Prepared for:

EXCIMAP

Atlas of Flood Maps

Examples from 19 European countries, USA and Japan

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Contents

1 Introduction

Aware of the growing need for flood mapping development in the future in Europe, early 2006 the European Water Directors decided to establish a European exchange circle on flood mapping (EXCIMAP).

Today EXCIMAP is an informal circle consisting of nearly 40 representatives from 24 European countries or organizations. It has been set up for encouraging and facilitating exchanges between European experts in view of developing flood mapping. The main objective of EXCIMAP is to produce a Handbook presenting the good practices (available in Europe) to mobilize when executing flood mapping.

In the mean time, the European Union has adopted a European Directive on the Assessment and Management of Flood Risks. This Directive 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 all regions and to select those regions on which to undertake flood mapping and flood risk management plans (see below)
- flood mapping, with a distinction between flood hazard maps and flood risk maps:
  - the **flood hazard maps** should cover the geographical areas which could be flooded according to different scenarios. These maps are also indicated by flood extension maps;
  - the **flood risk maps** shall show the potential adverse consequences associated with floods under those scenarios.
- 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. Examples are evacuation maps.

The focus in this Atlas is on river flooding, but some examples of coastal flooding are also included.

According to this directive Member states shall produce flood mapping according to some minimum recommendations. To be consistent with this proposed European document, EXCIMAP has decided to focus its work on the minimum requirements of the Directive concerning flood mapping.

As part of the work to be done for this Handbook an inventory was made of examples of maps and mapping programmes in the participating countries. The result of this inventory is this “Atlas of Flood Maps”. It contains examples from 19 European countries, not counting the subdivisions that are made in some instances (Belgium, Great Britain and Germany) and from the USA and Japan. In addition special chapters are dedicated to transboundary flood mapping, flood maps for insurance purpose and evacuation maps.
In each chapter the authors of this Atlas have made remarks on content and layout of the maps, based on general cartographic principles.

The Atlas is compiled by the Netherlands Ministry of Transport, Public Works and Water Management. The material is submitted by the EXCIMAP members. WL|Delft Hydraulics assisted to collect and organize the material and has made both the descriptions and the analysis of the maps. After the publication of a draft edition, the material was reviewed by representatives of the various countries.

We hope that this valuable collection of examples will stimulate flood mapping efforts in countries that have to start with it, and discussion to improve these practices in countries that have experiences with it already.

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2 Flood mapping

For the purpose of consistency, this Atlas is based on the same definitions as the EXCIMAP Handbook on Good Practices on Flood Mapping:

- **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
- **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
- **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 >=100y); floods with a high probability, where appropriate
- **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 where appropriate; where appropriate, flow velocity or the relevant water flow direction
- **Flood risk maps** indicate 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
- **Damage** is the negative effect of an event or process
- **Residual risk** is the portion of the risk remaining after the flood risk management actions have been implemented and taken into consideration

3 Cartographic aspects of flood risk mapping

This Chapter aims to describe the basic content and cartographic good practices of flood risk mapping. It is meant to form the background information for the description of the compilation of various examples of flood maps from countries that are part of EXCIMAP. The text in the first paragraph on map layout and the use of GIS is identical to the text on cartographic aspects in the 'Handbook of Good Practice for Flood Mapping in Europe' produced as part of EXCIMAP. In the second paragraph, map content is discussed.

3.1 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.

3.1.1 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.

3.1.2 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.

3.1.3 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, Figure 4.88 and Figure 4.89).

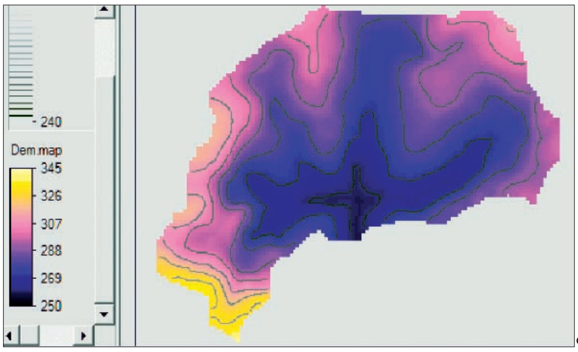
3.1.4 Location and navigation

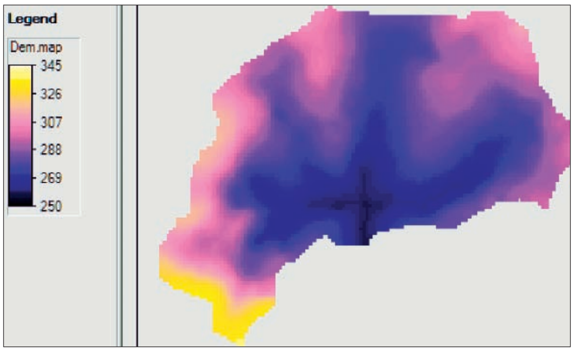
A location plan is often provided alongside the principal flood map to help users identify the geographical location that the flood map represents. This plan, which may be an appropriately scaled map or schematic plan (with appropriate key locations, such as towns, roads, rivers, etc.), shows the coverage 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)

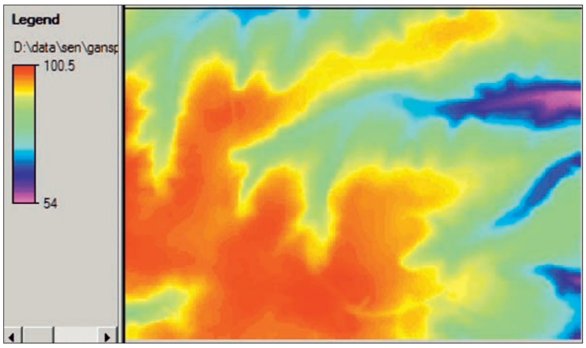
3.1.5 Colour palettes and symbols

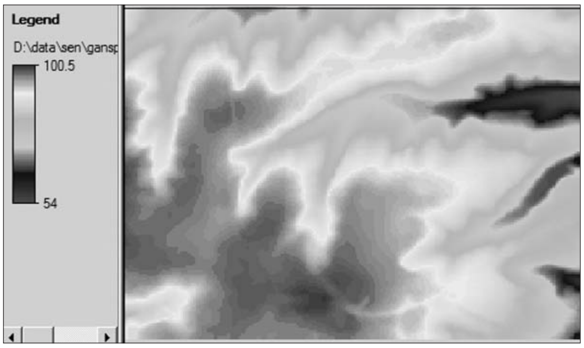
Simple flood maps may show only a single flood parameter (such as the flood extent for one flood frequency or return period) using a single coloured layer over a background map. The use of different colours (or shades of a single colour) may be used to present multiple parameters (such as flood extents 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. An example of discrete and continuous graduation is shown in the next two figures.





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. An example of a colour palette that does not translate well into grey scales (both the blue and red translate into dark grey, but the blue is low and red is high) as can be seen in the next two figures.





- 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)

3.1.6 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.

3.1.7 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.

3.2 Map Content

3.2.1 Flood extent

The extent of potential flooding has to be presented as surface covering the topography for a specified flood level /frequency. For reference roads, railways, houses, property boundaries and the permanent waterbodies from which the floods may originate may be included. Recently Google Earth has become a powerful tool to use as background layer for this kind of information. A drawback of the use of Google Earth is the fact that the interactive site depends on third-party software which, although it is rather new on the internet, might easily be discontinued and there is always the risk that the server producing the images goes off-line for whatever reason. Other problems may occur when the layout c.q. technical aspects of Google Earth are changed.

Flood extent should be presented for a specified frequency, e.g. 1/10, 1/100 or 1/1000. In addition the protecting effect of defence works may be shown.

3.2.2 Flood probability, depth, progress

A very useful, but more advanced tool, for flood inundation mapping is the use of 2-D hydrodynamic models for the presentation of the actual process of inundation in a simulation movie. Evidently it is not possible to capture this type of information on a (hard-copy) map, although successive stages of the inundation process can be shown. Nevertheless this type of information is extremely valuable, especially for the assessment of most reliable escape c.q. evacuation routes. It is very important for the presentation of this information to describe precisely the specifications that form the boundary conditions of the simulation. There are an infinite number of possibilities, in terms of location of a dyke breach, initial size and development of the breach, form of the flood hydrograph that produces the flood (in case of river floods), local roughness conditions in the flooded area, etc.

When many computations from different locations are available (scenario simulations), the resulting information can be combined into probability of flooding of a gridcell and maximum inundation depth per gridcell. However, since this requires many computations, these maps are relatively scarce. These probability maps can also be produced as flood likelihood maps for reassurance purposes.
Potential (maximum) inundation depth maps exist on national, regional and local scales (1:2.500.000 – 1:10.000). In the legend it is possible to present the important relationship between inundation depth and “what to do”, depending on inundation depths of e.g.: 50 cm, 1 m, 2 m, 5 m and > 5m, (see Japan). Other related information may be evacuation routes, shelter areas.

3.2.3 Potential damage and casualties

Maps about flood damage may use **indicators** of potential damage like:
- land use (rural, urban, infrastructure, water, etc.)
- real estate value /ha (shown per dike-ring, or municipality)
- population density /ha (shown per dike-ring or municipality);

When more sophisticated models and information is available potential damage can be **computed** per gridcell as a result of different flooding scenarios and damage functions that relate water depth to damage to structures and land use as well as to numbers of casualties. Since this is very sensitive information the data, models and assumptions have to be explained in detail in accompanying reports.

Relevant information related to this theme has to do with the objects/services that may increase flood damage substantially: storage of chemicals, vital networks and services (highways, railways, airport, lifeline services like electricity, sewerage and drinking water, hospitals, etc). This information is expressed as line or point symbols, and may be combined with inundation-class maps.

3.2.4 Flood risk

Risk is often defined as probability x adverse effects. Consequently, a flood risk map may express flood risk as expected annual flood damage or casualties per gridcell, given the level of protection. When different flood scenarios are available, the resulting flood level frequency curve per gridcell, population density and casualty function may be combined into personal risk of decease per gridcell. However, the availability of these types of maps is very limited, and not public. They are also difficult to interpret and it might lead to confusing information when presented e.g. on the Internet.

3.2.5 Flood Hazard

Flood hazard maps present information on the typical dangerous aspects of floods that are important for e.g. evacuation and rescue operations: current velocity, sometimes in combination with inundation depth and/or debris content. This type of information may be relevant for very specific locations, e.g. near breaches in the embankment or narrow passages in river valleys, where current velocities become relevant. Therefore this information is presented on detailed maps (1:2.500).

Current velocity may be presented as (magnitude) classes or vector (magnitude and direction). However, it should be kept in mind that current velocity depends very much on local topography and may be of limited accuracy. Vector maps may be difficult to read when flow direction and vector locations coincide.

3.2.6 Evacuation maps

Evacuation maps present public information on “what to do”. USA has a large tradition with evacuation routes in coastal areas related to hurricane and storm surge threats, but other countries start to produce these types of maps as well. Evacuation maps relate the magnitude of the threat (hurricane category) to areas (zipcodes!) that are evacuated or should consider it. In addition recommended evacuation routes may be shown, with detailed road maps about traffic contra flow direction on junctions.
Complementary information may be added about things to carry with you to survive the trip (food, water, batteries, emergency telephone numbers, etc.).

In general for river flooding there are too many options for evacuation maps, as the best evacuation route depends on the flood characteristics e.g. It is therefore suggested that such information is used as background data for decision makers instead of published information to the general public for taking decisions on evacuation routes themselves.

3.3 Conclusions

Establishing guidelines to the cartographic aspects of flood risk maps should be given priority, not only to avoid problems of the public not understanding flood risk maps, but also to assure for instance that specialists dealing with floods actually use the same basis for information, in particular where river systems are concerned that cross national boundaries. Maps and GIS products should be tested on the public to see if they are as effective as scientists like to believe. However, it is unlikely that flood maps in the EU countries will become completely comparable as not only the underlying methodology is different, but also the data collection and method of measurement are different. It is possible, though, to arrive at a more generalized layout of the maps. This is particularly interesting now that most countries are in the process of producing interactive Internet sites where any user can access the map layers.