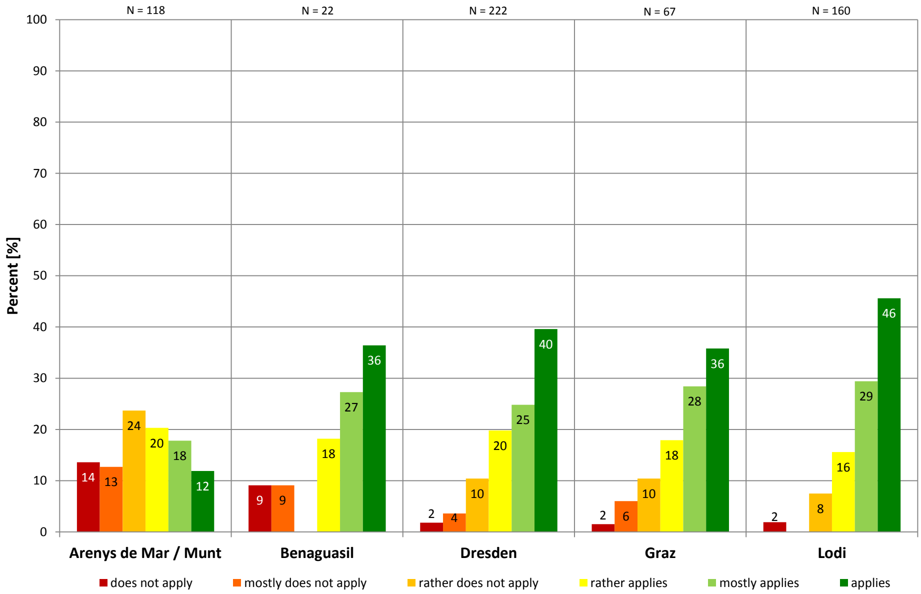

Figure 2-24: Q6 – What would you suppose are the causes of flood events – extreme weather conditions?

Q6: Causes of flood events – non-natural interferences

Again, the people in Spain have a different opinion regarding the relation between floods and non-natural interferences. In Benaguasil 81% of the interviewed people think that this does not apply. In Arenys de Mar / Munt the percentage is much lower, but this tendency is also visible. Mainly in Lodi, but also in Graz and Dresden a high percentage agrees that there is a relationship.

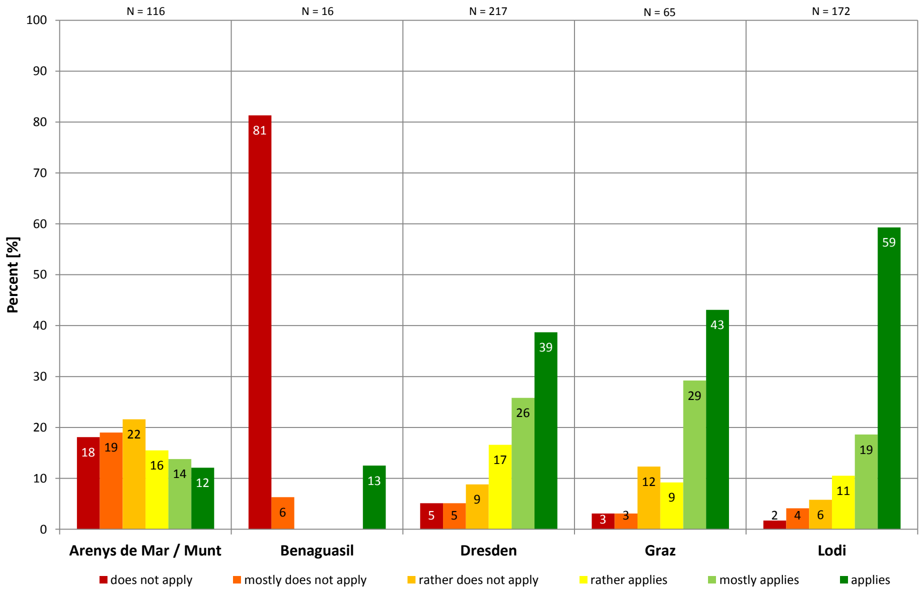

Figure 2-25: Q6 – What would you suppose are the causes of flood events – non-natural interferences?

Q6: Causes of flood events – sewer construction

The citizens in Benaguasil are aware of the problem, that they have an undersized sewer system in their city. 63% indicated that this is the cause of flood events. In the other case studies a tendency torwards the assumption that this is one of the causes can be observed. Only in Dresden 19% think that this does not apply respectively 16% that it mostly does not apply.

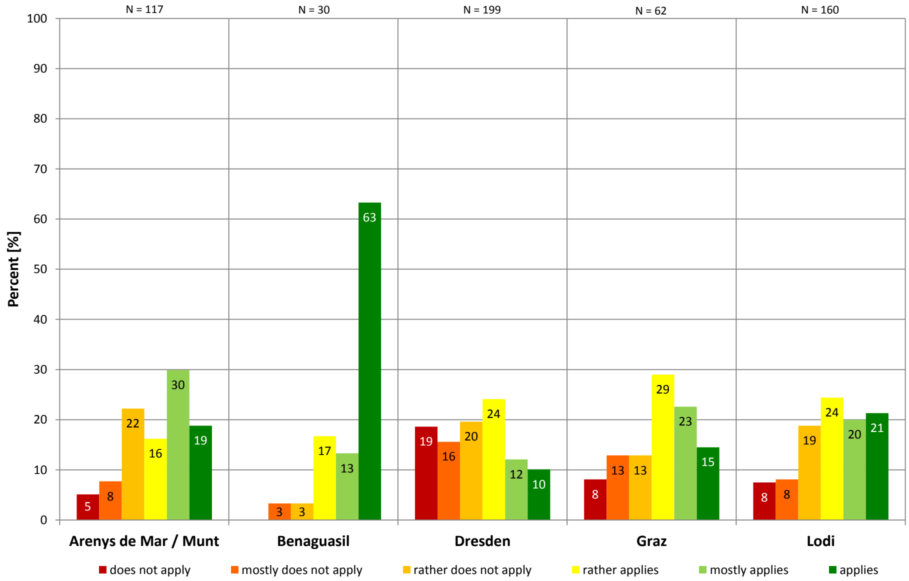

Figure 2-26: Q6 – What would you suppose are the causes of flood events – sewer construction?

Q6: Causes of flood events – spatial planning

In Lodi (60% applies or mostly applies) and in Graz (68% applies or mostly applies) spatial planning is assumed to have a high influence on flood events. In Arenys de Mar / Munt 57% also believe in this cause, whereas 28% don't. In Dresden no clear tendency is visible. And in Benaguasil the relation between those who have the opinion that this does not apply is 36% : 32% who think this is one cause.

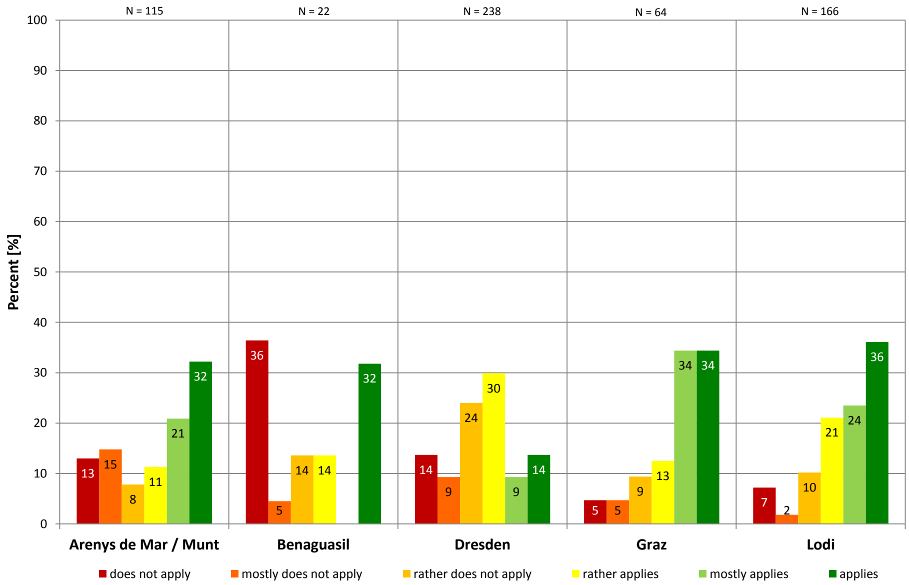

Figure 2-27: Q6 – What would you suppose are the causes of flood events – spatial planning?

Q7: Causes of flood events – spatial planning

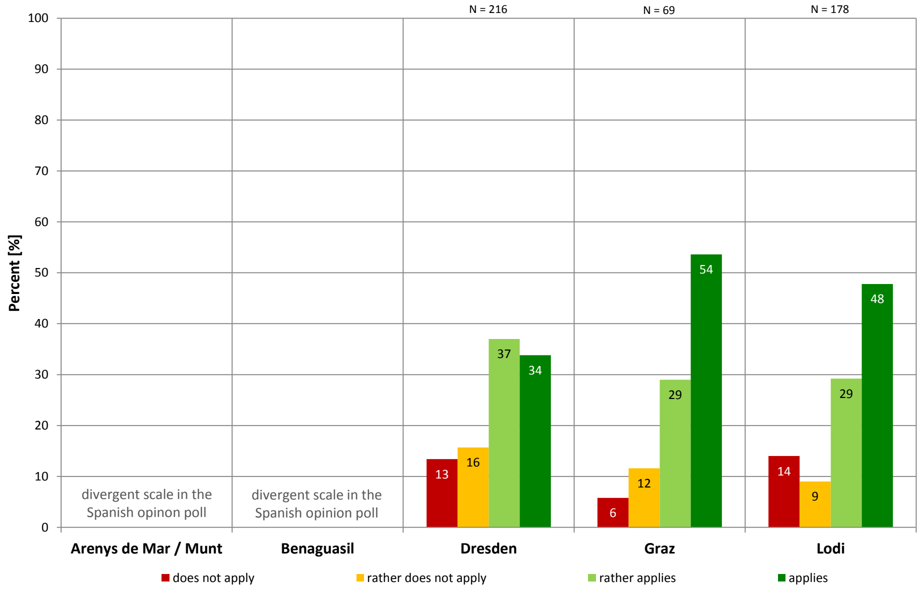

Figure 2-28: Q7 – With flood control measures my neighborhood can be protected sufficiently.

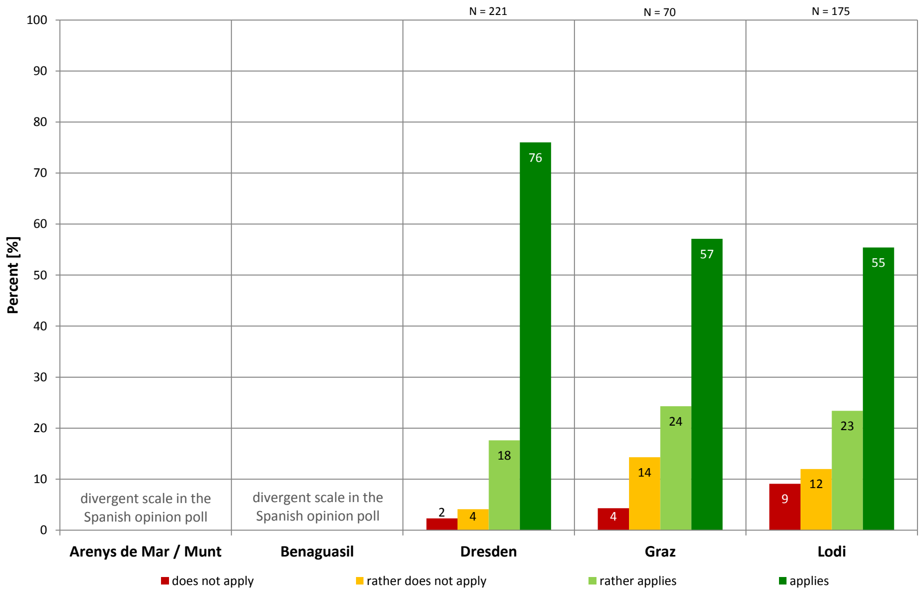

Figure 2-29: Q7 – Man cannot control nature entirely.

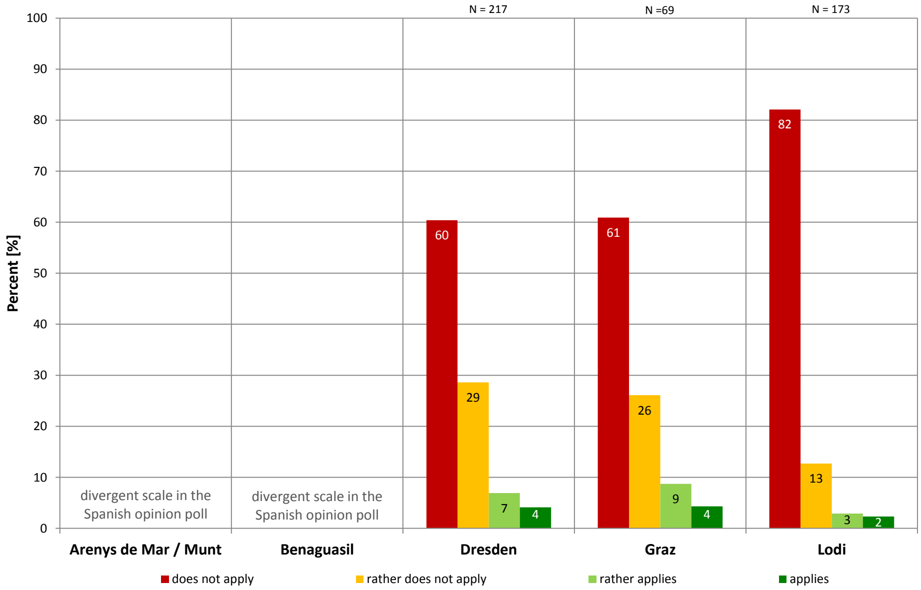

Figure 2-30: Q7 – One can protect oneself from floods completely.

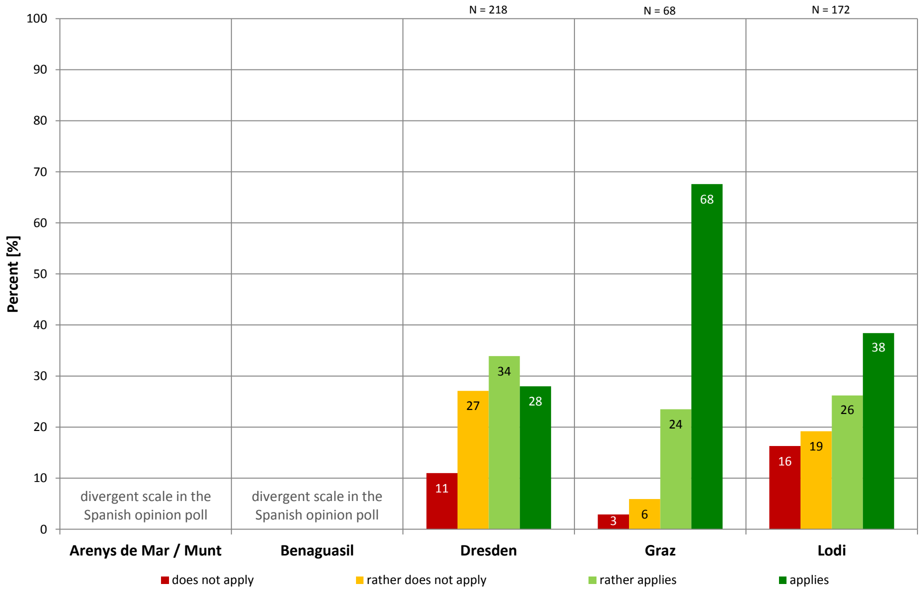

Figure 2-31: Q7 – Flood risk has increased due to a higher housing density.

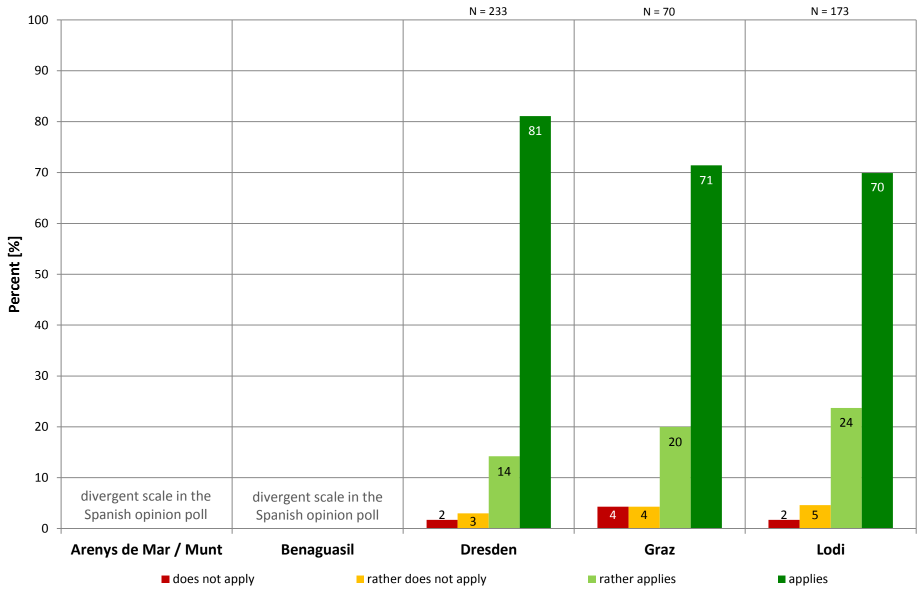

Figure 2-32: Q7 – There remains always a residual risk with natural hazards.

Q8: Measures in order to reduce flood risk – early warning

In Arenys de Mar / Munt 76%, in Dresden 73% and in Lodi 62% are of the opinion that early warning is most reasonable or reasonable to reduce flood risk. In Graz 46% of the people think so, but here the number of those who are in the opinion it's reasonable is with 28% higher. In Benaguasil the same interesting tendency could be observed. 40% believe early warning is most reasonable but at the same time 47% that is least reasonable.

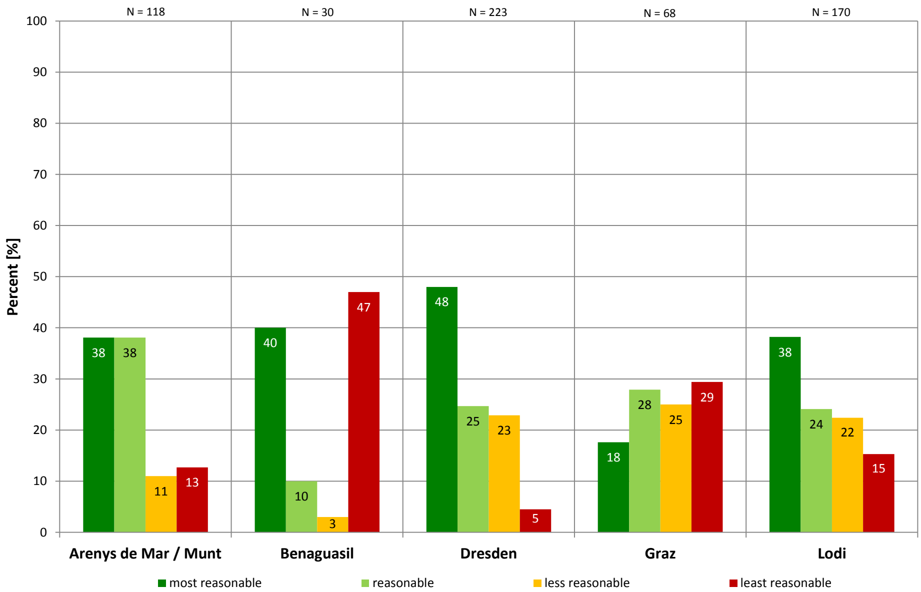

Figure 2-33: Q8 – Which of the following measures do you consider reasonable in order to reduce flood risk – early warning?

Q8: Measures in order to reduce flood risk – self-protection
In the Spanish case studies self-protection is assigned more sensuousness, e.g. Benaguasil and Arenys de Mar / Munt 69% most reasonable or reasonable. In Benaguasil at the same 24% stated self-protection as least reasonable. In Dresden 47% of the interviewed people think that it's least reasonable. In Graz and Lodi the opinions are more in the middle field reasonable or less reasonable.

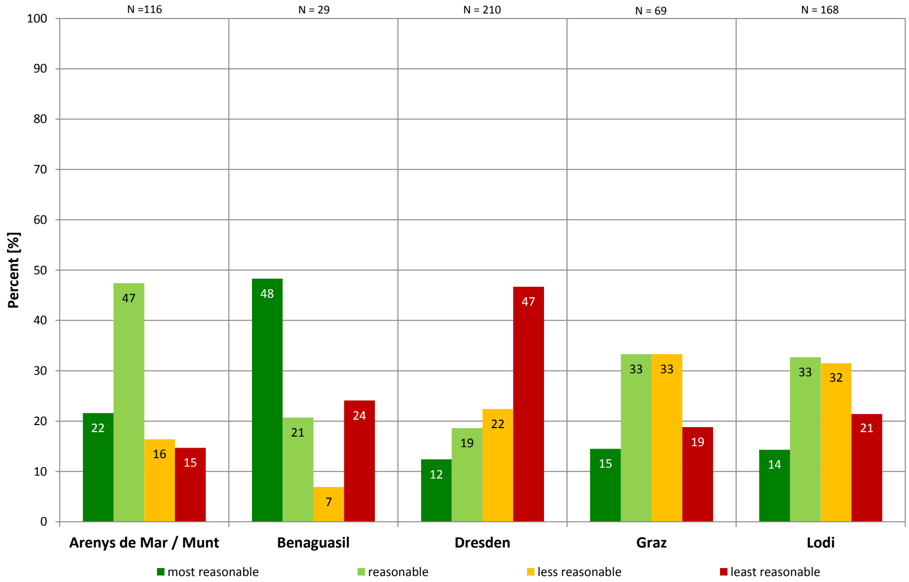

Figure 2-34: Q8 – Which of the following measures do you consider reasonable in order to reduce flood risk – self-protection?

Q8: Measures in order to reduce flood risk – protective structures
In all case studies the tendency is clear. Protective structures are considered as most reasonable or reasonably by the majority of the respondents. Due to a too low number of answers an analysis was no possible for Benaguasil.

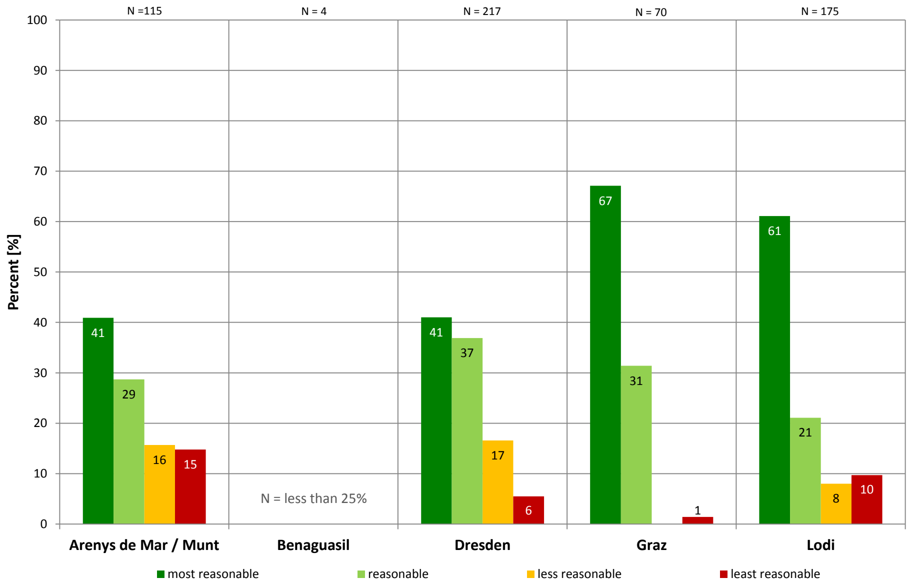

Figure 2-35: Q8 – Which of the following measures do you consider reasonable in order to reduce flood risk – protective structures?

Q8: Measures in order to reduce flood risk – nature orientated watercourses

In the case studies Dresden, Graz and Lodi the tendency is clear. Nature orientated watercourses are considered as most reasonable by a majority of the respondents (>47%). In Arenys de Mar / Munt 58% believe that it's less or least reasonable. Due to a too low number of answers an analysis was no possible for Benaguasil.

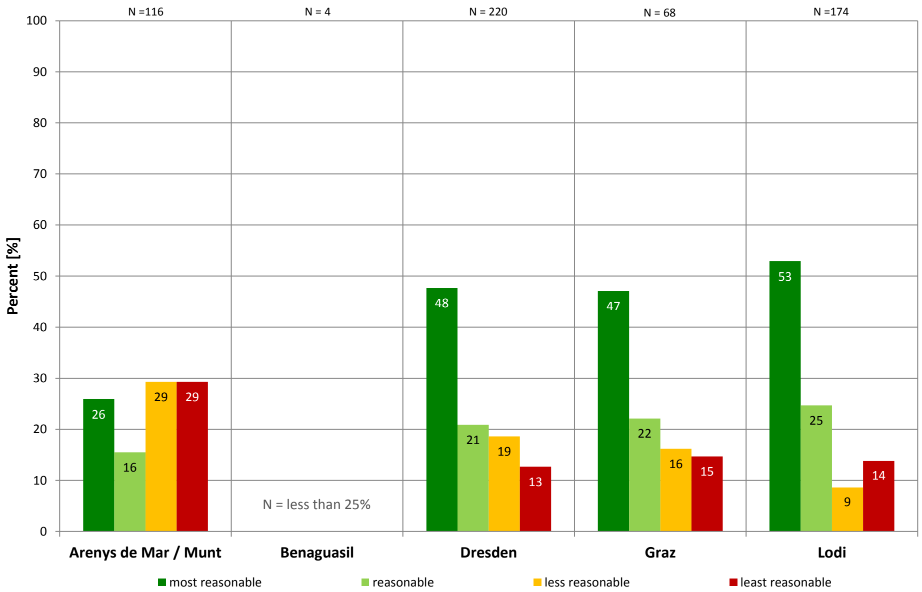

Figure 2-36: Q8 – Which of the following measures do you consider reasonable in order to reduce flood risk – nature orientated watercourses?

Q9: Present feasibility of flood forecast in your district

It is obviously that the percentage of those who think the flood forecast is very good is very low (between 2 – 10%) in all case studies. In Lodi the present feasibility of flood forecast is rated very bad. In Graz only 3% are the opinion that the flood forecast is very good. The remaining answers are relatively equal distributed with around 20% between very bad, mostly bad, somewhat bad, somewhat good and mostly good. In Benaguasil 35% of the interviewed people have indicated that it's mostly good, followed by 24% with somewhat good. In Arenys de Mar / Munt the majority with 42% think it's somewhat good and 24% it's mostly good.

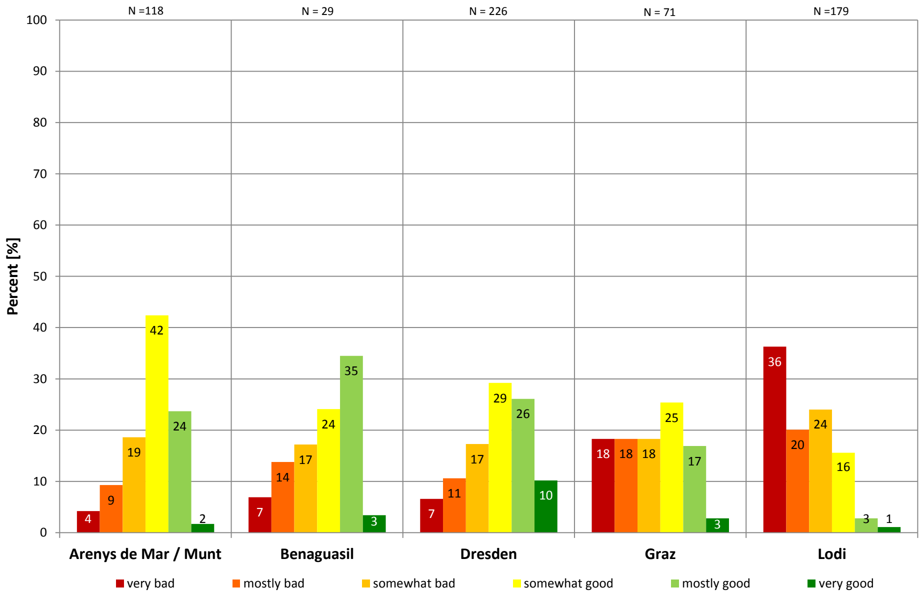

Figure 2-37: Q9 – How would you rate the present feasibility of flood forecast in your district?

Q10: Affected by floods

Nearly 2/3 of the interviewed people have been affected by floods in their present household during the last 10 years. The highest percentage occurs in Lodi with 86%. The only exception is Arenys de Mar / Munt, where only 7% have been affected. This has to be taken into consideration in the following analysis and interpretation of the results.

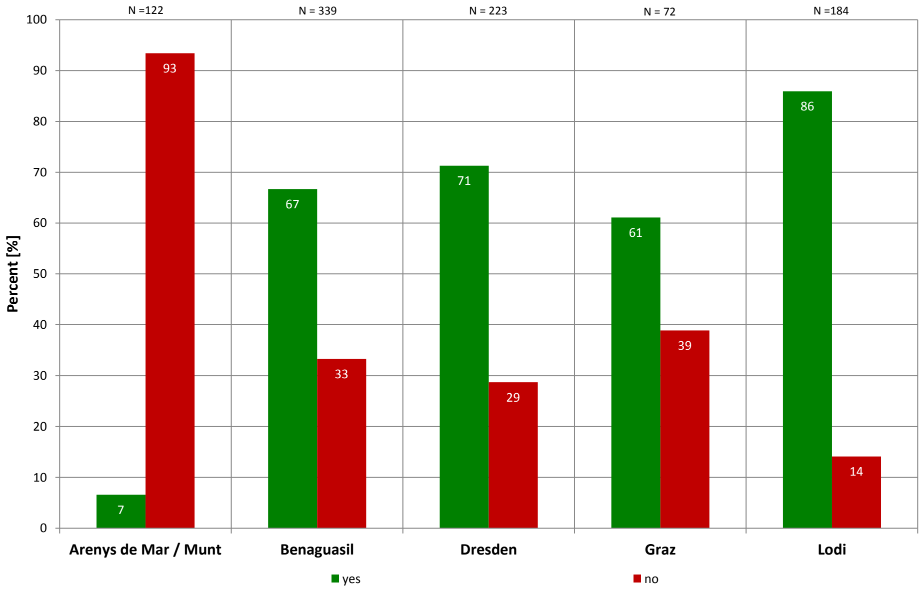

Figure 2-38: Q10 – Have you been affected by floods in your present household during the last 10 years?

Q11: Frequency of affectedness by floods

In Benaguasil the citizens have been affected by floods very often. 40% stated that they have been affected more than 5 times. Also in Graz the frequency is quite high. 16% stated they have been affected more than five times and 10% five times, 7% four times, 19% three times and 31% twice. In Dresden and Lodi there was in each case one flood event, where the majority of the people have been affected (Dresden 94%, Lodi 87%). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

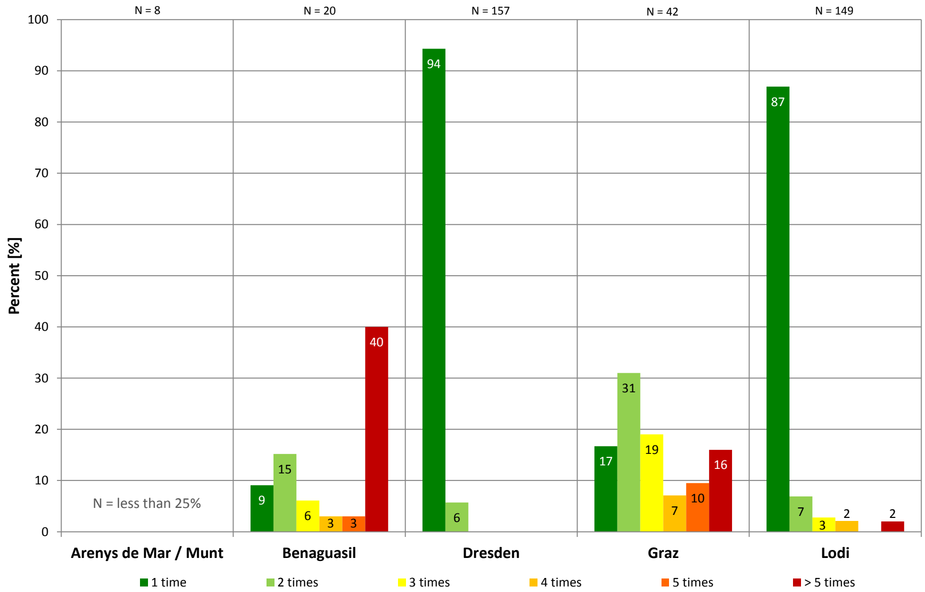

Figure 2-39: Q11 – In case you have: How often have you been affected by floods in this period?

Q13: Personal damage – material and financial causalities

Most personal damage regarding material and financial causalities occurred in Lodi, where 36% indicated they have suffered from massive damage, 26% great and 21% rather great. Only 2% didn't have any material or financial causalities. In Graz the number of those who had no damage is the highest with 33%. But also here occurred massive (14%) and great (7%) damages. In Dresden the majority with 36% stated that they suffered from rather great damage. In Benaguasil the types of damage vary from non (14%) to great (29%). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

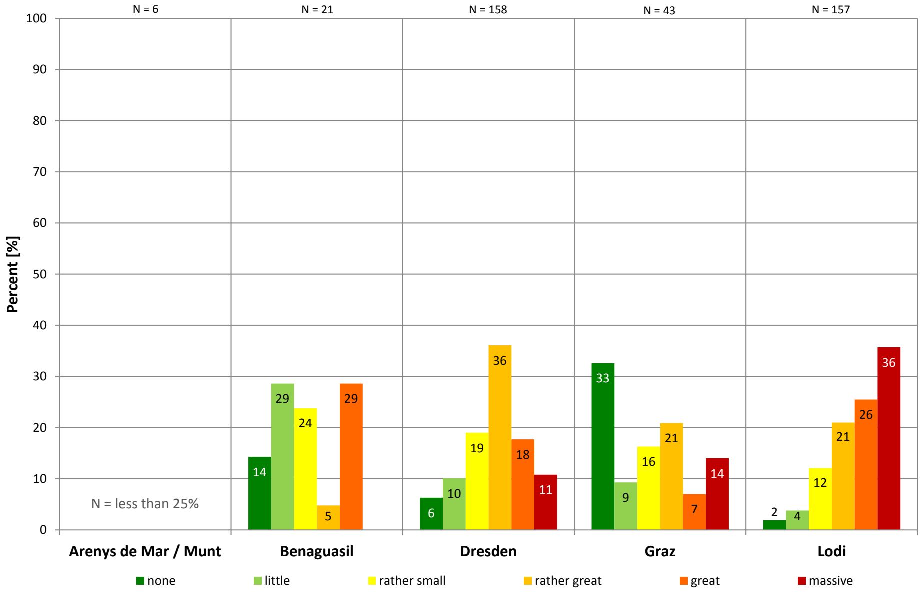

Figure 2-40: Q13 – How would you rate the personal damage you suffered from the last flood – material and financial causalities?

Q13, Q14: Personal damage – health problems

In Benaguasil no one had any health problems after the flood events. In Dresden 75% and in Graz 66% stated, that they had no health problems. The number of those who had great or massive health problems is very low with 3% respectively 7%. In Lodi the floodings had more influence on the health of the interviewed persons. Here only 31% indicated they had no health problems. The most indicated types of health problems in all case studies are panic attacks/axiety states, insomnia, irritability/anger and restlessness (see Figure 2-42, p. 28 to Figure 2-52, p. 33). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

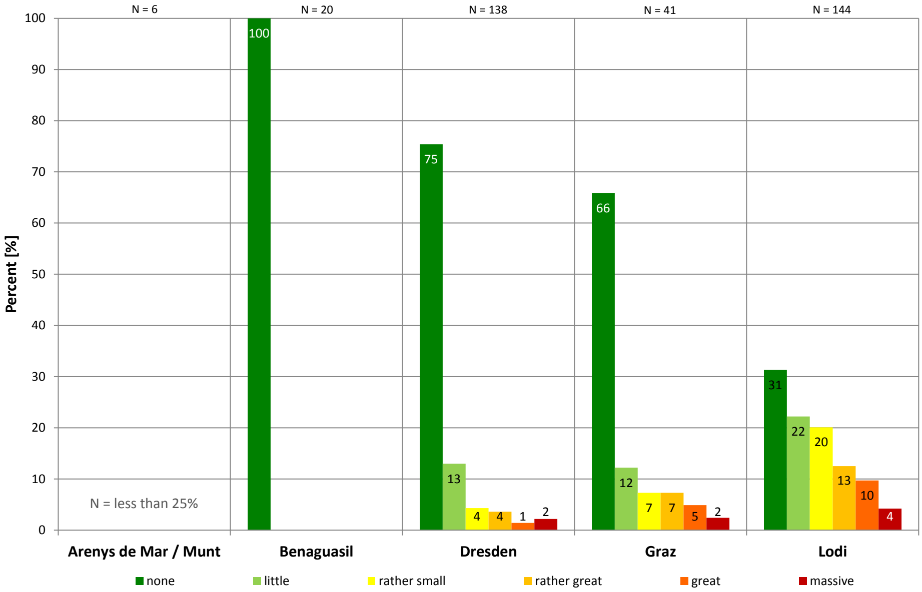

Figure 2-41: Q13 – How would you rate the personal damage you suffered from the last flood – health problems?

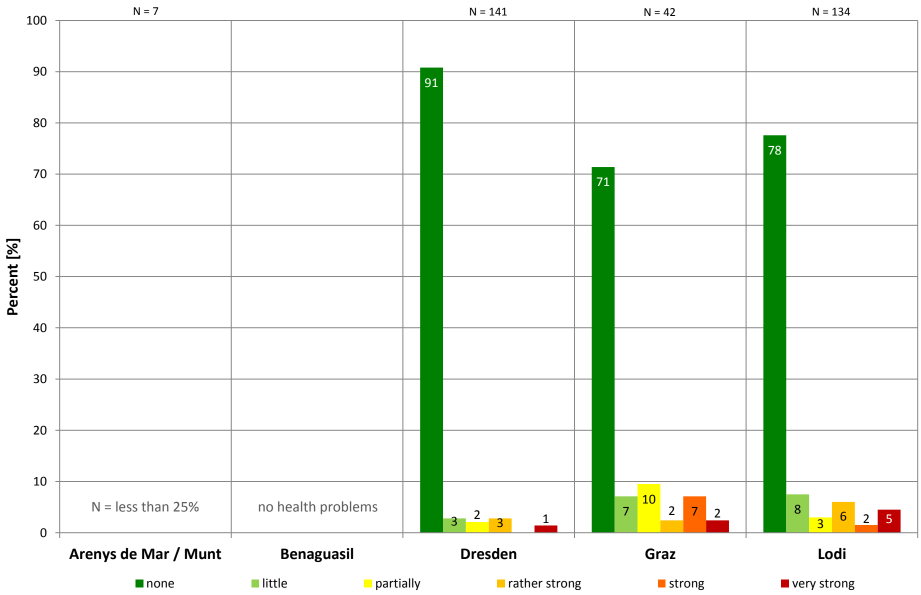

Figure 2-42: Q14 – Have you suffered from any headache due to the flood event?

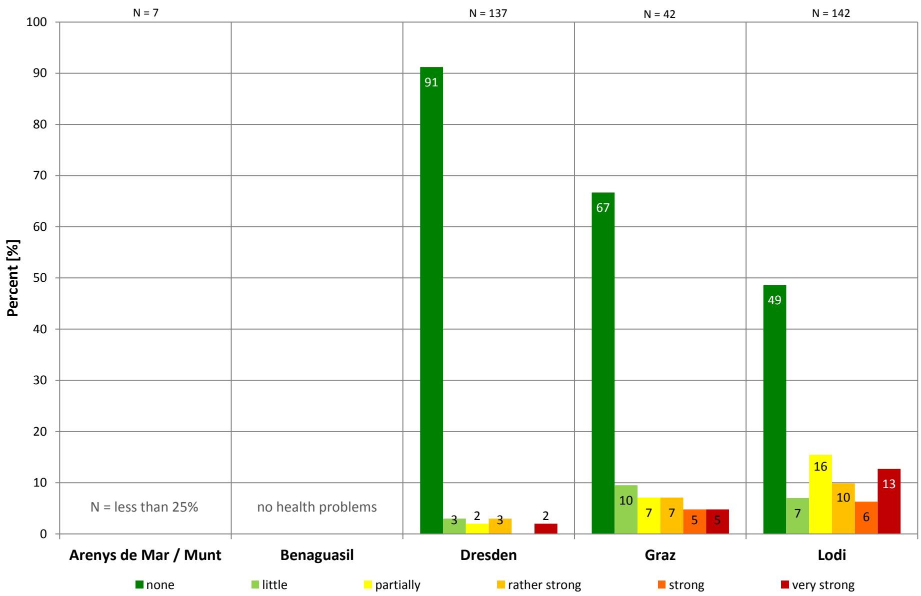

Figure 2-43: Q14 – Have you suffered from any joint pains or aching limbs due to the flood event?

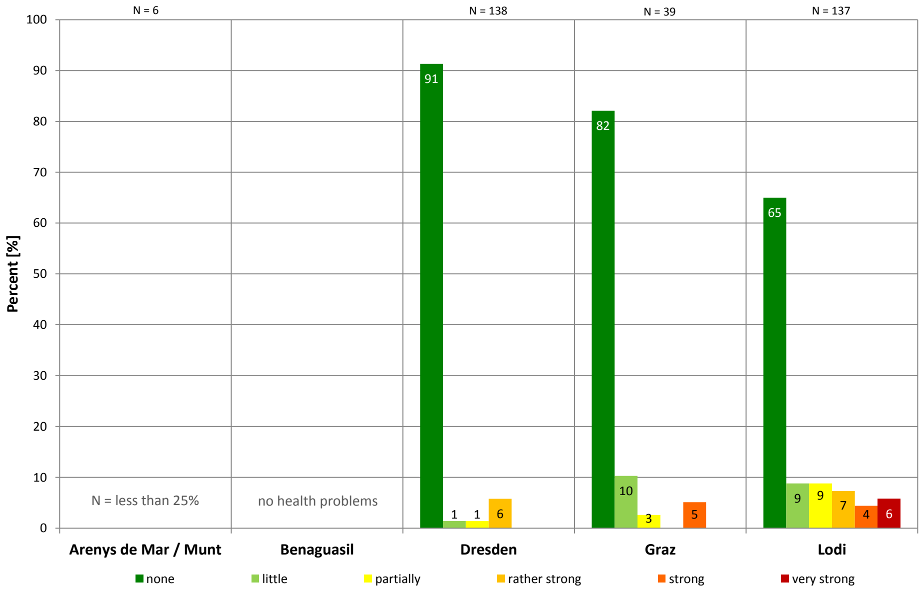

Figure 2-44: Q14 – Have you suffered from any gastrointestinal complaints due to the flood event?

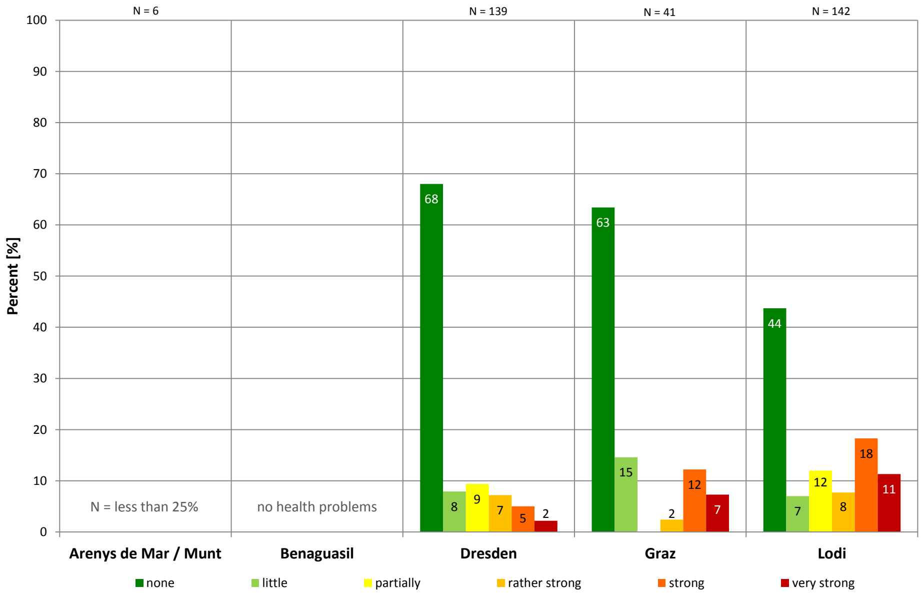

Figure 2-45: Q14 – Have you suffered from any panic attacks or axiety states due to the flood event?

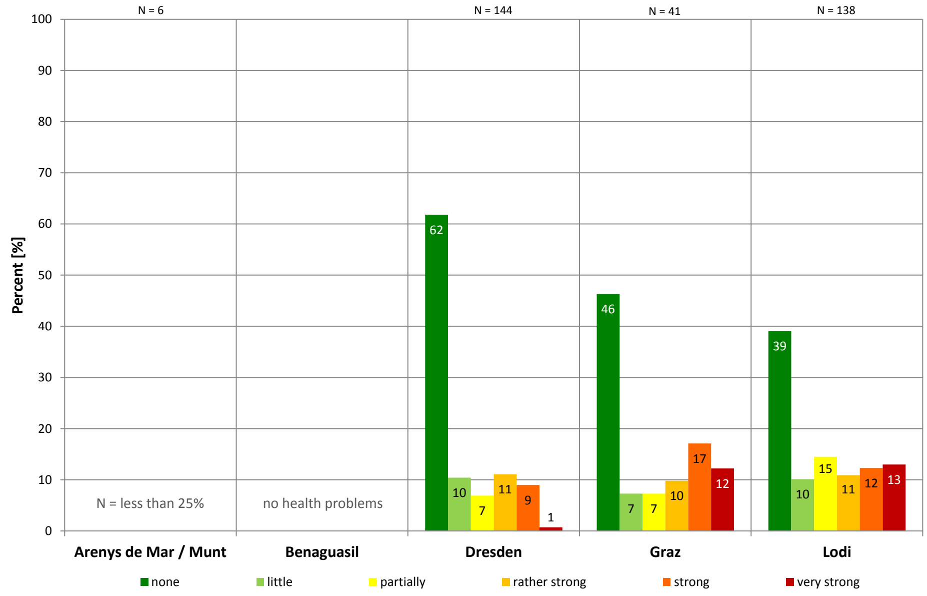

Figure 2-46: Q14 – Have you suffered from any insomnia due to the flood event?

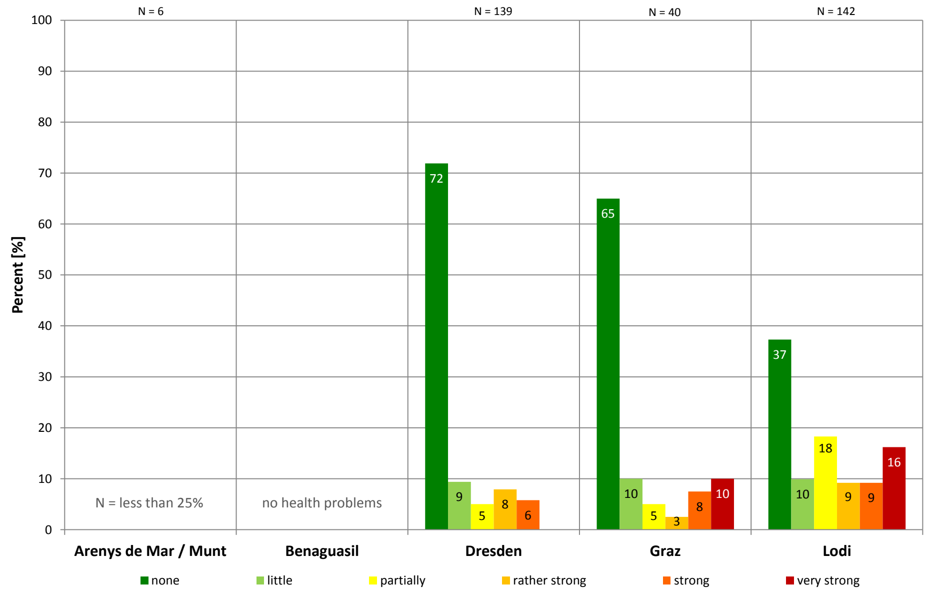

Figure 2-47: Q14 – Have you suffered from any irritability or anger due to the flood event?

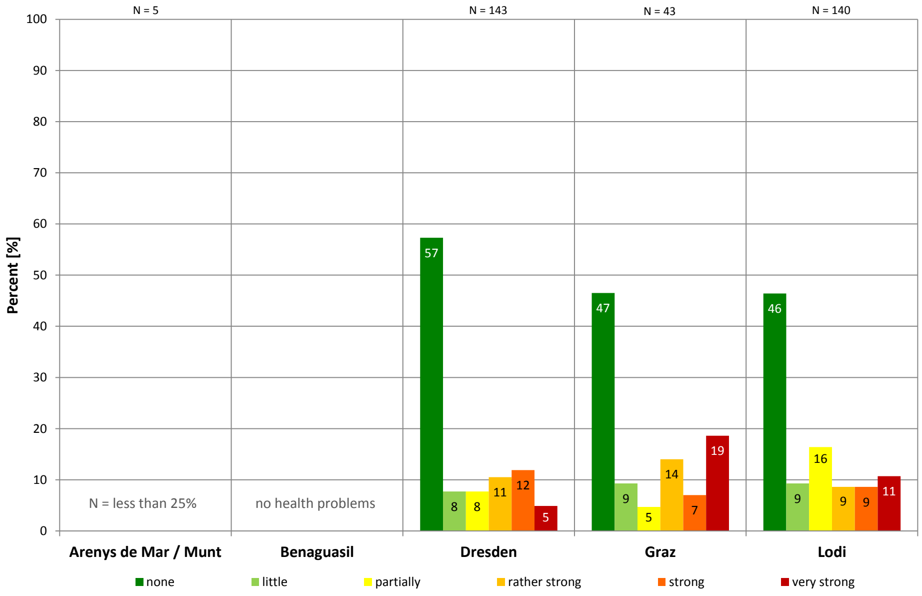

Figure 2-48: Q14 – Have you suffered from any restlessness due to the flood event?

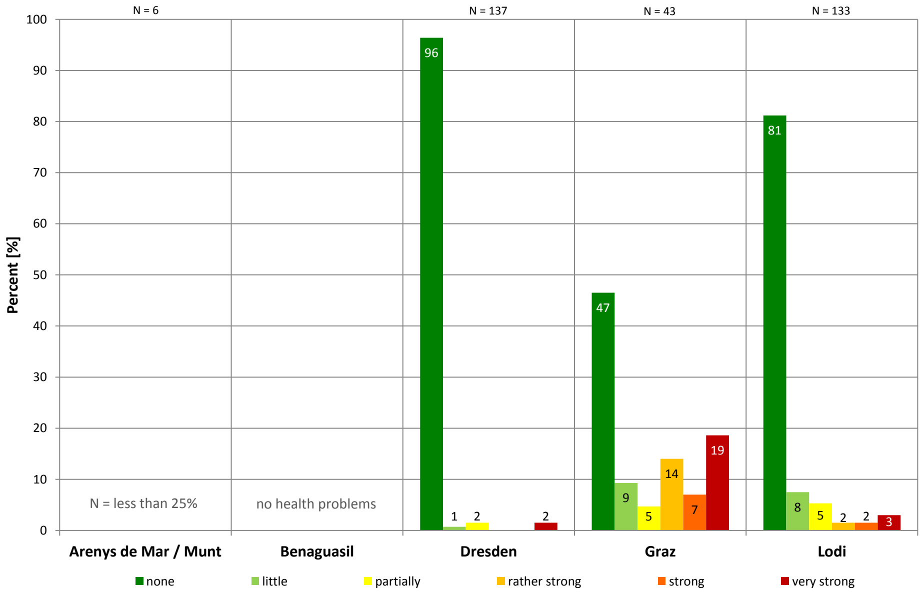

Figure 2-49: Q14 – Have you suffered from any breathing difficulties due to the flood event?

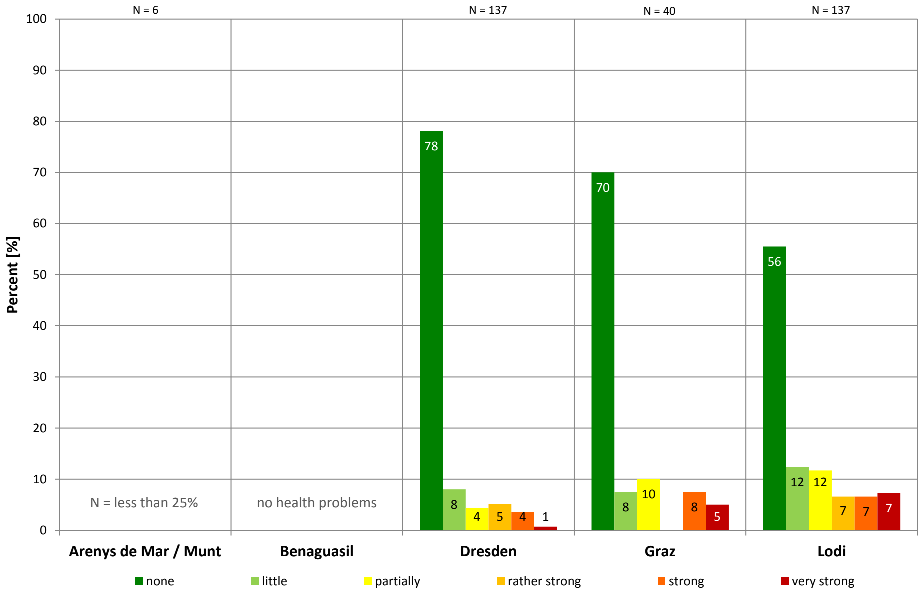

Figure 2-50: Q14 – Have you suffered from any quick exhaustion / fatigue due to the flood event?

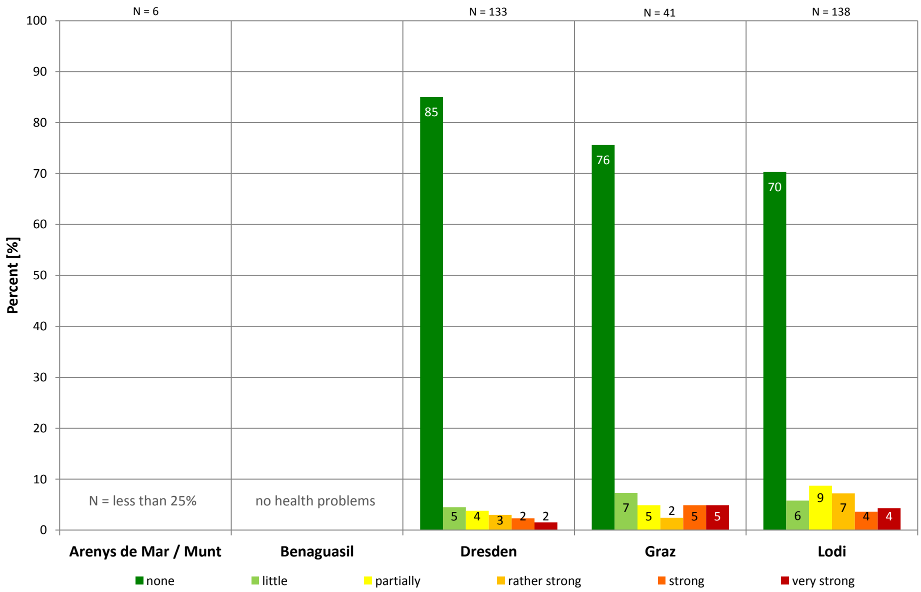

Figure 2-51: Q14 – Have you suffered from any loss of motivation due to the flood event?

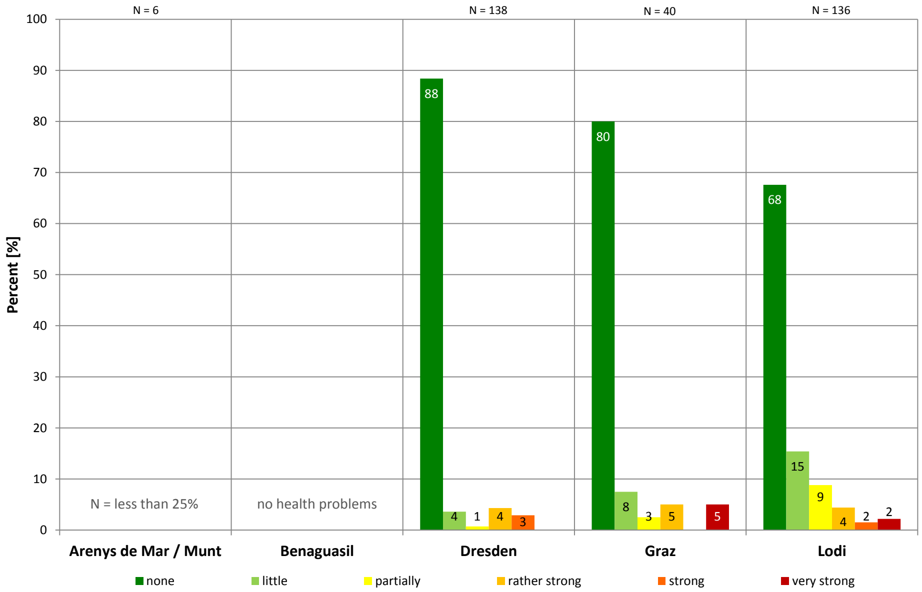

Figure 2-52: Q14 – Have you suffered from any attention difficulties due to the flood event?

Q15: Personal damage – physical impairments

Only a small number of the interviewed persons had suffered from any physical impairments (Dresden 4%, Graz 12%, Lodi 3%) respectively in Benaguasil none of them had any problems with that. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

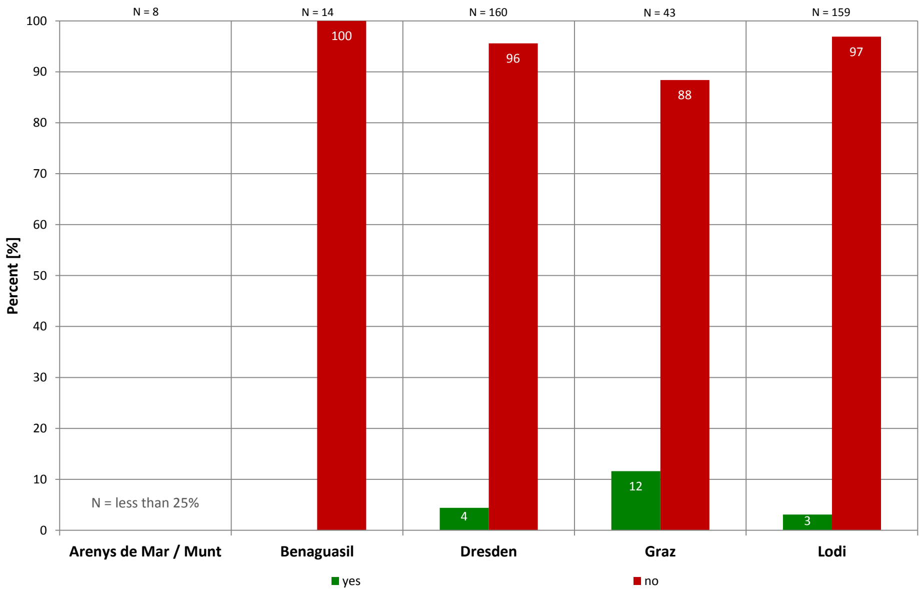

Figure 2-53: Q15 – Have you suffered from any physical impairments due to the flood event (bone fracture, etc.)?

Q17: Consultation of a doctor

The results of the Q15 are also reflected by the percentage of those people who needed to go and see a doctor, which is very low with 7% in Dresden, 9% in Graz and Lodi. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

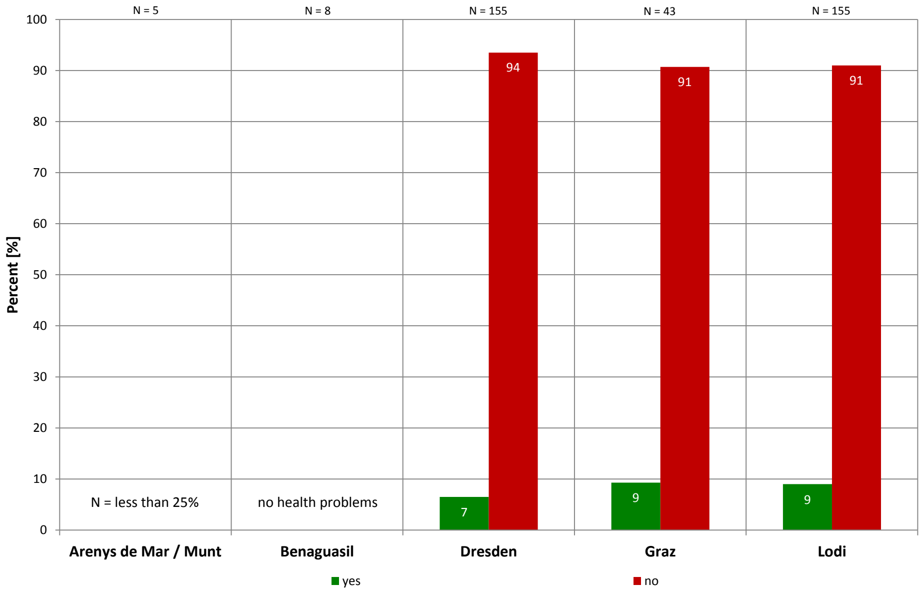

Figure 2-54: Q17 – Was it necessary to see a doctor due to flood events?

Q17: Consultation of a hospital

The results of the Q15 are also reflected by the percentage of those people who needed to go to a hospital, which is very low with 0% in Dresden, 3% in Graz and 2% Lodi. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

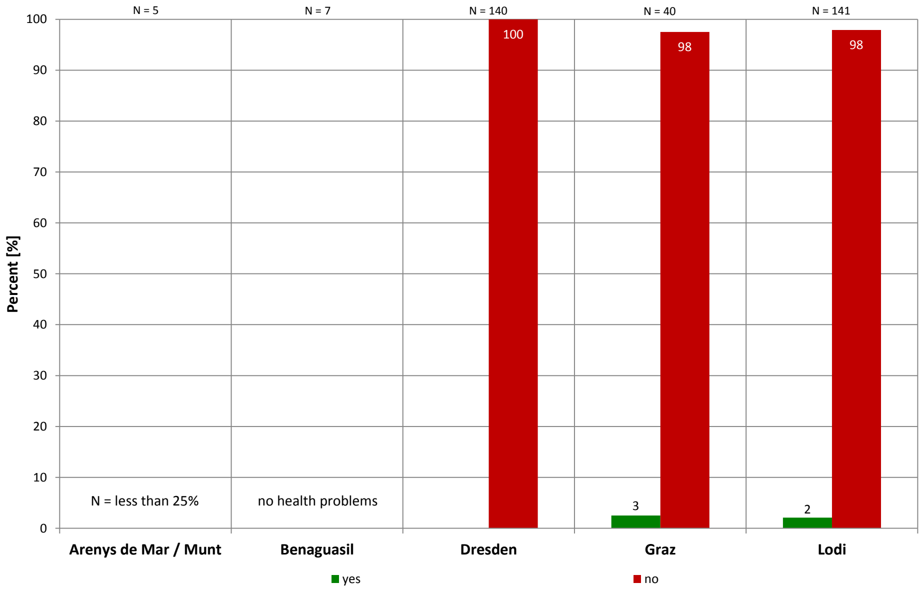

Figure 2-55: Q17 – Was is necessary to go to a hospital due to flood events?

Q21: Awarness of flood risk

The majority (> 55%) of the interviewed people in all case studies stated that they were not aware of the flood risk when they moved to this area. Especially high is this number in Dresden with 90%. In Benaguasil 23% of the citizen knew about the flood risk. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

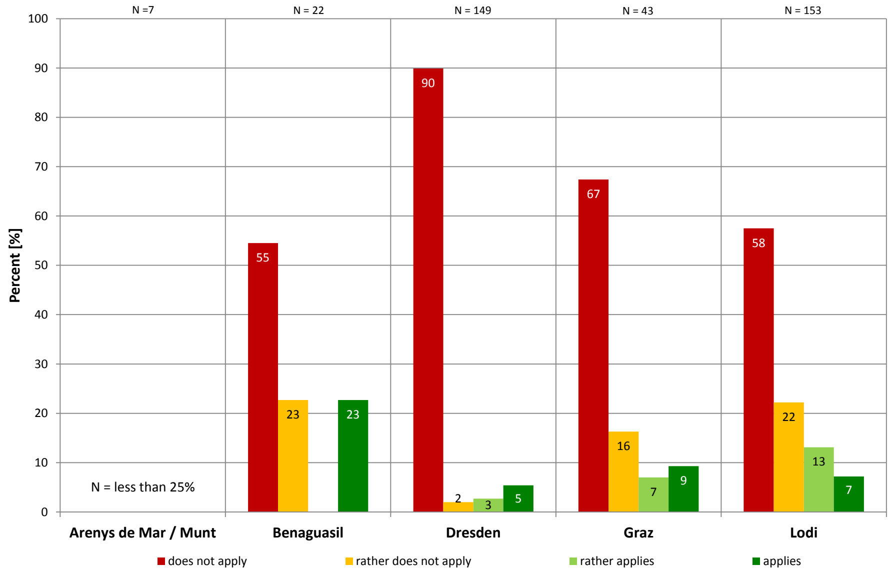

Figure 2-56: Q21 – When I moved to this area I was aware of the flood risk.

Q21: Psychologically coping

The majority (> 61% applies) of the interviewed people in the case studies Benaguasil, Dresden and Graz stated that they have coped psychologically very well with the previous floods. In Lodi this percentage is much lower with 32%. Additionally it has to be said, that in Dresden 16% and in Lodi 11% have indicated the opposite (not very well). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

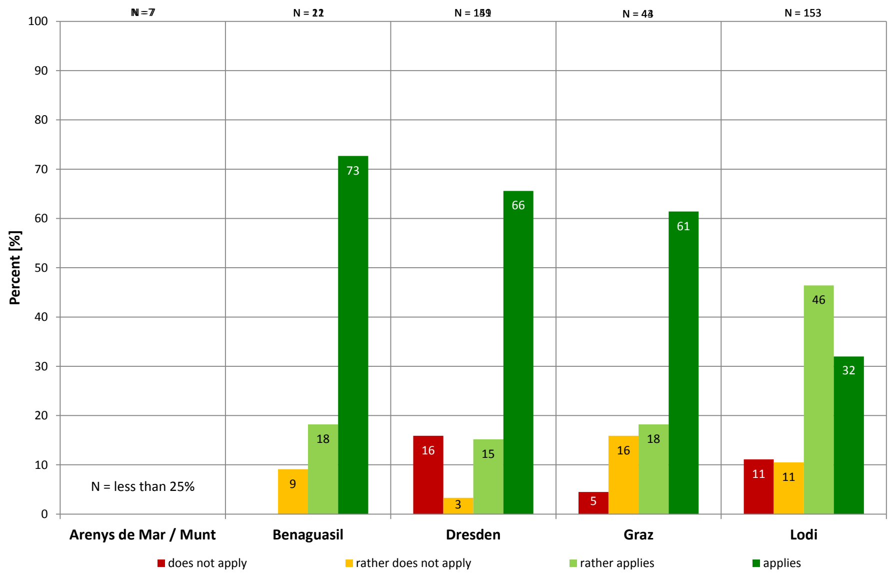

Figure 2-57: Q21 – I have coped psychologically with the previous flood events very well.

Q21: Reminiscence of previously flood events during heavy rain
The percentage of those people who remember previously flood events during heavy rain is very high in Graz (81% applies) and in Lodi (70% applies). Also in Benaguasil and Dresden more than 43% have stated this. But in this case study the number of people who don't remember such events the percentage is 27% (Benaguasil) respectively 25% (Dresden), in comparison Graz: 1%, Lodi 2%. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

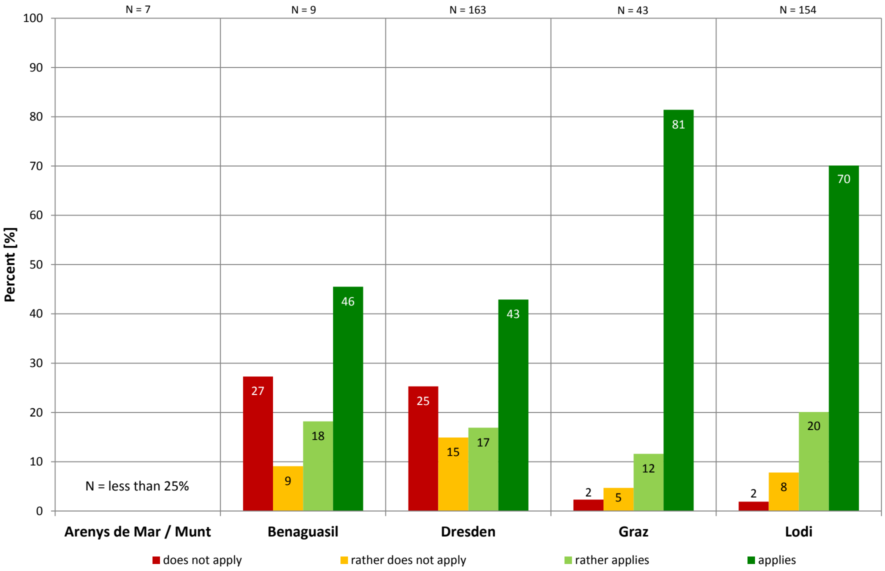

Figure 2-58: Q21 – During heavy rain I remember previously flood events.

Q21: Holiday
The fact that because of the financial burden someone can barely afford a holiday applies only for a small percentage in the case studies Benaguasil, Dresden and Graz (>79% does not apply). In Lodi only 60% indicated this, by contrast for 11% it applies respectively 10% rather applies. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

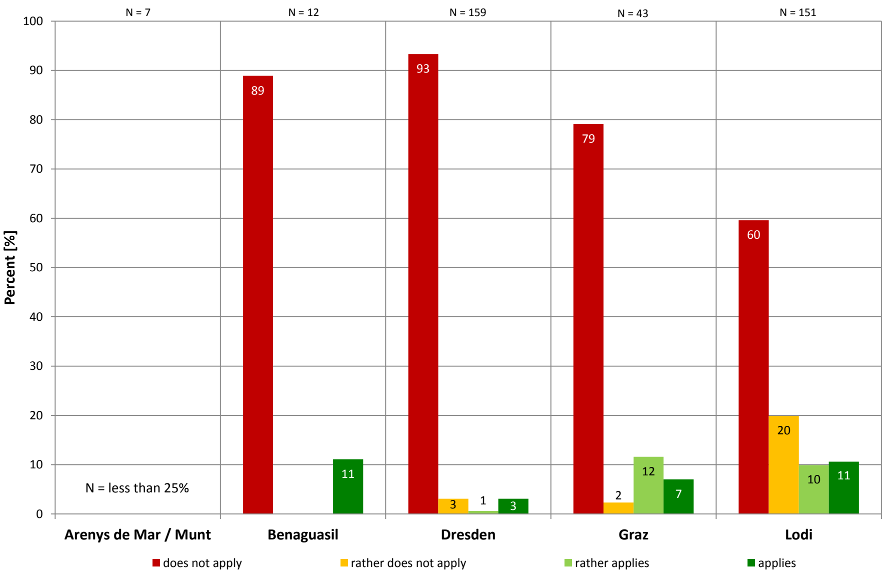

Figure 2-59: Q21 – Because of the financial burden I can barely afford a holiday.

Q21: Reduction quality of life

In each case study the opinions concerning the reduction of the quality of life due to flood risk differ. For the majority of the people in Benaguasil (58%) and in Dresden (54%) there is no reduction of the quality of life. But, by contrast, for 33% in Benaguasil and 36% in Dresden the quality of life is reduced due to it. In Graz and Lodi the opinions are distributed more widely. In Graz for 49% the quality is or rather is reduced and in Lodi the percentage is 63%. For 33% in Graz it is not and in Lodi for 22%. Due to a too low number of answers an analysis was no possible for Arenys de Mar / Munt.

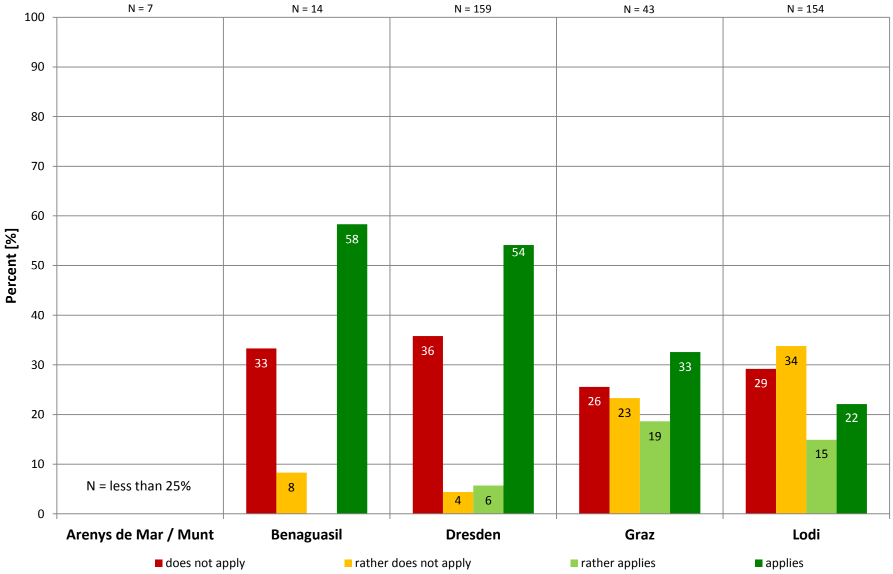

Figure 2-60: Q21 – My quality of life is not reduced by flood risk.

Q21: Move to another neigborhood

Only results for Benaguasil and Graz are available and here the majority(> 72%) stated that they will not move to another neighborhood if flood events happen furthermore. Neverless it's notable, that for 14% of the people in Graz this comes into question.

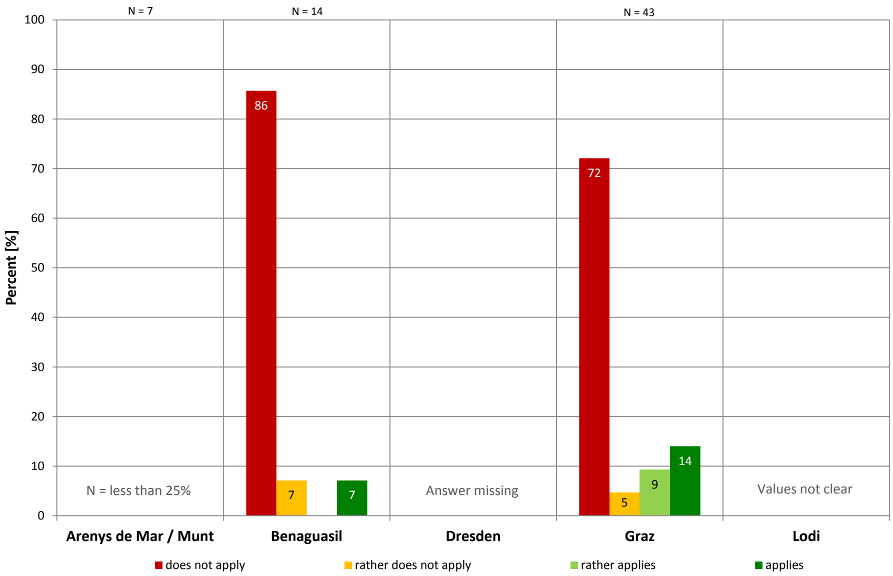

Figure 2-61: Q21 – If flood events happen furthermore I will move to another neighborhood.

2.4 Communication and Information

Q22: Time to need for a flood

The results show, that people in Spain need less time to prepare for a flood than people in the other countries (Arenys de Mar/Munt 47% and Benaguasil 89% less than 2 hours.) Although also in Graz the percentage is with 35% quite high. In Lodi 9% of the interviewed stated to need more than 6 hours and only 7% less than 2 hours.

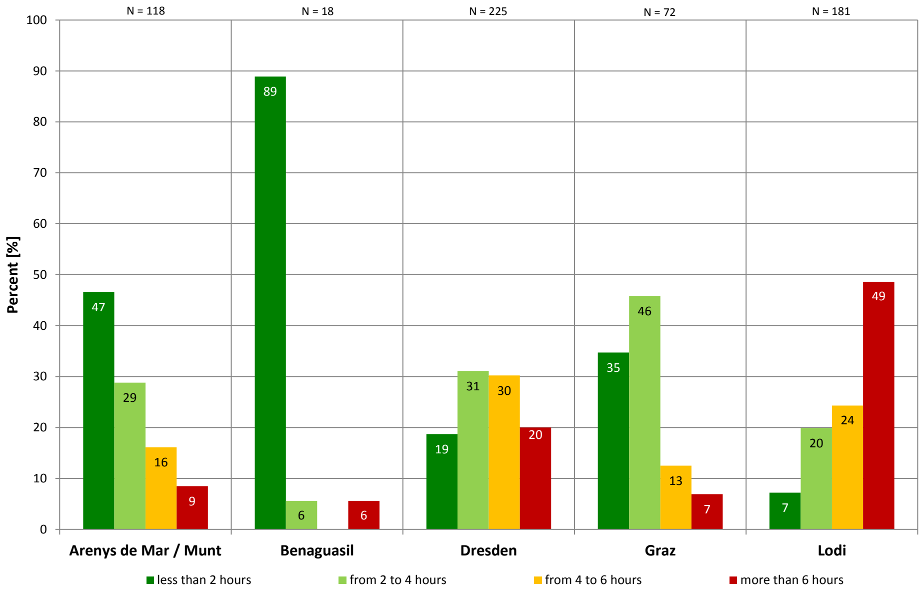

Figure 2-62: Q22 – How much time do you need to prepare sufficiently for a flood?

Q24: How to obtain information about flood in case of emergency

People in all case studies don't like to obtain information about flood in case of emergency by internet (> 69%), by on-site information centre (> 73%), by friends/relatives (> 88%)

All people like to be informed by the media (>58%) with exception of Lodi, where 72% don't want to be informed this way. Information by emergency services are liked by all interviewed people (> 65%), except those in Benaguasil, where 92% stated that they don't like this option.

An information by the community / local council is preferred by the people in Lodi (67%). In Arenys de Mar / Munt the supporter and those who are against it are quite similar with 53% pro and 48% contra. In Benaguasil, Dresden and Graz the citizen don't like to be informed this way (>60%).

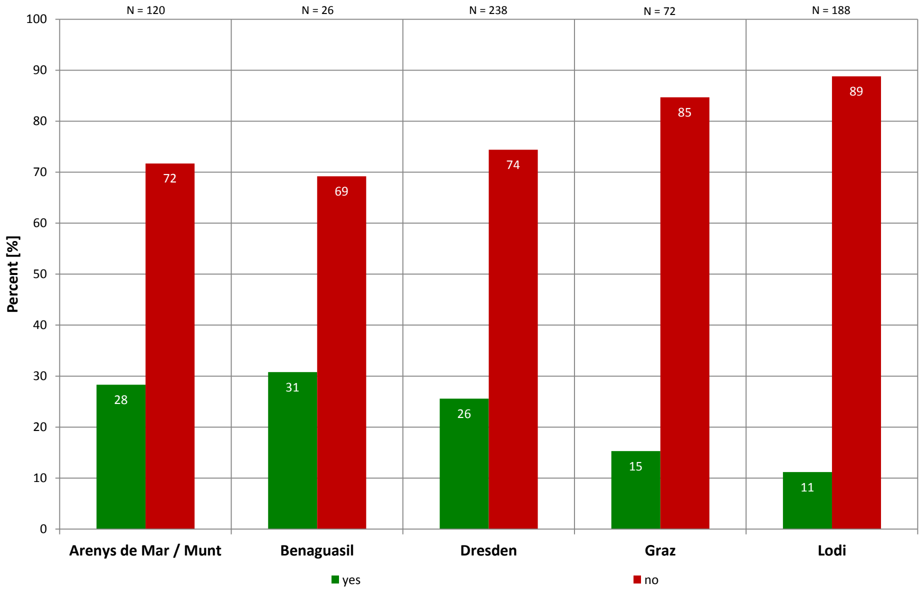

Figure 2-63: Q24 – How would you like to obtain this information – Internet?

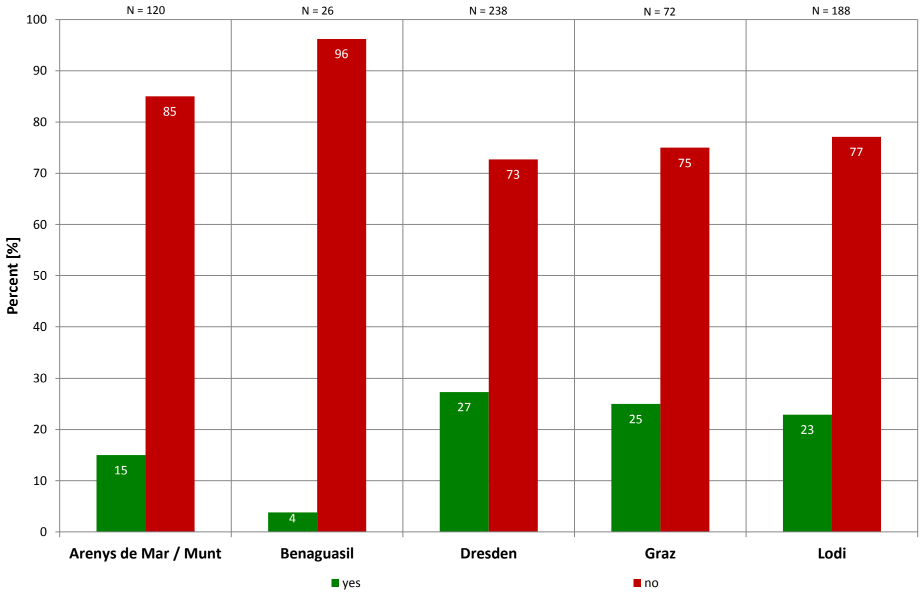

Figure 2-64: Q24 – How would you like to obtain this information – On-site information centre?

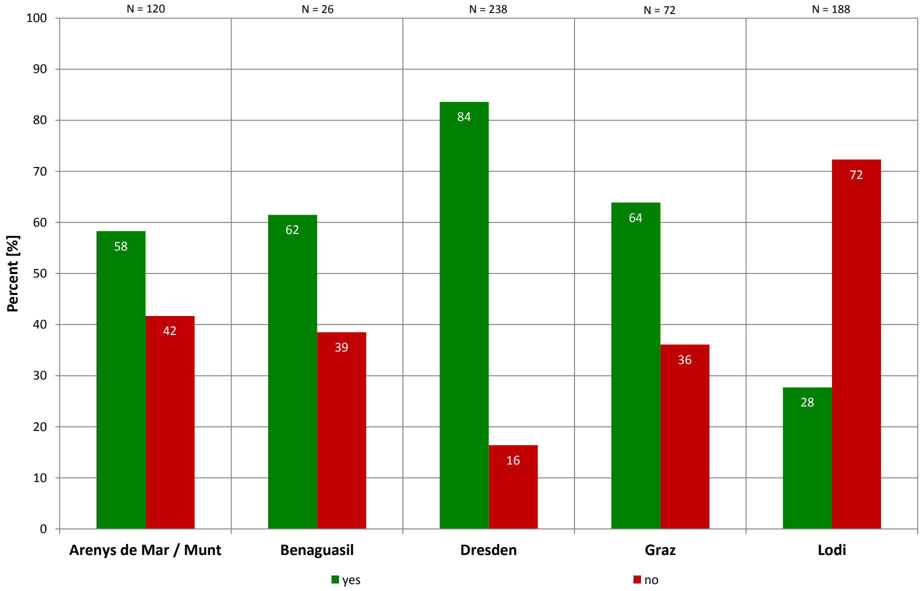

Figure 2-65: Q24 – How would you like to obtain this information – Media?

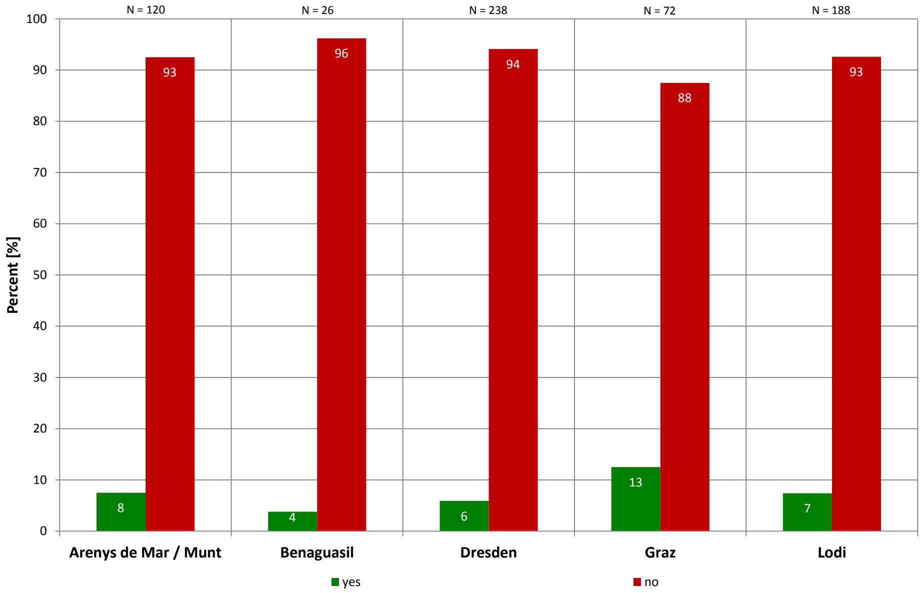

Figure 2-66: Q24 – How would you like to obtain this information – Friends / Relatives?

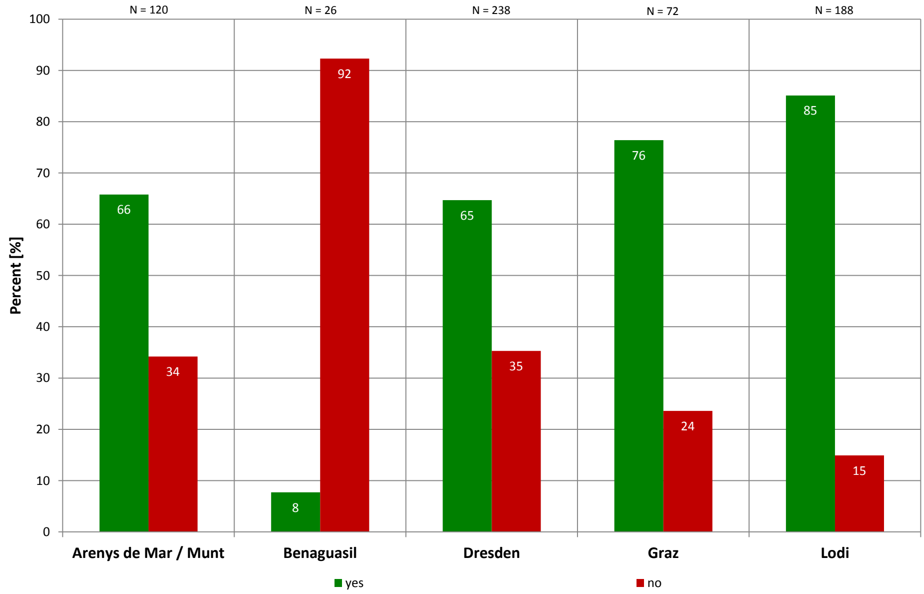

Figure 2-67: Q24 – How would you like to obtain this information – Emergency Services

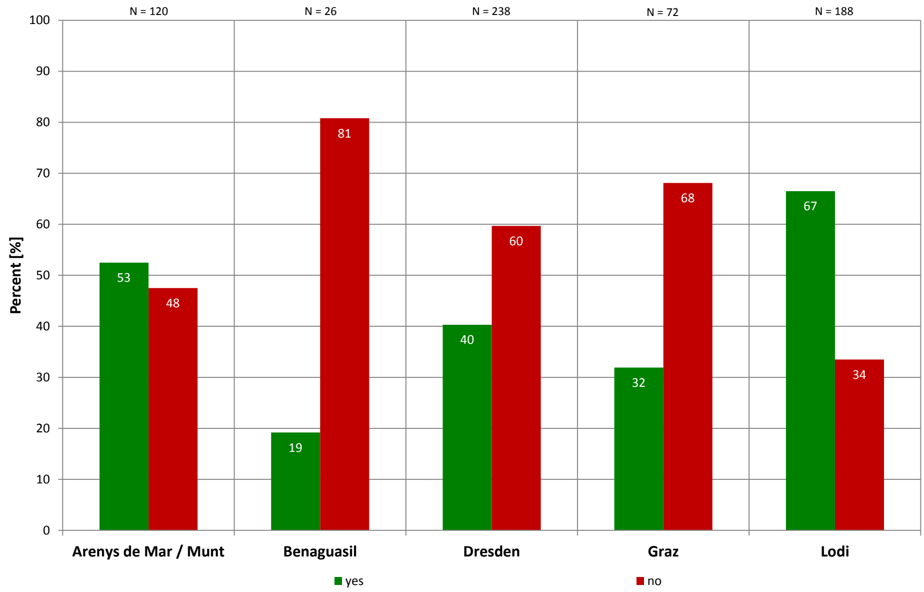

Figure 2-68: Q24 – How would you like to obtain this information – Community / Local Council?

Q25: I can evaluate flood risk well.
In Benaguasil the percentage of those who agree with this statement is with 69% very high. In Graz 40% stated that this rather applies respectively 18% that it applies. In Lodi 40% indicated that they cannot evaluate flood risk well and only 7% the converse.

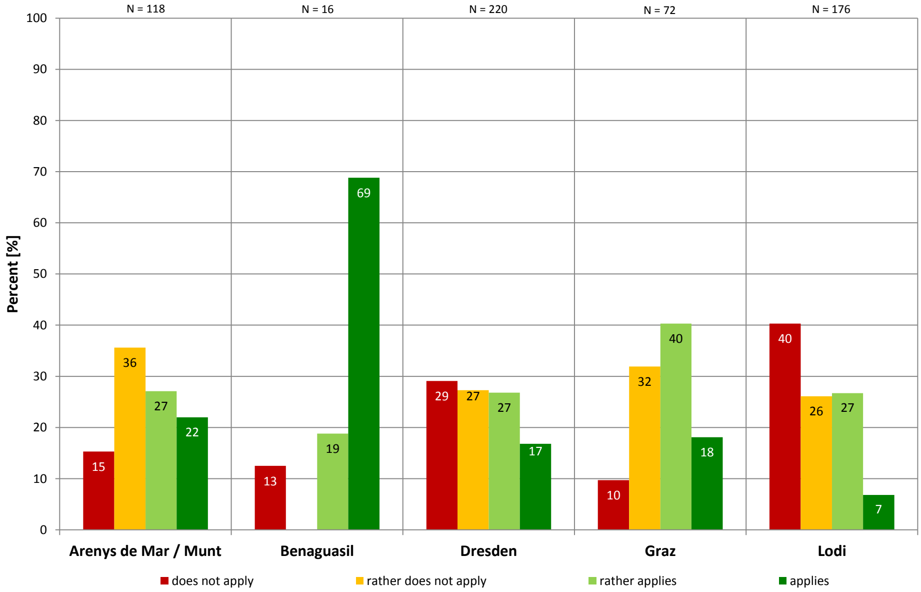

Figure 2-69: Q25 – I can evaluate flood risk well.

Q25: Because of missing information I start to feel uncomfortable.
The results show that people in Lodi have a great information demand. 89% of them start to feel uncomfortable because of missing information, followed by Arenys de Mar / Munt with 45%, Benaguasil 43%, Dresden 38% and Graz 31%. In Graz the highest number of those who don't feel uncomfortable has been achieved with 30%.

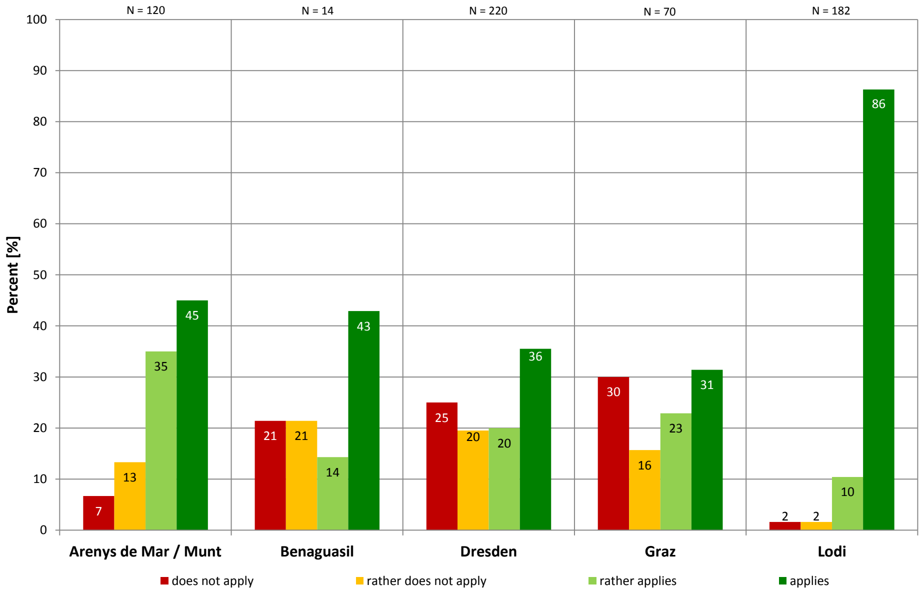

Figure 2-70: Q25 – Because of missing information I start to feel uncomfortable.

Q25: Flood is a high risk in comparison to other natural hazards.
The results show that more than 50% of the people in Lodi have the feeling, that flood risk is a high risk in comparison to other natural hazards. Also in Graz flood risk is perceive as something dangerous, where 36% stated that this applies and 30% that it rather applies. 36% of the people in Benaguasil assess this does not apply.

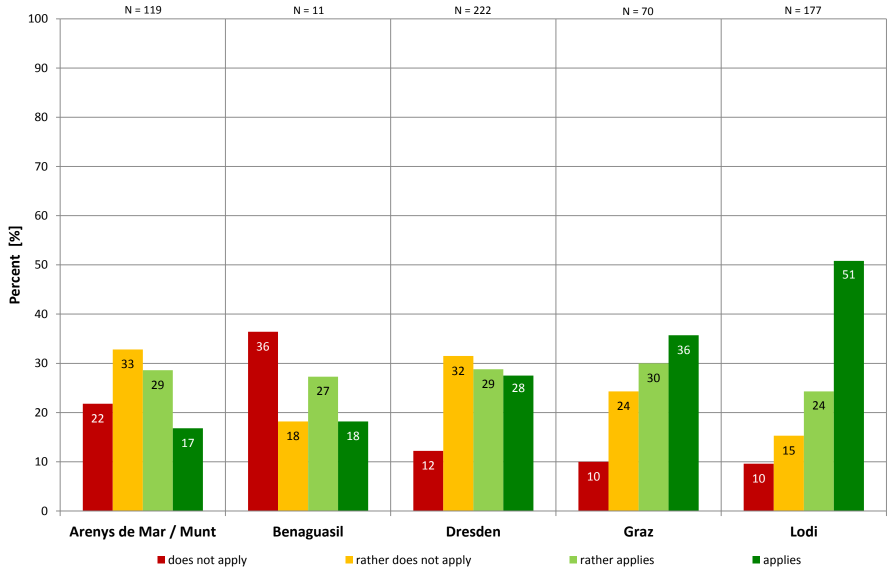

Figure 2-71: Q25 – Flood is a high risk in comparison to other natural hazards.

Q25: Flood is not a danger for my life.
The results show clearly that people in Lodi see flood as a danger for their life (72% does not apply). In Graz (44%), Dresden (33%) and Benaguasil (55%%) people don't think so. It has to be said, that there exists also a percentage of people, who see a threat for their life (Benaguasil 30%, Dresden 21%, Graz 17%). In Arenys de Mar / Munt such clear tendency not occurred. Here 33% agree with this statement, 13% don't.

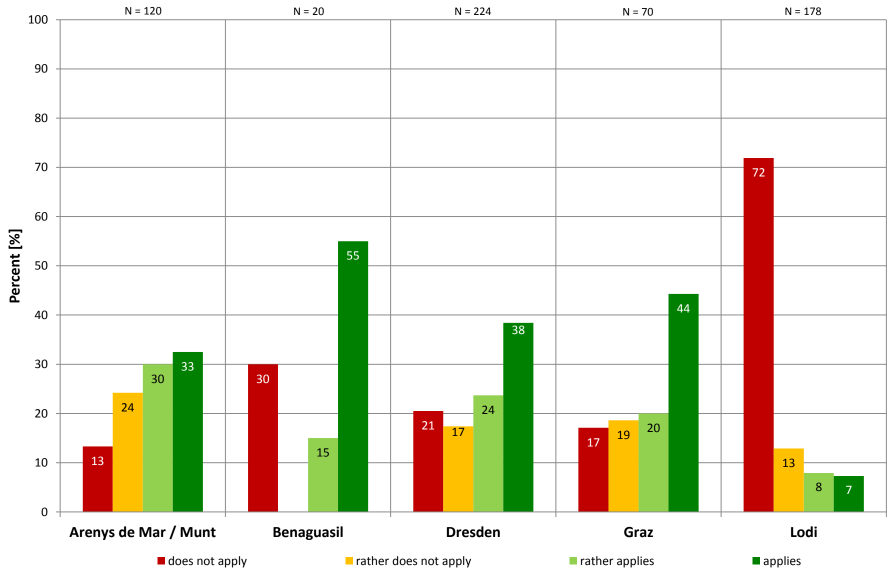

Figure 2-72: Q25 – Flood is not a danger for my life.

Q25: I am familiar with the risk of flooding.
Especially the interviewed people in Benaguasil indicated that they are not familiar with the risk of flooding (56%), although 33% stated they are. In Lodi 42% are not familiar with the risk, 19% are. In Graz the situation turns out to be that a quite high percentage (69%) agree with this statement or rather agree. In Arenys de Mar / Munt 61% said that this does not or rather does not apply.

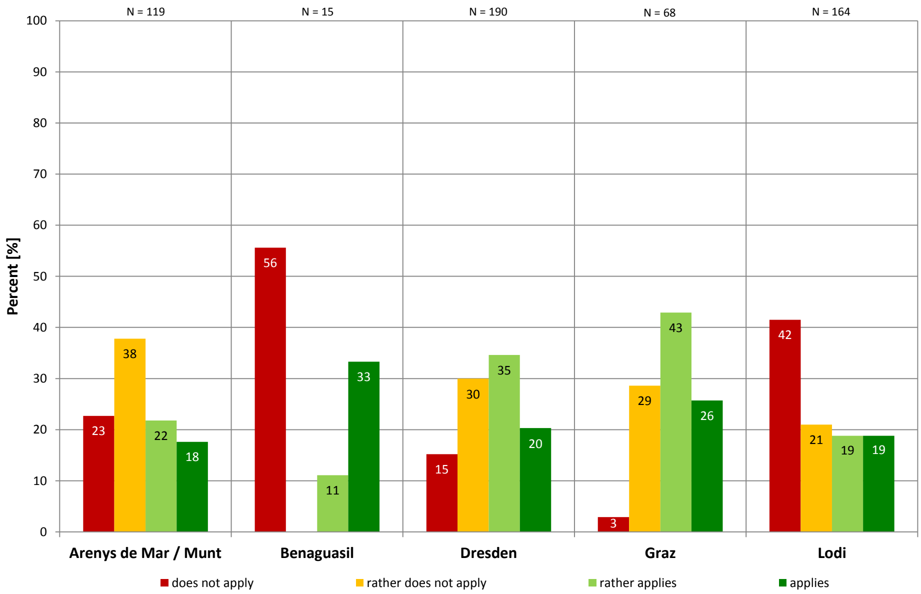

Figure 2-73: Q25 – I am familiar with the risk of flooding.

Q26: Measures of communication to keep oneself informed on a regular basis
Regarding this topic the results show, that information by the media is preferred in all case studies. The highest percentage of agreement can be found in Benaguasil and Dresden with 71% (most reasonable), followed by Graz (57%), Arenys de Mar / Munt (47%) and Lodi (37%). Further a tendency for the support of on-site information centers can be seen in all case studies. Here the highest percentages can be found in the assessment with most reasonable in Arenys de Mar / Munt with 25%, Benaguasil 50%, Dresden 24%, Graz 36% and Lodi 40%. Flyer are not liked in Lodi (35% least reasonable) and Dresden (30% least reasonable). It must be remarked, that the opinions regarding this topic are mostly wide spread. For a detailed overview please have a look at the corresponding figures Figure 2-74, p. 45 to Figure 2-78, p. 47.

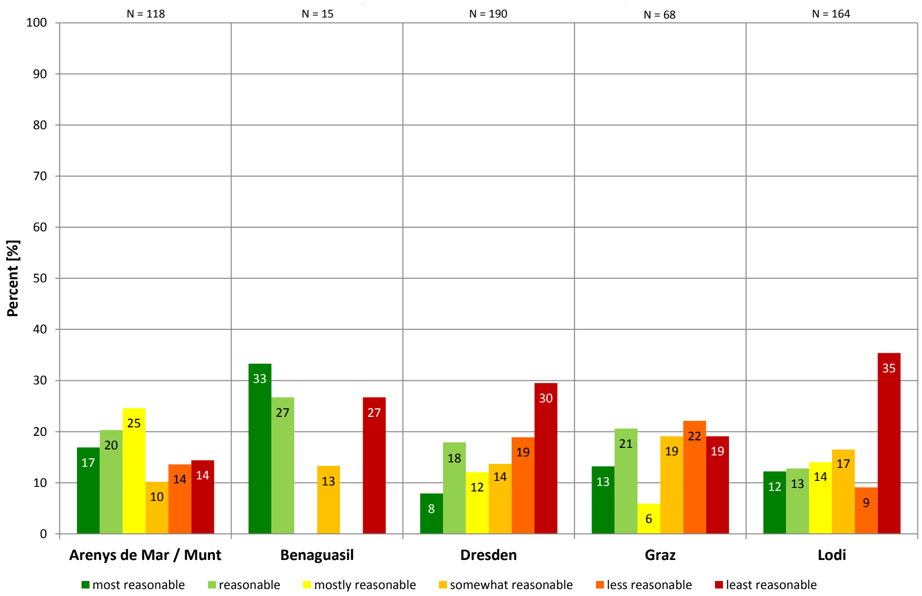

Figure 2-74: Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues - Flyer

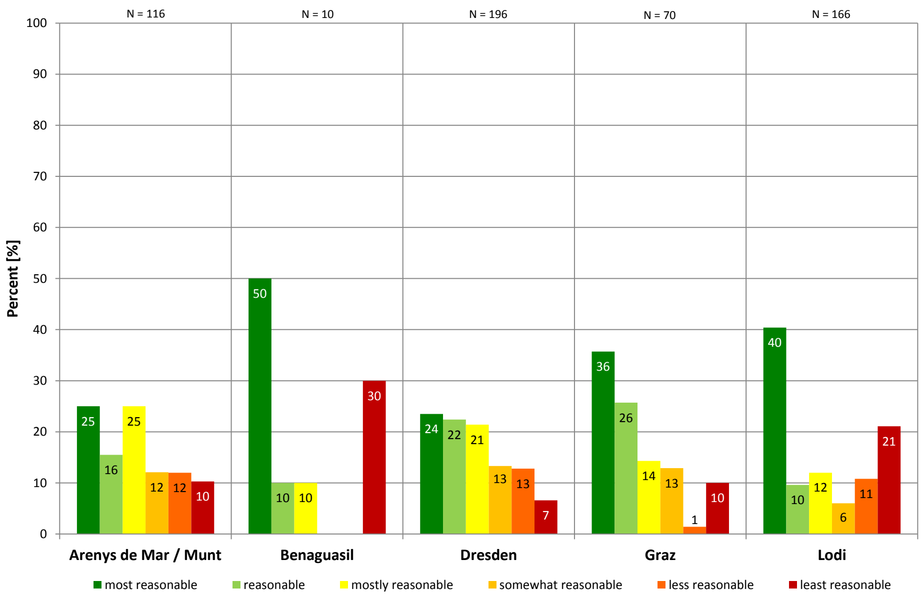

Figure 2-75: Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues – On-site information centre

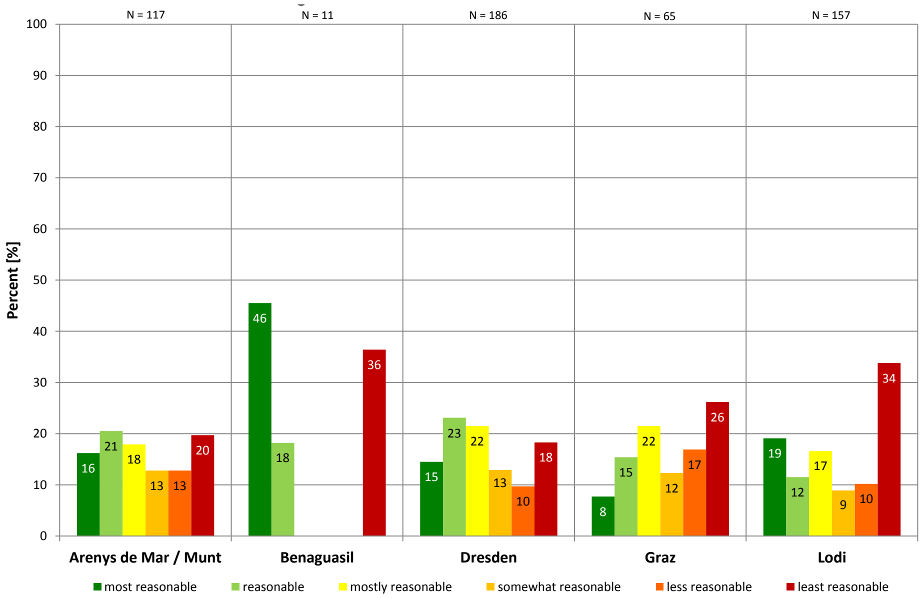

Figure 2-76: Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues – Site on the Internet

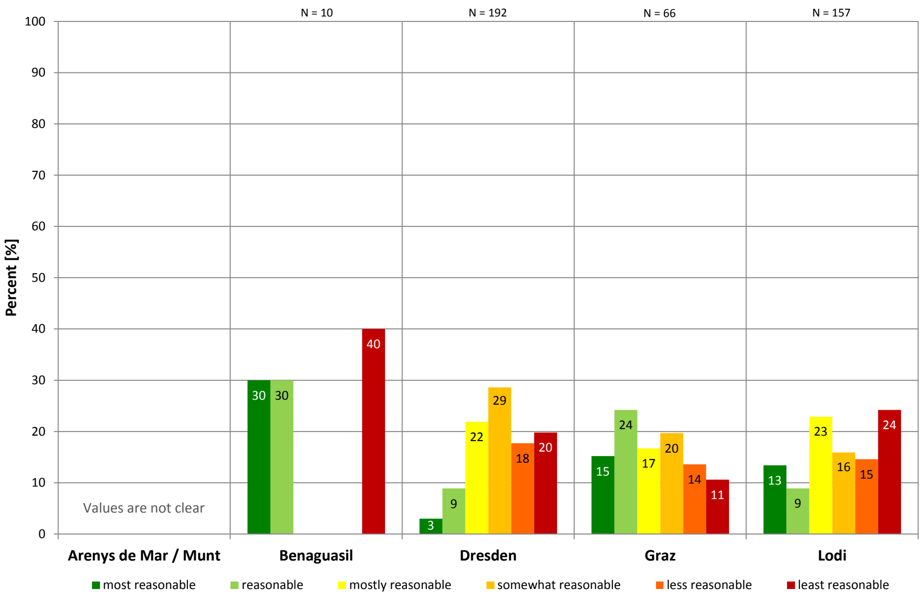

Figure 2-77: Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues – Assemblies / Information Sessions

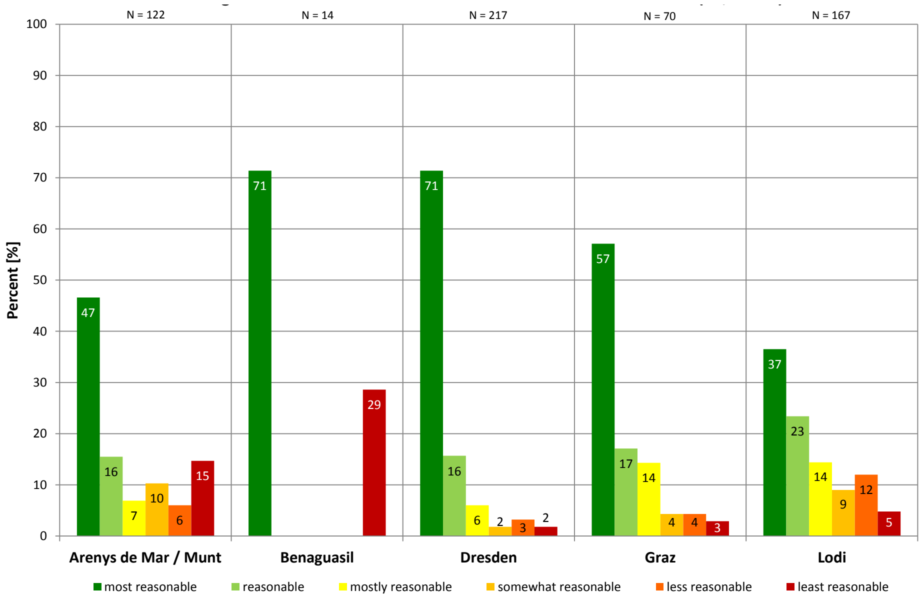

Figure 2-78:Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues – Advertisement in the Media (TV, Radio)

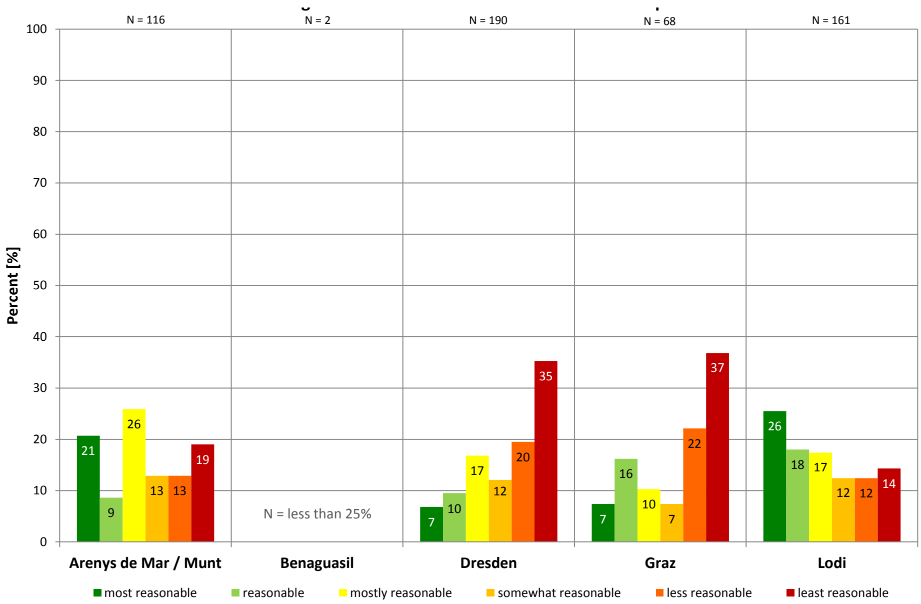

Figure 2-79: Q26 – How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues – Poster in the public

Q28: Level of information during the last flood event
The results show clearly that the majority of the people felt informed very badly during the last flood event. The percentage is escpecally high in Lodi with 85%, followed by Benaguasil with 68%, Graz 53% and Dresden 52%. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt.

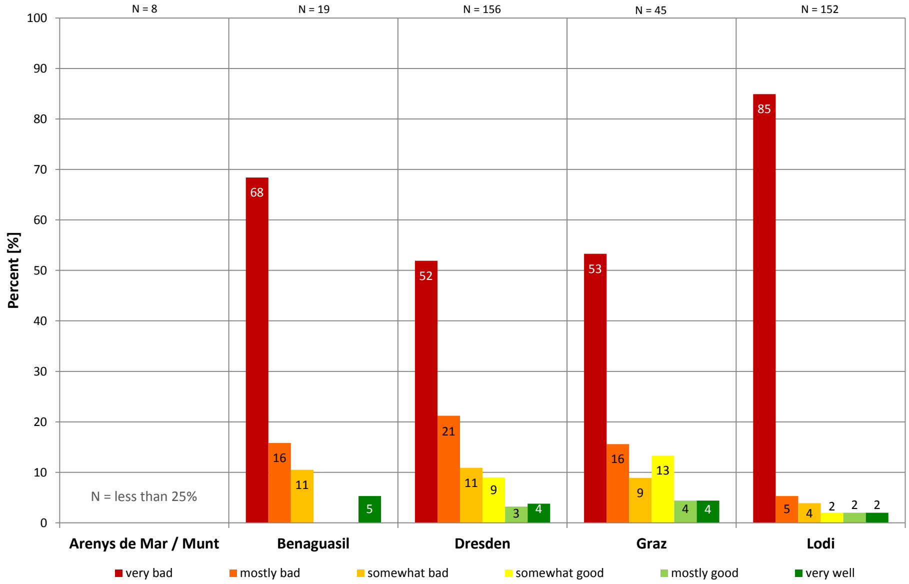

Figure 2-80: Q28 – How well informed have you felt during the last flood event?

Q29: Time between warning and onset of flood.
In Lodi and in Graz more than 50% of the interview people stated that the time span between the first warning and the onset of the flood were less than 0,5 hours. In Dresden this applies for 33% and for 28% 0,5 to 2 hours have been available. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt. Due to a too low number answers an analysis was no possible for Benaguasil.

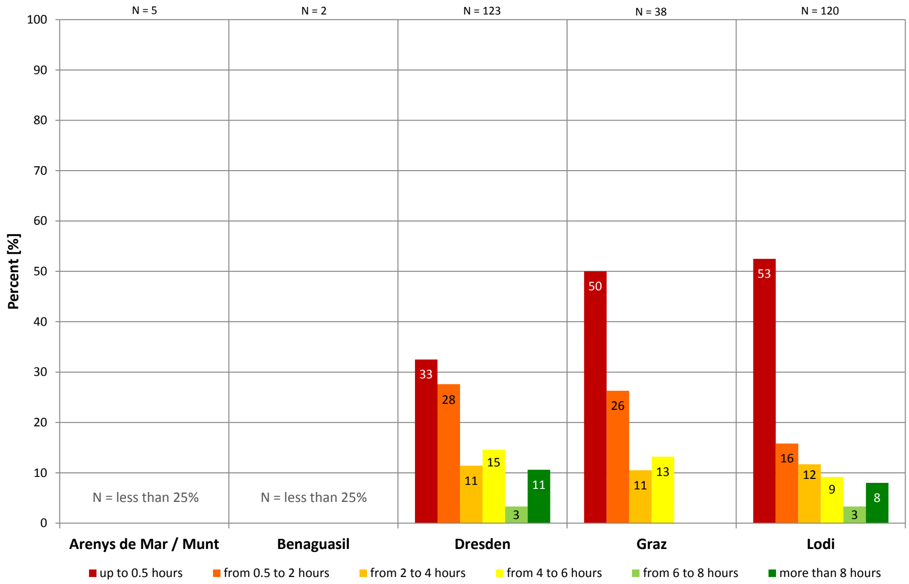

Figure 2-81: Q29 – How much time has passed between the first warning to the onset of the flood?

Q30: Assessment of the available time span
The available time span was far too short for most of the interviewed persons (Dresden 63%, Graz 56%, Lodi 82%). Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt. Due to a too low number answers an analysis was no possible for Benaguasil.

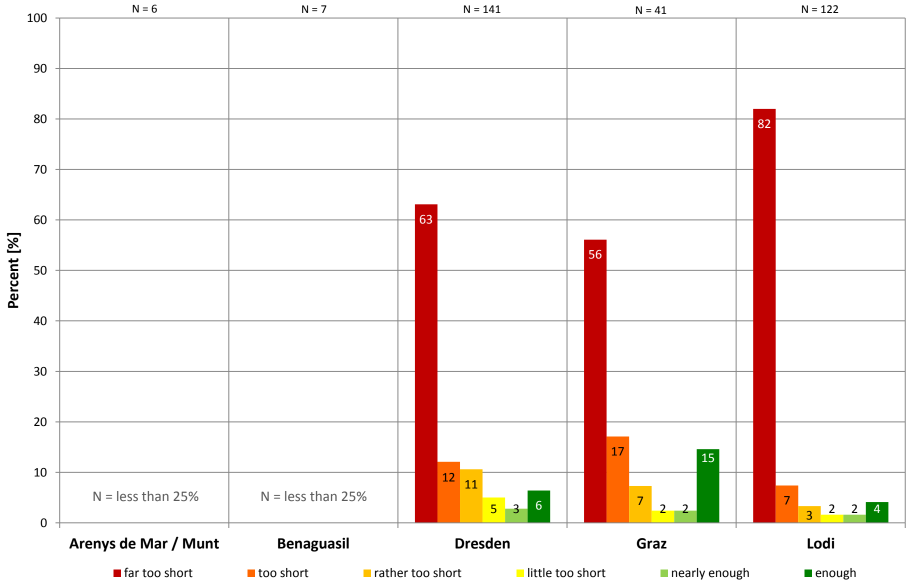

Figure 2-82: Q30 – This time span was …?

Q31: Sufficient information during the last flood
The percentage of those, who indicated they had no sufficient information during the last flood events is with 81% very high in Lodi, followed by 56% in Graz. In Dresden 42% stated the same, but also 41% have answered that they got information once in a while. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt. Due to a too low number answers an analysis was no possible for Benaguasil.

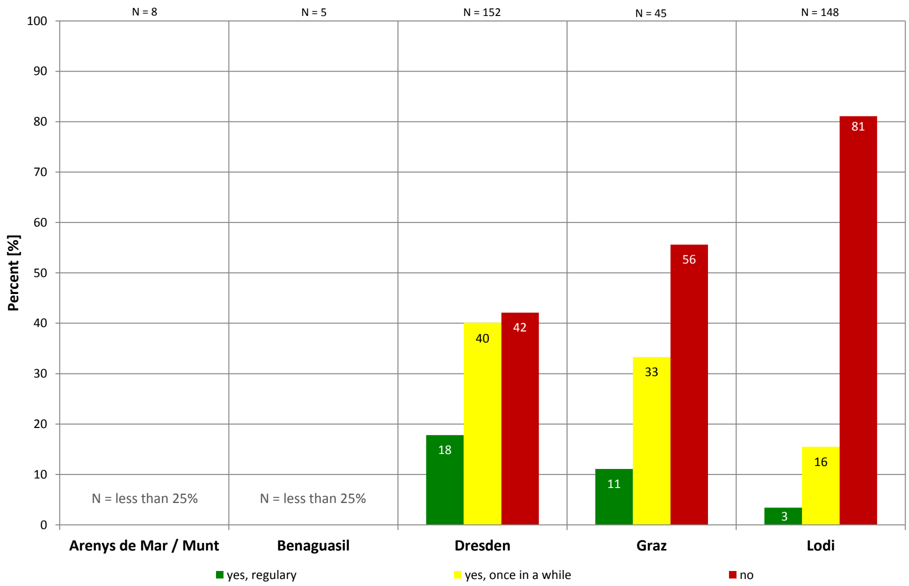

Figure 2-83: Q31 – Have you obtained sufficient information about the current flood situation during the last flood?

Q33: From where have you obtained this information?

Regarding this figures is must be remarked that multiple answers have been possible, so that the stated percentages can be more or less than 100%.

In Dresden 60% of the people obtained information during the last flood from the media, 25% from friends / relatives and 18% emergency services. In Graz with 46% also a high percentage obtained this information by media, but also 50% from emergency services. 25% indicated to have other information sources. In Lodi 35% got their information by emergency services, 36% by the community and 24% by friends / relatives. Due to a too low number of affected people an analysis was no possible for Arenys de Mar / Munt. Due to a too low number answers an analysis was no possible for Benaguasil.

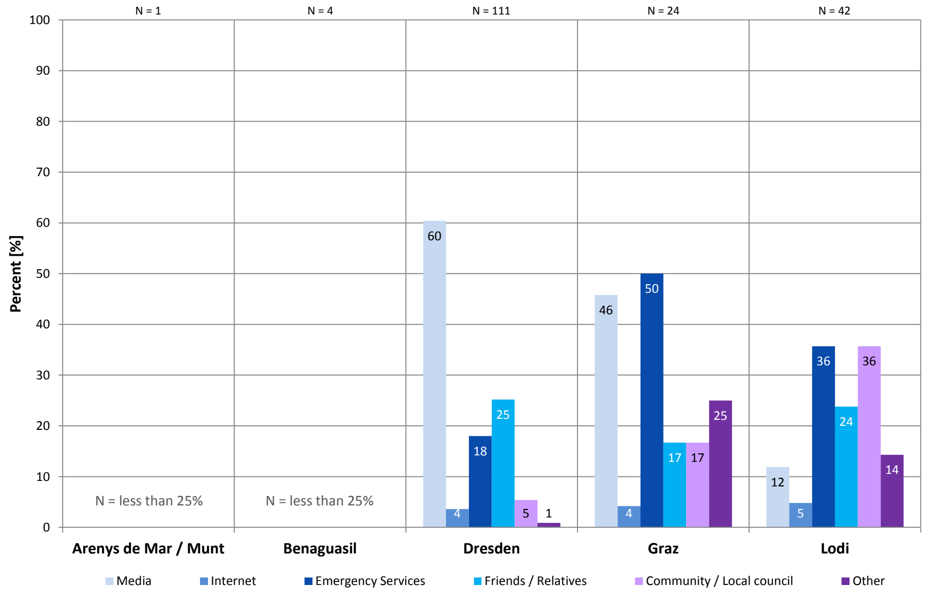

Figure 2-84: Q33 – From where have you obtained this information? (multiple answers possible)

Q34: Helpful information

A tendency can be seen for all case studies that the obtained information was assessed as partly, mostly or helpful. The highest percentage occurred in Graz where 41% of the persons stated that the information was helpful. Due to a too low number answers an analysis was no possible for Arenys de Mar / Munt and Benaguasil.

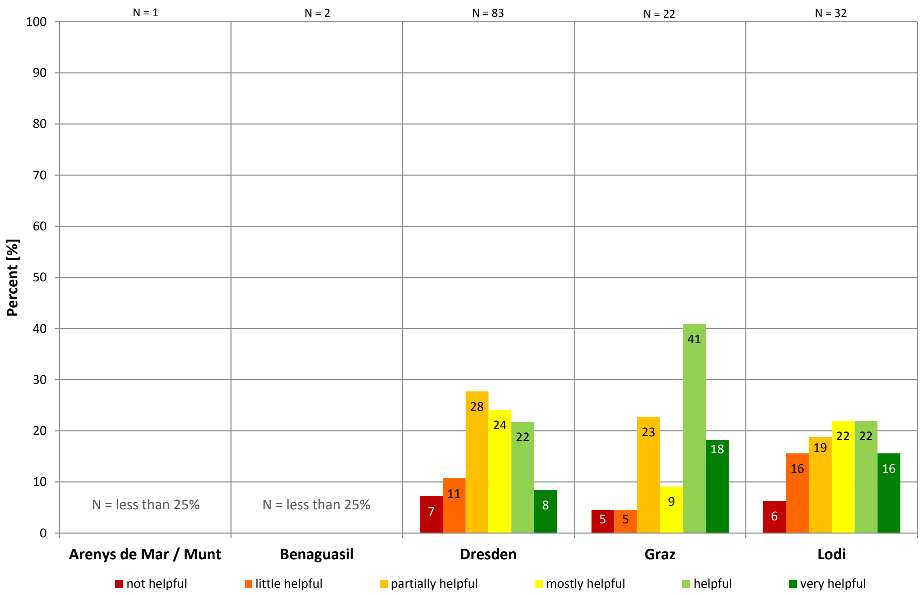

Figure 2-85: Q34 – The obtained information was …

Q35: Satisfaction of emergency services

The highest satisfaction rate in all case studies can be noted for the rescue service. In Dresden 78% stated they were somewhat satisfied or very satisfied, in Graz 93% and in Lodi 60%. A quite similar satisfaction was stated for the fire department, Dresden 73%, Graz 85% and Lodi 63%. The performance of the police was assessed different in the case studies. In Graz 81% of the people stated to be somewhat or very satisfied and in Dresden 57%. In Lodi 47% of the people were not satisfied with the police. Due to a too low number answers an analysis was no possible for Arenys de Mar / Munt and Benaguasil.

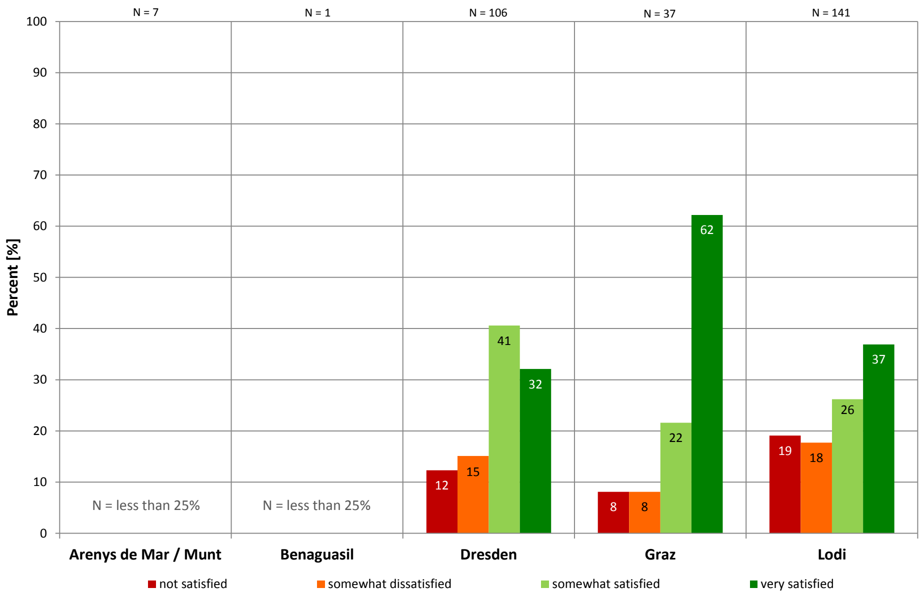

Figure 2-86: Q35 – How satisfied have you been with the performance of the fire department?

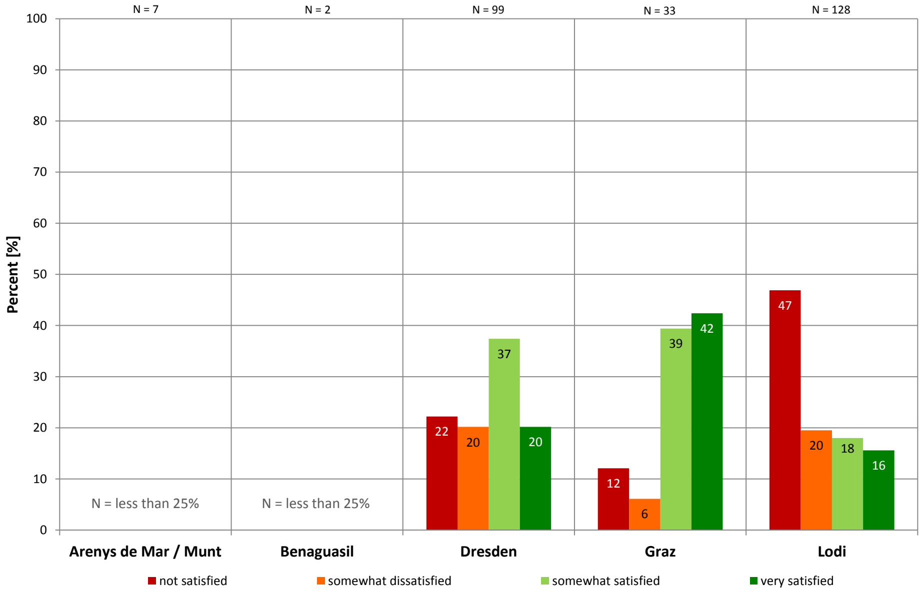

Figure 2-87: Q35 – How satisfied have you been with the performance of the police?

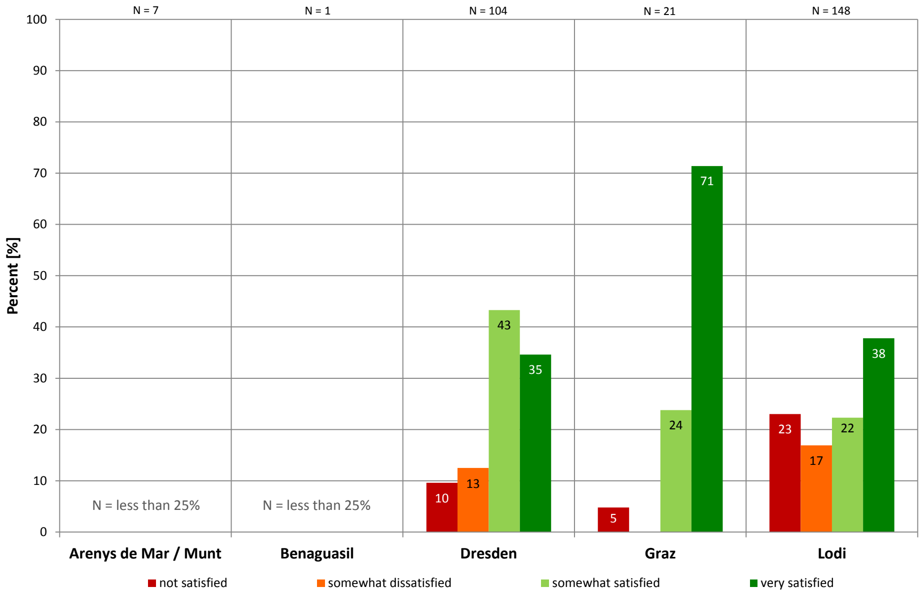

Figure 2-88: Q35 – How satisfied have you been with the performance of the rescue service?

2.5 Self protection and individual provisions

Q36: Knowledge about self-protection measures

The majority of the interviewed people in Benaguasil (73%) and Graz (67%) have indicated to know measures for self-protection. In Arenys de Mar / Munt 71%, in Dresden 67% and in Lodi 62% don't know about this measures.

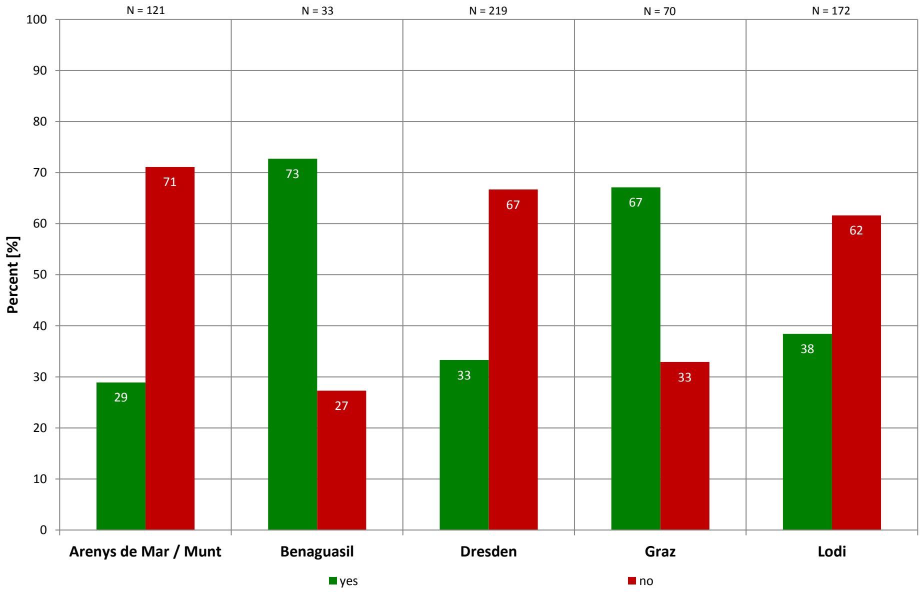

Figure 2-89: Q36 – Do you know concrete measures to protect yourself in case of flood?

Q38: Information about these measures

Regarding this figures is must be remarked that multiple answers have been possible, so that the stated percentages can be more or less than 100%.

The knowledge gained about this measures differes in all cases studies. The results show clearly that people in Spain have learned about this measures to a high percentage from friends or relatives (Benaguasil 83%, Arenys de Mar / Munt 49%). In Dresden the highest percentage can be noted for the media (46%). In Graz also the media (34%) plays an important role, but not as high as the emergency service with 55%. In Lodi also friends and relatives (34%) followed by emergency services (22%) have been stated. It must be remarked that a high percentage of the people have other information sources than those have been available.

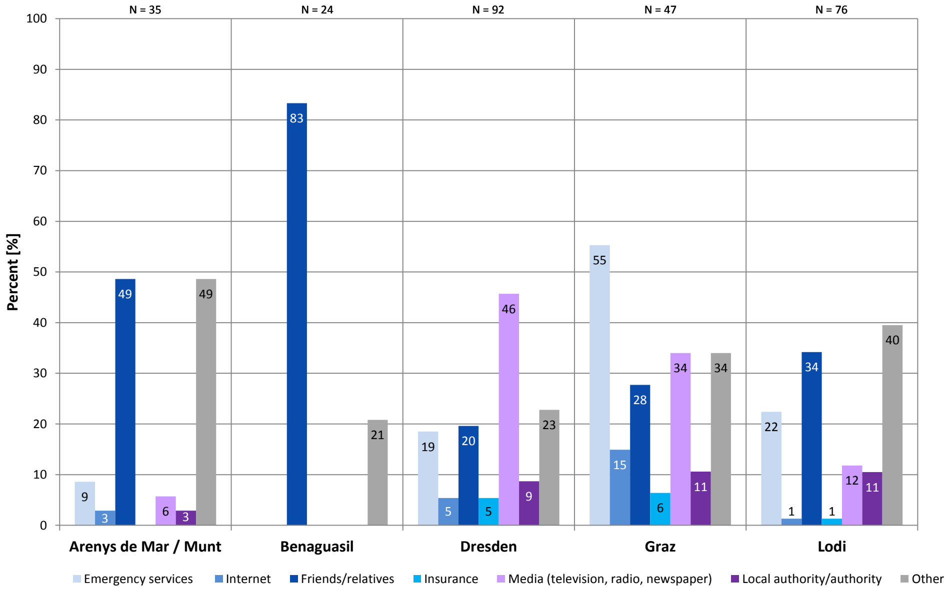

Figure 2-90: Q38 – Where have you learned about these measures? (multiple answers possible)

Q39: How reasonable are self-protection measures?

In Benaguasil, Dresden and Graz, there is a clear tendency towards a positive assessment of self-protection measures. 62% of the persons in Benagausil stated that self-protection measures are effective or very effective, in Dresden 55% and in Graz 73%. In Arenys de Mar / Munt the agreement is lower with 36%, although 54% indicated that these measures are partly effective or mostly effective. By contrast, in Lodi 44% think that they are not effect or only little effective.

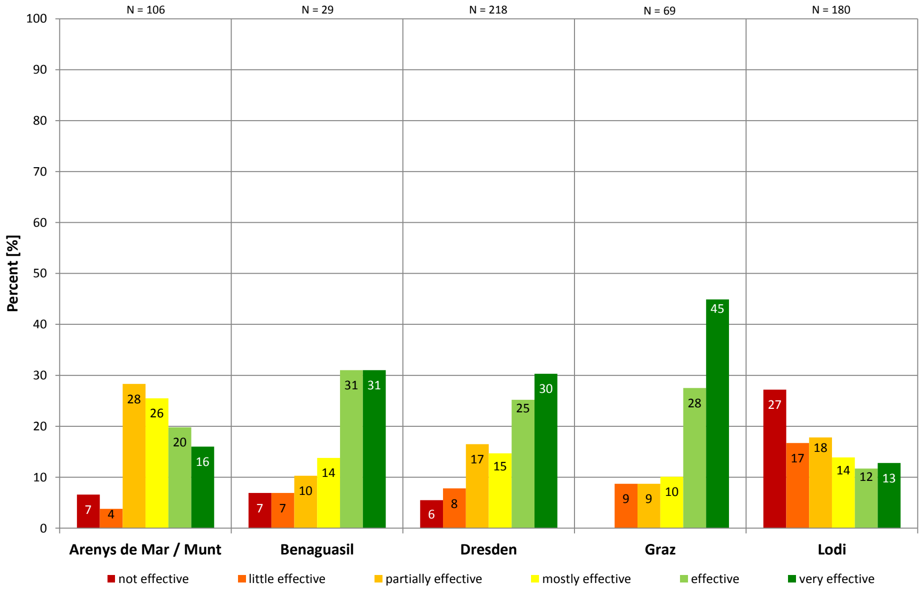

Figure 2-91: Q 39 – How reasonable are self-protection measures in respect of flood events in your opinion?

Q39: Self-protection measures during the last flood

The majority of the interviewed person in all case studies did not take any self-protection measures. The highest percentages of those who took self-protection measues can be found in Benaguasil (34%) and Graz (35%).

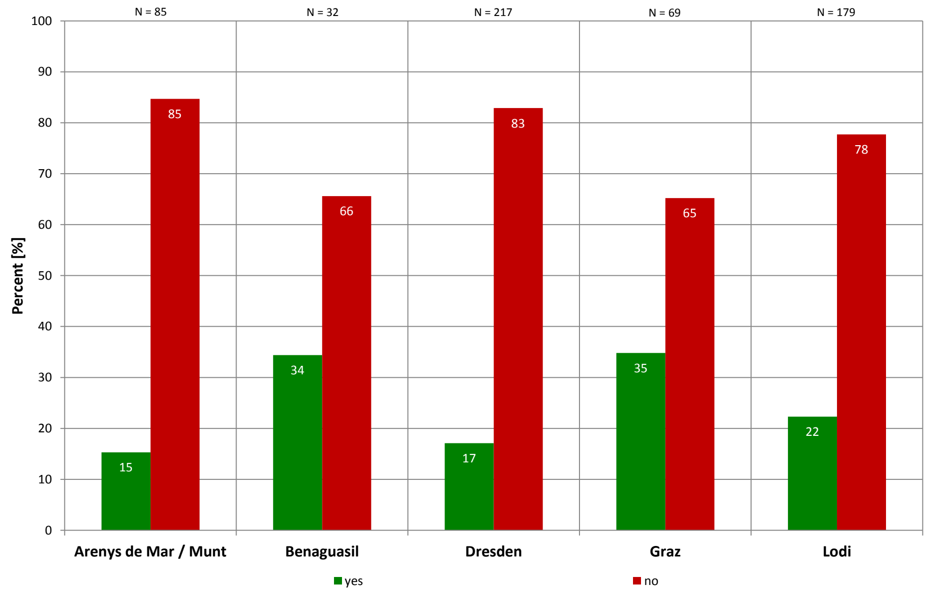

Figure 2-92: Q40 – Have you taken self-protection measures before the last flood?

Q41: No self-protection measures? Why?

It's to be assumed that due to the fact that only a small percentage of the people in Arenys de Mar / Munt have been affected during the last flood event, 84% stated that self-protection measures have not been necessary. In Graz this percentage is 60%, in Dresden 47%, in Benaguasil 37% and in Lodi 23%. There is only a low percentage of people who think that some else is responsible for that.

It must be remarked that especially in Benaguasil an in Lodi a high percentage of the people have other reason why they didn't took self-protection measures.

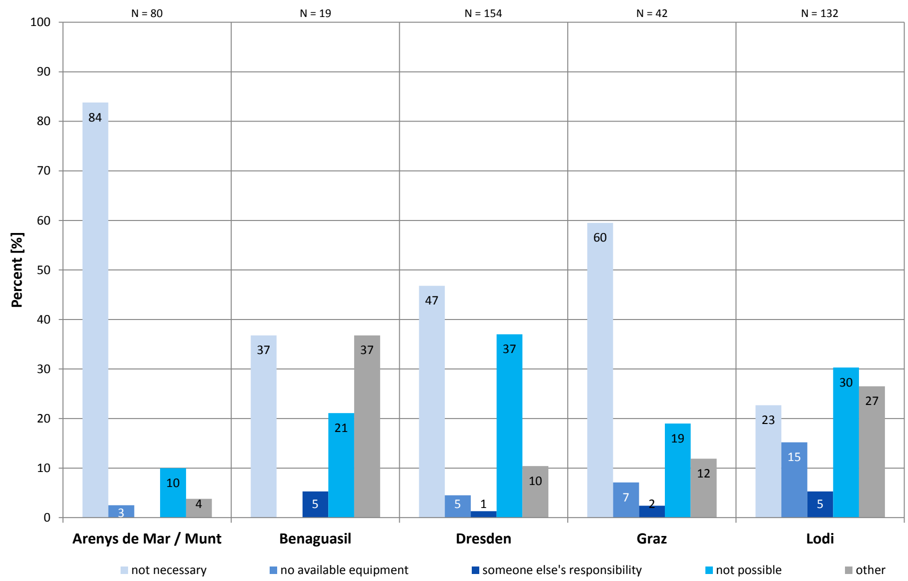

Figure 2-93: Q41 – In case you have not: Why haven't you?

Q44: Assessment of efficiency of self-protection measures

Self-protection measures are assessed in Benaguasil as very effective by 56% (attention only 27% of the interviewed persons answered this question). In Graz also a tendency torwards a positive assessment of these measures can be observed (54% effective respectively very effective). By contrast in Dresden 45% and Lodi 41% of the people think that they are not or only little effective. Due to a too low number answers an analysis was no possible for Arenys de Mar / Munt.

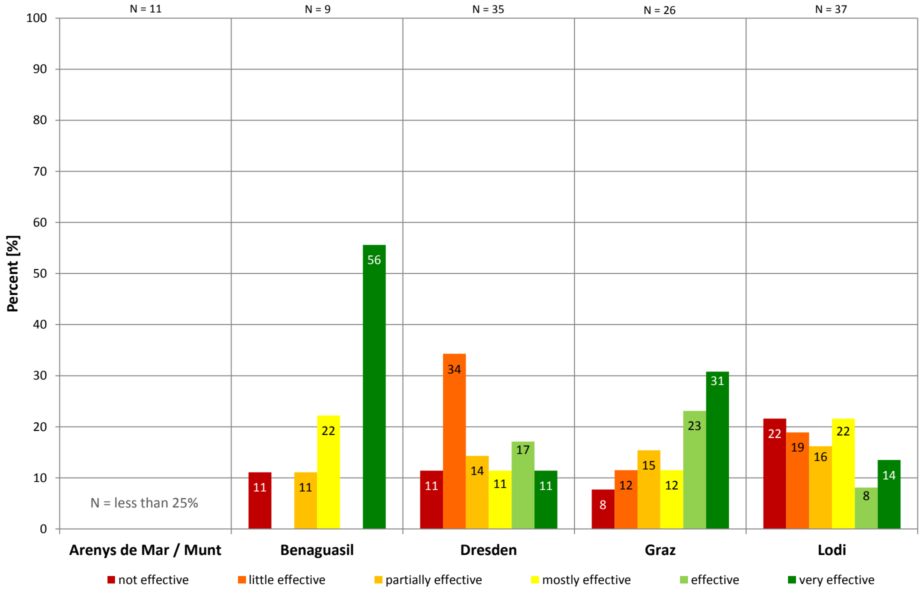

Figure 2-94: Q44 – How effective were the applied measures?

Q45: Protective measures in the future

In all case studies, except in Benaguasil, the majority of the people will take protective measures in the future again (> 67%). In Benaguasil 62% of the interviewed persons will not.

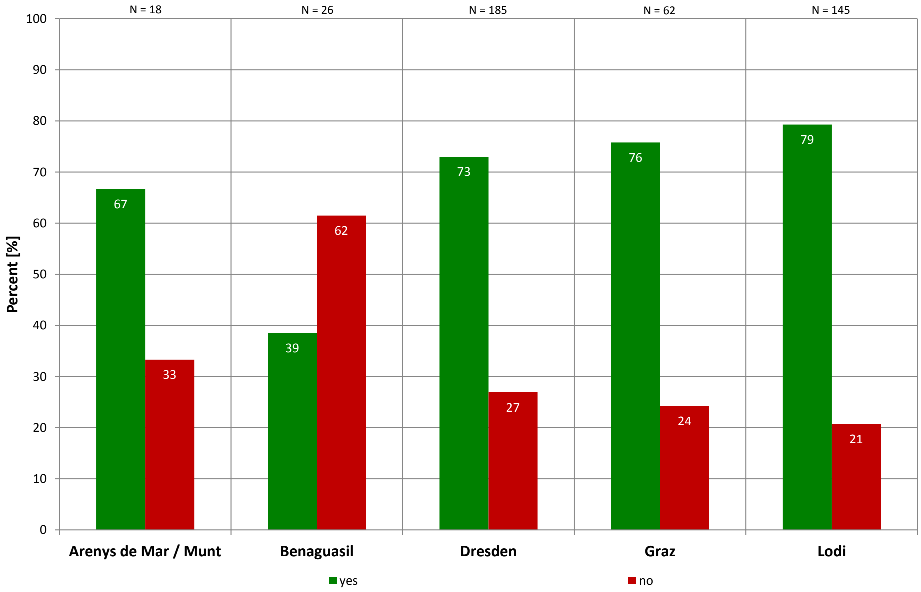

Figure 2-95: Q45 – Will you take protective measures in the future (again)?

Q46: Assessment of solidarity efforts in the neighborhood

There is a clear tendency in all case studies, except Benaguasil, to assess the solidarity efforts in the neighborhood positive. In Benaguasil the opinions concerning this topic differ wider than in the other case studies, although 27% evaluated the solidarity efforts in the neighborhood as very good.

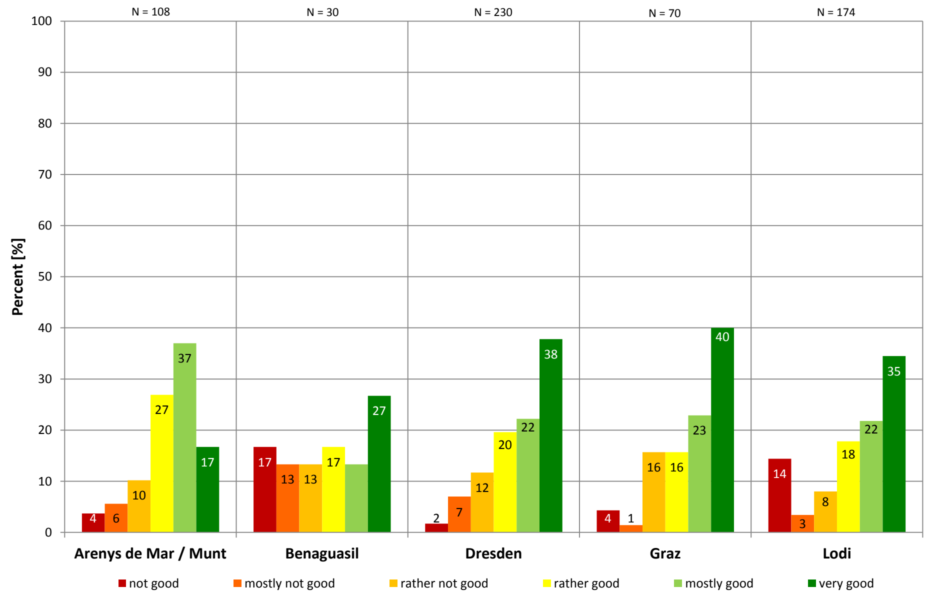

Figure 2-96: Q46 – How would you evaluate the solidarity efforts in your neighborhood

Q47: Importance of neighborly help

The results show, that for a very high percentage (> 67%) neighborly help is very important or important to the people in all case studies, whereas this is assessed with the highest percentage in Dresden (94%) and in Graz (96%).

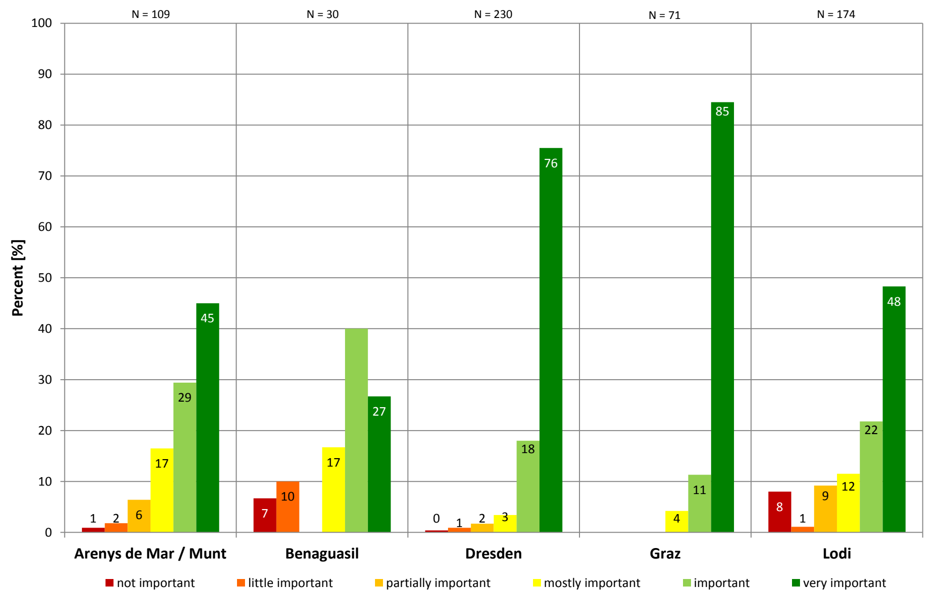

Figure 2-97: Q47 – Neighborly help is to me in case of a flood event ...?

Q48: Neighborly help during the last flood event
In Arenys de Mar / Munt 87% did not help each other during the last flood event. In Benaguasil 56% of the interviewed persons stated that this has happened. In all other case studies neighborly help was provided respectively gained of more than 50% of the citizens.

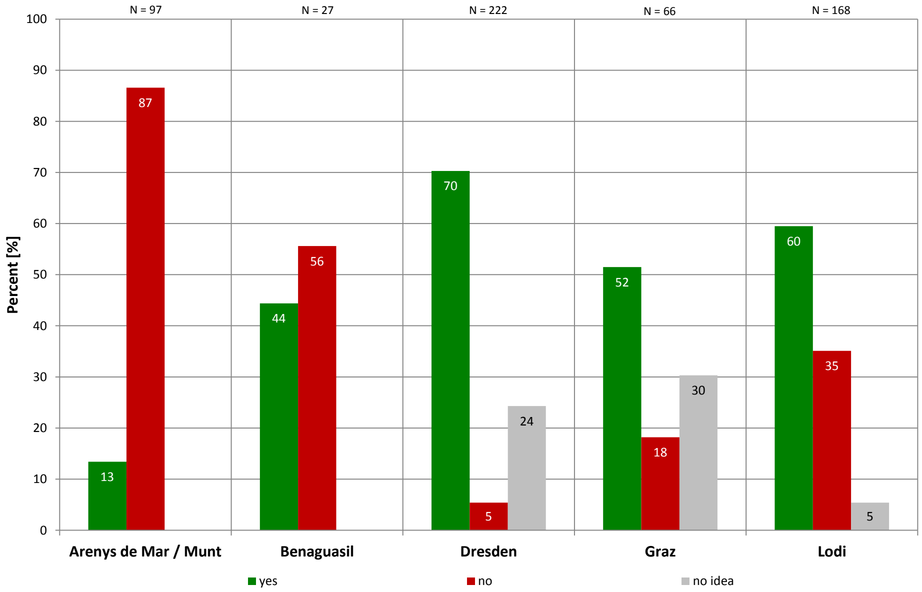

Figure 2-98: Q48 – Have you helped each other during the last flood in your neighborhood?

Q50: Importance of the provided neighborly help
There is a clear visible tendency towards the assessment of neighborly help as important or very important in Dresden (84%), Graz (89%) and Lodi (63%). In Arenys de Mar / Munt people 77% of the people believe that it's partly important or mostly important.

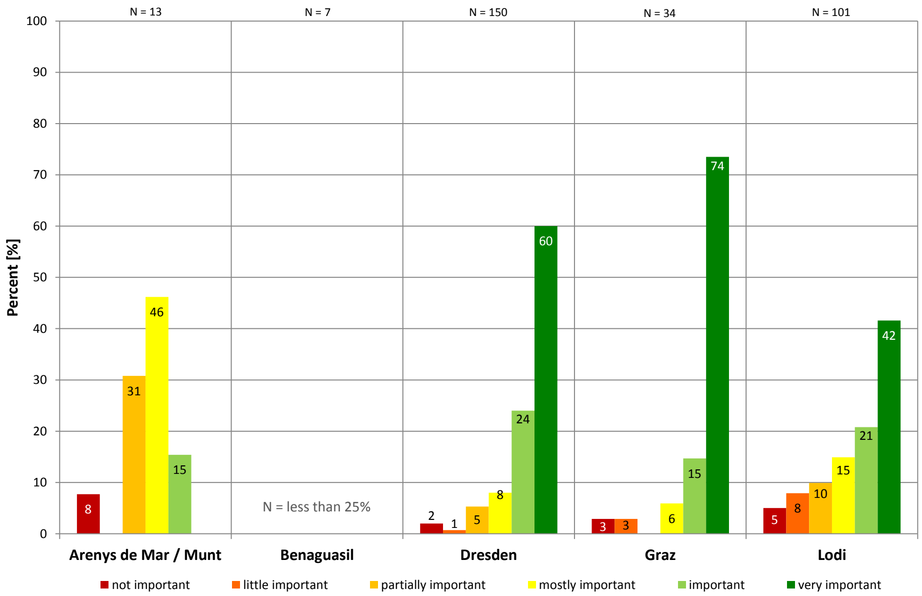

Figure 2-99: Q50 – How important was this provided help?

2.6 Financial consequences of flooding

Q51: Labor slack due to the last flood event

In all case studies a high percentages have experience a labor slack due to the last flood event (>61%), whereas this percentage is especially high in Arenys de Mar / Munt (94%) and Graz (96%).

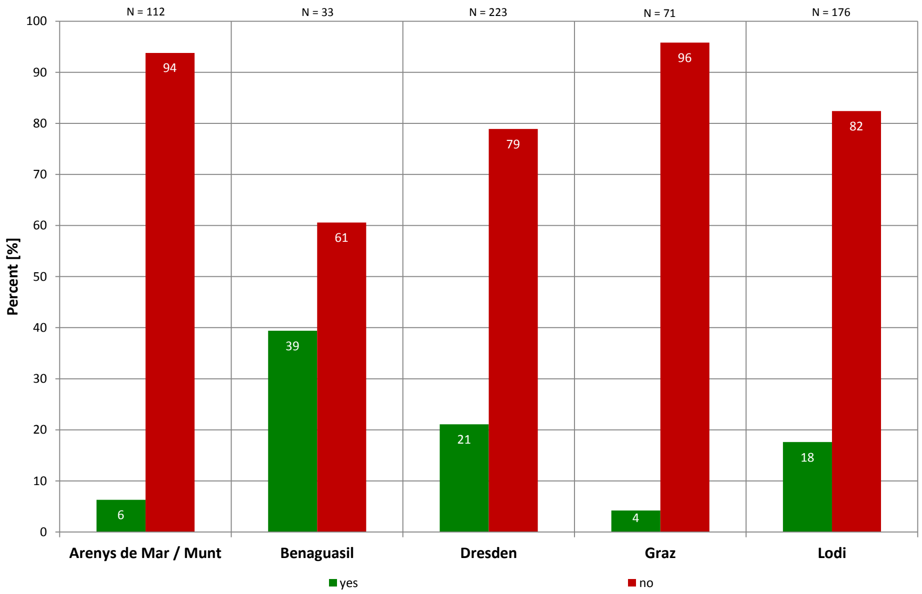

Figure 2-100: Q51 – Did you or a member of your household experience a labor slack due to the last flood?

Q53: Insurance against catastrophic losses at the last flood event

In Arenys de Mar / Munt and in Lodi 88% respectively 89% did not have an insurance against catastrophic losses at the last flood event. In Benaguasil the highest percentage of the interviewed people who had an insurance could be observed with 68%, followed by Graz with 64% and Dresden with 52%.

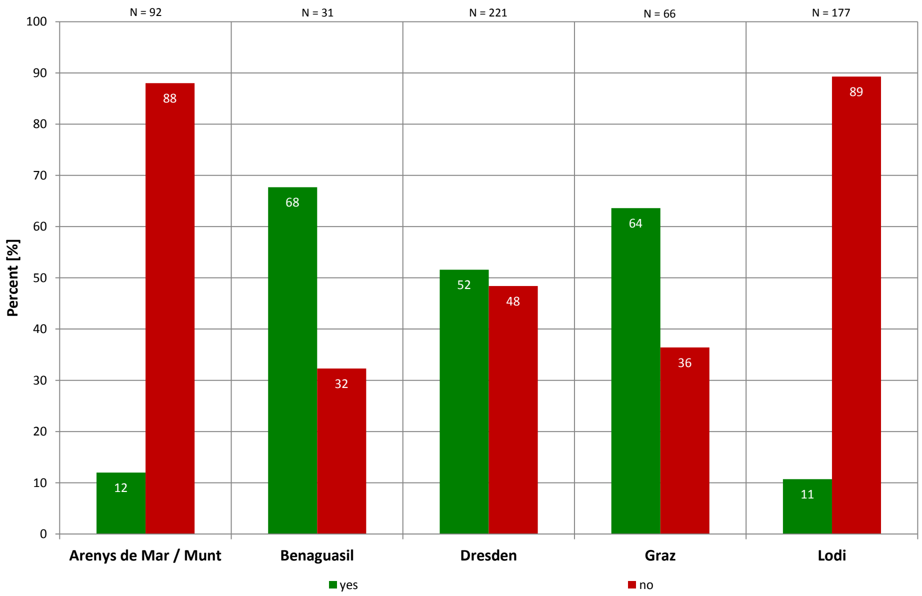

Figure 2-101: Q53 – Have you been insured against catastrophic losses at the last flood event ?

Q54: Insurance coverage

Only in Dresden the majority of the people (62%), of those who sustained damages, had a total insurance coverage. In Lodi the highest percentage of those where the insurance compensation did not correspond to the full amount of the flood damages can be registered with 65%. In Benaguasil and in Graz 26% respectively 33% the insurance did not cover all the losses.

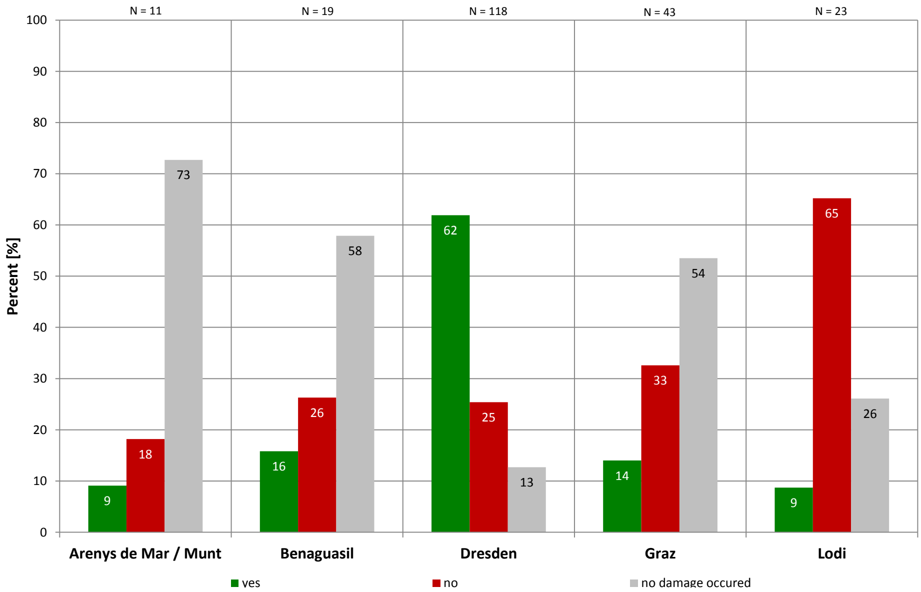

Figure 2-102: Q54 – Did the insurance compensation correspond to the full amount of the flood damage?

Q55: Funds form the disaster fund

The majority of the people in all case studies did not receive funds form the disaster fund. In Arenys de Mar / Munt the percentage was 100%, in Benaguasil 85%, in Dresden 87% in Graz 76% and in Lodi 53%.

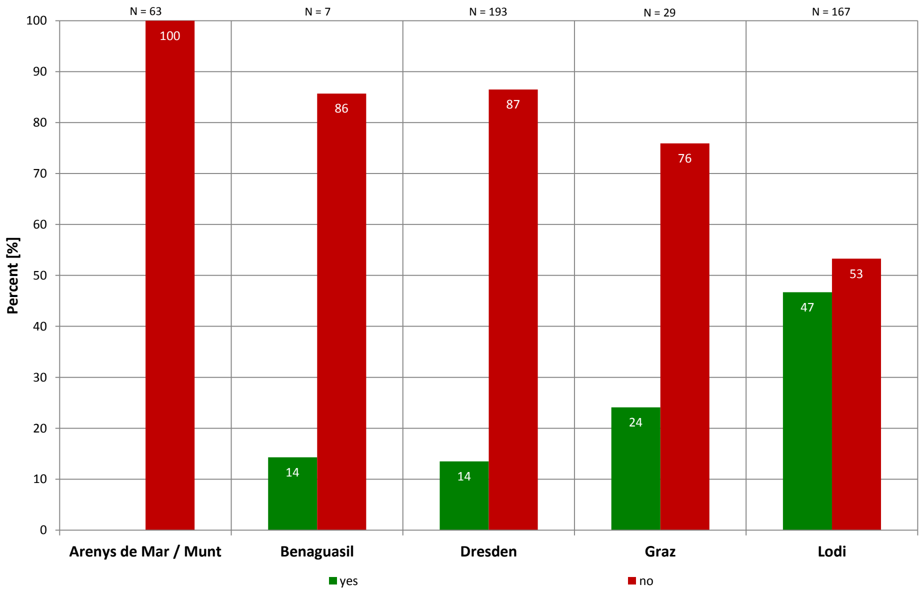

Figure 2-103: Q55 – Did you receive funds from the disaster fund?

Q56: Cover of all losses by financial compensation

In Dresden the highest rate of a total cover of losses has been achieved with 45%. In Graz 24% and in Lodi only 6% have stated that the losses have been covered by financial compensation. Due to a too low number of answers an analysis was no possible for Arenys de Mar / Munt and Benaguasil.

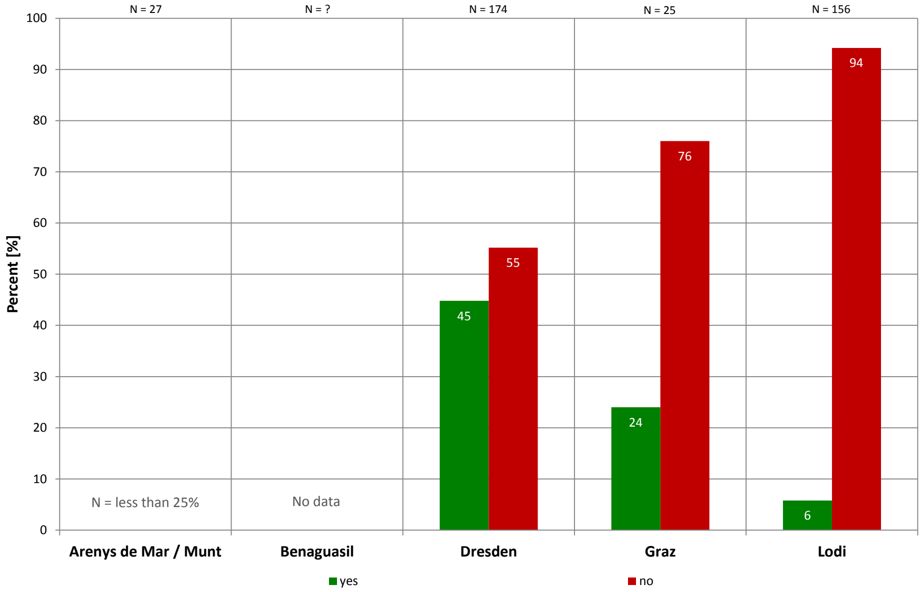

Figure 2-104:Q56 – Have all financial compensations (insurance, disaster fund etc.) covered all your losses?

Q57: Amount of loss not covered by financial compensation

Only in Dresden and in Lodi enough people answered this question for analysis. In Dresden 91% had to pay up to € 10.000 for their losses, in Lodi 59%. And in Lodi 3% stated that they had losses in the amount of more than € 100.000.

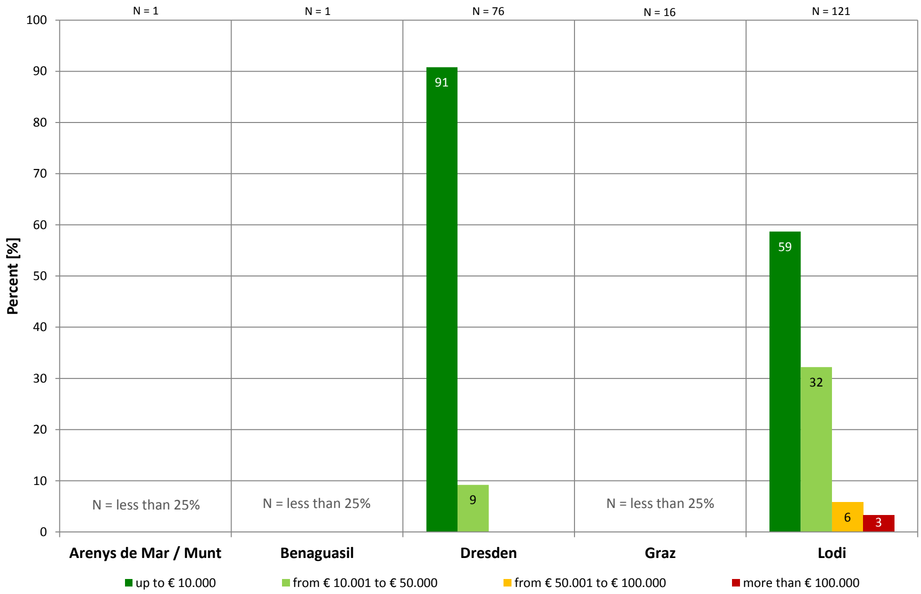

Figure 2-105: Q57 – In case they have not: How high was the loss that you had to pay for?

Q58: Duration back to normal life

For the majority of people in Benaguasil it takes up to 1 week to get back to normal life (90%). Also in Graz this time period was stated by 45%. In Dresden the opinions differ widely from 23% with up to 1 week to 20% more than 20 weeks. In Lodi people need the longest for getting back to normal life. Here 45% indicated to need more than 20 weeks.

Due to a too low number of answers an analysis was no possible for Arenys de Mar / Munt.

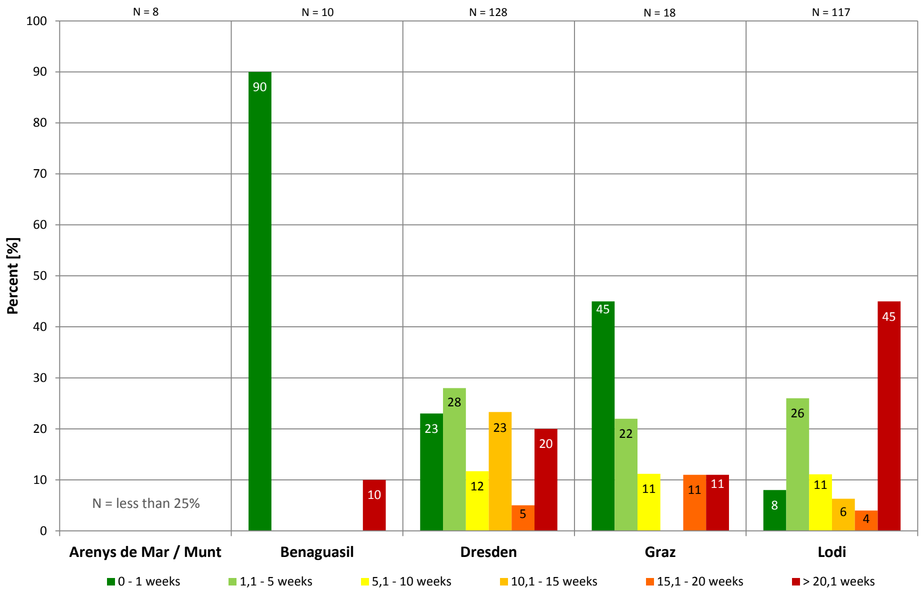

Figure 2-106: Q58 – How long will it take you to get back to your normal course of life after the last flood event?

Q59: Insurance against catastrophic losses in future

In Benagusail, Dresden and Graz more than 58% of the people have stated, that they will insure themselves against catastrophic losses in the future. In Lodi only 46% will and in Arenys de Mar / Munt 90% of them will not.

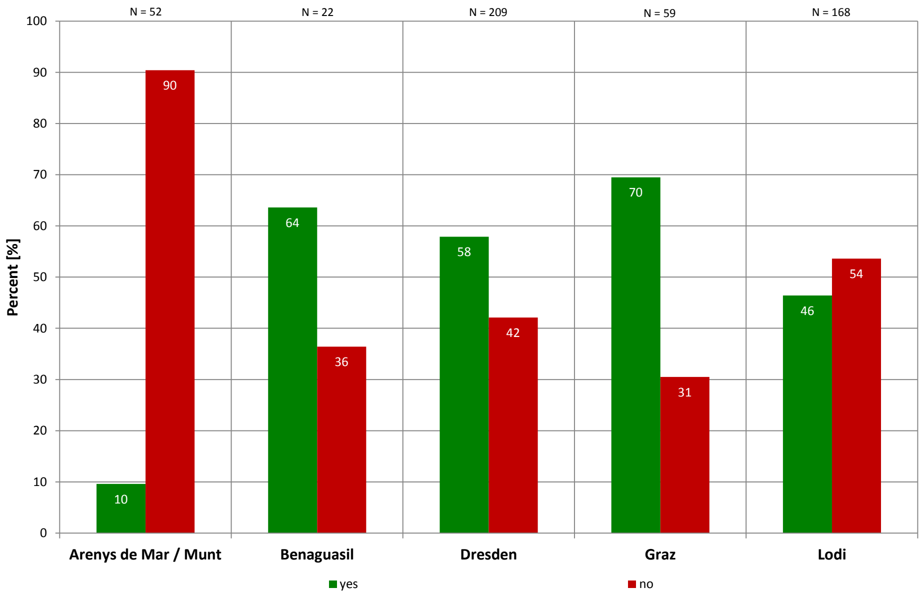

Figure 2-107: Q59 – Will you insure yourself against catastrophic losses in the future?

3 Results of the opinion poll Hypothesis / Correlations

3.1 General

Alongside a descriptive analysis, supposed correlations have been statistically checked. Therefore the Chi² test and the Spearman correlation coefficient have been used.[4]
29 hypotheses have been tested for each case study (main results: chapter 3.2, p. 65).
They are divided in three sections:
 Chapter 1: Risk Awareness, Self-Protection and Individual Precaution (H1 – H17)
 Chapter 2: Communication and Information (H17 – H27)
 Chapter 3: Financial Consequences of flood events/ insurances (H28 – H29)

Further five Hypothesis have been tested for all case studies (see chapter 3.3, p. 85).
All in all it can be summarized that for none of the tested hypothesis there is a significant relation or correlation in all case studies. Only for some of the hypothesis for single case studies a relation respectively a correlation could be noticed (21 cases out of 150 possible). For the majority of the hypothesis for which a significance tests could have been conducted, showed no correlation or relation (58 cases out of 150 possible). For all those tested hypothesis where a significance test was not possible because of different reasons (e.g. multiple answers, problematic cell composition, and so on) as far as it was possible tendencies have been indicated. It has to be noted that an analysis of the hypothesis for Arenys de Mar / Munt respectively Benaguasil was not possible in majority of cases due to too less answers or due to a problematic cell composition.
Table 21, p. 63 gives an overview of the results of the carried out statistical tests. It shows if there is a correlation respectively relation in regard to the corresponding hypothesis. Five different results can be distinguished:

Table 20: Legend to the Table 21

---	No significance test was possible, no further analysis was possible
YES	No significance test was possible, but a tendency could be observed
YES	A significance test was possible, a significant relation could be observed
NO	No significance test was possible, but no tendency could be observed
NO	A significance test was possible, no significant relation could be observed

[4] The Chi² test tests the null hypothesis that no coherence exists between line and column variables.
The Spearman correlation coefficient (ordinal scaled variables) provides information on the strength of the coherences between line and column variables.

Table 21: Overview Results Test Hypothesis, each case study

Hypothesis	Arenys de Mar / Munt	Benaguasil	Dresden	Graz	Lodi
H1 a	---	---	YES	YES	YES
H1 b	---	YES	YES	YES	NO
H2 a	YES	YES	YES	NO	NO
H2 b	NO	NO	NO	YES	NO
H3	NO	---	NO	NO	NO
H4	NO	---	NO	YES	NO
H5	NO	---	NO	NO	NO
H6 a	---	---	YES	YES	YES
H6 b	YES	---	YES	YES	YES
H7 a	---	---	YES	YES	YES
H7 b	---	YES	NO	YES	YES
H8 a	---	---	NO	NO	NO
H8 b	NO	---	NO	NO	NO
H9 a	NO	YES	NO	NO	NO
H9 b	NO	---	NO	NO	NO
H10 a	---	---	NO	YES	NO
H10 b	---	---	---	YES	NO
H11 a	---	---	NO	YES	YES
H11 b	---	---	NO	YES	---
H12 a	---	YES	NO	NO	NO
H12 b	---	YES	YES	NO	NO
H13	---	---	NO	NO	NO
H14	---	---	NO	---	NO
H15 a	---	---	NO	YES	YES
H15 b	---	---	NO	---	NO
H16	---	NO	NO	YES	NO
H17	NO	NO	NO	YES	NO
H18	NO	NO	NO	NO	NO
H19	NO	---	NO	NO	NO
H20	NO	---	NO	NO	NO
H21	NO	YES	YES	NO	YES
H22	---	---	YES	NO	YES
H23	YES	YES	YES	YES	YES
H24	YES	NO	YES	NO	YES
H25	---	---	YES	YES	YES
H26	---	---	NO	NO	NO
H27	---	---	YES	NO	NO
H28	---	---	YES	NO	NO
H29	---	---	---	YES	NO

3.2 Analyzed Hypotheses for each case study

Chapter: Risk Awareness, Self-Protection and Individual Precaution

HYPOTHESIS 1
The more knowledge people have about floods, the higher is the awareness about the residual risk and the willingness to take self-protective measures in future.

Table 22: Hypotheses 1a - Assessment of the residual risk of natural disasters in respect of the information need

ARENYS DE MAR / MUNT	Analysis was not possible.	**---**
BENAGUASIL	Analysis was not possible.	**---**
DRESDEN	Due to the problematic cell compositions it can't be tested how people assess residual risks of natural disasters in respect of the information needed. However, the data show the following tendency: 72 of the 185 respondents, who think that natural disasters always entail a residual risk do not need information on flooding, 43 do.	**YES**
GRAZ	The assessment of the residual risk is to a large extent independent of the information need. This means: A general tendency is prevalent, that is to view residual risks as given. The aspect of relevance could not be tested due to the different cell compositions and too few samples.	**YES**
LODI	Due to the problematic cell compositions it can't be tested how people assess residual risks of natural disasters in respect of the information needed. However, the data show the following tendency: 78 of the 121 respondents, who think that natural disasters always entail a residual risk do not need information on flooding, 43 do.	**YES**

Table 23: Hypothesis 1b - Self-protective measures, which will be taken in future in respect of the information need

ARENYS DE MAR / MUNT	This hypothesis can't be tested: only 17 people have answered this question (105 haven't).	**---**
BENAGUASIL	Due to the problematic cell composition this hypothesis can't be tested. The data shows the following tendency: Within the group of respondents, who don't need information on flooding, the share of people who don't intend to take self-protective measures in future is larger.	**YES**
DRESDEN	There's a significant relation between the intention to take self-protective measures in future and the information needed (Chi2 = 5.302, df = 1, N = 182, p = 0.021). Within the group of respondents, who don't need information on flooding, the share of people who intend to take self-protective measures in future is larger.	**YES**
GRAZ	If someone intends to take self-protective measures or not is independent of the individually estimated information need, i.e. the correlation is insignificant (Chi2 = 0.094, df = 1, N= 61, p = 0.759).	**YES**
LODI	There's no significant relation between the intention to take self-protective measures in future and the information needed (Chi2 = 0.857, df = 1, N = 144, p = 0.355). The data show the following tendency: Within the group of respondents, who don't need information on flooding, the share of people who don't intend to take self-protective measures in future is larger – but there are only very small differences to the respondents, who need knowledge on flood.	**NO**

HYPOTHESIS 2
The higher the risk-awareness of a person is the more probable is it, that the person knows about self-protective measures and that s/he has taken such also prior to the last flood.

Table 24: Hypothesis 2a - Knowledge about self-protective measures according to the residual risk awareness

ARENYS DE MAR / MUNT	There is a significant relation between the residual risk awareness and the knowledge about self-protective measures (Chi2 = 6.946, df = 1, N = 117, p = 0.008). Those who presume that a residual risk is always given have more knowledge about self-protecting measures.	**YES**
BENAGUASIL	None of the respondents have low risk awareness. Thus it can't be tested if the knowledge about self-protective measures differs according to the residual risk awareness. The data show the tendency that – within the group of respondents with high risk awareness – 85.7% of the respondents have knowledge on self-protective measures, 14.3% haven't.	**YES**
DRESDEN	There is a significant relation between knowledge about self-protective measures and the residual risk awareness of the interviewed people (Chi2 = 4.350, df = 1, N = 216, p = 0.037). The data shows that 36.6% of those people, who have high risk awareness, have knowledge on self-protective measures. (Again: only very small differences)	**YES**
GRAZ	There is no significant correlation between the residual risk awareness and the knowledge about self-protective measures (Chi2 = 0.091, df = 1, N = 68, p = 0.763).	**NO**
LODI	There is no relation between knowledge about self-protective measures and the residual risk awareness of the interviewed people (Chi2 = 1.955, df = 1, N = 163, p = 0.162). The data show that 62.9% of those people, who have high risk awareness, don't have knowledge on self-protective measures. (Again: only very small differences)	**NO**

Table 25: Hypothesis 2b - Measures taken at the last flood event according to residual risk awareness

ARENYS DE MAR / MUNT	There is no significant relation between the residual risk awareness and the conduct during previous environmental catastrophes. (Chi2 = 0.040, df = 1, N = 83, p = 0.841).	**NO**
BENAGUASIL	Again, none of the respondents have low risk awareness. Thus it can't be tested if the measures taken at the last flood differ according to the residual risk awareness. (This applies also all other hypothesis which aim to test something according to residual risk awareness). The data show the tendency that – within the group of respondents with high risk awareness – 57.1% of the respondents have taken self-protective measures during the last flood, 42.9% haven't.	**NO**
DRESDEN	There's no significant relation between measures taken at the last flood event and the residual risk awareness (Chi2 = 0.649, df = 1, N = 214, p = 0.420). The data show that only 15.8% of those with high risk awareness have taken self-protective measures during the last flood (only very small differences).	**NO**
GRAZ	There is a significant correlation between the residual risk awareness and the conduct during previous environmental catastrophes. Those, who presume that a residual risk is always given, have taken averagely more self-protection measures (Chi2 = 4.842, df = 1, N = 67, p = 0.028).	**YES**
LODI	There's no significant relation between measures taken at the last flood event and the residual risk awareness (Chi2 = 0.915, df = 1, N = 168, p = 0.339). The data shows that only 21.2% of those with high risk awareness have taken self-protective measures during the last flood (only very small differences).	**NO**

HYPOTHESIS 3
The higher the educational level is, the higher is the awareness in regard to a residual risk.

Table 26: Hypothesis 3

ARENYS DE MAR / MUNT	There is no significant relation between the educational level and the residual risk awareness (Chi2 = 6.800, df = 3, N = 86, p = 0.079). The figures shows that people who obtained professional training have low risk awareness; a lot of people who graduated from university (33.3%) have high risk awareness.	**NO**
BENAGUASIL	Not possible: All respondents have high risk awareness. It seems to be problematic that only a few people answered the question on the highest educational level (N=14) and the question on their risk awareness (N=7).	**---**
DRESDEN	There's no significant relation between education and the residual risk awareness (Chi2 = 3.167, df = 3, N = 218, p = 0.367). The only visible tendency is that 37.5% of the respondents with high risk awareness have obtained professional training, only 26.2% of those with low risk awareness. Only 12.5% of people with high risk awareness have graduated from upper secondary school	**NO**
GRAZ	There is no correlation between the educational level and the residual risk awareness (Chi2 = 0.232, df = 2, N = 68, p = 0.891).	**NO**
LODI	There's no significant relation between education and the residual risk awareness (Chi2 = 4.165, df = 4, N = 169, p = 0.384). The only visible tendency is that 54.9% of the respondents with low risk awareness have graduated upper secondary school (largest group).	**NO**

HYPOTHESIS 4
Dependent on the gender the residual risk awareness differs.

Table 27: Hypothesis 4

ARENYS DE MAR / MUNT	There's no significant relation between risk awareness and gender. (Chi2 = 0.235, df = 1, N = 113, p = 0.628). There are no differences between men and women visible.	**NO**
BENAGUASIL	Not possible: All respondents have high risk awareness.	**---**
DRESDEN	There's also no significant relation between gender and the residual risk awareness (Chi2 = 0.230, df = 1, N = 202, p = 0.632). There are no differences between men and women visible.	**NO**
GRAZ	Risk awareness bears a gender-based characteristic. Women tend to, rather than men, to establish a relation in case of natural catastrophes to residual risks (Chi2 = 4.842, df = 1, N = 68, p = 0.028).	**YES**
LODI	There's also no significant relation between gender and the residual risk awareness (Chi2 = 0.787, df = 1, N = 162, p = 0.375). 68% of the respondents with low risk awareness and 60.7% of the interviewed people with high risk awareness are male.	**NO**

HYPOTHESIS 5
How distinct the residual risk awareness is, depends on the information access.

Table 28: Hypothesis 5

ARENYS DE MAR / MUNT	There is no relation between the residual risk awareness and the preferred means of communication. Respondents prefer flyers advertisements and posters in public as means of communication. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
BENAGUASIL	All means of communication have been chosen only by 3 to 4 respondents – thus there are no meaningful results. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**---**
DRESDEN	Overall people with high and low risk awareness seem to prefer advertisements and posters in public. In addition information centres are liked. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
GRAZ	There is no correlation between the residual risk awareness and the preferred means of communication. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**
LODI	Overall people with high and low risk awareness seem to prefer the same means of communication. In general, advertisements and posters in public are very popular. In addition information centres are liked. (For multiple answers it is not possible to conduct significance tests in SPSS.)	**NO**

HYPOTHESIS 6
The estimated meaningfulness of self-protective measures and the willingness to take self-protective measures in future depend on the information access.

Table 29: Hypothesis 6a - Preferred communication channels of those, who intend to take self-protective measures in future

ARENYS DE MAR / MUNT	Only 10 people, who intend to take self-protective measures in future have answered this question. Thus the differences visible in the figure below aren't meaningful. (Also, the aspects of relevance can't be tested because multiple answers were possible.)	**---**
BENAGUASIL	Again, it is problematic that only a few people (only 3) have answered this question.	**---**
DRESDEN	Respondents who intend to take self-protective measures in future prefer advertisements or posters in public. They also like information centres and internet.	**YES**
GRAZ	It is striking that the on-site information center has been attributed equal importance to as has been to advertisements and posters in public	**YES**
LODI	Respondents who intend to take self-protective measures in future prefer advertisements or posters in public. They also like information centres, internet and assemblies.	**YES**

Table 30: Hypothesis 6b - Preferred communication channels of those, who regard self-protective measures as effective

ARENYS DE MAR / MUNT	The data shows that advertisements and posters in public have been attributed equal importance to. Internet and assemblies are the least preferred communication channels.	**YES**
BENAGUASIL	Again, it is problematic that only a few people have answered this question.	**---**
DRESDEN	The data show that advertisements and posters in public are of most importance to respondents who regard self-protective measures as effective; furthermore information centers and internet are popular.	**YES**
GRAZ	It is striking that the on-site information center has been attributed equal importance to as has been to advertisements and posters in public.	**YES**
LODI	The data show that advertisements and posters in public are of most importance to respondents who regard self-protective measures as effective; furthermore information centers are popular.	**YES**

HYPOTHESIS 7

The more persons felt threatened by floods, the more they have taken self-protective measures prior to the last flood and the likelier they will be taking self-protective measures in future.

Table 31: Hypothesis 7a - Subjectively perceived threat of floods and self-protective measures during the last flood

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the different cell compositions.	**---**
BENAGUASIL	The aspect of relevance can't be tested due to the different cell compositions.	**---**
DRESDEN	There is a significant relation between the subjectively perceived threat of floods and self-protective measures during the last flood awareness (Chi2 = 5.797, df = 1, N = 209, p = 0.016). 24.7% of the respondents who perceive floods as threat have taken self-protective measures during the last flood, but only 11,8% of the respondents who don't perceive floods as threats.	**YES**
GRAZ	The correlation is significant. Who felt threatened by floods, took during the last flooding respectively measures of self-protection (Chi2 = 5.113, df = 2, N= 62, p = 0.024).	**YES**
LODI	Due to the problematic cell composition this hypothesis can't be tested. However, the data show the following tendency: 23.9% of the respondents who perceive floods as threat have taken self-protective measures during the last flood, only 8.3% of the respondents who don't perceive floods as threats.	**YES**

Table 32: Hypothesis 7b - Subjectively perceived threat of floods and also in future

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the problematic cell compositions and the small sample size.	**---**
BENAGUASIL	The aspect of relevance can't be tested due to the different cell compositions. 50% of the people who feel threatened by flood take self-protective measures, only 26.7% of the respondents who don't feel threatened do so.	**YES**
DRESDEN	There is no significant relation between the subjectively perceived threat of floods and self-protective measures in future (Chi2 = 0.080, df = 1, N = 180, p = 0.777). The data shows no differences between respondents who do or don't feel threatened by floods.	**NO**
GRAZ	Another significant correlation became evident. Who felt threatened by floods, tended to project self-protective measurements in future (Chi2 = 4.970, N= 62, p = 0.026).	**YES**
LODI	Due to the problematic cell composition this hypothesis can't be tested. The data show that 80% of those who perceive floods as threats take self-protective measures in future.	**YES**

HYPOTHESIS 8

The higher the educational level of a person is, the more the know about measures of self-protection and the likelier they took self-protective measures prior to the last flood.

Table 33: Hypothesis 8a - Measures of self-protection corresponding to the level of education

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the problematic cell composition.	**---**
BENAGUASIL	Due to the problematic cell-occupations it can't be tested if the measures of self-protection correspond with the level of education. In addition only 14 people have answered this question – there are no meaningful results.	**---**
DRESDEN	There is no significant relation between the subjectively perceived threat of floods and self-protective measures in future (Chi2 = 3.264, df = 3, N = 208, p = 0.353). The share of people who graduated from upper secondary school in the group of respondents who have taken self-protective measures during the last flood is the smallest (6.5%).	**NO**
GRAZ	There appears to be no significant correlation, although tendencies are visible (Chi2 = 2.438, N = 67, df = 2, p = 0.295). Persons with a university degree have taken in comparison to other educational groups the least self-protective measures.	**NO**
LODI	There is no significant relation between the subjectively perceived threat of floods and self-protective measures in future (Chi2 = 1.359, df = 4, N = 174, p = 0.851). The differences between the educational groups are marginal; the share of people who obtained professional training in the group of respondents who have taken self-protective measures during the last flood is the smallest (15.4%).	**NO**

Table 34: Hypothesis 8b - Knowledge about measures of self-protection in respect of level of education

ARENYS DE MAR / MUNT	There's no significant relation (Chi2 = 3.936, N = 67, df = 3, p = 0.268). The knowledge about measures of self-protection seems to be evenly distributed among the layers of the population. Only people who graduated upper secondary school seem to know less about protective measures.	**NO**
BENAGUASIL	Due to the problematic cell-occupations it can't be tested if the measures of self-protection correspond with the level of education. In addition only 14 people have answered this question – there are no meaningful results.	**---**
DRESDEN	There is no significant relation between knowledge about measures and the level of education (Chi2 = 1.200, df = 3, N = 209, p = 0.753). Only 20% of the respondents with compulsory school have knowledge about measures of self-protection.	**NO**
GRAZ	The findings are unmistakable. The knowledge about measures of self-protection is evenly distributed among the layers of population (Chi2 = 0.515, N = 67, df = 2, p = 0.773).	**NO**
LODI	There is no significant relation between knowledge about measures and the level of education (Chi2 = 2.576, df = 4, N = 172, p = 0.631	**NO**

HYPOTHESIS 9

Dependent on the gender the knowledge about measures of self-protection differs, and relatively rather frequent they have taken self-protective measures prior to the last flood.

Table 35: Hypothesis 9a - Knowledge about measures of self-protection in respect of gender

ARENYS DE MAR / MUNT	There is no statistically significant relation between the knowledge about self-protection and gender (Chi2 = 0.284, N = 116, df = 1, p = 0.594).	**NO**
BENAGUASIL	It can't be tested if there is a relation between the knowledge about self-protection and the gender (problematic cell composition). A small difference can be observed: 76.2% of women have knowledge about protective measures, only 66.7% of the male respondents.	**YES**
DRESDEN	There is no significant relation between knowledge about measures and gender (Chi2 = 0.905, df = 1, N = 194, p = 0.341). The data only shows marginal differences between men and women.	**NO**
GRAZ	There is no correlation between the knowledge about self-protection and the gender (Chi2 = 0.034, N = 69, df = 1, p = 0.853).	**NO**
LODI	There is no significant relation between knowledge about measures and gender (Chi2 = 0.137, df = 1, N = 161, p = 0.711). Also, the data shows no differences between men and women.	**NO**

Table 36: Hypothesis 9b - Measures of self-protection in respect of gender

ARENYS DE MAR / MUNT	There is also no statistically significant relation between gender and the measures of self-protection taken (Chi2 = 2.039, N = 83, df = 1, p = 0.153).	**NO**
BENAGUASIL	It can't be tested if there is a relation between measures of self-protection and the gender. Again: more women in the sample have taken self-protective measures during the last flood.	**---**
DRESDEN	There's also no significant relation between measures of self-protection and gender. (Chi2 = 0.300, df = 1, N = 191, p = 0.584). Differences between men and women do not exist in the data.	**NO**
GRAZ	There is no correlation between the gender and the measures of self-protection taken (Chi2 = 0.117, N = 67, df = 1, p = 0.732).	**NO**
LODI	There's also no significant relation between measures of self-protection and gender. (Chi2 = 0.188, df = 1, N = 165, p = 0.665). Differences between men and women do not exist in the data.	**NO**

HYPOTHESIS 10
The longer persons live in their present household, the more improbable is a migration and the likelier the persons are willing to take self-protective measures in future.

Table 37: Hypothesis 10a - Migration and time in the present household

ARENYS DE MAR / MUNT	Only 7 persons answered this question – no useful results.	**---**
BENAGUASIL	Only 14 persons answered this question – thus there are no useful results.	**---**
DRESDEN	There is no significant relation between the time people lived in the household and migration.	**NO**
GRAZ	Those, who contemplated migrating, live averagely 15 years in this household. Those, who exclude a migration, are living in the respective household averagely 32 years. This is a significant difference (F = 6.203, df = 1, N = 42, p = 0.017).	**YES**
LODI	There is no significant relation between the time people lived in the household and migration.	**NO**

Table 38: Hypothesis 10b - Migration in case of flood and self-protective measures in future

ARENYS DE MAR / MUNT	Only one person answered the question; thus, there are no useful results.	---
BENAGUASIL	Due to problematic cell compositions it can't be tested if there's a significant relation between migration in case of flood and self-protective measures in future. The data shows the following tendency: There's an equal share of people who intend to take self-protective measures in future within the group of respondents who wouldn't move to another neighborhood in case of floods. The answers aren't meaningful because there's only one respondent who wouldn't migrate in case of flood.	---
DRESDEN	Due to the problematic cell composition this hypothesis can't be tested. In general the majority of the respondents intend to take self-protecting measures in future.	---
GRAZ	Due to the few number of cases tests for significance are not feasible. It can be stated though: Only those who do not think about migration also do not project self-protective measures.	YES
LODI	There's also no significant relation between migration and the intention to take self-protective measures in future (Chi2 = 0.152, df = 1, N = 122, p = 0.697). In general the majority of the respondents intend to take self-protecting measures in future.	NO

HYPOTHESIS 11

The more frequently persons have been affected by floods, the more useful they regard measures of self-protection and have also taken such.

Table 39: Hypothesis 11a- Affectedness due to floods and self-protective measures prior to the last flood catastrophe

ARENYS DE MAR / MUNT	Not applicable: only 8 people have answered this question (114=missing)	---
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). Also there's no significant Spearman-Correlation between these variables. In addition, only 17 people have answered these questions – thus there are no meaningful results.	---
DRESDEN	There's no significant correlation. Due to the problematic cell composition this hypothesis can't be tested with Chi2-test. The data shows the following tendency: 19.9% of the respondents who have rarely been affected by floods have taken self-protective measures during the last flood. More people who have fairly been affected have done so (33.3%).	NO
GRAZ	Those, who had been affected by floods 5 times or more than 5 times, have taken averagely more frequently self-protective measures. The correlation is significant. (Likelihood Ratio = 4.469, df = 2, N =41, p = 0.094).	YES
LODI	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). People who are rarely affected by floods seem to differ from the other two groups: only 23.5% of those respondents have taken self-protective measures during the last flood. There's also a significant Spearman-correlation that indicates a connection in this direction – even though it's not very strong (-0.179).	YES

Table 40: Hypothesis 11b - Affectedness due to floods and self-protective measures and estimated effectivity of self-protective measures

ARENYS DE MAR / MUNT	Not applicable: only 8 people have answered this question (114=missing)	**---**
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). There's also no significant Spearman-Correlation between these variables. Again, very few people have answered these questions.	**---**
DRESDEN	Due to the problematic cell composition this hypothesis can't be tested with Chi2-test. Also there's no significant correlation visible. There are no differences between the groups: the majority of the people who have rarely and fairly been affected by floods think of self-protective measures as effective.	**NO**
GRAZ	This tendency is worth mentioning: The more frequent someone had been affected by floods, the less effective this person estimates the effectivity of self-protective measures. Especially low has the effectivity been estimated from the group, who had been affected at least 5 times by floods. (Chi2 = 0.638, df = 2, N = 40, p = 0.727).	**YES**
LODI	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). But there's also no significant Spearman-Correlation between these variables There are too few cases in two of the three groups (fair/often affected) to have meaningful results. It can only be said that approximately 68% of the respondents who have rarely been affected by floods estimate self-protective measures to be not effective.	**---**

HYPOTHESIS 12
House owners and persons who live on the ground floor are likelier willing to take measures of self-protection.

Table 41: Hypothesis 12a - Housing situation and self-protective measures

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the problematic cell composition. The majority of people didn't answer this question.	**---**
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested. The data shows the following tendency: 14.3% of respondents who live in apartments are willing to take measures of self-protection, but 60% of the respondents who live in one-family houses.	**YES**
DRESDEN	Due to the problematic cell composition the hypothesis can't be tested (with Chi2). There are barely differences between people who live in multi-family houses or apartments. All respondents who have other living situations intend to take self-protective measures in future.	**NO**
GRAZ	No significant correlation is apparent. Especially residents of apartments and apartment buildings tend to take measures of self-protection in future. Generally the housing situation appears to have only a minor influence. (Chi2 = 0.655, df = 3, N = 62, p = 0.884).	**NO**
LODI	Due to the problematic cell composition this hypothesis can't be tested. There are barely differences between people who live in one- or multi-family houses or apartments.	**NO**

Table 42: Hypothesis 12b - Floor and self-protective measures

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the problematic cell composition. Again the majority of people's answers were coded with -88.	**---**
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). The data show the following tendency: All respondents, who live in a basement (N=2) are willing to take protective measures in future; 47.1% of the interviews people who live on the ground floor (N=8) are also willing to do so – none however of the respondents who live on the first floor or higher (N=7).	**YES**
DRESDEN	Due to the problematic cell composition the hypothesis can't be tested (with Chi2). However, the data show the following tendency: More People who live on higher floors don't intend to take self-protective measures in future; everybody who lives in a basement does.	**YES**
GRAZ	There is no apparent correlation between the position of the apartment and the tendency to take self-protective measures. The least distinctive is the willingness of the residents of the basement floor (Chi2 = 1.120, df = 4, N = 62, p = 0.891).	**NO**
LODI	Due to the problematic cell composition this hypothesis can't be tested. Also, the data show no conclusive tendency.	**NO**

HYPOTHESIS 13
The more distinct the understanding is, that the residential area can be protected sufficiently with structural measures, the inferior is the knowledge about measures of self-protection.

Table 43: Hypothesis 13

ARENYS DE MAR / MUNT	The aspect of relevance can't be tested due to the different cell composition.	**---**
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested. In addition only 7 people have answered this question – thus, there are no meaningful results.	**---**
DRESDEN	There appear no significant relations between the estimation of effectiveness of protective measures and awareness about self-protective measures (Chi2 = 1.724, df = 3, N = 205, p = 0.632). However, the data show the following tendency: approximately 54% of the respondents, who do (rather) not think that protective measures aren't effective, have knowledge about self-protective measures, so do approximately 75% of the respondents who think that protective measures are effective.	**NO**
GRAZ	There is no conclusive correlation (Chi2 = 5.693, df = 4, N = 70, p = 0.223).	**NO**
LODI	There appear no significant relations between the estimation of effectiveness of protective measures and awareness about self-protective measures (Chi2 = 5.954, df = 3, N = 163, p = 0.114). However, the data show the following tendency: approximately 30% of the respondents, who do not or do think that protective measures are effective, have knowledge about self-protective measures.	**NO**

HYPOTHESIS 14
The greater the damage caused by floods had been, which had to be born with individual resources, the likelier people are willing to take measures of self-protection in future.

Table 44: Hypothesis 14

ARENYS DE MAR / MUNT	This hypothesis cannot be tested due to too few numbers of cases. Only 1 person declared damages up to 10.000 Euro.	---
BENAGUASIL	This hypothesis cannot be tested due to too few numbers of cases. Only 6 people declared damages up to 10.000 Euro.	---
DRESDEN	There is no significant correlation between the amount of the damage and the willingness to take self-protective measures in future. (Attention: the majority of the respondents haven't answered this question!)	NO
GRAZ	This hypothesis cannot be verified due to too few numbers of cases. Only 3 persons declared damages above 10.000,- Euro.	---
LODI	There is no significant correlation between the amount of the damage and the willingness to take self-protective measures in future.	NO

HYPOTHESIS 15
When measures of self-protection had been taken, the damages suffered due to floods had been lighter.

Table 45: Hypothesis 15a - The correlation between suffered material and financial losses and the tendency to take self-protective measures

ARENYS DE MAR / MUNT	Again, most of people's answers are "not applicable". Due to the small sample size the hypothesis can't be tested.	---
BENAGUASIL	Due to the problematic cell-composition this hypothesis can't be tested (with Chi2-test). Due to the small sample size there are no meaningful results.	---
DRESDEN	There's no significant relation between the material and financial losses people suffered and their tendency to take self-protective measures (Chi2 = 0.837, df = 2, N = 146, p = 0.658), and also no correlation. There are no differences between the groups.	NO
GRAZ	For significance could not be tested. Tendentially incline those, who had to endure financial and material losses, more to self-protective measures.	YES
LODI	There's a significant relation between the material and financial losses people suffered and their tendency to take self-protective measures (Chi2 = 8.409, df = 2, N = 153, p = 0.015). Respondents who've only suffered none, small or medium material or financial losses were more willing to take self-protective measures during the last flood than those, who suffered a great/massive loss. This result can be confirmed with a Spearman correlation (0.234).	YES

Table 46: Hypothesis 15b - The correlation between health impairments caused by floods and the tendency to take self-protective measurements

ARENYS DE MAR / MUNT	Due to the very small number of relevant cases, an interpretation is not feasible.	**---**
BENAGUASIL	None of the respondents has health impairments caused by floods. 8 of these people say that they took self-protecting measures during the last flood, 11 say they haven't. (The significance of this aspect can't be tested).	**---**
DRESDEN	Due to the problematic cell composition this hypothesis can't be tested with Chi2-test. There's no significant correlation. There are no differences between people who suffered medium or none/little losses visible; everybody who suffered great/massive damages doesn't intend to take self-protective measures in future.	**NO**
GRAZ	Due to the very small number of relevant cases, an interpretation is not feasible.	**---**
LODI	There's no significant relation between health impairments caused by floods and the tendency to take self-protective measures (Chi2 = 5.068, df = 2, N = 142, p = 0.079; and also no significant correlation). However, the data show that approximately 50% of those people who suffered none or small losses have taken self-protective measures during the last flood, approximately 50% aren't. Again, the majority of people who suffered medium losses were willing to take self-protective measures. This is true for very few people who had great or massive damages.	**NO**

HYPOTHESIS 16
The more physical and psychological symptoms appeared due to flood events, the higher is the willingness to take self-protective measures in future.

Table 47: Hypothesis 16

ARENYS DE MAR / MUNT	This hypothesis can't be tested due to the small number of cases (there's only one mean for one person).	**---**
BENAGUASIL	There's no significant correlation between count and gravity of the reported physical and psychological impairments and the willingness to take self-protective measures in future.	**NO**
DRESDEN	There's no significant correlation between count and gravity of the reported physical and psychological impairments and the willingness to take self-protective measures in future.	**NO**
GRAZ	There is a significant positive correlation between count and gravity of the reported physical and psychological impairments and the willingness to take self-protective measures in future (F=3.735, df= 1, N = 32, p = 0.063)	**YES**
LODI	There's no significant correlation between count and gravity of the reported physical and psychological impairments and the willingness to take self-protective measures in future.	**NO**

HYPOTHESIS 17
In case of flood elderly persons accepted support more frequently than younger persons.

Table 48: Hypothesis 17

ARENYS DE MAR / MUNT	There is no significant (point-biserial) correlation between age and the acceptance of helping each other in neighborhood in case of flood.	**NO**
BENAGUASIL	Again, there is no significant (point-biserial) correlation between age and the acceptance of helping each other in neighborhood in case of flood.	**NO**
DRESDEN	There's no significant negative correlation between age and the willingness to accept support.	**NO**
GRAZ	Those, who state that there had been mutual (reciprocal) assistance in the neighborhood, are averagely younger (approx. 51 years) than those, who had not observed anything like that (approx. 62 years). The difference in years is insignificant ($F = 1.641$, $df = 1$, $N = 46$, $p = 0.207$).	**YES**
LODI	There's no significant correlation between age and the willingness to accept support .	**NO**

Chapter 2: Communication and Information

HYPOTHESIS 18
Depending on the experienced degree of threat the need for information in case of floods differs, especially the wish for information from the media, an on-site information center, task forces (emergency services), as well as communities/ authorities (local council).

Table 49: Hypothesis 18

ARENYS DE MAR / MUNT	People who experienced threat prefer information from the media, emergency services and communities (local council). These three types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. Therefore it cannot be tested in terms of significance.)	**NO**
BENAGUASIL	People who experienced threat prefer information from the media, internet and community/local council. These three types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
DRESDEN	People who experienced threat prefer information from media, emergency services and community/local council. Those two types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
GRAZ	There are no significant differences respective to the degree of threat (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**
LODI	People who experienced threat prefer information from emergency services and community/local council. Those two types of communication/information are also preferred by people who haven't experienced threats. (Attention: multiple answers. It cannot be tested in terms of significance, therefore.)	**NO**

HYPOTHESIS 19
Dependent on the level of education differs the need for information in case of floods, especially the wish of information from the media, an on-site information center, task forces (emergency services), as well as from communities/ authorities (local council).

Table 50: Hypothesis 19

ARENYS DE MAR / MUNT	People with upper secondary school don't need information from friends/relatives in case of floods. All other types of information are needed regardless to the level of education. The data show that media, emergency services and communities are considered as helpful sources of information of respondents, again: regardless to the level of education (Attention: multiple answers. It cannot be tested for significance.)	**NO**
BENAGUASIL	Due to the small sample size (N=12, 21 missing) there are no meaningful results. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**---**
DRESDEN	All respondents prefer media, emergency services and community/local councils. In general the data show no differences in using/needing different sources of information. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
GRAZ	There are no differences in regard to the level of education. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
LODI	All respondents prefer emergency services and community/local councils. In general the data show no differences in using/needing different sources of information. Only people who obtained professional training don't use the internet. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**

HYPOTHESIS 20
Dependent on the gender the need for information in case of floods differs.

Table 51: Hypothesis 20

ARENYS DE MAR / MUNT	There are no gender differences. The same sources of information (media, emergency services and communities) are listed as very useful by the respondents. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
BENAGUASIL	Due to the small sample size (N=12, 21 missing) there are no meaningful results. In addition one has to consider that 19 women but only 5 men have answered this question. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**---**
DRESDEN	There's the same pattern visible: there seem to be no gender differences. Men and women prefer information from media, emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
GRAZ	There are no gender differences. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
LODI	There's the same pattern visible: there seem to be no gender differences. Men and women prefer information from emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**

HYPOTHESIS 21
Affected differ from not-affected in the need of information in case of floods.

Table 52: Hypothesis 21

ARENYS DE MAR / MUNT	There are no differences in regard to the degree affectedness. People who are not affected tend to need less information from internet and emergency services. (Attention: multiple answers. It cannot be tested for significance.)	**NO**
BENAGUASIL	Due to the small sample size (N=24, 9 missing) there are no meaningful results. One can observe the following tendency: People who have been affected by floods seem to prefer information from internet and media and use in addition community/local councils or friends/relatives. Respondents who haven't been affected also prefer media, but also use community/local council, internet, emergency services and on-site-information centers as sources for information. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**
DRESDEN	The observed tendency doesn't change: people prefer information from media, emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance.)	**YES**
GRAZ	There are no differences in regard to the degree affectedness. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
LODI	The observed tendency doesn't change: people prefer information from emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance.)	**YES**

HYPOTHESIS 22
Subjectively people felt more informed in case of floods, when they obtained the information via media (television/ radio), task forces (emergency services) as well as communities/ authorities (local council) and not from the internet.

Table 53: Hypothesis 22

ARENYS DE MAR / MUNT	Due to the small number of cases the results can't be used.	**---**
BENAGUASIL	There are very few cases, only 13 people have answered this question – thus there are no meaningful results. (Attention: multiple answers. It cannot be tested for significance.)	**---**
DRESDEN	The observed tendency doesn't change: people prefer information from media, emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**
GRAZ	There are no relevant differences. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
LODI	The observed tendency doesn't change: people prefer information from emergency services and community/local councils. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**

HYPOTHESIS 23
Persons, who feel threatened by natural disasters, differ from such with a subjective minor threat estimation, that the means of communication, which are preferred by them, in order to inform themselves on a regular basis about flood concerns, is first and foremost an on-site information center, followed by assemblies, advertisements (announcements, reports) in the media, a platform (sites) in the internet, and flyers (leaflets, pamphlets).

Table 54: Hypothesis 23

ARENYS DE MAR / MUNT	For persons, who feel subjectively threatened, the following media are important: 1. Advertisments and posters in public 2. Flyers (leaflets, pamphlets)	**YES**
BENAGUASIL	For persons, who feel subjectively threatened, the following media are important: 1. Advertisements (announcements, reports) in the media and posters in public 2. Flyers (leaflets, pamphlets), on-site information center and sites on the internet	**YES**
DRESDEN	For persons, who feel subjectively threatened, especially the following media are important: 1. Advertisements (announcements, reports) in the media and posters in public 2. On-site information centers 3. Sites on the internet 4. Flyers 5. Assemblies	**YES**
GRAZ	For persons, who feel subjectively threatened, the following ranking applies: 1: Posters in public/ advertisements (announcements, reports) in the media 2. On-site information center 3. Assemblies/ information events 4. Flyers (leaflets, pamphlets) 5. Platform (sites) in the internet For persons, who subjectively do not feel threatened, the following ranking applies: 1 Posters in public/ advertisements (announcements, reports) in the media 2. On-site information center 3. Flyers (leaflets, pamphlets)/ assemblies 4. Plattform (sites) in the internet	**YES**
LODI	For persons, who feel subjectively threatened, especially the following media are important: 1. Advertisements (announcements, reports) in the media and posters in public 2. On-site information centers 3. Sites on the internet 4. Assemblies	**YES**

HYPOTHESIS 24
Persons affected from floods differ to those less affected through their preference in the means of communication to keep themselves informed on a regular basis about flood concerns, first and foremost the on-site information center, followed by assemblies, advertisements (announcements, reports) in the media, a platform (sites) in the internet, and flyers (leaflets, pamphlets).

Table 55: Hypothesis 24

ARENYS DE MAR / MUNT	People who were affected by floods prefer advertisements and poster in public, also on-site information centers and flyers. Respondents who weren't affected by floods prefer flyers, on-site information centers and assemblies. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**
BENAGUASIL	All respondents prefer advertisements and posters in public – regardless if they have been affected by floods or not. People who were affected by floods also use flyers and assemblies as sources for information. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
DRESDEN	Respondents who have been affected by floods prefer advertisements and posters in public. They also use on-site information centers and sites on the internet as sources for information. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**
GRAZ	There are only marginal differences. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**NO**
LODI	Respondents who have been affected by floods prefer advertisements and posters in public. They also use on-site information centers as sources for information. (Attention: multiple answers. It cannot be tested for significance, therefore.)	**YES**

HYPOTHESIS 25
The younger the persons are, the more they would like to retrieve (obtain) information from the internet.

Table 56: Hypothesis 25

ARENYS DE MAR / MUNT	Analyisis was not possible.	**---**
BENAGUASIL	Due to the small number of cases (N=10, 23=missing) the hypothesis (2.9) can't be tested.	**---**
DRESDEN	All respondents prefer posters and advertisements. Old people don't use sites on the internet as much as younger respondents.	**YES**
GRAZ	All respondents prefer posters and advertisements. Old people don't use sites on the internet as much as younger respondents.	**YES**
LODI	All respondents prefer posters and advertisements. Old people don't use sites on the internet as much as younger respondents.	**YES**

HYPOTHESIS 26
The greater the knowledge of a person is in regard to floods, the shorter is the necessary time span in order to be prepared sufficiently for floods.

Table 57: Hypothesis 26

ARENYS DE MAR / MUNT	Due to the problematic cell composition the hypothesis can't be tested.	---
BENAGUASIL	Due to the small number of cases and the problematic cell composition the hypothesis can't be tested.	---
DRESDEN	There's no significant relation between the knowledge of a person in regard to flood and the necessary time span in order to be prepared sufficiently for floods (Chi2 = 0,527, df = 3, N = 221, p = 0,913). There are also no differences between the groups that are worth mentioning.	NO
GRAZ	There are no significant differences. (Chi2 = 2.17, df = 3, N = 71, p = 0.538=).	NO
LODI	There's no significant relation between the knowledge of a person in regard to flood and the necessary time span in order to be prepared sufficiently for floods (Chi2 = 1.100, df = 3, N = 181, p = 0.777). There's no conclusive tendency.	NO

Chapter: Financial Consequences of flood events/ insurances

HYPOTHESIS 27
Dependent on the level of education the willingness to effect an insurance against catastrophes in future differs.

Table 58: Hypothesis 27

ARENYS DE MAR / MUNT	Due to the problematic cell composition the hypothesis can't be tested.	---
BENAGUASIL	Due to the small number of cases (N=8, 25 missing) and the problematic cell composition the hypothesis can't be tested.	---
DRESDEN	There's a significant relation between the level of education and the willingness to effect insurance against catastrophes in future (Chi2 = 12.275, df = 3, N = 197, p = 0.006): a lot of people with low education (compulsory education) intend to insure against catastrophes in the future. The higher the education the more likely people don't ensure against catastrophes – this tendency isn't that strong among people who graduated from university: approximately 55% aren't willing to effect an insurance, approximately 45% are.	YES
GRAZ	There is no distinctive correlation. Amongst persons with an educational level of *upper secondary school* the willingness is the least (Chi2 = 3.891, df = 4, N = 70, p = 0.421).	NO
LODI	There's no significant relation the level of education and the willingness to effect insurance against catastrophes in future (Chi2 = 1.946, df = 4, N = 164, p = 0.746). There's no conclusive tendency.	NO

HYPOTHESIS 28
Affected differ from not-affected in the willingness to insure themselves against damages of catastrophes in future.

Table 59: Hypothesis 28

ARENYS DE MAR / MUNT	Due to the problematic cell composition the hypothesis can't be tested.	---
BENAGUASIL	Due to the small number of cases (N=22, 11 missing) and the problematic cell composition the hypothesis can't be tested.	---
DRESDEN	There's also a significant relation (Chi2 = 7.864, df = 1, N = 197, p = 0.005). People who have been affected by floods are more likely to insure themselves against damages of catastrophes in future than people who haven't been affected by floods. (This result is also confirmed by a point-biserial correlation, 0.2).	YES
GRAZ	There are no significant differences. The tendency to effect insurance is only greater among effected than not-affected persons (Chi2 = 2.347, df = 2, N = 72, p = 0.309).	NO
LODI	There's no significant relation (Chi2 = 0.974, df = 1, N = 166, p = 0.324). There's no conclusive tendency.	NO

HYPOTHESIS 29
The higher the monthly income is, the more persons are willing to insure against catastrophes in future.

Table 60: Hypothesis 29

ARENYS DE MAR / MUNT	Due to the problematic cell composition the hypothesis can't be tested. In Addition, only 10 people answered the question (112 cases missing).	---
BENAGUASIL	Only 4 people were willing to answer this question. Thus the hypothesis can't be tested, there're no meaningful results.	---
DRESDEN	Due to the problematic cell composition this hypothesis can't be tested. However, the data show the following tendency: People who earn more than €3000 are less willing to insure against catastrophes than all other respondents.	---
GRAZ	The tendency is clear: With an increasing monthly income the intention to effect insurances rises (Chi2 = 11.378, df = 8, p = 0.181).	YES
LODI	There's no significant relation (Chi2 = 5.703, df = 3, N = 141, p = 0.127). However, the data show the following tendency: People who earn more than €3000 are more willing to insure against catastrophes than others.	NO

3.3 Analyzed Hypotheses for all case studies

HYPOTHESIS 1 – all case studies
Being personally affected by a flood incident leads the feeling of being at risk from a flood to increase.

Table 61: Hypothesis 1, all case studies (n = 620)

			affected by a flood in the last 10 years		
			yes	no	
threatened by floods in own neighbourhood	low		73	116	189
		%	19.3%	47.9%	30.5%
	middle		115	93	208
		%	30.4%	38.4%	33.5%
	high		190	33	223
		%	50.3%	13.6%	36.0%
			378	242	620
		%	100.0%	100.0%	100.0%

It is to be deduced from the contingency table that the threat of a flood in the respondents' own areas of the city is perceived as greater if the respondents have been personally affected by at least one flood incident in the last ten years. Pearson's chi-square value is very significant (p<0.001) and Spearman's correlation coefficient has a value of -0.393 and is very significant (p<0.001). It can thus be assumed that there exists a slightly stronger negative correlation between the variables of being personally affected and threat from a flood. Being personally affected by a flood affects, in an increasing way, the subjective perception of a threat from a flood in the respondent's own area of the city.

HYPOTHESIS 2 – all case studies
Being personally affected has an effect on knowledge about flooding and its causes.

Table 62: Hypothesis 2, all case studies (n = 625)

			affected by a flood in the last 10 years		
			yes	no	
personal knowledge	low		53	54	107
		%	13.7%	22.7%	17.1%
	middle		181	120	301
		%	46.8%	50.4%	48.2%
	high		153	64	217
		%	39.5%	26.9%	34.7%
			387	238	625
		%	100.0%	100.0%	100.0%

Of those affected, 13.7% and 39.5% indicate that they have a low and a high level of knowledge regarding floods respectively. The middle category was chosen the most frequently both by people affected (46.8%) and those not affected (50.4%). Pearson's chi-square value is significant (p=0.001) and Spearman's correlation coefficient has a value of -0.15 and is very significant (p<0.001). In this respect, being personally affected by a flood is associated with an increased estimation of knowledge of flooding and its causes. The correlation is, however, very weak and is no longer convincing.

HYPOTHESIS 3 – all case studies
There is a correlation between sex and the indicated level of knowledge regarding flooding and its causes.

Table 63: Hypothesis 3, all case studies (n = 589)

			sex		
			male	female	
personal knowledge	low		48	51	99
		%	15.2%	18.6%	16.8%
	middle		140	144	284
		%	44.4%	52.6%	48.2%
	high		127	79	206
		%	40.3%	28.8%	35.0%
Gesamt			315	274	589
		%	100.0%	100.0%	100.0%

The contingency table further shows that 18.6% of women indicate having a low level of knowledge regarding flooding whilst 52.6% think they have a fair knowledge and 28.8% a high level of knowledge. On the other hand, 40.3% of men assess their level of knowledge as high, 44.4% as fair and 15.2% as low. Pearson's chi-square value is significant (p=0.014) and Spearman's correlation coefficient has a value of -0.111 and is significant (p=0.007). Men rate their level of knowledge higher than women. The correlation is, however, very weak and is no longer convincing.

HYPOTHESIS 4 – all case studies
People with a higher level of education evaluate their level of knowledge regarding flooding and its causes as greater than people with a lower level of education.

Table 64: Hypothesis 4, all case studies (n = 417)

			highest educational achievement			
			Compulsory education	Upper secondary school	University	
personal knowledge	low		18	23	18	59
		%	24.3%	13.9%	10.1%	14.1%
	middle		39	79	83	201
		%	52.7%	47.9%	46.6%	48.2%
	high		17	63	77	157
		%	23.0%	38.2%	43.3%	37.6%
			74	165	178	417
		%	100.0%	100.0%	100.0%	100.0%

The contingency table shows that people with an obligatory school diploma indicate the following levels of personal knowledge regarding flooding as follows: 24% low, 53% fair and 23% high. People with a diploma from a higher high school level indicate that 13.9% have a low level of knowledge, 47% a fair level and 38% a high level of knowledge. University graduates indicate that 10.1% have a low level of knowledge with regards to flooding, 46.6% a fair level and 43% a high level of knowledge. Pearson's chi-square value is significant (p=0.009) and Spearman's correlation coefficient has a value of 0.16 and is significant (p=0.001). People with a higher level of education rate their knowledge of flooding and its causes as greater. The correlation is, however, very weak and is no longer convincing.

HYPOTHESIS 5 – all case studies
People with a higher level of education have more knowledge of self protection measures during a flood incident.

Table 65: Hypothesis 5, all case studies (n = 412)

			highest educational achievement			
			Compulsory education	Upper secondary school	University	
knowledge about self protection	yes		26	66	76	168
		%	35.6%	40.7%	42.9%	40.8%
	no		47	96	101	244
		%	64.4%	59.3%	57.1%	59.2%
			73	162	177	412
		%	100.0%	100.0%	100.0%	100.0%

36% of people with an obligatory school diploma indicate that they have knowledge of self protection measures, 65% indicate that they have no knowledge. For people with a high school diploma from a level higher than the obligatory level, 41% are aware of self protection measures and 59% have no knowledge. 43% of university graduates say that they have knowledge of self protection measures during a flood whilst 57% indicate that they have none. Pearson's chi-square value is not significant (p=0.563) and Spearman's correlation coefficient has a value of -0.049 and is not significant (p>0.05). It cannot be confirmed that people with a higher level of education have more knowledge of self protection measures.

4 Opinion poll in English

The opinion poll has been developed in English and has been translated into German, Italian and Spanish. Here representative the English version is listed on the next pages.

Chapter 1:
Natural hazards and floods in general

1. How satisfied are you with your current living situation?

not satisfied					very satisfied
☐	☐	☐	☐	☐	☐

2. Which of the following options applies to your current living situation?

☐ One-family house

☐ Multi-family house

☐ Apartment in an apartment building

☐ Other:__________________

3. To what extent do you feel threatened by the following natural hazards in your neighborhood?

	not at all					very much
Heavy storms	☐	☐	☐	☐	☐	☐
Flood	☐	☐	☐	☐	☐	☐
Hail	☐	☐	☐	☐	☐	☐
Land slides	☐	☐	☐	☐	☐	☐
Earthquakes	☐	☐	☐	☐	☐	☐

4. How would you rate the flood risk for the following categories of persons?

	little					great
For me personally	☐	☐	☐	☐	☐	☐
For the inhabitants of my house	☐	☐	☐	☐	☐	☐
For the inhabitants of my neighborhood	☐	☐	☐	☐	☐	☐
For the entire city	☐	☐	☐	☐	☐	☐

5. How would you rate your personal knowledge about floods and their causes?

very bad					very good
☐	☐	☐	☐	☐	☐

6. What would you suppose are the causes of flood events?

	does not apply					applies
Climate change	☐	☐	☐	☐	☐	☐
High housing density	☐	☐	☐	☐	☐	☐

	does not apply					applies
Sealing of the soil surface (streets, parking lots etc.)	☐	☐	☐	☐	☐	☐
Extreme weather conditions	☐	☐	☐	☐	☐	☐
Non-natural interference in the course of rivers or brooks	☐	☐	☐	☐	☐	☐
Sewer construction	☐	☐	☐	☐	☐	☐
Town planning	☐	☐	☐	☐	☐	☐

7. Rate the following statements:

	does not apply			applies
With flood control measures (heightening of embankments, widening of river beds, retention basins) my neighborhood can be protected sufficiently.	☐	☐	☐	☐
Man cannot control nature entirely.	☐	☐	☐	☐
One can protect oneself from floods completely.	☐	☐	☐	☐
Flood risk has increased due to a higher housing density.	☐	☐	☐	☐
There remains always a residual risk with natural hazards	☐	☐	☐	☐

8. Which one of the following measures do you consider reasonable in order to reduce flood risk? Please rate on a scale of 1 to 4 (1 = most reasonable, 4 = least reasonable)

	Rate
Early warning systems	_____
Self protection measures	_____
Protective structures (retention basins, heightening of embankments, etc.)	_____
Restoration to a near-natural course of rivers or brooks	_____

9. How would you rate the present feasibility of flood forecast in your district?

very bad					very good
☐	☐	☐	☐	☐	☐

Chapter 2: Consequences of flood events

10. Have you been affected by floods in your present household during the last 10 years?

☐ Yes

☐ No — If not → please continue with question 22

11. In case you have: How often have you been affected by floods in this period?

Number ______

12. When were you last affected by a flood?

Year _____ Month _____

13. How would you rate the personal damage you suffered from the last flood?

	none					massive
Material and financial losses	☐	☐	☐	☐	☐	☐
Health impairments	☐	☐	☐	☐	☐	☐
other:_______________	☐	☐	☐	☐	☐	☐

14. Have you suffered from any of the following physical or psychological symptoms due to the flood event?

	none					very strong
Headaches	☐	☐	☐	☐	☐	☐
Joint pains and aching limbs	☐	☐	☐	☐	☐	☐
Gastrointestinal complaints	☐	☐	☐	☐	☐	☐
Panic attacks / anxiety states	☐	☐	☐	☐	☐	☐
Insomnia	☐	☐	☐	☐	☐	☐
Irritability /anger	☐	☐	☐	☐	☐	☐
Restlessness	☐	☐	☐	☐	☐	☐
Breathing difficulties	☐	☐	☐	☐	☐	☐
Quick exhaustion /fatigue	☐	☐	☐	☐	☐	☐
Loss of motivation and interests	☐	☐	☐	☐	☐	☐
Attention difficulties	☐	☐	☐	☐	☐	☐
Other: ________________	☐	☐	☐	☐	☐	☐

15. Have you suffered any physical impairments due to flood events? (bone fracture, etc.)

☐ Yes

☐ No — If not → please continue with question 17

16. In case you have, what kind of impairments?

____

____

17. Was it necessary to see a doctor or to go to a hospital due to flood events?

Doctor	☐ Yes →	How often _____
	☐ No	
Hospital	☐ Yes →	How long _____
	☐ No	

18. Do you have to take any particular drugs since then?

☐ Yes

☐ No — If not → continue with question 20

19. If so: What kind of drugs?

☐ Sedatives

☐ Cardiovascular drugs

☐ Pain killer

☐ Drugs for breathing difficulties

☐ Other: _______________

20. How high do you estimate the expenses for the medical treatment, that has been necessary due to the flood events, and that you had to fund yourself (without being refunded)?

Amount € _________

21. Rate the following statements:

	does not apply			applies
When I moved to this area I was aware of the flood risk.	☐	☐	☐	☐
I have coped psychologically well with the flood events so far.	☐	☐	☐	☐
During heavy rain I am reminded of previous flood events	☐	☐	☐	☐

	does not apply			applies
Due to the financial burden of the flood disaster I can barely afford to go on holiday.	☐	☐	☐	☐
The quality of my life is not impaired by flood risk.	☐	☐	☐	☐
If flood events continue to occur I intend to move to another neighborhood.	☐	☐	☐	☐

Chapter 3: Communication and information

22. How much time do you need to prepare sufficiently for a flood?

☐ less than 2 hours ☐ 4 to 6 hours

☐ 2 to 4 hours ☐ more than 6 hours

23. Which information is the most pressing to you in case of a flood event?

____

____

24. How would you like to obtain this information? (More than one answer possible)

O Internet

O On-site information centre

O Media (television, radio, newspaper)

O Friends/relatives

O Emergency services (fire department, police, army)

O Local authority/authority

O Other: ___________

25. Rate the following statements:

	does not apply			applies
I can assess flood risk well	☐	☐	☐	☐
Floods do not present a life-threatening danger to me	☐	☐	☐	☐
Due to a lack of information, the feeling of insecurity may arise.	☐	☐	☐	☐

	does not apply			applies
Floods present a high risk in comparison to other natural hazards.	☐	☐	☐	☐
I am familiar with the subject flood events.	☐	☐	☐	☐

26. How reasonable are the following means of communication to keep oneself informed on a regular basis about flood issues. Please, make your rating on a scale from 1 to 6. (1 = most reasonable, 6 = least reasonable).

	Rate
Flyer	_____
On-site information centre	_____
Sites on the Internet	_____
Assemblies/information sessions	_____
Information broadcasted in media (television, radio)	_____
Billboards in public	_____

27. Do you have any alternative suggestions?

____

____

In case you were not affected by a flood during the last 10 years → please continue with question 36

28. How well informed have you felt during the last flood event?

very bad					very well
☐	☐	☐	☐	☐	☐

29. How much time has passed between the first warning to the onset of the flood?

☐ up to 0.5 hours ☐ 4 to 6 hours

☐ 0.5 to 2 hours ☐ 6 to 8 hours

☐ 2 to 4 hours ☐ more than 8 hours

30. This time span was

far too short					sufficient
☐	☐	☐	☐	☐	☐

31. Have you obtained sufficient information about the current flood situation during the last flood?

☐ Yes, regularly

☐ Yes, now and then

☐ No If not → please, continue with question 35

32. In case you have: What kind of information have you received?

____

____

33. From where have you obtained this information? (More than one answer is possible)

O Media (television, radio, newspaper)

O Internet

O Emergency services (fire department, rescue service, army)

O Friends/relatives

O Local authority/authority

O Other: ___________

34. The obtained information was…

not helpful					very helpful
☐	☐	☐	☐	☐	☐

35. How satisfied have you been with the performance of the following Emergency service?

	not satisfied			very satisfied
Fire department	☐	☐	☐	☐
Police	☐	☐	☐	☐
Rescue service	☐	☐	☐	☐

Chapter 4:
Self protection and individual precautions

36. Do you know concrete measures to protect yourself in case of flood?

☐ Yes

☐ No — If not → continue with question 39

37. In case you do: What kind of measures do you know?

____

____

38. Where have you learned about these measures? (More than one answer possible)

O Emergency services (fire department, rescue service, army)

O Internet

O Friends/relatives

O Insurance

O Media (television, radio, newspaper)

O Local authority/authority

O Other: ___________

39. How reasonable are self-protection measures in respect of flood events in your opinion?

not effective ☐ ☐ ☐ ☐ ☐ ☐ very effective

40. Have you taken self protection measures before the last flood?

☐ Yes — If so → continue with question 43

☐ No

41. In case you have not: Why haven't you?

☐ No necessity

☐ No means at disposal

☐ Someone else's responsibility

☐ It was not possible

☐ Other: ___________

42. What would you need to take self protection measures (Information, etc.)?

____

____ → continue with question 45

43. In case you have: What kind of measures have you taken?

____

____

44. How effective were the applied measures?

not effective ☐ ☐ ☐ ☐ ☐ ☐ very effective

45. Will you take protective measures in the future (again)?

☐ Yes

☐ No

46. How would you evaluate the solidarity efforts in your neighborhood?

not good ☐ ☐ ☐ ☐ ☐ ☐ very good

47. Neighborly help is to me in case of a flood event…

not important ☐ ☐ ☐ ☐ ☐ ☐ very important

48. Have you helped each other during the last flood in your neighborhood?

☐ Yes

☐ No — If not → please continue with question 51

☐ No idea — If no idea → please continue with question 51

49. If so: What kind of help was provided?

____

____

50. How important was this provided help?

not important ☐ ☐ ☐ ☐ ☐ ☐ very important

Chapter 5:
Financial consequences of flood events

51. Did you or a member of your household experience a labor slack (partial or complete loss of work volume) due to the last flood? (e.g.: destruction of the work place, inaccessibility of the work place, lack of child care etc.)?

☐ Yes

☐ No — If not → please continue with question 53

52. In case you did: Due to what?

____

____

53. Have you been insured against catastrophic losses at the last flood event ?

☐ Yes

☐ No — If not → please continue with question 55

54. Did the insurance compensation correspond to the full amount of the flood damage.

☐ Yes

☐ No

☐ No damage occured — If „no damage occured“ → please continue with qu. 59

55. Did you receive funds from the disaster fund?

☐ Yes

☐ No

56. Have all financial compensations (insurance, disaster fund etc.) covered all your losses?

☐ Yes — If yes → please continue with question 58

☐ No

57. In case they have not: How high was the loss that you had to pay for?

☐ up to € 10.000,--

☐ from € 10.001,-- to € 50.000,--

☐ from € 50.001,-- to € 100.000,--

☐ more than € 100.000,--

58. How long will it take you to get back to your normal course of life after the last flood event?

____

____

59. Will you insure yourself against catastrophic losses in future?

☐ Yes

☐ No

Chapter 6: Questions about yourself

60. How long have you lived in your present household?

____

61. In which district/ part of town do you live?

____

____

62. How many persons live in your household?

Number _____

63. How many of these persons are older than 18?

Number _____

64. On which floor do you live?

☐ Basement

☐ Ground floor

☐ First floor

☐ Second floor and higher

65. Do you use a cellar compartment or a basement garage?

☐ Yes

☐ No

66. Please state your gender:

☐ male

☐ female

67. How old are you?

Years _____

68. What is your highest educational achievement?

☐ Compulsory education

☐ Professional training (apprenticeship)

☐ High school

☐ College/ University

☐ None of the above

69. How high is your monthly household (net) income?

☐ up to € 1.000,--

☐ from € 1.001,-- to € 2.000,--

☐ from € 2.001,-- to € 3.000,--

☐ more than € 3.000,--

Comments and notes:
(Please quote the relevant number of the question(s), you refer to)

____
____
____
____
____
____
____
____
____
____
____
____
____
____

Thank you very much for your cooperation!

Appendix 5

International comparison of the results of the case studies

Criteria Catalouge

A Characteristics

B Warning systems

C Risk analysis

D Communication

E Disaster control management

Table 66: Criteria Catalouge – A Characteristics

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
A	**Characteristics of the case study area**								
A 1	*River characteristics*								
A 1. 1	Extent of the catchment area	A1 1.1	< 0,5 km²	-	-	-	-	-	-
		A1 1.2	0,5 - 10 km²	2.67 (GB) [*5]	-	-	-	X	*Arenys de Munt = 6.5 km²
		A1 1.3	10 - 50 km²	17.91 km² (AB) [*6] , 34.1 km² (SB) [*7]	-	-	-	-	Arenys Basin (Arenys de Munt + Arenys de Mar) = 16 km²
		A1 1.4	50 - 100 km²	-	-	-	-	-	-
		A1 1.5	> 100 km²	-	384	6300	X	-	-
A 1. 2	Annual probability of exceedance - discharge	A1 2.1	mean discharge [m³/s]	-	3.35	190	-	-	-
		A1 2.2	10-year flood [m³/s]	-	133	1252	-	-	47.937*
		A1 2.3	30-year flood [m³/s]	25.5 m³/s (AB), 27.1 m³/s (SB), 10 m³/s (GB)	159 (HQ20)	-	-	-	-
		A1 2.4	50-year flood [m³/s]	-	194	1642	-	-	75.605*
		A1 2.5	100-year flood [m³/s]	40 m³/s (AB), 41 m³/s (SB), 15 m³/s (GB)	234	1806	-	-	87.844*
		A1 2.6	1000-year flood [m³/s]	-	263 (HQ200)	-	X	-	-
		A1 2.7	5000-year flood [m³/s]	-	495 (EHQ)	-	-	-	-
A 1. 3	How many flood events occurred (including economic loss or / and loss of life)	A1 3.1	between 2000 - 2010	3	1	-	No more flood event since the construction of Loriguilla Dam and the new river course	10	4
		A1 3.2	between 1990 - 2000	2	0	64		6	2
		A1 3.3	between 1980 - 1990	1	1	52		-	2
		A1 3.4	between 1970 - 1980	1	1	50		-	3
		A1 3.5	between 1960 - 1970	-	0	39		-	1
		A1 3.6	between 1950 - 1960	-	3	73	1	-	1
		A1 3.7	befor 1950	1	25	15	10 reported flood events (since 1517)	-	23
A 1. 4	How often the listed flood events occurred?	A1 4.1	10-year flood [m³/s]	-	1954	-	-	0	-
		A1 4.2	30-year flood [m³/s]	-	-	-	-	1	-
		A1 4.3	50-year flood [m³/s]	-	-	-	-	0	22
		A1 4.4	100-year flood [m³/s]	-	1958	-	-	1	14
		A1 4.5	1000-year flood [m³/s]	-	1897 (HQ200), 2002 (EHQ)	-	-	0	-
A 1. 5	River capacity (m³/s)	A1 5.1	River capacity (m3/s)	-	-	650	5,000	-	-
		A1 5.2	Flow discharge that reaches the first households (m³/s)	-	-	1040	-	-	-

Arenys Basin = Arenys de Mar + Arenys de Munt

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
A 1. 6	What was the biggest flood event (return period) (m³/s)	A1 6.1	10-year flood [m³/s]	-	-	-		-	-
		A1 6.2	100-year flood [m³/s]	-	-	x	The return period of the biggest flood event has not been estimated yet. It ranges from 100 to 500 years. The maximum river discharge was 3,800 m³/s.	-	-
		A1 6.3	300-year flood [m³/s]	-	-	-		-	-
		A1 6.4	500-year flood [m³/s]	-	2002 (EHQ ~ HQ500)	-		-	X
		A1 6.5	1000-year flood [m³/s]	-	-	-	-	-	-
		A1 6.6	5000-year flood [m³/s]	-	-	-	-	-	-
		A1 6.7	other	nearly 30-year flood known, in large part unknown	-	-	-	-	-
A 2	*Characteristics of population and way of living*								
A 2. 1	Population	A2. 1.1	Total population	19319	63000	38939	815440	11144	Arenys de Munt = 8190; Arenys Basin = 22817
		A2. 1.2	Resident population	17865	-	38939	815440	11144	Arenys de Munt = 8190; Arenys Basin = 22817
		A2. 1.3	Seasonal variability	no quantitative information available	-	0.05	-	(+) 2000	[*1]Arenys de Munt (30%) = 11127; Arenys Basin (30) = 29662
		A2. 1.4	Daily variability	no quantitative information available	-	0.45	-	(-) 2500	[*2]Arenys de Munt = 2294; Arenys Basin = 5932
		A2. 1.3	Total number of affected people (100-year flood)	1321	4700	860	-	800	[*3]Arenys de Munt = 1150; Arenys Basin = 3200
A 2. 2	Residential types	A2. 2.1	One-family houses (> 70%)	-	-	-	-	-	-
		A2. 2.2	Apartment building (> 70%)	-	X	X	X	-	-
		A2. 2.3	Combination One-family houses - apartment building (nearly same parts)	X	-	-	-	X	X

[*1]The industrial and comercial zone do not have seasonal variability
[*2]The industrial and comercial zone have 100 % of daily variability. (The persons end of work at 18:00)
[*3]10% of the persons exposed at risk

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
A 2. 3	Identification of vulnerable areas or sectors: number of	A2. 3.1	Schools	3	3	3	115	2	0
		A2. 3.2	Kindergarten	-	1	-	-	-	1
		A2. 3.3	Hospitals	-	2	1	7	0	0
		A2. 3.4	Retirement home	-	3	0	39	1	0
		A2. 3.5	Chemical plants	-	0	0	0	0	0
		A2. 3.6	Sewage treatment plants	-	0	0	1	0	0
		A2. 3.7	Petrol station	-	> 1	some	35	1	0
		A2. 3.8	Others:	4 pharmacies	Felsenkellerbrauerei, Hofmühle Altplauen, Dr. Doerr Feinkost GmbH, Bürohaus am Weißeritzknick, Kleingewerbe am Weißeritzknick, Kleingartenanlage, Internat Paluccaschule, Geschäfte Prager Straße, 4 Hotels Prager Straße, Büro- ,Geschäftshäuser am Hbf, main station, World Trade Centre, Kraftwerk Mitte, art hotel, Schauspielhaus, Zwinger, Haus der Presse, Landtag, Theaterwerkstätten, Hochschule für Musik, Markthalle (Bf DD Mitte), Gewerbe (Fabrikstraße)	-	-	-	1 Municipal Library
A 2. 4	Land use of the study area	A2. 4.1	mainly agricultural areas (> 60%)	-	-	-	-	-	Arenys de Munt = 0%; Arenys Basin = 87%
		A2. 4.2	mainly residentual areas (> 60%)	-	-	x	X	X	Arenys de Munt = 100%; Arenys Basin = 11.7%
		A2. 4.3	mainly industrial/commercial area (> 60%)	-	-	-	-	-	Arenys de Munt = 15%; Arenys Basin = 0.8%
		A2. 4.4	mainly combination agricultural - residentual areas (~80 %)	-	-	-	-	-	-
		A2. 4.5	mainly combination agricultural - industrial areas (~80 %)	-	-	-	-	-	-
		A2. 4.6	mainly combination residentual - industrial areas (~80 %)	-	x	-	-	-	-
		A2. 4.7	combination agricultural - residentual - industrial areas (nearly same parts)	-	-	-	-	-	-
A 2. 5	Building typology	A2. 5.1	Average number of households per building	-	12	-	11.3	1.5	3 persons
		A2. 5.2	Average number of floors/building or average height	2	4	2.53	4.71	1.8	3 persons
		A2. 5.3	Average width of the streets	-	-	-	12	9.5	7
A 2. 6	Reference costs / land uses	A2. 6.1	Reference cost for residential areas	-	-	68.70 euro/m2	86.25	55.5	894.63
		A2. 6.2	Reference cost for industrial areas	-	-	-	16.7	16.7	717.26
		A2. 6.3	Reference cost for agricultural areas	-	-	0.34	0.3	0.3	-

Table 67: Criteria Catalouge – B Warning systems

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
B	**Warning Systems**								
B 1	*Weather forecast*								
B 1. 1	Are rainfall-runoff-models in use?	B1 1.1		no	no	-	yes	no	No, in the Arenys basin but the ACA, METEOCAT and CECAT are in currents implementation for the Maresme zone.
B 1. 2	Are forecast models in use?	B1 2.1		no	expert knowledge	-	yes	yes	Yes, is managed by the METEOCAT
B 1. 3	Measurements of	B1 3.1	precipitation (yes / no)	yes	yes	-	yes	yes	yes
		B1 3.2	precipitation (if yes, number of stations)	13 rainfall gauges	8	-	3	1	yes, 1 official rainfall station and 1 station managed by Antoni Sintes
		B1 3.3	river discharge (yes / no)	yes	yes	-	yey	no	no
		B1 3.4	river discharge (if yes, number of stations)	2	11	-	4	-	-
B 1. 4	First installation of	B1 4.1	river gauge	2010	1913	-	1922	-	1990
		B1 4.2	precipitation gauge	1938	-	-	1988	1992	Is posible to found information from earlers 1916. The official station was installed in 1990
B 1. 5	Measurement data will be	B1 5.1	collected	yes	yes	-	yes	yes	yes
		B1 5.2	analysed	probably yes	yes	-	It is already analysed in the Emergency Action Plan of Loriguilla Dam	yes	yes
B 2	*Warning system - inhabitants*								
B 2. 2	Warning message distribution	B2 2.1	TV, radio	yes	yes	-	yes	yes	yes
		B2 2.2	Internet (websites)	yes	yes	-	yes	yes	yes
		B2 2.3	SMS	yes	yes	-	no	no	yes
		B2 2.4	E-Mail	no	yes	-	-	-	yes
		B2 2.5	Diaphones	no	yes	-	-	-	no
		B2 2.6	Megaphones	yes	-	-	yes	yes	yes
		B2 2.7	Insurances	yes	-	-	-	-	no
		B2 2.8	Others	text messages from professional fire brigades of Graz to registered people	-	-	-	-	Warning Bell

Table 68: Criteria Catalouge – C Risk analysis

				Analysis Case Study					
Nr.	**Title**		**Criteria**	**Graz**	**Dresden**	**Lodi**	**Valencia**	**Benauasil**	**Arenyis de Mar / Munt**
C	**Risk Analysis**								
C 1	*Flood Protection Measures*								
C 1. 1	Existing structural measures	C1 1.1	retention basins	2	yes	no	no	no	yes
		C1 1.2	detention basins	-	-	no	no	no	no
		C1 1.3	reservoir (e.g. also use for energy production, water supply, ...)	no	yes	no	yes	yes	no
		C1 1.4	embankments	yes	-	no	yes	no	yes
		C1 1.5	river broadening	yes	yes	no	no	no	no
		C1 1.6	natural retention areas	no	-	yes	no	no	no
		C1 1.7	drainage system	yes	yes	yes	yes	yes	yes
		C1 1.8	Change of river bed roughness	-	yes	no	yes	no	yes
		C1 1.9	new channels	no	yes	no	yes	no	yes
		C1 1.10	mobile flood protection measures: stop-log next to the river (as a kind of embankment dam)	no	-	no	no	no	no
		C1 1.11	mobile flood protection measures: stop-log at windows and doors	yes	-	no	no	yes	yes
		C1 1.12	mobile flood protection measures: sand bags next to the river (as a kind of embankment dam)	yes	-	no	no	no	no
		C1 1.13	mobile flood protection measures: sand bags at windows and doors	yes	-	no	no	no	no
		C1 1.14	others	-	-	-	-	-	-
C 1. 2	Existing non-structural measures	C1 2.1	Urban planning and policies	no	-	yes	yes	yes	yes
		C1 2.2	Flood forecasting	yes	yes	yes	yes	yes	no*
		C1 2.3	Regular activities and plans for public education.	no	yes	no	no	no	yes
		C1 2.4	Warning systems	yes	yes	no	yes	yes	
		C1 2.5	Emergency action plan is already applied. It has not been proved or used	no	yes	yes	yes	yes	no*
		C1 2.6	Emergency action plan is already applied. It has been proved or used	yes	-	no	-	-	no*
		C1 2.7	Aids mechanisms	no	yes	no	no	no	no*
		C1 2.8	Communication mechanisms to the public	yes	-	yes	yes	yes	yes
		C1 2.9	Low coordination between emergency agencies and authorities	in case of preparation	-	no	no	no	no*
		C1 2.10	Medium coordination between emergency agencies and authorities	-	-	yes	no	no	-
		C1 2.11	High coordination between emergency agencies and authorities	in case of emergency	yes	no	yes	yes	yes
					-				
C 2	*Flood risk analysis*								
C 2. 1	Flood risk analysis	C2 1.1	River flooding (see C3)	yes	yes	yes	yes	no	no
		C2 1.2	Pluvial flooding (see C4)	no	-	no	no	yes	yes
		C2 1.3	River and pluvial flooding (see C3 and C4)	no	-	no	N/A	-	no
C 3	*Risk estimation (River flooding)*								
C 3. 1	Phase I - Scope of the study	C3 1.1	Number of case scenarios (including base-case)	2	-	2	3	-	-
		C3 1.2	Base-case (current situation)	yes	-	yes	X	-	-
		C3 1.3	Non-structural measures: yes/no	yes	-	yes	yes	-	-
		C3 1.4	Situation without any measures: yes/no	no	-	yes	yes	-	-
C 3. 2	Phase II - Available data	C3 2.1	Hydrologic studies (catchment areas, hydrographs, rainfall rates)		-	yes	yes	-	-
		C3 2.2	Hydraulic studies (hydraulic characteristics of the flood)		-	yes	yes	-	-
		C3 2.3	Flooding maps		-	yes	yes	-	-
		C3 2.4	1D-hydraulic model	yes	-	no	no	-	-
		C3 2.5	2D-hydraulic model	no	-	yes	no	-	-
		C3 2.6	Historical events	end of 1940s, 1975, 2005, 2009	-	no	yes	-	-
		C3 2.7	Number of time categories (TC)	2 (day / night)	-	4	4	-	-
		C3 2.8	Number of land use categories (CU)	for calculation reduced to 1	-	2	3	-	-

				Analysis Case Study					
Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
C 3. 3	Phase III - Base-case	C3 3.1	Existing structural measures which are included for calculations (see C1)	river broadening, embankments	-	no	LORIGUILLA DAM, RIVER EMBANKMENT		-
		C3 3.2	Existing non-structural measures which are included for calculations (see C2)	warning systems, communication systems, emergency plan	-	no	EMERGENCY ACTION PLAN		-
C 3. 4	Phase IV - Flood scenarios	C3 4.1	Number of flood scenarios (F) in case of structural failure	-	-	0	3	-	-
		C3 4.2	Minimum peak discharge (m^3/s) in case of structural failure	-	-	-	1907	-	-
		C3 4.3	Maximum peak discharge (m^3/s) in case of structural failure	-	-	-	117112	-	-
		C3 4.1	Number of flood scenarios (F) in case of no failure	-	-	8	3	-	-
		C3 4.2	Minimum peak discharge (m^3/s) in case of no failure	-	-	807	*ADDITIONAL CALCULATIONS UPDATED RESULTS (30/06/2011)	-	-
		C3 4.3	Maximum peak discharge (m^3/s) in case of no failure	-	-	2187	*	-	-
C 3. 5	Phase V - Risk model architecture	C3 5.1	Number of nodes of the influence diagram	-	-	7	14		-
C 3. 6	Phase VI- Input data	C3 6.1	Number of sub-areas for calculations depending on land use categories and homogenous zones	-	-	1	*	-	-
		C3 6.2	Category for loss of life estimation for the base-case (from C1 to C10, WP3)	-	-	C2	C4	-	-
		C3 6.3	Flood severity levels: Percentage of low, medium and high severity	-	-	15% low, 85% medium	*	-	-
		C3 6.4	Total number of input values in terms of loss of life (N): N = TC x F	-	-	see the table on the right	*	-	-
C 3. 7	Phase VII - Risk calculations	C3 7.1	Number of branches of the event tree	-	-	-	*	-	-
		C3 7.2	Societal risk: number of fatalitites/year	-	-	see the table on the right	*	-	-
		C3 7.3	Economic risk: economic losses (€)/year	-	-	-	*	-	-
C 3. 8	Phase VIII - F-N and F-D curves	C3 8.1	Number of potential fatalities in case of $F=1{\cdot}10^{-4}$ (cumulative annual probability of exceedance)	-	-	217 (base case)	*	-	-
		C3 8.2	Number of potential fatalities in case of $F=1{\cdot}10^{-6}$ (cumulative annual probability of exceedance)	-	-	680(base case)	*	-	-
		C3 8.3	Number of potential fatalities in case of $F=1{\cdot}10^{-8}$ (cumulative annual probability of exceedance)	-	-	-	*	-	-
		C3 8.4	Potential economic losses in case of $F=1{\cdot}10^{-4}$ (cumulative annual probability of exceedance)	-	-	140947221.605 (base case)	*	-	-
		C3 8.5	Potential economic losses in case of $F=1{\cdot}10^{-6}$ (cumulative annual probability of exceedance)	-	-	329339556 (base case)	*	-	-
		C3 8.6	Potential economic losses in case of $F=1{\cdot}10^{-8}$ (cumulative annual probability of exceedance)	-	-	-	*	-	-
C 3. 9	Phase IX - Risk evaluation	C3 9.1	There are available tolerability criteria to compare with results (yes/no)	-	-	no	no	-	-
		C3 9.2	Results can be compared with historical data (yes/no)	-	-	yes	yes	-	-
C 3. 10	Phase X - Non-structural measures	C3 10.1	Urban planning and policies	yes	-	yes	no	-	-
		C3 10.2	Improving of flood forecasting	-	-	no	no	-	-
		C3 10.3	Public education programmes on flood risk	yes	-	no	yes	-	-
		C3 10.4	Warning systems	yes	-	no	yes	-	-
		C3 10.5	Implementation of an emergency action plan	yes	-	yes	yes	-	-
		C3 10.6	Aids mechanisms	-	-	no	no	-	-
		C3 10.7	Communication mechanisms to the public	yes	-	yes	yes	-	-
		C3 10.8	Coordination strategies	-	-	no	yes	-	-
C 3. 11	Comparison between case scenarios	C3 11.1	Societal risk (number of fatalitites/year) for each case scenario	-	-	reduction of 10 times	*	-	-
		C3 11.2	Economic risk (economic losses (€)/year) for each case scenario	-	-	reduction of 4 times	*	-	-

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
C 4	*Risk estimation (Pluvial flooding)*								
C 4. 1	Phase I - Scope of the study	C4 1.1	Number of case scenarios (including base-case)	-	-	-	-	2	3
		C4 1.2	Base-case (current situation)	-	-	-	-	X	X
		C4 1.3	Non-structural measures: yes/no	-	-	-	-	yes	yes
		C4 1.4	Situation without any measures: yes/no	-	-	-	-	no	yes
C 4. 2	Phase II - Available data	C4 2.1	Hydrologic studies (catchment areas, rainfall rates, runoff rates)	-	-	-	-	yes	yes
		C4 2.2	Hydraulic studies (hydraulic characteristics of the flood)	-	-	-	-	no	yes
		C4 2.3	Flooding maps	-	-	-	-	no	yes
		C4 2.4	Map of the drainage system	-	-	-	-	no	no
		C4 2.5	Model of the drainage system	-	-	-	-	no	no
		C4 2.6	Historical events	-	-	-	-	yes	no
		C4 2.7	Number of time categories (TC)	-	-	-	-	4	yes
		C4 2.8	Number of land use categories (CU)	-	-	-	-	5	yes
C 4. 3	Phase III - Base-case	C4 3.1	Existing structural measures which are included for calculations (see C1)	-	-	-	-	DRAINAGE SYSTEM	sewer system
		C4 3.2	Existing non-structural measures which are included for calculations (see C2)	-	-	-	-	WARNING SYSTEM AND PUBLIC EDUCATION	Early warning system and other
C 4. 4	Phase IV - Flood scenarios	C4 4.1	Number of flood scenarios (F) in case of failure of the drainage system	-	-	-	-	7	7
		C4 4.2	Minimum runoff flow (m^3/s) in case of failure of the drainage system	-	-	-	-	3.31	T= 2 years (no hydrograph see WP5)
		C4 4.3	Maximum runoff flow (m^3/s) in case of structural failure	-	-	-	-	101.76	T= 500 years (no hydrograph see WP5)
C 4. 5	Phase V - Risk model architecture	C4 5.1	Number of nodes of the influence diagram	-	-	-	-	7	The same considered in the WP3 methodology
C 4. 6	Phase VI- Input data	C4 6.1	Number of sub-areas for calculations depending on land use categories and homogenous zones	-	-	-	-	8	2
		C4 6.2	Category for loss of life estimation for the base-case (from Cp1 to Cp3, WP3)	-	-	-	-	Cp1	Cp2, Cp3
		C4 6.3	Flood severity levels: Percentage of S0 (no victims), S1 (low), S2 (medium), S3 (high) and S4 (extreme)	-	-	-	-	S4 (30.36%), S3 (69.64%)	S3=85%; S2=1.4%; and S0=11.4%
		C4 6.4	Total number of input values in terms of loss of life (N): N = TC x F	-	-	-	-	28	28
C 4. 7	Phase VII - Risk calculations	C4 7.1	Number of branches of the event tree	-	-	-	-	64	-
		C4 7.2	Societal risk: number of fatalitites/year	-	-	-	-	0.28	Depends: Worst case 11 casualties. With all NSM implementation and considering the sewer system = 2 casualties. (see WP5)
		C4 7.3	Economic risk: economic losses (€)/year	-	-	-	-	733380	Depends: Worst case 8.3 M€. With all NSM implementation and considering the sewer system = 0.85 M€. (see WP5)
C 4. 8	Phase VIII - F-N and F-D curves	C4 8.1	Number of potential fatalities in case of $F=1\cdot10^{-2}$ (cumulative annual probability of exceedance)	-	-	-	-	2.6	-
		C4 8.2	Number of potential fatalities in case of $F=1\cdot10^{-3}$ (cumulative annual probability of exceedance)	-	-	-	-	4.06	-
		C4 8.3	Number of potential fatalities in case of $F=1\cdot10^{-4}$ (cumulative annual probability of exceedance)	-	-	-	-	4.06	-
		C4 8.4	Potential economic losses in case of $F=1\cdot10^{-2}$ (cumulative annual probability of exceedance)	-	-	-	-	4125883	-
		C4 8.5	Potential economic losses in case of $F=1\cdot10^{-3}$ (cumulative annual probability of exceedance)	-	-	-	-	4593257	-
		C4 8.6	Potential economic losses in case of $F=1\cdot10^{-4}$ (cumulative annual probability of exceedance)	-	-	-	-	4593257	-

				Analysis Case Study					
Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
C 4. 9	Phase IX - Risk evaluation	C4 9.1	There are available tolerability criteria to compare with results (yes/no)	-	-	-	-	no	no
		C4 9.2	Results can be compared with historical data (yes/no)	-	-	-	-	yes	no
C 4. 10	Phase X - Non-structural measures	C4 10.1	Urban planning and policies	-	-	-	-	no	yes
		C4 10.2	Improving of flood forecasting	-	-	-	-	no	yes
		C4 10.3	Public education programmes on flood risk	-	-	-	-	yes	yes
		C4 10.4	Warning systems	-	-	-	-	yes	yes
		C4 10.5	Implementation of an emergency action plan	-	-	-	-	no	yes
		C4 10.6	Aids mechanisms	-	-	-	-	no	yes
		C4 10.7	Communication mechanisms to the public	-	-	-	-	no	yes
		C4 10.8	Coordination strategies	-	-	-	-	no	yes
C 4. 11	Comparison between case scenarios	C4 11.1	Societal risk (number of fatalitites/year) for each case scenario	-	-	-	-	NON-STRUCTURAL MEASURES (0.11)	yes
		C4 11.2	Economic risk (economic losses (€)/year) for each case scenario	-	-	-	-	NON-STRUCTURAL MEASURES (495,150)	yes

Table 69: Criteria Catalouge – D Communication

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
D	**Communication**								
D 1	*Information about the participants*								
D 1. 1	Q66: Gender of participants [% in opinion poll]	D1 1.1	male	52.8	45.8	56.4	-	36.4	42.6
		D1 1.2	female	44.4	41.2	34	-	63.6	52.5
D 1. 2	Q68: Education of participants [% in opinion poll]	D1 2.1	professional training	26.4	33.6	8	-	9.1	17.2
		D1 2.2	upper secondary school	29.2	13.0	42	-	6.1	27
		D1 2.3	university	41.7	42.4	13.3	-	9.1	18.1
D 1. 3	Q67: Average of the age	D1 3.1	≤ 15 years	0.0	0.0	-	-	0	6.6
		D1 3.2	16 - 25 years	4.2	10.8	4.7	-	3	5.7
		D1 3.3	26 - 40 years	16.8	11.3	12.1	-	21	42.6
		D1 3.4	41 - 60 years	32.2	17.0	43.9	-	21	32.8
		D1 3.5	≥ 61 years	44.8	49.0	39	-	18	12.3
D 2	*Natural hazards and floods in gernal*								
D 2. 1	Q5: Knowledge of floods [% in opinion poll]	D2 1.1	very bad	4.2	10.0	11.7	-	9.1	-
		D2 1.2	average	36.1	50.8	75.5	-	30.3	-
		D2 1.3	very good	58.4	37.0	11.7	-	21.2	-
D 2. 2	Q6: Supposed causes of flood events by the participants CLIMATE CHANGE	D2 2.1	applies	25.0	32.4	31.4	-	6.1	3.3
		D2 2.2	on average	33.4	38.3	26.1	-	6	32.8
		D2 2.3	does not apply	33.4	19.3	1.6	-	54.5	33
D 2. 2	Q6: Supposed causes of flood events by the participants HIGH HOUSING DENSITY	D2 2.4	applies	8.3	40.7	10.1	-	12.1	7.4
		D2 2.5	on average	9.7	24.7	29.8	-	12.1	29.5
		D2 2.6	does not apply	79.1	21.8	18.1	-	33.3	27.9
D 2. 2	Q6: Supposed causes of flood events by the participants SEALING OF THE SOIL SURFACE	D2 2.7	applies	8.4	36.5	19.7	-	18.2	7.4
		D2 2.8	on average	15.2	31.5	28.2	-	9.1	37.7
		D2 2.9	does not apply	68.0	21.9	8	-	30.3	31.1
D 2.2	Q6: Supposed causes of flood events by the participants EXTREME WEATHER CONDITIONS	D2 2.10	applies	7.0	60.1	38.8	-	24.1	11.5
		D2 2.11	on average	26.4	28.2	-	-	-	-
		D2 2.12	does not apply	59.7	5.1	8	-	6.1	13.1
D 2.2	Q6: Supposed causes of flood events by the participants NON-NATURAL INTERFERENCE IN THE COURSE OF RIVERS OR BROOKS	D2 2.13	applies	5.6	58.8	54.3	-	39.4	11.5
		D2 2.14	on average	19.4	23.1	14.9	-	3	35.3
		D2 2.15	does not apply	65.3	9.2	1.6	-	6.1	17.2
D 2.2	Q6: Supposed causes of flood events by the participants SEWER CONSTRUCTION	D2 2.16	applies	18.0	18.5	18.1	-	57.6	18
		D2 2.17	on average	36.1	36.6	36.7	-	15.2	36.9
		D2 2.18	does not apply	31.9	28.5	6.4	-	3	4.9
D 2.2	Q6: Supposed causes of flood events by the participants TOWN PLANNING	D2 2.19	applies	8.4	19.8	31.9	-	21.2	30.6
		D2 2.20	on average	19.4	46.2	-	-		-
		D2 2.21	does not apply	61.2	19.8	6.4	-	24.2	12.3
D 2.3	Q8: Most important flood protection measure [% in opinion poll]	D2 2.22	Early warning systems	16.7	45.0	34.6	-	36.4	30.2
		D2 2.23	Self protection measures	13.9	10.9	12.8	-	42.4	26.85
		D2 2.24	Protective structures (retention basins,heightening of embankments, etc.)	65.3	37.4	56.9	-	3	26.85
		D2 2.25	Restoration to a near-natural course of rivers or brooks	44.4	44.1	48.9	-	6.1	16.1
		D2 2.26	Others	0.0	0.0	0	-	N/A	0

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
D 3	*Consequences of flood events*								
D 3. 1	Q11: How often have you been affected by floods in your present household in the last 10 years?	D3 1.1	never	38.9	26.9	2.1	-	N/A	93.4
		D3 1.2	1 time	9.7	62.2	67	-	9.1	1.6
		D3 1.3	2 - 3 times	29.2	3.8	7.4	-	21.3	2.5
		D3 1.4	4 - 6 times	14.0	0.0	2.1	-	6	1.6
		D3 1.5	> 7 times	5.6	0.0	0.5	-	24.4	0.8
D 3. 2	Q24: Wanted Information of the public by [%]	D3 2.1	Media (television, radio, newspaper)	63.9	83.6	27.7	-	48.5	57
		D3 2.2	Internet	15.3	25.6	11.2	-	24.2	-
		D3 2.3	Emergency services (fire department, rescue service, army)	76.4	64.7	85.1	-	6.1	64.8
		D3 2.4	Friends/relatives	12.5	5.9	7.4	-	3	-
		D3 2.5	Local authority/authority	31.9	40.3	66.5	-	15.2	51.6
		D3 2.6	On-site information centre	25.0	27.3	-	-	-	
		D3 2.7	Others	9.7	7.1	14.9	-	N/A	0.8
D 3. 3	Q13: Personal damage you suffered from the last flood MATERIAL AND FINANCIAL LOSSES	D3 3.1	none	25.0	10.9	1.6	-	9.1	4.1
		D3 3.2	a trifle	22.2	36.5	13.3	-	33.4	0.8
		D3 3.3	massive	12.5	18.9	29.8	-	18.2	0
D 3. 3	Q13: Personal damage you suffered from the last flood HEALTH IMPAIRMENTS	D3 3.4	none	44.4	51.3	23.9	-	93.9	4.9
		D3 3.5	a trifle	8.4	4.6	32.4	-	0	0
		D3 3.6	massive	4.2	2.1	3.2	-	0	0
D 3. 3	Q13: Personal damage you suffered from the last flood OTHERS	D3 3.7	none	16.7	23.1	3.2	-	97	0.8
		D3 3.8	a trifle	5.6	2.1	3.7	-	3	0.8
		D3 3.9	massive	7.0	5.0	2.7	-	0	0
D 3. 4	Q21: The quality of the participants life is not impaired by flood risk [%]	D3 4.1	applies	19.4	36.1	18.1	-	21.2	0.8
		D3 4.2	on average	25	6.7	39.9	-	3	1.6
		D3 4.3	does not apply	15.3	23.9	23.9	-	12.1	3.3
D 3. 4	Q21: If flood events continue to occur the participant intends to move to another neighborhood	D3 4.4	applies	8.3	4.2	21.8	-	3	2.5
		D3 4.5	on average	8.4	8.9	27.6	-	3	-
		D3 4.6	does not apply	43.1	55.9	33	-	36.4	3.3
D 4	*Communication and information*								
D 4. 1	Q22: How much time do the participants need to prepare sufficiently for a flood?	D4 1.1	less than 2 hours	34.7	17.6	6.9	-	48.5	45.1
		D4 1.2	2 to 4 hours	45.8	29.4	19.1	-	3	27.9
		D4 1.3	4 to 6 hours	12.5	28.6	23.4	-	0	15.6
		D4 1.4	more than 6 hours	6.9	18.9	46.8	-	3	8.2
D 4. 2	Q26: Most important communication instrument for participants? [%]	D4 2.1	Flyer	12.5	6.3	34	-	15.2	69.7
		D4 2.2	On-site information centre	34.7	19.3	54.7	-	15.2	73.9
		D4 2.3	Sites on the Internet	6.9	11.3	39.4	-	N/A	79
		D4 2.4	Assemblies/information sessions	13.9	2.5	37.7	-	9.1	80
		D4 2.5	Information broadcasted in media (television, radio)	55.6	65.1	65.9	-	30.3	-
		D4 2.6	Billboards in public	6.9	5.5	52.1	-	3	64.8
D 4. 3	Q 28: How well informed have the participants felt during the last flood event?	D4 3.1	bad	43.0	47.9	76.1	-	48.5	1.6
		D4 3.2	average	13.9	13.0	4.8	-	6.1	3.3
		D4 3.3	well	5.6	4.6	3.2	-	3	1.6
D 4. 4	Q 29: How much time has passed between the first warning to the onset of the flood?	D4 4.1	up to 0.5 hours	26.4	16.8	33.5	-	3	1.6
		D4 4.2	0.5 to 2 hours	13.9	14.3	10.1	-	0	0.8
		D4 4.3	2 to 4 hours	5.6	5.9	7.4	-	0	0.8
		D4 4.4	4 to 6 hours	6.9	7.6	5.9	-	0	-
		D4 4.5	6 to 8 hours	0	1.7	2.1	-	0	-
		D4 4.6	more than 8 hours	0	5.5	4.8	-	3	0.8

				Analysis Case Study					
Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
D 4. 5	Q 31: Sufficient information during a flood event (according to the public)	D4 5.1	Yes, regularly	6.9	11.3	2.7	-	0	0.8
		D4 5.2	Yes, now and then	20.8	25.6	12.2	-	0	-
		D4 5.3	No	34.7	26.9	63.8	-	15.2	5.7
D 4. 6	Q 33: Obtained Information of the public by [%]	D4 6.1	Media (television, radio, newspaper)		28.2	2.7	-	12.1	-
		D4 6.2	Internet		1.7	1.1	-	3	-
		D4 6.3	Emergency services (fire department, rescue service, army)		8.4	8	-	0	0.8
		D4 6.4	Friends/relatives		11.8	5.3	-	3	-
		D4 6.5	Local authority/authority		2.5	8	-	0	0.8
		D4 6.6	Others		0.4	3.2	-	N/A	-

D 5 Communication and information

D 5. 1	Q 36: Knowledge of concrete self-protection measures [%]	D5 1.1	yes	65.3	30.7	43.6	-	72.7	28.7
		D5 1.2	no	31.9	61.3	56.4	-	27.3	70.5
D 5. 2	Q 38: Where have the participants learned about self-protection measures? [%]	D5 2.1	Emergency services (fire department, rescue service, army)	16.7	7.1	9	-	0	2.5
		D5 2.2	Internet	1.4	2.1	0	-	0	0.8
		D5 2.3	Friends/relatives	5.6	7.6	0.5	-	60.6	13.9
		D5 2.4	Insurance	0	2.1	0.5	-	0	-
		D5 2.5	Media (television, radio, newspaper)	15.3	17.6	4.8	-	0	1.6
		D5 2.6	Local authority/authority	5.6	3.4	4.3	-	0	0.8
		D5 2.7	Other:	8.3	8.8	16	-	Own experience	13.9
D 5 .3	Q 40: Have the participants taken self protection measures before the last flood?	D5 3.1	yes	33.3	15.5	21.3	-	33.3	10.7
		D5 3.2	no	62.5	75.6	73.9	-	63.6	59
D 5 .4	Q 41: Why didn't the participants take self-protection measures?	D5 4.1	No necessity	34.7	30.3	16	-	21.2	54.9
		D5 4.2	No means at disposal	4.2	2.9	10.6	-	0	1.6
		D5 4.3	Someone else's responsibility	1.4	0.8	3.7	-	3	-
		D5 4.4	It was not possible	11.1	23.9	21.3	-	12.1	6.6
		D5 4.5	Other	6.9	6.7	18.6	-	21.2	2.5
D 5 .5	Q 46: Solidarity efforts in the neighborhood	D5. 5.1	not good	5.6	8.4	13.3	-	15.2	303
		D5. 5.2	average	30.6	30.2	23.9	-	15.2	32.8
		D5. 5.3	very good	61.1	58.0	31.9	-	24.2	14.8
D 5. 6	Q 53: Have the participants been insured against catastrophic losses at the last flood event ?	D5 6.1	yes	58.3	47.9	10.1	-	63.6	9
		D5 6.2	no	33.3	45.0	84	-	30.3	66.4
D 5. 7	Q 56: Have all financial compensations (insurance, disaster fund etc.) covered all the losses of the participants?	D5 7.1	yes	8.3	32.8	4.8	-	9.1	2.5
		D5 7.2	no	26.4	40.3	78.2	-	3	19.7

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
D 6	*Information Campaigns by Stakeholder*								
D 6. 1	Carried out information campaigns	D6. 1.1	brochures	-	-	yes	-	NO	yes
		D6. 1.2	flyer	yes	-	yes	-	NO	yes
		D6. 1.3	website	yes	-	yes	-	YES	yes
		D6. 1.4	workshop	yes	-	no	-	NO	no
		D6. 1.5	publications	yes	-	yes	-	NO	yes
		D6. 1.6	information boards	-	-	no	-	NO	yes
		D6. 1.7	radio, TV	-	-	no	-	YES	yes
		D6. 1.8	documentation (DVD)	-	-	no	-	NO	yes
		D6. 1.9	press work (press conferences, interviews, ...)	yes	-	yes	-	YES	yes
		D6. 1.10	high-water marks	-	-	no	-	NO	no
		D6. 1.11	others	opening, groundbreaking ceremony, flood bags for district leader	-	-	-	N/A	-
D 6.2	Audience of the information campaigns	D6. 2.1	population	yes	-	yes	-	YES	Yes
		D6. 2.2	kindergarten	-	-	no	-	NO	No
		D6. 2.3	school	-	-	no	-	NO	No
		D6. 2.4	stakeholder	-	-	yes	-	YES	Yes
		D6. 2.5	action forces	-	-	yes	-	YES	Yes
		D6. 2.6	others	district leader	-	-	-	N/A	-

Table 70: Criteria Catalouge – E Disaster control management

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
E	**Disaster Control Management**								
E 1	*Activities and Responsibilities of Entities before a flood event*								
E 1. 1	Development of guidlines and action plans (for flood event)	E1 1.1	national authorities	-	-	-	X	X	X
		E1 1.2	regional authorities	X	X	-	X	X	X
		E1 1.3	police	-	-	-	X	X	X
		E1 1.4	fire corps	X	X	-	X	X	-
		E1 1.5	military	-	-	-	X	X	-
		E1 1.6	dam owners	-	-	-	X	X	-
		E1 1.7	community boards - population	-	-	-	-	-	-
		E1 1.8	community boards - population + stakeholder	-	-	-	-	-	-
		E1 1.9	others	local authoritiy	-	-	-	-	-
E 1.2	Development of risk map	E1 2.1	national authorities	-	-	-	-	-	X
		E1 2.2	regional authorities	X	X	-	X	X	X
		E1 2.3	police	-	-	-	-	-	-
		E1 2.4	fire corps	-	-	-	-	-	-
		E1 2.5	military	-	-	-	-	-	-
		E1 2.6	dam owners	-	-	-	X	X	-
		E1 2.7	community boards - population	-	-	-	-	-	-
		E1 2.8	community boards - population + stakeholder	-	-	-	-	-	-
		E1 2.9	others	local authoritiy	-	-	-	-	-
E 1. 3	Organisation of the disaster management	E1 3.1	national authorities	X	-	-	X	X	X
		E1 3.2	regional authorities	X	X	-	X	X	X
		E1 3.3	police	-	X	-	X	X	X
		E1 3.4	fire corps	X	X	-	X	X	X
		E1 3.5	military	-	-	-	X	X	-
		E1 3.6	dam owners	-	-	-	X	X	X
		E1 3.7	community boards - population	-	-	-	-	-	-
		E1 3.8	community boards - population + stakeholder	-	-	-	-	-	-
		E1 3.9	others	local authoritiy	-	-	-	-	-
E 1. 4	Development of simulations and trainings in case of emergency	E1 3.1	national authorities	-	-	-	-	-	-
		E1 3.2	regional authorities	X	-	-	X	X	X
		E1 3.3	police	-	-	-	X	X	-
		E1 3.4	fire corps	X	X	-	X	X	-
		E1 3.5	military	X	-	-	X	X	-
		E1 3.6	dam owners	-	-	-	-	-	-
		E1 3.7	community boards - population	-	-	-	-	-	-
		E1 3.8	community boards - population + stakeholder	-	-	-	-	-	-
		E1 3.9	others	-	-	-	-	-	-

				Analysis Case Study					
Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
E 2	*Activities and Responsibilities of Entities during a flood event*								
E 2. 1	Which entities are informed in case of potential danger of flooding?	E2 1.1	national authorities	X	-	-	X	X	-
		E2 1.2	regional authorities	X	X	-	X	X	X
		E2 1.3	police	X	X	-	X	X	X
		E2 1.4	fire corps	X	X	-	X	X	X
		E2 1.5	military	X	-	-	X	X	-
		E2 1.6	dam owners	-	-	-	X	X	X
		E2 1.7	community boards - population (e.g. citizen`s group)	-	X	-	X	X	X
		E2 1.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	X	-	X	X	-
		E2 1.9	others	local authority, avalanche and torrent control	-	-	paramedics	paramedics	-
E 2. 2	Who informs the public in case of potential danger of flooding?	E2 2.1	national authorities	-	-	-	X	X	-
		E2 2.2	regional authorities	X	-	-	X	X	-
		E2 2.3	police	-	-	-	X	X	X
		E2 2.4	fire corps	-	-	-	X	X	-
		E2 2.5	military	X	-	-	-	-	-
		E2 2.6	dam owners	-	-	-	X	X	-
		E2 2.7	community boards - population (e.g. citizen`s group)	-	-	-	X	X	-
		E2 2.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	-	-	X	X	-
		E2 2.9	others	local authority	Saxon Flood Centre	-	Emergency Coordination Centers	Emergency Coordination Centers	X
E 2. 3	Who guards the public and private property (delinquency etc)?	E2 3.1	national authorities	-	-	-	-	-	-
		E2 3.2	regional authorities	-	-	-	-	-	-
		E2 3.3	police	X	-	-	X	X	X
		E2 3.4	fire corps	-	-	-	-	-	-
		E2 3.5	military	-	-	-	X	X	-
		E2 3.6	dam owners	-	-	-	-	-	-
		E2 3.7	community boards - population (e.g. citizen`s group)	-	-	-	-	-	-
		E2 3.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	-	-	-	-	-
		E2 3.9	others	-	-	-	-	-	-
E 2. 4	Who is responsible for the evacuation?	E2 4.1	national authorities	-	-	-	-	-	-
		E2 4.2	regional authorities	X	X	-	X	X	-
		E2 4.3	police	X	-	-	X	X	X
		E2 4.4	fire corps	X	X	-	X	X	X
		E2 4.5	military	-	-	-	X	X	-
		E2 4.6	dam owners	-	-	-	X	X	-
		E2 4.7	community boards - population (e.g. citizen`s group)	-	-	-	-	-	-
		E2 4.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	-	-	-	-	-
		E2 4.9	others	local authority	-	-	-	-	X

Nr.	Title		Criteria	Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
				Analysis Case Study					
E 2. 5	Who is responsible for medical services (drinking water supply, first aid, ...)?	E2 5.1	national authorities	-	-	-	-	-	-
		E2 5.2	regional authorities	-	X	-	X	X	X
		E2 5.3	police	-	-	-	-	-	-
		E2 5.4	fire corps	-	X	-	X	X	X
		E2 5.5	military	-	-	-	X	X	-
		E2 5.6	dam owners	-	-	-	-	-	-
		E2 5.7	community boards - population (e.g. citizen`s group)	-	-	-	X	X	-
		E2 5.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	-	-	X	X	-
		E2 5.9	Red cross	X	X	-	X	X	-
		E2 5.10	others	Green Cross Styria, helicopter rescue service	-	-	Basic Units (Paramedics, Logistics)	Basic Units (Paramedics, Logistics)	-
E 2.6	Exists a kind of crisis management group?	E2 6.1	yes	X	x (not permanent)	-	X	X	X
		E2 6.2	no	-	-	-	-	-	-
E 2. 7	Organisation of the disaster management (Cooperate with other entities for the reduction of the flood risk in case of emergency.)	E2 7.1	national authorities	-	-	-	X	X	X
		E2 7.2	regional authorities	-	X	-	X	X	X
		E2 7.3	police	-	-	-	X	X	X
		E2 7.4	fire corps	-	-	-	X	X	X
		E2 7.5	military	-	-	-	X	X	-
		E2 7.6	dam owners	-	-	-	X	X	X
		E2 7.7	community boards - population (e.g. citizen`s group)	-	-	-	X	X	-
		E2 7.8	community boards - population + stakeholder (e.g. auxiliary fire brigade)	-	-	-	X	X	-
		E2 7.9	others	crisis management group	-	-	-	-	-
E 2. 8	Who is responsible for the dam management in case of flood event	E2 8.1	national authorities	-	-	-	-	-	-
		E2 8.2	regional authorities	-	-	-	-	-	X
		E2 8.3	police	-	-	-	-	-	-
		E2 8.4	fire corps	-	-	-	-	-	-
		E2 8.5	military	-	-	-	-	-	-
		E2 8.6	dam owners	X	X	-	X	X	-
		E2 8.7	others	-	-	-	-	-	-
E 2. 9	Who is responsible for hydrological monitoring?	E2 9.1	national authorities	-	-	-	-	-	-
		E2 9.2	regional authorities	X	-	-	X	X	X
		E2 9.3	police	-	-	-	-	-	-
		E2 9.4	fire corps	-	-	-	-	-	-
		E2 9.5	military	-	-	-	-	-	-
		E2 9.6	dam owners	X	-	-	X	X	-
		E2 9.7	community boards - population	-	-	-	-	-	-
		E2 9.8	community boards - population + stakeholder	-	-	-	-	-	-
		E2 9.9	others	local authorities	Saxon Flood Centre	-	SAIH (River authorities)	SAIH (River authorities)	-

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenys de Mar / Munt
E 2. 10	Who is responsible and carries out flood protection measures (sand bags, control and removal of debris, ...)	E2 10.1	national authorities	X	-	-	-	-	-
		E2 10.2	regional authorities	X	X	-	X	X	-
		E2 10.3	police	-	-	-	-	-	X
		E2 10.4	fire corps	X	X	-	-	-	X
		E2 10.5	military	X	-	-	-	-	-
		E2 10.6	dam owners	X	-	-	X	X	-
		E2 10.7	community boards - population	-	-	-	-	-	X
		E2 10.8	community boards - population + stakeholder	-	-	-	-	-	-
		E2 10.9	others	local authorities (responsible), private people (responsible for their own property)	-	-	River authorities	River authorities	-
E 2. 11	On-site assistance for population regarding information	E2 9.1	national authorities	-	-	-	-	-	-
		E2 9.2	regional authorities	-	-	-	-	-	X
		E2 9.3	police	-	-	-	X	X	X
		E2 9.4	fire corps	X	-	-	X	X	-
		E2 9.5	military	X	-	-	X	X	-
		E2 9.6	dam owners	-	-	-	-	-	-
		E2 9.7	community boards - population	-	-	-	X	X	-
		E2 9.8	community boards - population + stakeholder	-	-	-	X	X	-
		E2 9.9	others	-	-	-	Advanced command post	Advanced command post	-
E 3	*Activities and Responsibilities of after a flood event*								
E 3. 1	Carrying out of cleanup efforts	E2 1.1	national authorities	-	-	-	X	X	-
		E2 1.2	regional authorities	-	X	-	X	X	-
		E2 1.3	police	-	-	-	X	X	X
		E2 1.4	fire corps	X	X	-	X	X	X
		E2 1.5	military	X	-	-	X	X	-
		E2 1.6	dam owners	X	-	-	-	-	-
		E2 1.7	community boards - population	-	-	-	X	X	X
		E2 1.8	community boards - population + stakeholder	-	-	-	X	X	-
		E2 1.9	others	population, local authorities	THW u. a.	-	Red Cross	Red Cross	X
E 3.2	Is there an evaluation of the disaster control management?	E3 2.1	Yes	X	X	-	-	-	X
		E3 2.2	No	-	-	-	X	X	
E 3.3	Will the flood event be documented?	E3 3.1	Yes	X	X	-	X	X	X
		E3 3.2	No	-	-	-	-	-	-
E 4	*Other*								
E 4. 1	Who promots and supports voluntariness?	E4 1.1	national authorities	-	-	-	X	X	-
		E4 1.2	regional authorities	-	X	-	X	X	-
		E4 1.3	police	-	-	-	-	-	-
		E4 1.4	fire corps	-	-	-	X	X	-
		E4 1.5	military	-	-	-	-	-	-
		E4 1.6	dam owners	-	-	-	-	-	-
		E4 1.7	community boards - population	-	-	-	X	X	-
		E4 1.8	community boards - population + stakeholder	-	-	-	X	X	-
		E4 1.9	media	X	-	-	X	X	-
		E4 1.10	others	Red Cross	-	-	-	-	-

Nr.	Title		Criteria	Analysis Case Study: Graz	Dresden	Lodi	Valencia	Benauasil	Arenyis de Mar / Munt
E 4. 2	Who is responsible for reporting missing people?	E4 2.1	national authorities	-	-	-	X	X	-
		E4 2.2	regional authorities	-	-	-	X	X	-
		E4 2.3	police	X	X	-	X	X	X
		E4 2.4	fire corps	-	-	-	-	-	-
		E4 2.5	military	-	-	-	-	-	-
		E4 2.6	dam owners	-	-	-	-	-	-
		E4 2.7	community boards - population	-	-	-	X	X	X
		E4 2.8	community boards - population + stakeholder	-	-	-	X	X	-
		E4 2.9	Media	-	-	-	-	-	-
		E4 2.10	others	-	-	-	-	-	-
E 5	*Action Plan (Risk Management Planning)*								
E 5.1	Exist a Risk Management Plan (called Action Plan)?	E5.1.1	Yes	X	X	-	X	X	
		E5.1.2	No	-	-	-	-	-	X
	if (E5.1 = yes)								
E 5.2	Which kind of non-structural measures are included/involved the Action Plan?	E5.2.1	Urban planing measures		-	-	X	X	-
		E5.2.2	Flood Forecasting measures		-	-	X	X	-
		E5.2.3	Comunication Improvement measures		X	-	X	X	-
		E5.2.4	Mobilization measures		X	-	X	X	-
		E5.2.5	Coordination and disaster excercises		X	-	X	X	-
		E5.2.6	Insurances policies, public and private aids		-	-	X	X	-
E 5.3	Which of the following non-structural measures could be included?	E5.3.1	Urban planning measures		-	-	X	X	-
		E5.3.2	Flood Forecasting measures		-	-	X	X	-
		E5.3.3	Comunication Improvement measures		-	-	X	X	-
		E5.3.4	Mobilization measures		-	-	X	X	-
		E5.3.5	Coordination and disaster excercises		-	-	X	X	-
		E5.3.6	Insurances policies, public and private aids		-	-	X	X	-
E 5.3	Is the Action Plan optimized?	E5.3.6	Respect to the resources demand.	no	-	- -	-	-	*
		E5.3.6	Respect to the response time.	no	-	- -	-	-	*
	if (E5.1 = no)								
E 5.4	Which of the following tasks could be implemented for Action Plan development	E5.4.1	Hazard estimation	-	-	-	-	-	X
		E5.4.2	Vulnerability estimation	X	-	-	-	-	X
		E5.4.3	Hazard maping	-	X	-	-	-	X
		E5.4.4	Risk maping	X	-	-	-	-	X
		E5.4.5	Evaluation of the organization (Activities E1, E2 and E3 of the present list)	X	-	-	-	-	X
		E5.4.6	Applying Urban planing measures	-	-	-	-	-	X
		E5.4.7	Applying Flood Forecasting measures	X	-	-	-	-	X
		E5.4.8	Applying Comunication Improvement measures	X	-	-	-	-	X
		E5.4.9	Applying Mobilization measures	?	-	-	-	-	X
		E5.4.10	Applying Coordination and disaster excercises	X	-	-	-	-	-
		E5.4.11	Applying Insurances policies, public and private aids	-	-	-	-	-	X