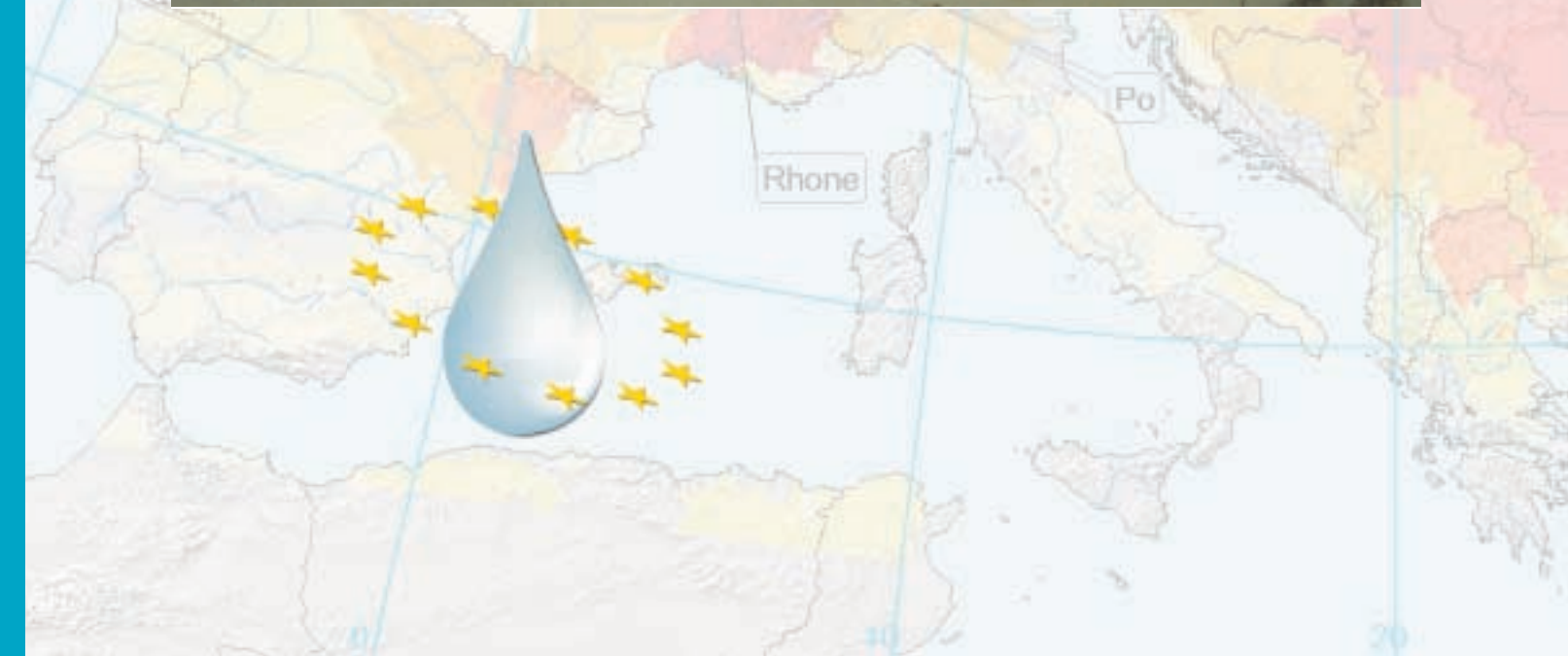


Handbook on good practices for floodmapping in Europe

**EXCIMAP**

European exchange circle on flood mapping

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## Handbook on good practices for flood mapping in Europe

Prepared by EXCIMAP (a European exchange circle on flood mapping)  
Endorsed by Water Directors, 29-30 November 2007.



# DISCLAIMER

The present document has been elaborated with the participation of :

- Austria, Belgium (Flanders, Wallonia), Croatia, Finland, France, Germany (Saxonia, Rhinland-Palatinate, Bavaria), Greece, Hungary, Ireland, Latvia, Norway, Poland, Slovenia, Spain, Sweden, Switzerland, The Netherlands, UK
  - CEA, EFG
  - FLOODSITE, TIMIS, FLAPP
  - ICPDR, ICPR
  - European Commission, JRC
- all being members of [EXCIMAP](#).

The work has lasted from January 2006 till October 2007 finishing with the publication of the document at hand.

The present document is an handbook showing a non-exhaustive picture of the current, existing and accessible good practices for flood mapping in Europe in the year 2006. It is based on experiences and knowledge available at that time in the countries represented in [EXCIMAP](#).

The work of [EXCIMAP](#) started before the "Directive on the assessment and management of flood risks" endorsement (18 September 2007). The handbook doesn't intend to present any guidelines on how to implement the Directive despite the work done to produce it having remained as close as possible to the Directive's principles. Neither does the handbook address all requirements of the Directive.

It has not been verified if the maps and examples presented in this handbook, including in the Atlas, is compliant with the requirements of the Directive.

Neither the European Commission, nor any person acting on behalf of this Commission is responsible for the use which might be made of this publication.



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# 1 Context

## 1.1 Rationale

In November 2002, a few months after the dramatic floods in Europe (among others Austria, Czech Republic, Germany), the Water Directors of the European Union (EU), Norway, Switzerland and the then Candidate Countries agreed to take the initiative for stern action in the field of flood prediction, prevention and mitigation. A core group led by the Netherlands and France prepared a "Guide of best practices on flood prevention, protection and mitigation".

A prerequisite for effective and efficient flood management is the in-depth knowledge of the prevailing hazards and risks. This includes information about the type of floods (static, dynamic, coastal etc.), the probability of a particular flood event, the flood magnitude, expressed as flood extent, water depth or flow velocity, and finally, the probable magnitude of damage. Flood maps are indispensable tools to provide information about hazards, vulnerabilities and risks, and to implement the necessary preventive and preparedness measures. The exchange of information, knowledge and experience in this field in Europe is facilitated by [EXCIMAP](#).

## 1.2 What is [EXCIMAP](#)?

[EXCIMAP](#) is a European exchange circle on flood mapping. The aim of the European Exchange Circle on Flood Mapping is to gather all existing experiences and know-how in Europe and to improve flood mapping practices. This exchange circle facilitates the exchange between European countries, helps to build a common work base, and improves comprehension and communication on the subject in Europe. As a practical outcome [EXCIMAP](#) established the present guide to give an overview of the existing good practices for flood mapping in Europe, including an atlas of examples from all over Europe as an annex to this guide.

[EXCIMAP](#) was launched in January 2006. In 2007 [EXCIMAP](#) consists of nearly 40 representatives from 24 European countries or organizations. They all contributed to the guide at hand.

## 1.3 European flood risk directive

The European "Directive on the assessment and management of flood risks", endorsed in 18 September 2007, aims to reduce the adverse consequences on human health, the environment, cultural heritage and economic activity associated with floods in the Community. The European Flood Directive (EFD) sets out the requirement for the Member States to develop three kinds of products:

- a preliminary flood risk assessment: the aim of this step is to evaluate the level of flood risk in each river basin district or unit of management and to select those areas on which to undertake flood mapping and flood risk management plans. To be completed by 2011.
- Flood mapping comprising of flood hazard maps and flood risk maps: the flood hazard maps should cover the geographical areas which could be flooded according to different scenarios; the flood risk maps shall show the potential adverse consequences associated with floods under those scenarios. To be completed by 2013.
- Flood risk management plans: on the basis of the previous maps, the flood risk management plans shall indicate the objectives of the flood risk management in the concerned areas, and the measures that aim to achieve these objectives. To be completed by 2015.

This directive asks the Member states to implement flood mapping according to some minimum recommendations. These are outlined in Article 6.3 and 4 of the directive:

"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  $\geq 100$  years);
- (c) floods with a high probability, where appropriate.

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."

and article 6.5:

"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 September 1996 concerning integrated pollution prevention and control<sup>1</sup> 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."

## 1.4 Flood maps as a basis for the management of flood risks

Flood management covers the holistic and continuous assessment, evaluation and reduction of flood hazard and flood risks. As such flood management has three distinct goals:

- 1) to prevent the further build-up of risks through appropriate and risk-conscious development (i.e. development in safe places, appropriate forms of construction etc.)
- 2) to reduce existing risks through preventive and preparedness measures (e.g. construction of flood dikes and implementation of early warning systems)
- 3) to adapt to changing risk factors (e.g. climate change adaptation)

A prerequisite for effective and efficient flood risk management is the in-depth knowledge of the prevailing hazards and risks throughout a river basin and areas of coastal flood risk. This includes information about the type of floods (river, coastal, lake and groundwater), the probability of a particular flood event, the flood magnitude expressed as flood extent, water depth or flow velocity, and finally, the probable magnitude of damage (life, property economic activity). Flood maps are indispensable tools to show information about hazards, vulnerabilities and risks in a particular area. Only the clear understanding of flood risks permits the Member States to decide on type and scale of appropriate action to avoid, mitigate, transfer, share, or accept the risks. Flood risk mapping plays a very important role in this process.

In June 2003, following the initiative of Water Directors of the European Union, a core group led by the Netherlands and France prepared a "Guide of best practices on flood prevention, protection and mitigation". This guide makes clear reference to the identification and the mapping of flood hazards and areas of high-risk and the implementation of this information into spatial planning, risk and emergency management or in overall awareness building of the population:

"It is essential that people recognise flooding as part of their environment. [...] If there is no hazard awareness, even incentives will not be of any help. If persons concerned have not yet experienced flooding, knowledge about the risk must be passed on with the help of the flood hazard maps, other information and education.

[...]

The authorities should ensure that the information concerning flood prevention and protection plans is transparent and easily accessible to the public. This can achieve by:

- (a) Flood hazard maps point out areas at risk and are necessary for planning. Maps must be easily readable and show the different hazard levels. They are necessary for the co-ordination of different actions. They are a planning tool and ascertain that all actors have the same information on spatial extend of a certain hazard. Flood maps should be used for the reduction of damage potential by integrating its outputs into spatial planning and emergency planning. Both type of utilisation requires that the flood hazard / zoning / risk maps should include the worst-case scenario as well.
- (b) Information based on Geographic Information Systems (GIS) should be widely diffused and explained. Media plans should be prepared, following an agreed procedure.

[...]

*Extract from the "Guide of best practices on flood prevention, protection and mitigation.*

<sup>1</sup> OJ L 257, 10.10.1996, p. 26. Directive as last amended by Regulation (EC) No 166/2006 of the European Parliament and of the Council (OJ L 33, 4.2.2006, p. 1).

## 1.5 Why this EXCIMAP handbook?

Discussions among the members of EXCIMAP revealed the necessity to present to a wider audience the good practices for flood mapping available in Europe. This handbook should serve as a technical instrument for practitioners, showing general aspects and features of flood maps and provide examples from all over Europe. While the European Flood Directive gives a minimum basis required for flood mapping (see 1.3), the EXCIMAP's handbook addresses more details and steps of the flood mapping process. It has been developed in order to:

- (i) support Member States in understanding the requirements for flood mapping as set out in article 6 of the European Floods Directive
- (ii) suggest methods and approaches that are available for flood mapping
- (iii) provide examples of flood maps available and used in Member States.

The handbook refers to the experiences of Member States gained through the number of flood mapping projects and work programmes that have taken place across Europe. Many countries have specific experiences and expertise which is captured in this handbook and to be shared with others.

Moreover this handbook can be useful for local authorities and other specific stakeholders (e.g. the insurance sector) to assist them in understanding flood risks and preparing for flooding, and to decide what mapping has to be done to meet their needs.

This handbook is neither prescriptive nor mandatory; it presents only “representative examples” of flood mapping in Europe, nevertheless remaining close to the basic principles contained in the EFD.

## 1.6 Who will use this EXCIMAP's handbook?

The main users of this handbook will be

- Member State's authorities in charge of flood mapping, at any level of competence, according to subsidiarity levels, and any stage of the process, from production to dissemination and use.
- Authorities of non-EU countries, with which the EU develop cooperation in the area of natural risk management policies, may also be interested.

To inform oneself on risk exposure is becoming a must, in order to develop one's strategies and actions in avoiding, reducing or limiting vulnerability to flooding. Therefore, this handbook may be disseminated to other stakeholders as well. Further readers of this handbook might be

- private sector, in particular risk management experts and advisors,
- insurance and real estate business sectors,
- utility networks and critical infrastructure operators,
- individual industrial and commercial concerns.

Each umbrella organisation of these various categories of stakeholders is expected to be a potential user of this handbook.



## 2 Scope and content

The purpose of flood hazard / flood risk mapping is the geographical identification and illustration of areas at different level of risk from flood hazard. In this respect flood maps need to be designed to meet the end-user needs. This is important in order to convey the complex messages about flooding and flood risk.

In this chapter some basic definitions related to flood hazards and flood risks are given. The types of floods which might occur in member state's territories are briefly explained. And finally, a short overview on some basic flood map products is provided.

### 2.1 Definitions

In order to be consistent with the European Floods Directive (EFD), [EXCIMAP](#) agreed to use the same vocabulary and references as it is in the European document. For the purpose of this handbook, the following definitions are adopted.

- Flood is a temporary covering by water of land normally not covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems (EFD)
- Flood risk is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with a flood event (EFD)
- Flood hazard maps shows areas which could be flooded according to three probabilities (low, medium high) complemented with: type of flood, the flood extent; water depths or water level as appropriate; where appropriate, flow velocity or the relevant water flow direction (EFD)
- Flood risk maps indicate the potential adverse consequences associated with floods under several probabilities, expressed in terms of: the indicative number of inhabitants potentially affected; type of economic activity of the area potentially affected; installation which might cause accidental pollution in case of flooding [...] ; potentially affected ; other information which the Member State considers useful (EFD)

And on top of these definitions above coming from the EFD, the handbook will refer to the following definitions deriving from the EFD definitions:

- Flood plain maps indicate the geographical areas which could be covered by a flood (from all sources except sewerage systems – see above definition of flood) according to one or several probabilities: floods with a very low probability or extreme events scenarios; floods with a medium probability (likely return period  $\geq 100y$ ); floods with a high probability, where appropriate
- Damage is the negative effect of an event or process
- Residual risk is the portion of risk remaining after flood risk management actions have been implemented and taken into consideration.

### 2.2 Type of floods

Flooding occurs along rivers and torrents or in coastal areas of the sea and along lakes. The effects are always the same: water and/or sediments in an unwanted place outside the watercourse, irrespective of the cause of flood.

The flood maps described in this handbook consider the following types of floods:



Type of flooding	Causes of flooding	Effect of flooding	Relevant parameters
River flooding in flood plains	<ul style="list-style-type: none"> <li>• Intensive rainfall and/or snowmelt</li> <li>• Ice jam, clogging</li> <li>• Collapse of dikes or other protective structures</li> </ul>	<ul style="list-style-type: none"> <li>• Stagnant or flowing water outside the channel</li> </ul>	<ul style="list-style-type: none"> <li>• Extent (according to probability)</li> <li>• Water depth</li> <li>• Water velocity</li> <li>• Propagation of flood</li> </ul>
Sea water flooding	<ul style="list-style-type: none"> <li>• Storm surge</li> <li>• Tsunami</li> <li>• High tide</li> </ul>	<ul style="list-style-type: none"> <li>• Stagnant or flowing water behind the shore line</li> <li>• Salinisation of agricultural land</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above</li> </ul>
Mountain torrent activity or rapid run-off from hills	<ul style="list-style-type: none"> <li>• Cloud burst</li> <li>• Lake outburst</li> <li>• Slope instability in watershed</li> <li>• Debris flow</li> </ul>	<ul style="list-style-type: none"> <li>• Water and sediments outside the channel on alluvial fan; erosion along channel</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above;</li> <li>• Sediment deposition</li> </ul>
Flash floods in Mediterranean ephemeral water courses	<ul style="list-style-type: none"> <li>• Cloud burst</li> </ul>	<ul style="list-style-type: none"> <li>• Water and sediments outside the channel on alluvial fan</li> <li>• Erosion along channel</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above</li> </ul>
Groundwater flooding	<ul style="list-style-type: none"> <li>• High water level in adjacent water bodies</li> </ul>	<ul style="list-style-type: none"> <li>• Stagnant water in flood plain (long period of flooding)</li> </ul>	<ul style="list-style-type: none"> <li>• Extent (according to probability)</li> <li>• water depth</li> </ul>
Lake flooding	<ul style="list-style-type: none"> <li>• Water level rise trough inflow or wind induced set up</li> </ul>	<ul style="list-style-type: none"> <li>• Stagnant water behind the shore line</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above</li> </ul>

In general, flood mapping addresses the effects of flooding and those effects are represented in hazard and risk mapping. However, for management purposes the cause of flooding are of very high importance. Early warning systems, warn and alarm schemes, clearance of channels etc. are fully based on the cause and development of flood events. This has to be kept in mind when performing flood mapping.

## 2.3 Type of flood maps currently produced in Europe

Referring to overview of current practices for flood mapping in Europe, it has been possible to identify the following characteristics for flood maps available in Europe:  
(see also the synthesis of current practices in Annex)

	<b>Flood hazard map</b>	<b>Flood risk map</b>
Content	Flood parameters such as <ul style="list-style-type: none"> <li>• flood extent according to probability classes,</li> <li>• according to past events</li> <li>• flood depth</li> <li>• flow velocity</li> <li>• flood propagation</li> <li>• degree of danger</li> </ul>	Risk parameters such as <ul style="list-style-type: none"> <li>• assets at risk</li> <li>• Flood vulnerability</li> <li>• Probable damage</li> <li>• Probable loss (per unit time)</li> </ul>
Purpose and use	<ul style="list-style-type: none"> <li>• Land use planning and land management</li> <li>• Watershed management</li> <li>• Water management planning</li> <li>• Hazard assessment on local level</li> <li>• Emergency planning and management</li> <li>• Planning of technical measures</li> <li>• Overall awareness building</li> </ul>	<ul style="list-style-type: none"> <li>• Basis for policy dialogue</li> <li>• Priority setting for measures</li> <li>• Flood Risk Management Strategy (prevention, mitigation)</li> <li>• Emergency management (e.g. the determination of main assets)</li> <li>• Overall awareness building</li> </ul>
Scale	<ul style="list-style-type: none"> <li>• Local level: 1:5,000 to 1:25,000: various parameters</li> <li>• National level, whole river basin: 1:50,000 to 1:1,000,000: in general only flood extent</li> </ul>	<ul style="list-style-type: none"> <li>• 1:5,000 to 1:25,000</li> <li>• 1:50,000 to 1:1,000,000</li> </ul>
Accuracy	<ul style="list-style-type: none"> <li>• high: cadastre level for detailed maps</li> <li>• low: whole river basin, national level</li> </ul>	<ul style="list-style-type: none"> <li>• high: cadastre level</li> <li>• low: whole river basin, national level</li> </ul>
Target group / use	<ul style="list-style-type: none"> <li>• National, regional or local land-use planning</li> <li>• Flood managers</li> <li>• Emergency services</li> <li>• Forest services (watershed management)</li> <li>• Public at large</li> </ul>	<ul style="list-style-type: none"> <li>• Insurance</li> <li>• National, regional or local emergency services</li> <li>• National, regional or local water and land use managers</li> </ul>

The flood hazard maps are explained in detail in chapter 4, the flood risk maps in chapter 5.

Some countries have made flood plain maps that present the possible flooded areas. They are normally very general maps and water depth is not presented in order to make them easy for everyone to understand. They may be prepared for certain flood probabilities.

The flood plain maps can't be considered as flood hazard maps but they are important tools to be used in preliminary flood risk assessment<sup>2</sup>.

<sup>2</sup> The flood directive asks for a preliminary flood assessment consisting of maps of the river basin district at the appropriate scale including the borders of the river basins, sub-basins and, where existing, coastal areas, showing topography and land use.



### 3 Use of flood maps

Based on the experience available among European country in the field of flood mapping, the following can be stated.

Flood maps are used by many different stakeholders. The maps serve at least one of the three purposes of flood risk management:

- (i) prevent the build-up of new risks (planning and construction),
- (ii) reduce existing risks, and
- (iii) adapt to changing risks factors.

Depending on the purpose, the stakeholders have very specific demands on content, scale, accuracy or readability of the map. Flood maps are primarily used for:

- Flood Risk Management Strategy (prevention, mitigation)
- Land-use planning, land management
- Emergency planning
- Public Awareness raising
- Private sector, in particular insurance sector

Flood maps may be required for other activities that may be less systematic in application, localized in demand or necessary as secondary or supplementary information for decision-making on issues not directly related to flooding, such as environmental planning or soil contamination after flood.

For each of these categories the demands of the end-users are described below, distinguishing between local and regional/national level and between **essential parameters** (content required for the relevant purpose) and **desirable parameters** (content required in some countries / regions for the relevant purpose only, or would be advantageous for the purpose if available). The following aspects are considered:

- content (extent of flooding, dynamic parameters of floods, hazard level, risk level)
- level / scale (overview of large area, detailed information)
- readership (expert, practitioner, decision maker, population at large) and complexity (simple, complex)

Depending on different contexts, and particularly legal requirements, within different countries or regions / states, the requirements of a map to meet a specific purpose will vary. As such, it is recognized that the information below is generic, and will need to be reviewed within its proposed context of application through assessment of the relevant legal requirements, and with appropriate stakeholder engagement (e.g., initial consultation of needs and ongoing review of suitability after publication).

#### 3.1 Flood Risk Management: Strategy and planning

Flood risk management requires appropriate strategies and plans for the effective and efficient implementation of flood risk reduction measures. The following parameters are required:

Level / scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
National / regional 1:100,000 - 1:1,000,000	<ul style="list-style-type: none"> <li>• Broad-scale planning / prioritisation of flood risk management measures / strategies</li> <li>• Flood risk management within the river basin</li> <li>• Delineation of strategic flood storage zones (retention areas, wash lands)</li> </ul>	<ul style="list-style-type: none"> <li>• Decision makers</li> <li>• Technical services</li> <li>• Easy to understand, simplified maps</li> </ul>	<ul style="list-style-type: none"> <li>• Flood extent</li> <li>• Flood risks</li> <li>• Sites of environmental vulnerability</li> <li>• Pollution risks</li> <li>• Assets at risk</li> </ul>	<ul style="list-style-type: none"> <li>• Indicative vulnerability</li> </ul>
Local 1:5,000 - 1:50,000	<ul style="list-style-type: none"> <li>• Planning, design and evaluation of localised / specific flood management measures</li> </ul>	<ul style="list-style-type: none"> <li>• Decision makers</li> <li>• Technical services</li> <li>• Complex maps possible</li> </ul>	<ul style="list-style-type: none"> <li>• Flood extent</li> <li>• Water depth</li> <li>• Other flood parameters (if appropriate, e.g. velocity)</li> </ul>	<ul style="list-style-type: none"> <li>• Vulnerability</li> <li>• Risk (economic assessment)</li> <li>• Environmental impacts</li> </ul>



For flood risk management planning and decision making, questions arising are:

- Where is the greatest risk?
- Where should be target investment first? Prioritise our work.
- Seek the best return on any investment across a range of social, environmental and economic benefits; support the business case for funding in competition with other demands on resources.
- Select the best options and range of measures to reduce flood risk. Not just defences but also other activities such as spatial planning and control of development (avoidance), asset system management (defences, flood storage areas, river systems, estuaries and coasts – managing the pathways), flood preparation (flood detection, forecasting, emergency planning) and flood incident management and response (flood warning, actions of emergency services, healthcare providers and flood risk management authorities, public, community support organisations), and recovery (insurance, local authorities, reconstruction)

### 3.2 Land-use planning

Risk-conscious land-use planning and land management is an important contribution to sustainable development. The geographical level (national/regional, local) decides on the necessary scale.

Level / scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
National / regional 1:100,000 - 1:500,000	<ul style="list-style-type: none"> <li>• High-level spatial planning</li> <li>• Allocation of land for development</li> <li>• Suitability of land for different types of development</li> <li>• Planning of national infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>• Decision makers</li> <li>• Land-use and spatial planners</li> <li>• Simplified maps</li> </ul>	<ul style="list-style-type: none"> <li>• Flood extent</li> <li>• Flood risks</li> <li>• Sites of environmental vulnerability</li> <li>• Pollution risks</li> <li>• Assets at risk</li> </ul>	<ul style="list-style-type: none"> <li>• some indicators (to define) allowing to evaluate the hazard (considered useful if available or derivable, although a requirement in some contexts)</li> </ul>
Local 1:5,000 - 1:25,000 (cadastre level)	<ul style="list-style-type: none"> <li>• Specific city or village planning</li> <li>• Watershed management</li> <li>• Meeting specific needs of planners as a basis or guidance for decisions (e.g., provide for land zoning that forms the basis of planning decisions, support local flood risk assessments for development, determine appropriate land uses and development types, assessment of individual planning applications).</li> </ul>	<ul style="list-style-type: none"> <li>• City, village planners</li> <li>• Rural planners</li> <li>• Local authorities</li> <li>• Simplified maps</li> </ul>	<ul style="list-style-type: none"> <li>• Flood extent (typically for a range of event probabilities) either ignoring flood defences or assume a breach of defences</li> </ul>	<ul style="list-style-type: none"> <li>• Various flood parameters (e.g., depth, velocity, duration, erosion and debris accumulation, defended areas, etc.) and / or Hazard classes (in terms of probability and intensity), particularly where the planning process is linked to this type of information</li> </ul>

### 3.3 Emergency planning and management

Emergency management units require specific flood information for the planning process as well as for the management of an on-going crisis. The following parameters are required:

Level / scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
National / regional 1:100,000 - 1:500,000	<ul style="list-style-type: none"> <li>Broad-scale planning for major emergencies that may require national or regional intervention (including flood defences distribution)</li> </ul>	<ul style="list-style-type: none"> <li>Spatial planners</li> <li>Emergency planners</li> <li>Politicians and high level decision makers</li> </ul>	<ul style="list-style-type: none"> <li>Flood extent</li> <li>Flood risk indicators (such as number of people potentially affected)</li> <li>Utility infrastructure affected</li> <li>Road/rail and other communication infrastructure)</li> </ul>	<ul style="list-style-type: none"> <li>Other relevant data (such as summary of vulnerability or risk data, although this does not necessarily need to be mapped, but may be presented in database / tabular format)</li> <li>Information of disruption of infrastructures or utilities with a national or regional impact (e.g. power supply, traffic, water supply, functions of importance for society)</li> </ul>
Local 1:5,000 - 1:25,000	<ul style="list-style-type: none"> <li>Planning of localised emergency response (e.g., evacuation and access routes, road closures, etc.).</li> </ul>	<ul style="list-style-type: none"> <li>Emergency planners</li> <li>Politicians and local level decision makers</li> <li>Emergency services</li> <li>Health authorities</li> </ul>	<ul style="list-style-type: none"> <li>Flood extent and depth (for different return periods) and other flood parameters as relevant to location</li> <li>Vulnerability (incl. social and other risks)</li> <li>Risks (significant assets requiring specific attention, incl. sensitive infrastructure, installation which might cause accidental pollution in case of flooding, historical heritage, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>Real-time information (e.g. extent, remotely sensed) is useful where / when available</li> </ul>

### 3.4 Public Awareness

Flood maps for public awareness should provide information to anyone to enable to find out whether risks from flooding exist. The maps for flood awareness should cover the populated areas of the country (for some member states this will be national coverage).

Level / scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
Local 1:10,000 - 1:25,000	<ul style="list-style-type: none"> <li>Developed at Local Scale (i.e., to provide local information)</li> </ul>	<ul style="list-style-type: none"> <li>Public</li> <li>Professional advisors</li> <li>Easy to read</li> </ul>	<ul style="list-style-type: none"> <li>Flood extent (for different probabilities) (and depth?), defended areas? Ignoring flood defences or assume a breach of defences</li> </ul>	<ul style="list-style-type: none"> <li>Historic flood event information (extents, depths, photographs) as point of reference</li> <li>Flood depth, velocity, rate of onset, erosion and debris hazard, etc. as appropriate and where significant</li> </ul>

The national or regional scale of mapping is generally not required for public awareness, as members of the public tend to be interested in the flood risk that directly applies to them. The high-level flood management planning maps (see below) may be used to provide information to those interested in wider risk issues, where required. There is an argument for different levels of accuracy at a local scale where more populated areas may require greater investment in data collection and modelling. Less accurate mapping may be sufficient for sparsely populated areas.

Where the public is involved in FRM decision making it may need to understand the risk to better understand the decision.

### 3.5 Insurance

For this domain all consequences (everything that is potentially insured) have to be addressed:

- Exposure (financial loss) of houses and contents
- Loss of life (life insurance)
- Exposure of installations (business premises, business continuity and disruption insurance)

Level / scale	Use of flood maps	Readership / Complexity	Content of flood maps:	
			Essential parameters	Desirable parameters
National / regional 1:10,000 - 1:25,000	<ul style="list-style-type: none"> <li>• Insurance assessments and pricing, underwriting, claims / portfolio assessments, incentive at prevention</li> <li>• Re-insurance: Portfolio exposure assessment at a broader level (i.e. national or regional level)</li> </ul>		<ul style="list-style-type: none"> <li>• Extent (for different return periods or probabilities)</li> </ul>	<ul style="list-style-type: none"> <li>• Water depths, velocity (if significant)</li> </ul>

It is noted that information on public, critical infrastructures and networks at risk may be useful for business interruption coverage assessment. The necessary geo-information on insured private assets is collected, stored and processed by each market player of the insurance industry for its own uses, as described below.

It is also noted that information collected and collated by each insurance market may, for commercial reasons, not be made available to the public sector. It is only on an aggregated level that such information (exposure and loss aggregates, in number of assets and cumulated losses) may be made available by insurance market associations to public authorities.

## 4 Flood hazard maps: type and content

According to the European flood directive flood hazard maps shall cover the geographical areas which could be flooded using at least three scenarios: low, medium, and high probability of occurrence. For each scenario the flood extent, the water depths or water level, as appropriate, and where appropriate the flow velocity, have to be represented on the maps.

“The flood hazard maps include historic as well as potential future flood events of different probability, illustrating the intensity and magnitude of hazard in a selected scale and are at the basis of considerations and determinations in land use control, flood proofing of constructions and flood awareness and preparedness”

*Extract from the Guide of best practices on flood prevention, protection and mitigation.*

This statement of the Guide of best practices on flood prevention, protection and mitigation has been translated into the EFD requirements.

The following parts describe the various practices for presenting flood hazard on maps in Europe.

### 4.1 Flood hazard maps: basic information

The proper use and application of flood hazard maps into planning processes and awareness campaigns require the consideration of some very basic information on the map. The most important aspects are:

- Title of the map: making clear reference to the map content such as
  - Flood parameter: Flood extent, depth, flow velocity, past event
  - Probability consideration: defining more precisely what mean low, medium and high probability of occurrence,
- Location of the map as part of the catchment or country: provision of a small inset map
- Legend:
  - parameters shown on the map with easy to read symbols or colour schemes;
  - class or ramp for numerical values
- North and scale: preferably using scale bar as this allows for changes in page size
- Responsible authority or institute with address, website (and/or telephone number)
- Base date for the data and date of publication
- If necessary: a disclaimer, including remarks on the quality of information can be added.

### 4.2 Flood extent map/flood plain map

The flood extent map is the most widely distributed instrument.

The European flood directive requests flood extent maps for an extreme (low probability) and an  $\geq 100$ -years scenario (medium probability). And where appropriate, a high probability scenario can be added.

Most examples available in Europe go much farther; they are compiled in the following descriptions of practices. The examples noted below can be seen in the Atlas of European maps (Annex).

*Nota:* Only in few cases a clear distinction is made between river flooding and sea flooding. That may be done sometimes to keep the presentation of the data very simple so it is understood by the intended audience.

#### Map content

The potential flood extent for single or a small range of flood event frequencies has to be presented as a surface covering the topography. For reference roads, railways, houses, property boundaries and the permanent water bodies from which the floods may originate may be included. In addition, the protecting effect of defence works and areas designated for flood storage may be included.

- The flood extent for one particular recurrence interval is shown for the Daugava River in Latvia (4-72). Such maps are easy to read as the information is limited.
- Coastal flooding is represented on a Danish example (4-22). The recurrence interval for the event indicated is 1/4000 years.



- A French example (4-37) uses two recurrence periods (1/10 yrs and 1/100 yrs). The extent of past floods is overlaid.
- The example from England and Wales (4-24) uses two probabilities for river flooding (1 % - 0.1 % and > 1%) and, using the same symbols, two probabilities for flooding from the sea (0.5 % - 0.1 % and > 0.5 %). The effect of flood defence works is shown on the map.
- The flood extent is given for return periods 10-, 30-, 50-, 100-, 300 years, extreme event in Baden Württemberg, Germany: 4-42, or for return periods 30-, 100-, 300-, extreme event in Switzerland (4-101). The extreme event is used to mark the so-called residual danger.
- Flood extent from mountain torrents is shown in the Swiss example (4-101). There is no difference made between water floods and sediment accumulation.
- Sweden: Flood extent superimposed on a general map with two the flood extent for two scenarios, the 100-year flood and the 10 000-year flood. Water depth is shown in the cross-sections.

#### Map use

- Serves as a basic product to establish danger maps and risk maps
- Land use planning (legally binding)
- City and village planning
- Rural planning
- Risk management
- Awareness building (particularly when combined with past events)

#### Scale considerations

- Detailed scale required if flood map is used for urban planning (1:2,000 to 1:25,000), particularly if in mountainous or hilly areas where affected territory is narrow.
- Overview scale possible for rural planning in large flood plains (1:100,000 to 1:1,000,000). The scales used to present that data must be appropriate to the original scale and accuracy of the modelling and mapping work

#### Colour scheme

In practice, the colour frequently used for the flood extent information is blue: e.g. dark blue for frequent floods and light blue for the areas covered during less frequent floods.

### 4.3 Flood depth map

The flood depth map is a widely distributed instrument in European countries. The values of water level (depth) can be derived from flow models (2D and 1D) for river flooding, from statistical analyses or from observations. Normally in rivers numerical models have to be used and for lakes and sea statistical methods can be used. There is a wide range of applications of such maps.

#### Map content

The flood depth map provides information about the water depth in a particular location for a given recurrence interval (or probability) of flood. Depending on the local conditions the water depth is given in centimetres or metres.

The following examples exist in practice and can be seen in the Atlas (Annex):

- On detailed Finnish maps (1:20,000) the flood depth is given for a particular probability of occurrence (1/1000). The depth scale is non-linear and ranges from 0 to > 3 m (4-30).
- In Sachsen, Germany, the flood extent for particular probabilities (HQ 20, HQ 100) is shown (4-54, 4-55). The water depth for the extreme event is added with four classes (0-0.5 m, 0.5-2 m, 2-4 m, > 4m). In Baden-Württemberg the water depth is shown for HQ 100 in a step size of 0.5m.
- Ireland produces flood maps for particular probabilities (e.g. 1/100) with flood depths of 0.2 m increment (4-64). The maps are produced on a detailed digital terrain model using 2-D modelling.
- The Netherlands are using small-scale flood depth maps covering large parts of the country. They use depth increments of 1 m (0 - 8 m). Dry areas are particularly delineated. (4-77)

### Map use

- Serve as a basic product to establish danger and flood damage maps
- City and village planning
- Risk management (evacuation)

### Scale considerations

- Potential (maximum) inundation depth maps exist on national, regional and local scales (1:2.500.000 – 1:10.000).
- Flood depth maps in urban areas have a large scale, appropriate for local land-use planning or emergency management.
- For large areas, like Hungary or the Netherlands, medium and small scales are in use as well.

### Colour scheme

In most cases the depths are represented in various shades of blue. For instance, the Irish example has a broad palette ranging from red, yellow, and green to various shades of blue.

## 4.4 Flow velocity and flood propagation map

The European flood directive asks for maps which represent the flow velocity, where appropriate. Flow velocity information is much more difficult to get than water depth information. Normally reasonable flow velocity information can be derived only from 2D-flow models and in some cases also from 1D-flow models. There are few examples where flow velocities are shown on maps. Such products are highly technical.

### Map content

The flood hazard in a particular location is represented by the velocity of the flowing water (or sediment in case of debris flow) or by the velocity of the flood propagation. The following examples exist:

- The flow velocities can be shown as vectors, the length of the vector representing the velocity. The Austrian approach (4-4) provides fine lines for the speed and direction of flow. Based on the flow velocity the Austrian approach provides as well the shear stress (4-5). For both cases the return period should be provided.
- In Luxemburg interactive maps (4-75) are available for the Mosel River showing flow velocity from 0 to 10 m/s by colour shading. The velocity can be retrieved for various recurrence intervals (50, 100, and 200 years and an extreme event).
- The propagation of floods along major rivers is given in Hungary (4-63). The scale is discrete and shows steps of 24 hours. Included is the whole area affected by the flood. The maps are produced by hydraulic modelling.
- The Netherlands produce flood maps along the coast and rivers. The flood propagation map (4-78) shows the affected areas in days after the breach of a particular dike failure. There is a discrete scale in hours and days.

### Map use

- Flow velocity: planning of flood defence measures or any structure within the flood area. Tool for technicians.
- Flood propagation: Planning tool for emergency response. Evacuation schemes, implementation of temporal flood protection measures. The information requires a well-functioning early warning and alert system.

### Scale considerations

- Flow velocity: this is highly localized information which has to be represented in a detailed scale. The Austria example ranges from 1:1,000 to 1:5,000. The interactive version of Luxembourg is of the order of 1:5,000.
- In general, the flood propagation covers large areas. Accordingly, the scale of the respective maps is rather small. The Netherlands' example is a map 1:250,000.

### Colour scheme

There are various possibilities to represent flow velocity or flood propagation in the map. A discrete scale is generally easier to read than a steady (ramp) scale.

## 4.5 Other types

Two other types of flood maps may be classified as hazard maps despite they are not fitting exactly with the definition above. They are called: flood danger maps and event maps.

### 4.5.1 Flood danger map

The flood danger map combines various flood parameters to form a level (degree) of danger (depth, velocity, debris often combined with recurrence interval). The information can be of qualitative or quantitative type. The colour scheme utilised is of particular importance as the colours represent also the level of severity, i.e. a direct link to possible impact. This type of map is not requested by the flood directive but it is useful, e.g. for land use planning.

#### Map content and utilised parameters

The flood danger in a particular location is represented by a level of danger. The level basically expresses the severity of the flood hazard. It is classified and often directly combined with the way of production.

- The approach of Wallonia, Belgium considers three levels of danger, namely high, medium, low (4-15). In this example the degree is established using 3 return periods (25, 50, 100+ years) and 3 depths classes. The scheme is explained in 4-13.
- A number of countries are using four levels of danger: Rheinland-Pfalz, Germany (4-52) or Switzerland (4-97). Both approaches express danger as a combination of recurrence interval (4 levels) and intensity (3 levels). The intensity reflects specific discharge ( $m^3/s \cdot m$ ), flow depth or accumulation depth (sediments).
- An English approach uses a hazard rating with 7 classes (4-27). The hazard class is calculated using three parameters: water depth, flow velocity and a debris factor. The map is for technicians.
- In contrary to the above mentioned examples the four degrees of danger in Austria (4-3) are mainly based on the water extent of particular recurrence intervals (red: maximum extent of extreme event). The same approach uses the Italian example of Tevere river basin (4-70): the three levels of danger (red, yellow, green) directly represent the flood return periods respective of 50, 200 and 500 years, the limits of the three areas correspond to the flood extension in these recurrence interval. From the maps is also possible to know water depth because the water surface and the digital terrain model (DTM) were overlaid. The overlay required software refining procedures, image processing and manual corrections.

#### Map use

- Planning tool on town/village level. Direct implementation of danger levels into land-use plans is possible.
- Awareness rising
- Emergency response (particularly English approach)

#### Scale considerations

Considering the use of the maps the scale is in the range of 1:1,000 (Austria) to 1:20,000 (Great Britain). The topographic background requires city / village plans, where individual land plots / houses can be identified.

### Colour scheme

The colour scheme uses red as the most severe class. Orange and yellow represent the lower classes. Switzerland, Austria or Great Britain have blue in their graduation. This might be misleading with the hues of blue used for water depth or water extent.

The Italian approach, in the case of Tevere river basin, uses the traffic light (red, yellow, green), where green is the least probable case.

### 4.5.2 Event map

The analysis and the display of past events constitute a first approach to assess flood hazards. The proper delineation of areas affected by floods serves as a basis for further assessment and it provides excellent arguments for awareness building in flood risks and flood risk management. In general, the information is easy to understand and striking.

### **Map content and way of production**

Historic flood incident maps (i.e., presenting point data of locations where records identify that floods have occurred in the past) may be presented using defined symbols either separately from, or overlain on, flood extent maps. Associated data (such as date of the event, magnitude, etc.) may be attached to a specific flood incident. The source of information are: Water level records in river, velocity records (gauge), flood marks, photographs, painting or drawing, newspapers referring to flood events, manual cartography, local knowledge from provinces, municipalities, consultants etc.

In most cases the flood extent of one or more events is shown.

- Recently flooded areas are mapped for the province of Flanders, Belgium (4-6, 4-7). Information of all flood events from 1988 to 2002 are integrated and presented in an overview scale (whole province) and in detailed scales (up to 1:10,000).
- The outline of two particular events (1856 and 2003) is overlaid on calculated flood extent for the Rhone River in France (4-36). The information is given in a scale 1:25,000. The representation of floods which occurred many decades back might be of limited importance as the riverbed and adjacent areas might have considerably changed in the mean time.
- The Irish interactive flood hazard mapping allows viewing point information about past events as well as past flood extent. Additional flood information about past events is available (e.g. photographs).

### **Map use**

- Awareness rising: simple and striking information
- Basis for follow-up flood hazard assessment, calibration of models etc.
- Emergency management and planning tool (priority setting), if continuously updated (Irish example)

### **Scale considerations**

Depending on the size of the flooded areas the scale may vary from 1:10,000 (hilly areas with limited extent) to 1:250,000 (large flood plains, whole province).

### **Colour scheme**

The information can be given as lines or as a transparent symbol. In general colours are given in various shades of blue.





## 5 Flood risk maps

The European Flood Directive makes clear reference to flood risks. It is stated:

“Flood risk is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with a flood event.”

Reference: European Flood Directive

The flood Directive hence states that flood risk maps shall show the potential adverse consequences associated with floods, 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 September 1996 concerning integrated pollution prevention and control<sup>3</sup> 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*.

In fact, the flood directive asks for vulnerability parameters only. The risk as such is not explicitly requested, but implicitly the notion of risk is an integrated part.

Addressing risks, i.e. the combination of hazard and vulnerability, is more complex than addressing hazards alone. In most European countries flood risk maps and related products are much less developed than flood hazard maps. Before presenting the good practice of flood risk maps, some basics about risk and risk mapping are given.

### 5.1 The notion of risk and its representation on maps

As stated in (e.g. ISDR) the risk may be calculated as follows:

$$\text{Risk} = C * p_h$$

where **C** is the potential adverse consequence ((taking into account factors such as exposure and vulnerability) and **p<sub>h</sub>** the probability of the hazardous process. Risk is expressed as a potential loss in a particular area (e.g. ha, km<sup>2</sup>) within a given period of time (in general one year).

$$C = V * S (m_h) * E$$

where V, S and E are the vulnerability parameters:

**V** = value of the element at risk: in money terms or human life

**S** = susceptibility: damaging effect on element at risk (as a function of magnitude of hazard; e.g. depth-damage and damage-duration curves (for example from FHRC Middlesex)). The susceptibility ranges from 0 to 1.

**E** = exposure: the probability of the element at risk to be present while the event occurs. The exposure ranges from 0 to 1.

The following information can be mapped with regard to flood risks:

- Individual vulnerability parameter “Value” as a direct demand of the flood directive
  - Population: number of people, special groups, etc.
  - Economic assets and activity: private property, lifelines, infrastructure, etc.; type of production, number of jobs, etc.
  - Environmental issues: installations potentially damaging the environment
- Potential adverse consequence (flood damage; loss per unit area) =  $V * S * E$
- Risk (loss per unit area in a given period of time)

<sup>3</sup> OJ L 257, 10.10.1996, p. 26. Directive as last amended by Regulation (EC) No 166/2006 of the European Parliament and of the Council (OJ L 33, 4.2.2006, p. 1).

There are a number of constraints when producing this type of assessments and finally represent the information in the maps:

- The necessary information does not exist in the required accuracy (basically a question of scale)
- The information is not made available by other levels of government because it is considered to be sensitive information (privacy protection; i.e.: the data are not publicly available)
- The information is not available in digital form.

An important point to consider when working with risks: Risk is unlikely to remain constant in time and it is often necessary to predict changes in risk in the future, to make better decisions. Some causes of change are well recognised for example:

- Vulnerability parameters can rapidly change:
- Increasing vulnerability: development, changing value of assets at risks, land use, behaviour of people during the flood, capacity for recovery
- Decreasing vulnerability: delocalisation/moving of assets, reducing sensibility of assets, improvement of flood warning, changing use of land, behaviour of people during the flood, capacity for recovery
- Permanent, semi-permanent or non-permanent flood defences (deterioration, maintenance, new works)
- The hazard parameters can change due to:
- Climate (natural variability, climate change)
- Environmental change (deforestation, reforestation, major forest fires,
- Erosion rate (changing geological exposures)
- Man's intervention

## 5.2 Mapping the assets at risk (vulnerability maps)

Mapping the assets at risk as asked in the EFD means provide information (vulnerability parameters) such as population, assets and economic activity, and environmental issues, potentially affected by a flood.

### Map's content

#### a) Population

- Distribution of population (either people per municipality, postal code or address/building, or average number of people per building/property)
- Distribution of particular vulnerable groups (homes for the elderly, location of schools, hospitals, sports facilities, other infrastructure with concentration of people; concentration of tourists)
- Distribution of buildings (as indicator for population affected): The Norway example (4-89) shows buildings potentially affected by a 100-years flood. In addition, buildings with potential damage to basements are mapped.
- Social vulnerability outlined by the English example (4-28). Here the social vulnerability is expressed using a Social Flood Vulnerability Index (SFVI) based on three social groups (long-term sick, single parents, elderly) and four indicators for economic conditions (unemployment, overcrowding, non-car ownership, non-home ownership). Social vulnerability is given in four classes: very high, high, medium, low.
- Any other vulnerable group that might be of interest for particular Member States.

#### b) Assets and economic activity

- Criteria may help identify the economic activities concerned by the Directive
  - Susceptibility to damage – type of industry, products
  - Impact of damage on economy e.g. only location for particular activity
  - Agriculture: fresh water or saline flooding
- Various classifications for land-use exist, and can be adapted according to needs:
  - residential areas: metropolitan, urban, rural, recreation
  - essential services and infrastructure: roads, electricity, telephone, gas, sewer, water supply, hospitals, schools, fire brigade, railway, sports facilities
  - special economic zones: industrial, commercial service
  - agricultural land, forest
- The Finnish hazard map (4-31) serves as well as a vulnerability map, as main land-use classes are overlaid

on water depth of a 250-years flood. The following classes are used: urban, industrial estates, discontinuous urban, agricultural areas, traffic infrastructure (airport, port)

- The Latvia example (4-73) uses several land-use classes with a 100-years flood extent. A clear topographic background (town plan) provides high accuracy.
- In the Danish example (4-22) the important infrastructure is overlaid on the extent of extreme flood event.
- In Saxony, Germany, essential services and infrastructure (hospital, water and energy supply, major industrial complex), are overlaid on the flood depth map. This implies the severity of possible flood damage.
- In the Italian example (4-69) the vulnerability of the assets exposed to risk was identified attributing a numeric coefficient to each functional typology (continuous residential buildings, productive areas, schools, hospitals and so on). The numeric coefficient, so called K, assumes an increasing value considering the increasing possibility of human loss in relation to the specific use of the assets distributed on the territories at risk. The accuracy of the maps depends from the accuracy of land use coverage that in the Italian example is developed on 1:10.000 scale

### **c) Potentially affected installations causing pollution**

A non-exhaustive list of installations of interest in this regard are:

- Chemical industry and respective warehouses
- Petroleum industry and storage facilities for oil products
- Thermo-electric power stations: oil, gas, coal, nuclear
- Fuel/gas stations
- Agricultural warehouses for fertilisers, herbicides, pesticides, poisonous substances, nutrients
- Special dump sites for chemical or industrial waste
- Waste water treatment plants

Not to forget is the potential impacts of flooded installations on particular environmental assets, such as:

- Potential damage to habitat and wildlife
- Uniqueness of the habitat and rarity of wildlife
- National parks and other protected areas like wetlands, virgin forest, etc.

### **Map use**

- Basic product to determine damage and risks
- Emergency management
- Flood expert (planning of flood defence measures)
- Land-use planning and land management
- On small scale (large areas): priority setting

### **Scale considerations**

- Overview information on village and town level. On large areas only the approximate population per municipality, village, or town can be represented. Scale is of the order of 1:100,000 to 1:500,000. Only feasible for large flood plains.
- Broad-scale infrastructure like road or rail network, or agriculture and forestry may use small to medium scales (1:100,000 to 1:250,000)
- Detailed information about individual buildings, social structures or social groups or about individual facilities require maps with a large scale (1:5,000 to 1:25,000; city or village plan).

### 5.3 Other types of information

The article 6.4d) of the flood Directive provides the possibility for the Member State to map any type of information it considers useful.

#### 5.3.1 Flood defences

Flood defences may be part of this information. On risk maps flood defences/dikes and their capacity for protection may be outlined.

"Structural measures (defence structures) will remain important elements and should primarily focus on the protection of human health and safety, and valuable goods and property. We will have to keep in mind that flood protection is never absolute, and may generate a false sense of security. The concept of residual risk, including potential failure or breach, should therefore be taken into consideration."

*Extract from the guide of Guide best practices on flood prevention, protection and mitigation*

For the case of flooding in protected floodplains there are two types of solution used:

- inundation of the floodplain is determined without taking into consideration of the existence of flood defences, the fact that part of the floodplain is protected can be indicated by hatching of the area or by application of other legend;
- inundation of the protected floodplain area is modelled with the assumption of the failure of the defences, applying two possible approaches:
  - arbitrary selection of the breach section of the defences leading to the worst case scenario (breach parameters determined by expert judgement, transformation of design flood wave to the breach point – this is how the flood maps in Hungary were produced in 1976),
  - modelling failure probability of the defences as well as the parameters of the breach as input data to the inundation modelling using full analysis of the defences and their foundation soil – disadvantage of this method the high level of data needed)
- inundation resulted from the breach is determined by quasi 2D or 2D hydrodynamic models, hazard parameters provided by the modelling: flood extent, flood depth, velocity distribution, velocity of inundation front (as inputs to logistical modelling of confinement/ localization, evacuation). In most of the cases coupling of 1D river flow and 2D overland flow models is needed to capture the hydraulic interaction of the river and the (protected) floodplain.

#### 5.3.2 Flood damage

The flood damage map represents the potential damage caused by a particular flood event (having a certain probability of occurrence) and giving the number of casualties or damage (in euros) per land unit. A presentation format may be to indicate a degree of risk for a given location / town, using different sizes of bars or circles to indicate different degrees of risk.

##### Map content

Within the flood extent is given:

- Potential damage for an extreme event in euro/m<sup>2</sup> (Sachsen, Germany, 4-56; 4-57). The land-use is classified and a particular damage per m<sup>2</sup> attributed:  
Industrial estate: moderate (< 10 €/m<sup>2</sup>) and high (> 10 €/m<sup>2</sup>)  
Residential area: low (< 10 €/m<sup>2</sup>), moderate (10 - 50 €/m<sup>2</sup>), high (> 50 €/m<sup>2</sup>)  
Agricultural and other land-use: no damage attributed
- In Baden-Württemberg, Germany, a detailed analysis of various land uses (specifically industry, trade and housing) together with the sensitivity to flooding provided the opportunity to determine the flood damage along the river Danube and to develop flood risk maps.
- The potential damage (in million euros per ha) for a particular event: the breaking of a control structure along the coast line in the Netherlands (4-80). The scale is non-linear, ranging from Euro 0 to 2.5 B per hectare in various shades of red.
- In Italy the hydraulic risks (4-71) are established by an overlay of the three hazard classes, corresponding to the flood return periods and the three vulnerability classes (see chapters 4.5 and 5.2.2). From the

combination of hazard and vulnerability of the exposed assets, the areas at risk were derived and represented in the map according to four increasing levels of risk: R1 (corresponding to hazard and therefore not identified in the map) R2 (green) R3 (blue) R4 (red). The maps are developed on a 1:10.000 scale. It can be classified as a simplified risk map, without providing economic - quantitative information in the case of Tevere river basin

- Risk in a detailed (non-linear) scale Flanders, Belgium (4-10).
- Risk map: Spanish example

#### **Map use**

- Flood risk management, decision making: Where is the greatest risk? Priority setting for measures
- Flood risk management, planning: Select the best options and range of measures to reduce flood risk like spatial planning and control of development (avoidance), asset system management (defences, flood storage areas, managing the pathways of rivers, estuaries and coasts), flood preparation (flood detection, forecasting, emergency planning) and flood incident management and response (flood warning, actions of emergency services, healthcare providers and flood risk management authorities, public, community support organisations), and recovery (insurance, local authorities, re-construction).
- Emergency and crisis management at national / local level: number of people involved, evacuation route, safe havens/temporary refuge centres, hospital response plans, transport disruption (roads & rail)

#### **Scale considerations**

- Detailed information required. Maps need to have large scale (from about 1:5,000 to 1:25,000)
- For large flood areas (e.g. the Netherlands) a less detailed scale is possible (1:250,000)





## 6 Flood maps: Initiatives, projects and special products

### 6.1 Trans-boundary flood maps

#### 6.1.1 Rationale and examples

Most of the European water resources are shared by two or more countries. European rivers, as for instance Rhine, Odra or Danube, often cross or (partially) form national borders. Flood mapping in these border areas is not an easy task due to various technical, legal, institutional and communicational problems.

Trans-boundary flood hazard/risk mapping within a particular watershed or along the respective river can be done in bi- or multilateral co-operation. Examples of trans-boundary flood maps can be derived from the relevant activities and results of the various commissions of particular rivers or about shared projects, like the Rhine Commission, or the Safecoast.

Several transboundary commissions, working groups and particular projects have been working to develop consistent maps crossing the boundaries. The references of these projects can be seen in Annex.

Annex...The following trans-boundary Commissions, working groups and particular projects exist:

- ELLA: In the Elbe-Labe preventive flood management project 23 authorities along the Elbe River are collaborating to establish a common strategy, develop hazard maps and integrate them into spatial planning to provide information for planning of settlements and infrastructure.  
<http://www.ella-interreg.org/>
- I CPDR: The International Commission for the Protection of the Danube River works to ensure the sustainable and equitable use of waters and freshwater resources in the Danube River Basin.  
<http://www.icpdr.org/>
- Safecoast: The project Safecoast enables coastal managers to share their knowledge and experience to broadening their scope on flood risk management in order to find new ways to keep our feet dry in the future. Safecoast is the follow-up project of Comrisk (project on common strategies to reduce the risk of storm floods in coastal lowlands).  
<http://www.safecoast.org/>
- FRaME: Flood Risk Management in Estuaries: Sustainable New Land Use in Flood Control Areas - is an international project which aims to develop innovative solutions to reduce the risk of flooding in estuaries. It involves five partner organisations, led by the Dutch Government Service for Land and Water Management with project sites in the UK, Belgium and the Netherlands.  
<http://www.frameproject.org/>
- FLAPP: Flood Awareness and Prevention Policy in border areas. It is an EU-funded network which enables responsible local and regional actors in European river systems and their feeders to form partnerships.  
<http://www.flapp.org>
- ICPR: Since 1950, the countries along the Rhine co-operate under the roof of the ICPR (International Commission for the Protection of the Rhine) to jointly protect the Rhine. An important result is the "Atlas on the risk of flooding and potential damage due to extreme floods of the Rhine".  
<http://www.iksr.org>
- TIMIS: The Trans-national Internet Map Information System is a contribution to an uniform EU policy for flood protection and is meant to become a model for other regions with trans-national issues. TIMIS focuses on both flood hazard mapping and flood forecasting for the border region of Luxembourg, Germany and France.  
<http://www.timisflood.net/en/>

#### 6.1.2 Use of trans-boundary flood maps

A river basin approach based on the principle of solidarity between countries upstream and downstream is broadly accepted in European water management policies. In addition the EU flood directive states that negative impacts of flood relief measures on neighbourhood countries should be avoided. In this context trans-boundary flood maps can be a first step and a basis for investigating and discussing cross-border effects and impacts of flood control measures. Additional benefits of trans-boundary maps are, *inter alia*:

- Production of one single flood map can be more cost efficient than producing separate maps for both sides of the border. For example, the cost of expensive data collecting techniques like laser scanning can be reduced by 50% if the entire river section is scanned at once instead of each river bank area separately.
- In case of urban areas situated on either side of the border (for example cities Goerlitz/Zgorzelec) common flood maps can facilitate effective cooperation in emergency and calamity management across borders. This ultimately improves the safety of citizens.
- Trans-boundary flood maps can provide a common basis for an integrated cross border approach of flood risk management, spatial planning and nature conservation and development.
- The process of developing a common trans-boundary flood map may strengthen trans-national co-operation and exchange between responsible authorities and may help to increase mutual confidence.

### **6.1.3 Technical and operational recommendations for successful trans-boundary flood mapping projects**

There is no doubt that creating trans-boundary flood maps can be a valuable task. However, in practice it takes quite some time and effort of relevant authorities in border areas to create such maps. Differences in the legal framework and practices of flood mapping may lead to different preconditions, expectations and purposes of flood maps on either side of the border.

Recognizing the fact that most issues are solvable on an operational level through good communication between experts, the following recommendations can be given:

1. In the starting phase of the project special attention should be given to the terminology. Definitions of 'damage' or 'sensitive areas' might be different on either side of the border.
2. The type of product, its content, layout and use have to be defined clearly before starting the technical work.
3. Scenario definitions have to be agreed among the partners before starting the hydraulic and other type of modelling.
4. Storage of relevant geo data in a common GIS system "on the fly" can avoid necessary transformation of data between different coordinate systems.
5. Relevant input data and parameter for hydraulic modelling like water level-discharge relationship and hydrological data (statistics and / or rainfall-run-off models) have to be harmonized. Attention should be paid also to possible differences of water levels due to national elevation standards.
6. Adjustment for soft data (vulnerability parameters).
7. Define ways of implementation at the very beginning of the cross-border initiative.

### **6.1.4 Policy recommendations for stimulating and supporting the development of trans-boundary flood maps**

Apart from the more operational problems on project level mentioned above there might be political, institutional and legal obstacles that hinder trans-boundary flood mapping. Based on the experiences of the FLAPP Network the following recommendations are given:

#### *a) Involvement of regional and local experts and stakeholders*

When decisions to make trans-boundary flood maps are taken in bi-lateral or multi-lateral agreements between Member States (e.g. in standing bi-lateral border committees or international river basin commissions), it should be recognized that creating and implementing such maps essentially is a regional/local responsibility. Therefore, to identify users and technical definitions and requirements of trans-boundary maps, local and regional water management experts should be involved in an early stage for the development of cross-border flood maps.

#### *b) Broaden the scope of transboundary mapping*

Although the EU flood directive requires coordination between member states within trans-boundary river basins, there is no obligation to create one common cross-border map. As a result, the realization of these maps may depend on the political will / sense of urgency to cooperate as well as on the existence of individual contacts between responsible policy makers / experts across the border.

Broadening the scope of cross-border mapping may lead to an increased willingness to create such maps. Trans-boundary maps might be a valuable tool for other sectors too, for example for noise reduction, air quality, spatial development, or calamity management in other policy fields. The process of developing joint flood maps can help to establish long term confidential relationships in cross border cooperation.

c) *Free data availability/access across the border*

Flood mapping requires high quality data from authorities of different governmental levels as well as policy sectors. Since structure and responsibilities of authorities on either side of the border are often quite different, data acquisition for trans-boundary mapping can be a critical factor to meet the project goals. An easy and free access to existing data across borders can improve the quality of flood maps significantly and supports a time and cost efficient mapping process.

## 6.2 Interactive map systems

Many countries, regions or thematic initiatives have interactive flood map tools for various applications. Some of them serve authorities, practitioners and experts while others address the local population. These different user groups have specific demands on content, readability, accuracy, or resolution.

The following list provides an overview of existing interactive flood mapping systems (the list is non-exhaustive):

- Austria: Hochwasser Risikozonierung Austria HORA (<http://www.wassernet.at/>)
- Flanders, Belgium: Geoloket Overstromingskaarten (<http://geo-vlaanderen.agiv.be/geo-vlaanderen/overstromingskaarten/>)
- England & Wales (GB): Environment Agency (<http://www.environment-agency.gov.uk>)
- Scotland (GB): Scottish Environment Protection Agency (<http://www.multimap.com/clients/places.cgi?client=sepa>)
- France: Ministère de l'écologie, de l'aménagement et du développement durables (<http://cartorisque.prim.net/index.html>)
- Baden-Württemberg, Germany: Hochwassergefahrenkarten in Baden-Württemberg (<http://www.hochwasser.baden-wuerttemberg.de>)
- Bavaria, Germany: Informationsdienst Überschwemmungsgefährdete Gebiete in Bayern (<http://www.iug.bayern.de>)
- Rheinland-Pfalz, Germany: Atlas der Überschwemmungsgebiete im Einzugsgebiet der Mosel: (<http://www.gefahrenatlas-mosel.de>)
- Sachsen, Germany: Various maps under the subject „Wasser“ (water) ([www.umwelt.sachsen.de/de/wu/umwelt/lfug/lfug-internet/interaktive\\_karten\\_10950.html](http://www.umwelt.sachsen.de/de/wu/umwelt/lfug/lfug-internet/interaktive_karten_10950.html))
- Ireland: National Flood Hazard Mapping (<http://www.floodmaps.ie/>)
- Italy: Tevere river basin Authority ([www.abtevere.it](http://www.abtevere.it) – click on “cartografia on line”) or the other river basin Authority web sites
- Luxembourg: (see TIMIS project, further down)
- Netherlands: Dutch Ministry of Interior ([www.risicokaart.nl](http://www.risicokaart.nl))
- Norway: Norwegian Water Resources and Energy Directorate (NVE) (<http://webb2.nve.no>)
- Spain: Catalan Water Agency ([www.mediambient.gencat.net/aca/ca/planificacio/inundabilitat/delimitacio/pl\\_periode.jsp](http://www.mediambient.gencat.net/aca/ca/planificacio/inundabilitat/delimitacio/pl_periode.jsp))
- Zug, Switzerland: Naturgefahren Kanton Zug ([http://www.zug.ch/forstamt/99\\_50.htm](http://www.zug.ch/forstamt/99_50.htm))

In Sweden during a flood event new calculations are made for the actual situation. The hydraulic models are calibrated with figures for actual water levels and discharges. The prognosis for precipitation etc is put into the model and new water levels are calculated and distributed to the users in the affected municipalities. So far no new maps have been produced by the authorities in a flood situation – but the municipalities can interpolate the water levels over a DEM to get the extent of the flood, for the actual situation.

The use of interactive mapping enables many users to have easy access to the flood mapping products and data. However there are a number of considerations that countries should take into account, such as how the information is displayed – see chapters 7 and 8 of this handbook.

### Advantages and constraints

- Accuracy, particularly when zooming in
- update possible
- hi-speed internet access
- false interpretation

### 6.3 other types of maps

Other types of maps can be developed to supplement the flood hazard maps and the flood risk maps identified in the Floods Directive. These are for different users and the data and information can be presented in many different ways according to how it is to be used. Two such examples are Emergency Maps and Insurance maps.

#### 6.3.1 Emergency map

For crisis management and rescue services, information of importance are:

- Number of people to plan the scale of response and resources needed, evacuation route, safe havens/temporary refuge centres, hospital response plans
  - Installations at risk that could lead to pollution or environmental damages as a result of flooding or for functions of importance for the society
  - Transport disruption – temporary or semi-permanent short or long period – roads & rail
- Emergency maps may include a range of different information, such as:
- Flood extent maps linked to different flood warning trigger levels
  - Locations where operational flood response is required (e.g., erection of temporary defences, closing of flood gates, etc.)
  - Areas where evacuation is required / advised for given event severities,
  - Properties of particular vulnerability (e.g., houses of people requiring assistance during evacuation)
  - Evacuation routes and shelter areas

Different levels of map are likely to be required for public information and for use by emergency response authorities.

#### 6.3.2 Insurance maps

Insurance maps can be simple maps showing how the probability of flooding varies taking into account all the flood risk reduction measures (including flood defences) i.e. the residual probability, or they can be more complex and illustrate the potential flood losses (i.e. the exposure of insured goods or risks). In the UK, the Environment Agency produces national postcode and property databases to give the insurance category for the land area where each property is located, and spatial data in the form of a map to show areas covered by different insurance categories

## 7 Production of flood maps

To produce the maps data and models are required. The following presents some good practices in this regard in Europe.

### 7.1 Databases

#### 7.1.1 Topography, digital elevation models (DEM)

To enable accuracy of inundation modelling as well as to secure the identification of the endangered properties detailed and accurate digital maps and digital elevation models (DEM) are required. Taking into consideration the most flat character and the very slight slope of the floodplain as well as that of the river flood surface, appropriate selection of horizontal and vertical accuracy of the maps/DEM has significant impact on the reliability and accuracy of the end product.

Minimum requirements are 10 m\*10 m (possibly 5 m\*5 m) horizontal and minimum 0.5 m vertical resolution.

Possible tools/methods to generate DEMs of the required accuracy:

- LiDAR
- SAR and variations (IFSAR, GeoSAR, AIRSAR)
- orto-maps, DTM derived from digital satellite images (SPOT 5; multispectral res 10 m, panchromatic res 3-DTM/DEM derived from aerial digital ortophotos (terrain pixel size: 0,5-2,0 m; vert. res. 0,3-0,5 m)
- DEMs derived from the vectorised contour lines of 1:10 000 scaled digital map segments (terrain pixel size: 0,85-2,0 m; contour lines available in 1.0 m resolution, on flat territories also the median 0.5 m contour lines are given) interim terrain surfaces to be determined by non-linear interpolation

#### 7.1.2 Historical data

Historical data are very important for public awareness rising as well as for the calibration of flood modelling (as long as past and modelling conditions can be compared).

Historical data interesting to be collected are:

- Flood maps
- Water level records in river
- Velocity records (gauge)
- Flood marks
- Pictures, painting or drawing
- Newspapers relating flood events
- Historical reports or books on floods, focusing on damages and on protection upgrade studied or decided after the flood
- Aerial and satellite photos.

#### 7.1.3 Land use and related data

The types of land use and related data used by European countries and the place where to get them are as described below.

- Population data – data acquisition: statistics (ZIP-code based registers)
- Corine Land Cover: The pan-European project CORINE Land Cover (CLC) provides a unique and comparable data set of land cover for Europe. It is part of the European Union programme CORINE (Coordination of Information on the Environment).  
[http://www.corine.dfd.dlr.de/intro\\_en.html](http://www.corine.dfd.dlr.de/intro_en.html)
- Typical, aggregated depth-damage functions are attributable to land use types, differentiated by CORINE Land Cover. In the UK, as may be with other countries, depth-damage relationships have been established for different land use and property classes using research and evidence of flooding over many years, looking at the economic losses incurred - both tangible and intangible. (link to Flood Hazard Research Centre, Middlesex University, UK)
- Economical data – data acquisition: land use maps, statistics, (ZIP-code based registers)
- Basic services: transportation, energy supply, communication, water supply, sewerage, healthcare, social and education facilities– partly from statistics, or ZIP code based registers, land registry, databases and



maps of linear infrastructures.

- Environment – pollution sources and protected areas: facilities and pipelines of chemical industry, filling stations, agricultural pollution sources (herbicides, pesticides, fertilizers, manure, poisonous substances and nutrients), wastewater treatment plants, waste storage, septic tanks; - Protected areas– Natura 2000, nature conservation– thematic databases and maps.
- Cultural heritage – thematic databases and maps.

## 7.2 Flood modelling

### 7.2.1 Hydrological models:

Various rainfall-runoff (RFRO) models or statistical models are used to determine hydrological parameters of the flood waves (which are input data of hydrodynamic models). The RFRO models are typically used to simulate the flash floods of mountain torrents and watercourses of mountain toe regions, but are also used for flood forecasting purposes even in large catchments where the time required for accumulation and runoff enables early warning of operational and/or emergency organisations.

Most widespread RFRO models in Europe are HBV, LISFLOOD and TOPKAPI, however, there are wide range of other models used (e.g. HEC-HMS). Concerning hydrological / hydraulic model combinations applied in operational flood forecast systems the *Mike11 Flood Watch* system (Danish Hydraulic Institute) and the *EFFORTS* system (Environmental Technologies & Products) are to be mentioned.

### 7.2.2 Hydraulic models

*River flood routing* (flood propagation in rivers) can be described by one dimensional (1D) mathematical model. This solution is suitable for the modelling of inundation of open floodplains as well but in case of sophisticated morphological conditions application of quasi 2D or 2D models might be necessary. There is a wide range of tools for this modelling. To be mentioned: Mike11, telemac, HEC-RAS, FLO-2D.

Parameters of *flood hazard in open floodplains* provided by the hydrodynamic models are:

(i) level of inundation, (ii) intersection of flood level with terrain (creates flood extent), (iii) flood depth as the difference between flood level and the terrain, and in case of application of 2D model, (iv) the distribution of velocity.

### 7.2.3 Large flood plain areas

Some countries have made flood plain maps that present the possible flooded areas. They are normally very general maps and can't be considered as flood hazard maps, but they are important tools to be used in preliminary flood risk assessment. They may be prepared for certain flood probabilities.

Two methods exist to outline large-scale flood prone areas without considering defences/dikes: a projection method and a propagation method. The information can be used for spatial planning and flood awareness rising.

- The projection method is predominantly used in Netherlands and is accurate for large areas with little relief or slope. This is called a “filler knife” method. The projection method requires an approximate digital elevation model and “design water levels”.
- The propagation method, is mainly used in the UK. It is adapted to sloping terrain. An approximate DEM and basic 1D modelling is required.

### 7.2.4 Coastal flooding

Lakes are not mentioned in the flood Directive proposal. However floods caused by high water level in lakes may be a very common reason for flooding in several countries. In the flood mapping process coastal areas (sea) and lake areas may be handled with the same methods.

Both flood projection and 2D modelling can be used for coastal inundation modelling, depending upon the coastal conditions. Flood defences can be included or ignored depending upon the reason for the flood map and how the data will be used. The UK achieved national coverage for its entire coastline using a 2D tidal inundation model (called HYDROF), which used a model grid built on merged marine and land topographic data. The HYDROF model computed water surface elevation and depth-integrated flow at intersection points on the model grid. Model runs for tide and tide with surge were calculated, which, when calibrated, produced the required flood outlines.

## 7.3 Specific cases

Some countries have specific situations or kind of floods asking an adapted method.

The methods used to model and map the possible extent of some of these other forms of flooding are outlined in this section

### 7.3.1 Torrent flows

Hazards caused by torrent flow are very important in some European countries. In mountain torrents the hazard is controlled by

- Water flood (discharge, velocity)
- Debris flow (discharge, velocity)
- Debris accumulation (height)
- Erosion (depth)

The probability of activity normally cannot be calculated directly from data because of the lack of measurements. For this reason the probability must be estimated from the frequency of disasters in the past (chronicle) and from the statistics of extreme rainfall events.

Modelling of torrent activity is only partly possible it needs special knowledge and there are big differences between modelling of torrent flows and river floods. As one example of practices the Austrian approach to torrent assessment and mapping is described in the following paragraphs:

- Hazard zone mapping is based on a design event with a return period of approx. 150 years. Hazard zones represent the sum-line of all possible hazard scenarios within the framework of this design event.
- Hazard zone mapping in Austria is normally based on an intensive survey in the field supported by the results of remote sensing methods and geo-data (e.g. geological maps, hydrological data, soil maps, vegetation maps, terrain models). Also of major importance is information on disaster events in the past, derived from chronicles, testimonials in the field (so called "silent witnesses"), disaster documentation (torrent cadastre) as well as observations by local residents.
- Recently some computer based models describing hydrological processes (floods, debris transport, debris flows) have been developed; however, the application in torrent catchments is still very limited.
- The outline of the hazard zones is an "expert decision" based on all available data and models and is normally done in the field. The fixed hazard zones are then digitally processed and integrated into GIS. Hazard zones are shown on plans based on the land register/cadastre in scale 1:2,000.

### 7.3.2 Groundwater flooding

Groundwater flooding is more complex than surface water flooding as it depends upon the underlying geology, rainfall and antecedent groundwater levels. To generate groundwater flooding there has to be very high prolonged (extreme) rainfall combined with initially high groundwater levels in areas geologically predisposed to groundwater flooding. Groundwater responds to rainfall more slowly than rivers, and only prolonged rainfall results in significant groundwater flooding.

A recent project undertaken in England for the Environment Agency has investigated a number of screening approaches for indicating areas susceptible to groundwater flooding, including:

- Using geo-statistical methods to screen areas with a high Base Flow Index, based upon local catchment descriptors from the Flood Estimation Handbook CD-ROM (Institute of Hydrology, 1999).
- Areas potentially vulnerable to groundwater flooding due to increased development pressure can be identified by the presence of a thin near surface aquifer (geological mapping), where the development can have a significant impact on groundwater flow. This type of flooding is not likely in areas of low permeability or areas underlain by thick or deep aquifers.
- Groundwater flooding resulting from reduced abstraction can be mapped by identifying areas with a reduction in abstraction, or areas which may have a reduction in abstraction in the future. Simple screening models based upon likely levels of rebound have been developed, and some in-depth study of mine water rebound has been undertaken.
- Areas where groundwater flooding has been recorded – this is the most reliable source of data, but may not include all instances of flooding. Furthermore, it cannot provide any certainty of future flooding.

In the UK, three main approaches have been developed for mapping groundwater flooding resulting from high rainfall, and these methods are most applicable to areas underlain by the Chalk aquifer:

- Groundwater Emergence Maps provide an indication of areas where there may be groundwater emergence

at or near the surface in areas underlain by major aquifers

(<http://www.defra.gov.uk/envIRON/fcd/policy/strategy/gw1.pdf>). The method involves raising a groundwater level surface to intersect the ground surface and encompass known locations of groundwater flooding. The maps do not indicate the likelihood of flooding. For the Chalk aquifer the outlines have been correlated with actual flood incidents.

- The British Geological Survey (BGS) has produced a groundwater flood susceptibility map for the UK based on process-based models of groundwater flooding. These currently include models of typical 'Chalk valley' type groundwater flooding and groundwater flooding in alluvial environments. The susceptibility map is produced using the permeability characteristics of mapped geology (at 1:50,000 scale) and groundwater level data. In addition, an associated confidence map has also been produced to be used in conjunction with the susceptibility map.
- A groundwater flood risk mapping method has been developed for the Chalk aquifer, and trialled in two catchments (Environment Agency, 2006a). This uses frequency analysis of groundwater levels to obtain a groundwater level with a particular annual exceedance probability (e.g. 1%, 2%, 4%, 10% and 20% AEP). These levels are then used to define a groundwater surface which, combined with ground elevations, indicates areas at risk of groundwater flooding. However, as the location of groundwater emergence depends upon highly localised geology, soils and topography, not all areas within the 1% AEP groundwater flood envelope will experience flooding in a 1% flood.

### 7.3.3 Flash floods and Mediterranean ephemeral water courses

Flash floods (FF) suddenly and violently pass in a quite terrifying way, posing a high hazard to life, damage and property.

The FF-prone basins mainly lies along the Mediterranean coast, and may also include other short, steep basins which have suffered FF in the past. Most of water courses in these basins are characterized by being ephemeral, with little or no water at all for most of the year. Thus risk assessment over these water courses should focus on the identification into hazard maps of being FF-prone areas, on the basis of geomorphologic analysis, and being susceptible for implementation of FF warning measures, based on risk maps.

Flash floods, on the contrary to Central Europe river floods, are normally caused by heavy rainfall in a short time frame over basins with a short time response, so the flood has the same time frame that the rainfall it originates. The ratio  $Q_{max}/Q_{med}$  can easily get a value of 100 and rise up to 1000.

Several aspects can be highlighted in relation to flash-flood hazard and risk map delineation:

- Flash-flood prone areas can be identified in a first approach by using meteorological criteria, in terms of rainfall amounts and intensities above a threshold that have impacted the same area in the past.
- Geomorphologic criteria are of primary importance in flash-flood prone areas, since water in most of these rivers do not flow for most of the year.
- Classical 1-D hydraulic modelling for hazard delineation may not be useful in small to medium flash-flood prone areas. Modelling of solid transport is particularly important, since it highly affects the extent of the flood.
- Risk assessment is of great importance in flash-flood prone areas, because many of them have been highly developed and thus presenting a high vulnerability.
- Flash-flood risk maps should therefore comprise of: hazard identification by delineated extents mainly based on meteorological and geomorphologic aspects, and vulnerability analysis in order to prevent or mitigate settlements on hazard areas from suffering their devastating effects.

## 7.4 Layout issues and GIS approaches

Cartographic aspects are important issues in flood mapping. They need to be adequate to the intended user to help ensure that the content of the maps is correctly understood and that the maps might convey the relevant information to their users, thus achieving the objectives for which they have been developed. This Section discusses some of the key issues related to the presentation of flood maps.

### 7.4.1 Basic and explanatory information

Information that is important for use and that explain the content of the map includes:

- Title: brief description of the map, including its content and / or purpose (for flood maps particularly important are the considered probabilities or recurrence intervals)

- Responsible authority (organisation responsible for the development and publishing of the maps, with contact details)
- Date of preparation / publication
- Legend (textual description of symbols, colours, line features, etc.)
- Purpose of development and intended use
- Method of development
- Limitations of map and / or assessment of uncertainty (if available)
- Disclaimer (to enforce explanatory information and limitations, and provide legal protection to the responsible authority against adverse consequences of misuse)
- North and scale: preferably using scale bar as this allows for changes in page size

The scope and detail of the explanatory information should be appropriate to the intended audience.

- Maps intended for public use should be simple and self-explanatory and include a clear legend, such that as little supporting or explanatory information as possible is required for correct interpretation.
- Maps intended for organisational users (governments, local authorities, etc.) will generally be used by professionals to inform decision makers that may potentially have significant impacts, and will often contain more information than public maps. They are therefore likely to require more detailed explanatory information to help the user to fully understand the development and limitations of the maps, particularly in relation to methods of development, limitations and uncertainty.

#### **7.4.2 Meta-data**

Appropriate meta-data should be provided where maps are issued / downloadable in GIS format. Such data should include standard meta-data (dates, responsible organisation, etc.) as well as information necessary for use of the GIS data, including the map projection and any datum levels used. Consideration should also be given to any relevant meta-data protocols or requirements, particularly with respect to uncertainty of data and quality control. Add also coordinate system and height reference system. That's important so that the data can "communicate" with other information like warning levels etc etc

#### **7.4.3 Background mapping or imagery**

Background mapping (i.e., maps showing topography, towns / buildings, roads, rivers and waterbodies, land use, etc.) or imagery (often ortho-rectified aerial photographs) are almost universally provided to a flood map to provide geographical reference for the flood information.

Clear, and appropriately scaled, background mapping facilitates location directly from the principal map (although it might be noted that at very detailed scales this can be difficult to achieve). Care should be taken to ensure that background mapping colours will not be readily confusable with those used in the flood mapping (or vice versa), and background mapping is sometimes provided in black-and-white or grey-scale to improve clarity of the overlying flood map information.

Imagery may be more readily interpreted than mapping as a background layer, although users may find it more difficult to geographically locate the relevant area, particularly if they are not closely familiar with the specific area. Imagery can also be expensive to procure if not already available, although Google Earth has recently become a powerful tool to provide affordable imagery (see Polish examples, 4-88, 4-89).

#### **7.4.4 Location and navigation**

A location plan is often provided alongside the principal flood map to help users identify the geographical location that the flood map represents. This plan, which may be an appropriately scaled map or schematic plan (with appropriate key locations, such as towns, roads, rivers, etc.), shows the coverage and the location of the map within a wider geographical area (e.g., the nation, region or river basin).

Navigation tools will be required for internet-based maps to enable users find an area of interest. Tools often include zooming (in and out) and panning and can include relocation from a location plan (as described above) or a return to default view (e.g., regional or national scale view).

An indication of orientation (direction of North bearing) and map scale are also required for correct interpretation. Scale information may be provided by:

- A written scale (e.g., 1:10 000) in the title box or legend
- A scale bar provided on the map; this allows easy change in paper size

- Grid squares provided on the map (with the grid square size defined in legend)

Background map can be a simple black and white map (eg topographic map) just to serve as an orientation

#### 7.4.5 Colour palettes and symbols

Simple flood maps may show only a single flood parameter (such as the flood extent for one flood frequency or return period) using a single coloured layer over a background map. The use of different colours (or shades of a single colour) may be used to present multiple parameters (such as flood extents for multiple flood frequencies, flood depths within a given flood extent, or classes of flood hazard or risk) in a clear and comprehensible format on a single map.

The choice of colour coding may be guided by a number of factors:

- Social conditioning: People are conditioned to interpret information based on colour, e.g., blue may be taken to represent flood extents, and red, orange and green are taken to represent danger, caution and safety respectively. Care should be taken with respect to possible interpretations of colour, and particularly misunderstandings.
- Graduations of colour: Graduations of colour (or within similar colours, such as red, orange and yellow or purple, blue and green) may be used to represent different degrees of a single parameter (e.g., deeper shades to represent more severe flooding or higher risk). The graduation may be discrete or continuous, whereby:
  - Discrete graduation is used to represent a set number of ranges or classes of degree (e.g., flood extents for a small number of flood event frequencies, or specified ranges of flood depth). The choice of range or class of degree may be based on equal divisions, or perhaps more appropriately, on classifications related to consequence (e.g., depth categories related to safety and the ability of people to evacuate, or to depth-damage data for economic damage calculation)
  - Continuous graduation is used to represent a continuum of degree. This provides more detail but may not be as easy to interpret as discretely graduated maps
- Black and White Reproduction: The possible reproduction of a colour map in black-and-white might be considered in choosing a colour scheme, noting that different colours may appear as the same shade of grey once copied.
- Accessibility: The accessibility of maps for the partially-sighted or colour-blind should be considered in choosing colour-schemes, particularly within the context of any national, regional or organisational regulations, policies or guidelines.
- Clarity: Strong colours may be used to provide clarity over a coloured background map, although it might be noted that an excessive number of strong colours can make a map difficult to interpret

Hatching may be used as an alternative to different shades or colours in representing different parameters or, as is more often the case, parameter variants. Examples might include hatching of flood extent areas that are defended by protection measures or form flood storage areas / washlands, to differentiate these types of area from those that are undefended or naturally flooded respectively.

The use of different line types that bound a polygon or flood extent provides another opportunity for differentiation. This approach is generally more suitable to visualise variants of a parameter or meta-data associated with the primary mapped parameters, such as differentiation between observed historic and predictive flood extents, or an indication of uncertainty associated with a flood extent.

Line types variations that might be used include ranges of line:

- Thickness
- Colour
- Continuity (e.g., solid, chain, dashed, dotted)
- Definition (e.g., clearly defined line of set thickness as opposed to fuzzy boundary)

#### 7.4.6 Numerical flood data

Flood maps represent information graphically. This visualisation can be supplemented with numerical data, such as values of water level or flow, either directly as text on the map or in a table on the legend. Such data can also be provided as attributes or tables associated with the flood maps where the maps are issued or downloadable in digital GIS format.

#### 7.4.7 Additional considerations

In preparing flood maps, other considerations may be relevant to the presentation.

The location, type, standard and condition of flood defence assets, and other flood-related information such as evacuation routes, shelter areas, flow direction, properties, etc., can also be shown on flood maps. The scope of the information provided might be more or less detailed dependent on the intended purpose and audience (i.e., public or organisational). This information may be associated with the flood maps, and possibly with particular flood cells, where the maps are provided in digital GIS format.

The presentation of flood maps in trans-national or trans-regional river basins should, as far as reasonably possible within the requirements and constraints prevalent in each jurisdiction, be co-ordinated and consistent in presentation.

Consistency should also exist between different types of flood maps for a given area. For example, the outer extents of flood risk zones should be spatially consistent with flood extent maps for a given flood event frequency, and a given colour should preferably not be used to represent more than one parameter within a related set of maps.

Most EU countries now have a multi-cultural, and hence multi-lingual, society. Minority language versions of maps may therefore be deemed appropriate where significant minorities exist.

### 7.5 Organisational requirements

Flood mapping can be expensive and complex. As part of a flood management strategy it would need a dedicated budget at different levels over several years (depending on the size of the country or the region). In addition, it would need skilled and experienced people, appropriate tools, and the necessary data.

To reach this goal that may be considered as necessary to rely on a technical force at national, regional and local level in order to:

- Create / identify / draw up methods, depending on the quality, the accuracy and the support of data (digital or not) needed to mapping and depending also on knowledge and capacity of technicians in charge of the implementation (competences in GIS, database, mapping, hydraulics, etc.);
- Organise trainings on the implementation of the suggested methods;
- Apply the methods together with representatives of the stakeholders or of the communities;
- Circulate the maps towards elected officials, stakeholders or riparians, and organize workshops for the operational people who will use the map
- Provide the maps with a booklet which present the river basin, explain his running, the flood process and describe the flood plain areas
- Check the accessibility of the flood maps, for each inhabitant and for each company's owner in the flood plain;

Existing method approved by the authorities at the national or regional level, could be used by private consultant to allow maps to be elaborated in only few years. In this case, the task force has to be in charge of validation of maps produced by private consultancies, to be sure of the harmonization between all the maps produced by different private companies.

### 7.6 Documentation of flood mapping process

Two examples of flood mapping processes are presented below; they are based on Swedish and Norwegian practices.

#### 7.6.1 Sweden

- 1 - Decision about what rivers that are in priority for mapping  
Official purchase
- 2 - Mapping process:  
Preparing of area and background data as input data  
DEM  
Calculation of discharges, 100-year and 10 000-year  
Topography and geometry for the river  
Construction drawings for bridges, dams, etc  
Cross sections, where and how many for the stretch of the river  
Estuaries



- Lakes
- Border conditions
- Ground truth
- Calibration of the model
- Calculations of waterlevels
- Interpolation of waterlevels on the DEM
- Calculations of the flood extent
- Map and database production
- Writing the report
- Production of the Metadatabase

### 3 - Costs

The most costly parts are the digital elevation model and the hydraulic model.

#### **7.6.2 Norway**

After the extreme flood of 1995, the Norwegian Water and Energy directorate (NVE) initiated preliminary flood mapping in Norway. Throughout the country all the local authorities were asked to describe and show on map sketches the locations that had been exposed to historical floods.

Based on the information received, the different locations were evaluated with respect to potential economical loss caused by flooding. This was done mainly by counting numbers of exposed buildings. The 134 most exposed locations, combined with high potential economic loss were pinpointed. A plan was set up for detailed hydraulic modelling and GIS mapping for these sites. The plan was send back to the local authorities for hearing and later approved by the leadership of NVE.

The project (flomsonekartprosjektet – flood zone mapping project) started up in 1997 and will be finalized by the end of 2007. An annually budged of 5-5.5 mill NOK has been received from the Norwegian government over these 10 years.

The method used is detailed surveyed cross sections, HEC-RAS modelling of water levels is performed and GIS analyses to visualize the inundations. Up to one third of the annual budget has been spent on surveying firms doing the cross sections survey. Around one third of the costs have been to produce the hydraulic results and reporting the results and around one third of the costs have been spent on the GIS, data acquisition and producing inundation maps. The inundation maps are published on the internet.

## 8 Flood map dissemination

### 8.1 User-specific issues

The dissemination of maps basically addresses to groups of users:

- General public (that ought to be made aware of the risk):
- Professional users (e.g., public sector authorities, involved in planning, execution and maintenance of measures, and/or decision making in policy and/or crisis management; private companies)

#### 8.1.1 Public dissemination

The primary purpose of public dissemination of flood maps is to increase public awareness. This is to empower individuals to take appropriate preparatory and response measures, and to inform them regarding decisions such as the purchase or otherwise of a property, or the assignment of use, layout and design of an area of land. The public dissemination via the Internet is essential (single-point update, low-cost dissemination, reducing risks of use of superseded (aged) data, etc.), although hard copies of maps should also be available in public offices (e. g. in local libraries, local authority offices, and town halls) to make the information available to those who do not have Internet access. However, it should be remembered that a lot of people can't understand easily technical information available on the Net.

Simply making the maps available via the internet is inadequate to meet public awareness objectives, A website and availability of information must be actively promoted (via insurance, flyers, billboards), and be supported (where possible) by teaching in schools and public meetings organised by municipalities.

Web based GIS technology is currently being developed at an extremely fast pace. Popular freeware tools such as Google Earth are increasingly capable of showing thematic maps from a variety of GIS systems (e.g. ArcGIS). This could mean that availability of flood information for the larger public could simply be a spin-off of the professional GI systems in the form of data layers made available in a format of these public tools. Separate development of public accessible web-GIS may not be necessary, and the emphasis can be on the cartographic content of the information.

#### 8.1.2 Professional users

The Internet, with restricted access if necessary, is also considered to be the most appropriate media for dissemination of flood maps to professional users. It is however noted that maps for these users should generally be downloadable in GIS (for integration into the existing GIS of the relevant organisation) or PDF format. Data format, data collection and data availability should be compliant with the principles of the INSPIRE initiative. That means:

- Data should be collected once and maintained at the level where this can be done most effectively
- It must be possible to combine seamlessly spatial data from different sources across the EU and share it between many users and applications
- It must be possible for spatial data collected at one level of government to be shared between all levels of government
- Spatial data needed for good governance should be available on conditions that are not restricting its extensive use
- It should be easy to discover which spatial data is available, to evaluate its fitness for purpose and to know which conditions apply for its use.

(Source: <http://eu-geoportal.jrc.it/gos>)

Dedicated concentration and dissemination facilities of numeric flood maps might be recommended operational solutions, where needed, for integration of these specific data into data services, with appropriate referential and various other sources and layers of data :

- At appropriate administrative levels: Floodplain management authority, national, regional, county or municipal authority levels, through dedicated data management platforms,
- For specific sectoral needs such as insurance/reinsurance, real estate, etc., in most cases through an umbrella association.

Dissemination to the insurance industry may be through restricted access, possibly to an umbrella association. Notwithstanding provisions of INSPIRE Directive (when coming into force)<sup>4</sup>, the scope of the information made

<sup>4</sup> Organizing a European infrastructure for delivery of public data and metadata on the environment (flood risk zoning information is included in the Annex III)- add latest reference of the directive

available will generally be determined by national legislation or agreements, possibly including considerations of national security.

## 8.2 Uncertainty

Flood mapping is not an exact science. There is a level of uncertainty for any modelling and mapping of flood risks. This uncertainty dictates the accuracy of mapping products, and needs to be understood in order to know how closely the mapping represents what users would see as an accurate representation.

There are two types of uncertainty:

- uncertainty related to natural phenomena, hydrology, climate
- uncertainty associated with data, modelling, measurement

There is a range of scientific methods available for estimating uncertainty. Many however are quite sophisticated quantitative approaches, requiring a large number of model runs and therefore generally not viable for widespread (national or regional scale) mapping. An alternative approach may be to estimate uncertainty through a qualitative assessment, based on availability and quality of calibration data, hydrological and hydraulic analytical methods, quality of DTM data, etc.

### 8.2.1 Uncertainty and natural phenomena

Risk related to natural phenomena always includes some degree of uncertainty associated with it. The uncertainty can result from lack of knowledge, the disability to measure certain phenomena or the natural variability.

Uncertainty associated to climate change, hydrology, etc. has to be considered carefully depending to whom it has to be communicated.

In terms of mapping floods there are three possibilities:

- ignore it
- assume change happens and so consider it for the work
- an intermediate position where both is mapped with one scenario predominant.

### 8.2.2 Uncertainty associated with method

For the decision making process sensitivity analyses can be an adequate approach to evaluate results.

The European project Floodsite<sup>5</sup> (more precisely its Taskgroup 3) has undertaken a study about the Flood hazard mapping. The activity program of the Taskgroup 3 targets:

- to set a framework, based on Floodsite methods, to establish a European Flood Hazard Atlas,
- to study the question of the uncertainty in flood mapping and suggest appropriate techniques to handle this,
- to test the methods in 2 pilot sites (Ebro delta and German Bight)

These tasks have to be completed by February 2008.

### 8.2.3 Dissemination of the uncertainty

Flood mapping is a tool to provide information to people to assist the decision making processes. To make the most appropriate decision, and particularly those with potentially significant impacts, it is important to know how reliable the information is therefore, it may be useful to define levels of confidence or degrees of uncertainty associated with the flood information presented on the flood maps, such as flood extents, levels, flows, etc.

In general the methodology for the assessment of flood maps has to fit state-of-the-art, based on a reasonable expense. It has to be considered, that the uncertainty of a result is generally dependent on the "weakest link in a chain". For disseminating results in maps this e.g. means, that the topographic background maps and scale used for presentation should fit to the level of detail of presentation (should be adjusted based on the accuracy of flood mapping). The smaller scale map is used the more generalized background map must be used. Scale limits can be adjusted also to flood map services in the Internet. An adequate instrument to express the uncertainty of the information in flood maps is the use of classes and intervals.

<sup>5</sup> see [www.floodsite.net](http://www.floodsite.net)

**Dissemination to the public**

Accompanying text about uncertainties in map production and presentation (e.g. last update) is advisable for the public dissemination of flood maps. A very general and comprehensible description of the data collection and the modelling could be very helpful, as well as a disclaimer. As a basic principle, no more information than necessary for understanding should be presented to avoid misunderstandings or produce something that is counterproductive to public flood risk awareness.

**Dissemination to the professional users**

Within the dissemination for professional users maps and explanatory texts (metadata) may indicate methodological uncertainties and uncertainties in mapping in a direct way.



## 9 Concluding remarks

In the EU flood maps Atlas which is available in Annex, a large number of examples of floods maps are shown, produced by various EU member countries. The aim of this Atlas is to provide the reader with illustrative examples of various types of flood maps that might form an inspiration for future mapping efforts.

The Atlas allow to measure the wide range of practices existing today in Europe to face the need of flood mapping.

Together with the core handbook at hand those elements are presented by the members of [EXCIMAP](#) as basis to help undertaking flood mapping in the best possible way given the present knowledge.





## 10 Annexes

1. Questionnaire 1 – flood mapping current practices - synthesis
2. Atlas of flood maps [separate document]



# Annex I : Questionnaire 1 – flood mapping current practices - Synthesis – June 2006

Questionnaire issued : 28 February 2006

Respondent country/organisation: Austria(Au), BGS, CEA, England&Wales(E&W), Finland(Fi), Flanders(Fl), France(Fr), Germany-Bavaria (Ge), Hungary(Hu), Ireland(Ir), Italy(It), Latvia(Lv), Poland(Po), Slovenia (Sn), Sweden (Swe), Switzerland (Swi), The Netherlands(Ne), TIMIS, Wallonia(Wa)

Contact point: [EXCIMAP](#)

Date: 21 June 2006

## PART A – GENERAL INFORMATION

### A1 - flood maps available in your country

#### A1a- flood plain map ...

- ... is made by : every respondents (except CEA, Au for torrent and Wa, and only on request of municipalities for Lv).  
Often carried out in support of a legal process (flood protection building, land use planning)
- ... covers: All the territory in majority.  
Exception with BGS, Ge, Ir, Lv, Ne, Swe, Swi (and TIMIS project by nature) who concentrate on a limited number of areas of interest
- ... consists of: A delineation of flood prone areas for events of one or several return periods.  
Is built on either historic and recorded floods or models outputs.  
In some cases: settlement of major infrastructures (Hu), location of flood defences (E&W) are added
- ... scale is : various situations exist :  
1:2 500 (Fl, Ge); 1:5 000 (Sn); 1:10 000 (Po, It, Fl, BGS); 1:20 000 (Fi) 1:25 000 (Fr, Ge, Sn, Swi, TIMIS), 1:50 000 (Au, BGS, Fi, Hu, Swe); 1:100 000 (Hu); 1:150 000 (Sn)

#### A1b - flood hazard maps

- ... is made by: Is part of an existing process (Au, BGS, CEA,E&W, Fl, Fr, Ge, It, Po, Swi, Wa, TIMIS) or is under development (Hu, Fi, Sn)
- ... covers: Only restricted areas for every respondents, except E&W (all the territory)
- ... consists of: Spatial extent of water for one or several given scenarios + characterisation of the hazard level (from water depth, flow velocity, duration, rate of inundation).  
In addition, in some cases: dam break hazard (Fi, Ne)
- ... scale is : Various situations exist :  
1 :500 (Sn) ; 1:1 000-1:5 000 (Au, Swi); 1:10 000 (Po, Wa); 1:20 000-50 000 (Fi)

#### A1c- flood risk maps

- ... is made by: Produced not everywhere: either under development (Fi, Ge, Ir, Ne, Sn, Swi), or already existing (Fl, Swe, TIMIS, Wa)  
Sometimes: only assessment and no mapping (Fr)
- ... covers: When produced: only some restricted areas; except Swi: all territory
- ... consists of: Crossing of hazard (or probability of flooding) and vulnerability (or potential damage in €, or number of potential casualties)
- ... scale is : When produced: 1 :500 (Sn) ; 1:10 000; except Swi: 1: 25 000 to 1: 5 000

#### A1d- flood damage maps

- ... is made by: Produced or under development in few countries (Au, Fi, Ne, Swi, Wa)
- ... covers: When produced: only some restricted areas; except Swi: all territory
- ... consists of: Economic direct and indirect, and internal damage (combination of flood hazard levels and

socio-economic data) in €/year or €/km<sup>2</sup>. Swi: potential damage evaluation for at-risk assets; protection goals; protection deficit; costs-benefits studies for flood protection measures  
 ... scale is : When produced: 1:10 000. Swi: 1: 5 000

## **A2 - Types of flood addressed (fluvial, coastal, flash, urban floods, ...)?**

<b>Type of flood</b>	<b>countries</b>
fluvial	All respondents
coastal/tidal/estuarine	BSG, E&W, Fi, Fl, Ir, Ne, Sn
flash	BSG, E&W, Fl, Ne, Sn, Swi
urban	Existing or investigation: BSG, E&W, Fi, Fl, Ir, Ne
groundwater	Existing or investigation: E&W Fr, Ne

## **A3 - Legal value of the maps**

<b>legal value</b>	Ge (for areas affected by HQ100 floods), Ne
<b>non legal value</b>	All respondents except Ge, Ne
<b>support land use planning</b>	Au, E&W, Fl, Fr, Hu, It, Sn, Swe, Swi, Wa

## **A4 – Access the flood maps**

**Maps are freely accessible at desk** Everywhere (except Wa, and on request in Lv)

**In addition, maps are accessible through the Internet** Au, E&W, Fl, Fr, Ge, Ir, It, Ne, Sn, Swe, Swi, TIMIS

## **A5 - In what format are the maps available?**

<b>hard copy</b>	everywhere
<b>digital GIS</b>	Almost everywhere
<b>Pdf-format</b>	Almost everywhere

## **A6 - Who are the stakeholders involved in the map implementation? Who is responsible for what?**

<b>government and local authorities</b>	Involved in every countries; for financing, execution and final approval.
<b>other stakeholders</b>	In some cases: environmental agencies, river basin authorities, water agencies, general public, universities also involved for technical development

## **A7 - Quality management**

<b>quality management (or quality checking process)</b>	
<b>exists or is in preparation</b>	Au, BGS, E&W, Fi, Fl, Ge, Ir, Ne, Swe, Swi, TIMIS
<b>It consists in</b>	Various kinds of quality evaluation and approval procedures, more or less intensive

# **PART B – FLOOD MAPS DEVELOPMENT PROCESS**

## **B1 - methodologies used for developing the maps; process and different steps for each type of map**

### **B1a- flood plain map**

<b>Methods used:</b>	All respondents: hydrological analysis and modelling (hydrogeomorphological for Fr) crossed with topographical maps; Hydraulic simulations Sometimes: defences and/or breaches possibilities are located (Hu, E&W)
<b>Models used:</b>	All respondents: 1D or 2D hydraulic models high-precision digital elevation/terrain model (DEM/DTM)
<b>Content:</b>	All respondents: theoretical flood extents for one or several flood events probabilities

### **B1b- flood hazard maps**

- Methods used:** Determination of several hazard/danger levels depending on water depth/level, flow velocity (duration and sometimes debris factors) for one selected flood scenario (for a given probability of occurrence)  
Mapping of areas exposed to the different levels of hazard
- Models used:** Matrix or diagram for hazard rating (function of velocity, depth and debris factor)  
Or 1D-2D models
- Content:** Delineating of extents of areas of several given hazard level (characterized as high, medium, low; and sometimes very high)

### **B1c- flood risk maps**

- Methods used:** Not produced everywhere  
Sometimes risk is only evaluated and not mapped.  
Usually the definition used for "Risk" is from Varnes-1994: Risk=the probability of occurrence within a specific period of time in a given area of a potentially damaging natural phenomenon (Varnes).  
Based on a vulnerability to and/or annual damages from floods assessments. Also Swi: definition of protection goals; comparison with actual protection level
- Models used:** Usually: Varnes-1994.  
In addition, sometimes: assessment of the vulnerability sorted in several categories of sensitivity (It)
- Content:** Usually: several levels of risk.  
Sometimes: risk mapping for restricted areas

### **B1d- flood damage maps**

- Methods used:** Damage maps are rarely produced (E&W, FI, Nt, Swi, Wa)
- Models used:** Damage=consequence of flooding in terms of social, economic and environmental impacts
- Content:** Potential damage evaluation is a monetary (and sometimes non-monetary) evaluation of impacts on people at risk, land use, infrastructure, property and assets

## **B2 - Main data sources (hydrology, topography, rating curves, dike databases, assets databases)**

- Types of data:** Always listed:  
hydrological and meteorological data  
detailed topographic (and geological) information  
land use/urban development information  
information on flood defences.  
And sometimes, in addition:  
GIS datasets of population, postal addresses, habitats, high sensitive objects; insurance data
- Models used:** DTM model  
local topographic models  
photogrammetry  
cadastre  
Corine land cover

## **B3 - Use of satellite data**

**For mapping process** nowhere

**For other use:** Sometimes for flood event recording (flooded areas mapping) or land use information.

## **B4 - Hydrological models in use**

**B4a - ... to evaluate frequency of flood**

- Methods used:** Statistical analysis of extreme observed discharges (Gumbel distribution)  
Hydrological models outputs
- Models used:** Rainfall-runoff models

Probabilistic models, best fitting probability functions.  
 Various models references are named:  
 "the flood estimation handbook (FEH) statistical procedures: automation, appraisal and future development" DG Morris, AC Bayliss, EJ Stewart (E&W)  
 HYFRAM(Wa)  
 SHYREG (Fr)  
 Peasron III (Sn)  
 HBV model produced at Swedish meteorological institute (Swe)

#### **B4b - what flood events do you refer to? (HQ20, HQ50, HQ100, HQ300?)**

**HQ:** Large range of references: from HQ5 to HQ40 000.  
 The more frequently referred to: 10, 50, 100, 1000  
**associated indicators:** Flood events reference are sometimes associated with an indicator such as: very frequent, frequent, rare or extreme event;  
 low, moderate, high or very high probability

#### **B5 - Use of a land use numerical representation**

**Used in:** Fi, Fr, Fl, Ge, It, Ne, Swi, Wa  
**Models:** Often named:  
 Corine Land cover (CLC)  
 Numerical cadastral plans  
 Numerical geographical map or numerical orthophotoplans

#### **B6 - Hydraulic models in use**

**Methods used:** 1D or 2D hydraulic models  
**Models used:** Often named: HEC-RAS, MIKE, ISIS

#### **B7 - For flood plain maps ...**

##### **B7a - extent of flood evaluation**

**Methods used:** Usually:  
 water levels derived from 1D or 2D hydraulic model and digital terrain data.  
 In addition:  
 Hydrogeomorphological method (Fr).  
 Survey in-the-field (Wa)  
**Outcomes:** Flood-prone areas limits;  
 Limits of the flood channels

##### **B7b - how do you take past flood events into account?**

**Methods used usually:** Use of historical observations to determinate discharges for different event probabilities.  
**In addition:** Historical data are used for models calibration, and mapping

##### **B7c - how do you take flood protection installation and associated risks of failure into account?**

**Methods:** Often taken into account in flood plain delineation (Au, Fi, Fl, Hu, Ir, It, Ne, Swe, Swi, TIMIS, Wa) or flood risk mapping (E&W, Ge in project, Sn).  
**Data used:** Use of information on dyke heights and strength (which give associated performance/risk of collapse or overtopping),  
 Combined with probability of defences failure  
 And defences failure scenarios for a flood of a given return period  
**Outcomes:** Evaluated inundated areas and water depths zones in case of overtopping or breaching of defences



**B7d - how do you take foreseen situation (in terms of land use and climate change effects) into account?**

<b>Climate change effects:</b>	Rarely taken into account : E&W: foresight 2050 Ne: in project on sea level rising Fi: 2 pilot projects Hu: in project for 1000y flood event). Swe: a governmental committee is investigating the regional effect of global change Swi: through pessimistic scenarios
<b>Future land use:</b>	Rarely taken into account: It, Ne, Sn, Wa
<b>Outcomes:</b>	Climate change effects: Potential for change from current day flood flows and water levels in the long term (E&W); Design flood under 4 different climate change scenarios (Fi)

**B7e - What GIS software is used?**

**More frequently named:** ArcInfo, ArcGIS, ArcView, AutoCAD

**B8 - For flood hazard maps...**

**B8a – evaluation of flood likelihood or probability of flooding**

<b>Methods used:</b>	Usually: Statistical analysis based on validated historical data (past flood events: records or in-the-field surveys) Recorded gauging data. In addition, when available: information on height and strength of defences infrastructure . Return period=number of flood events/number of flood events exceeding the threshold values=1/probability
<b>Outcomes:</b>	Return periods or recurrence interval of a flood; Average time between 2 flood events, in years

**B8b – evaluation of danger levels**

<b>Methods used:</b>	Usually danger is a function of water depth and flow velocity. Sometimes in addition: Potential risk (Ir) or damage parameter (Fi), debris factors (E&W), probability of occurrence (TIMIS)
<b>Outcomes:</b>	Hazard levels or damage level parameters, Dangerous areas zoning

**B8c - techniques of comparing geographical data on exposure with that of hazard zoning**

<b>Methods used:</b>	A technique of comparison does not exist everywhere. When available: Combination of vulnerability maps and hazard map (Fi, Sn); identification of relation between land use and natural flooding phenomena (It), Combination of chance of flooding and potential damage (Ne) GIS-based approach (Swi)
<b>Outcomes:</b>	Risk levels; Flood risk maps with zoning; Vulnerability classes to guide the decisions making

## B9 - For flood damages maps...

### B9a - development process

- Methods:** Damage evaluation carried out in: E&W, Fi (damage evaluation used in flood risk mapping), Ir, Ne, Sn (testing), Swi, Wa
- Models:** Different models used  
E&W, Ir: Risk=damage=likelihood of flood (depending on water depth and flow velocity)\*impact of flood;  
Swi: Assets maps / potential damage (vulnerability)  
Wa: hazard map crossed with vulnerability map
- Outcomes:** Annual average damage;  
Number of casualties per year;  
Swi: Risk evaluation; sometimes Risk maps; Protection goal / protection deficit  
Expressed in level of damage (high, medium, low) in Wa

### B9b - damage/costs functions in use for damage evaluation

- Methods:** E&W: "The benefits of flood and coastal risk management: a handbook of assessment techniques" ("multi-coloured manual" ) - Middlesex university flood hazard research centre;  
Ir: the same as E&W adapted to Irish conditions.  
Fi: investigation of paid flood damage compensations.  
Ne: use of statistical data, with the "Standard method 2004 damage and casualties caused by flooding (DWW-2005-009)" distinguish primary and secondary and indirect damage, depending on the location where the damage occurs .  
Swi: damage function giving expected loss per acre in relation to the hazard level for floods of an hazard map (BUWAL 1999)
- Outcomes:** E&W, Ir: property-type specific depth-damage costs.  
Fi: rate of flood damages of main feature classes (block of flats, ...).  
Ne: direct damage, direct damage as a result of operational failure, indirect damage as a result of flood  
Sn: damage curves  
Swi: expected loss per acre in relation to the hazard level for floods of an hazard map (BUWAL 1999)

## PART C - VULNERABILITY ASSEMENT

### C1 - Topographic survey methodology

- Methods used:** Often named methods:  
Remote sensing (aerial photographs, LIDAR)  
Ground survey
- Models used:** Digital elevation model

### C2 - Land use documents analysis

- Methods used:** When analyse is carried out, it consists in :  
An evaluation of vulnerability or the assets at risk of flood;  
prospective and investigation of the potential impact of present and future development on flood risk
- Models used:** Integration on flood risk assessment when exists
- Outcomes:** Typology of assets at risk; level of sensitivity

### C3 - In-the-field surveys

- Methods used:** Sometimes, some national recommendations exist(Au, E&W, Ir, It, Sn (in test))  
Sometimes the survey is carried out by specialised staff (sometimes: special contractors)  
Swi: For planning of protection measures

**Models used:** identification of property types and classification

#### **C4 - Stakeholders involved in the mapping process**

**Stakeholders:** For every respondents, many stakeholders are involved:  
general public, local authorities, water board, government.  
And in addition, in some cases:  
insurance companies, industries, scientific communities, various interest groups

**Methods:** Public presentation and hearings (Au),  
Public consultations days (Ir)

### **PART D – FURTHER INFORMATION**

#### **D1 - Other known flood mapping current practices overviews**

**In Europe:** European commission 2003;  
ICPDR review;  
German manual with recommendations for flood plain mapping and hazard mapping  
Project FLOWS WP1C-1 “Best practices evaluation”  
Switzerland

**Out of Europe:** USA, Japan

#### **D2- Involvement in the production of flood map at a transboundary river basin level in Europe**

Austria	Salzach river with Bavaria; Rhine with Switzerland
Finland	project VIVATVUOKSIA
France	Rhine; rapid mapping service operated by SERTIT
Sweden	Coming in 2007
Switzerland	Rhine with Austria; ICPR
The Netherlands	Rhine atlas hazard maps for transboundary dyke rings with the Nord Rhein (Germany) Bundesland
TIMIS	Co-operation between Luxemburg, Germany, France

#### **D3 - Steps of the flood mapping process to investigate more**

**Technical matters:** Efficient and cost-effective data collection,  
vulnerability assessment,  
damage mapping  
flood risk mapping,  
climate change effect,  
assessment of level of confidence in the mapping provided,  
cost-benefit and economic analysis,  
technical management to rate contracts per hazard level,  
assess accumulated exposure  
time scale/return periods  
spatial analysis of hazard scenarios

**Management-related matters:** refine the subscription policy,  
provide a tool aimed at the people at-risk and/or insured,  
participation of the users and public relation,  
governance aspects of flood mapping and functioning of flood mapping as a policy instrument,  
aiding information provision for crisis management preparation,  
communicating flood risk  
cost/benefit evaluation for flood protection projects

#### **D4 - Methods to study more**

- In relation with of flood**      torrential flooding evaluation,  
groundwater flooding evaluation, acquisition and use of geographical data
- In relation with impacts**      damage function, cost function  
vulnerability assessment

#### **D5 - Methods to know more about**

- Mapping:**      other methods developed and used,  
or future methods for mapping in Europe
- Modelling:**      modelling of dyke breaching,  
geocoding of exposed addressees and alternative GPS technology,  
estimating discharges and water levels for rare and major flood events  
model sensitivity

#### **D6 - Specific problem/difficulty faced**

- Often named:**      use of common language on flood mapping and common criteria for flood prone areas  
occupation,  
communicate the information (the right to information on natural risks, web access, public participation)
- In addition:**      evaluate, take into account and disseminate uncertainty,  
data acquisition (geographical data in particular) and data integration  
integrate/re-use existing maps

#### **D7 - Advantages and disadvantages of your method?**

- Advantages:**      Usually the method used is considered as satisfactory, adapted to the needs, flexible and easy-to-use
- Disadvantages:**      Focus on too restricted and localised areas;  
A non financial damage assessment is missing (Wa),  
Methods not homogeneous enough (Fr) or not usable for land use analysis (Fi)  
High calculation power needed (Ge)  
Method costs a lot of money, manpower and time (Sn)  
Not all stakeholders use the helpful technical basis at its best (optimizing implementation) (Swi)

#### **D8 - other comments**

## Colophon

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