Introduction

Assessing the exposure to flood hazard, expressing flood risk and amount of possible damage belong to very topical issues not only in the water management.


There were already proposed and standardized methods for flood mapping in the Czech Republic.

Assessing flood danger and flood risk of flood plains is carried out through so-called method of risk matrix (Říha a kol., 2005). The method is one of the easiest procedures for assessing potential danger and risk in flood plains. The method does not require quantitative estimate of the damage caused by flood, but expresses flood risk through colour scaling. Whole process is closely connected to the standard database established, operated and administrated within the Czech Republic. These maps will be a base for main goal of Flood Directive – to prepare flood risk management plans for areas with significant flood risk.

DEFINITIONS

Flood hazard is characterized by flooding zones, depth of water and water flow velocity in floodplain.

Vulnerability is an inclination of objects to damages according to their robustness,

Exposure is a period of time when the countryside and the society are exposed to a negative event.

RISK
- probability of occurrence of negative event and its negative impacts on society and environment,
- is a combination of hazard, vulnerability and exposure,
- risk rises up with higher hazard, higher vulnerability and longer exposure.

Risk is considered as a function of probability of exceeding and intensity of flood. The intensity of flood expresses a devastating impact of flood, which depend on a water depth and a water flow velocity.

Method of Risk Matrix

Assessing flood danger and flood risk of flood plains is carried out through so-called method of risk matrix. The method is one of the easiest procedures for assessing potential danger and risk in flood plains.

Input Data are results of hydraulic modelling (1D, 2D): water depths, flow velocity for required flood scenarios with return period 5, 20, 100 and 500 years.

Flood Intensity $IP$ is understood as a criterion of flood destructiveness and is defined as a function of the water depth $h$ [m] and water flow velocity $v$ [m/s].
The flood intensity $IP$ calculation has to be performed for all monitored scenarios of flood hazard (according to return periods - standardly for 5, 20, 100 and 500 years return periods). The result of calculations are raster data in which every raster cell includes information on Flood Intensity for individual flood scenarios.

**Flood Danger** $R_i$ for a given flood scenario $i$ with the exceedance probability $p_i$ and a return period of $N_i$ years is evaluated using the so-called “risk matrix” based on the calculated flood intensity $IP$.

**Maximal Flood Danger**

The next phase means assessing the maximum value of danger $R$ for individual partial dangers $R_i$ corresponding to all hazard scenarios according to the relation:

$$R_{(k/v)} = \max_{i=1}^{n} R_i$$

$n$ means the number of assessed flood hazard scenarios.

The result is one raster containing maximum values of danger $R$ in the studied area.
Maximal flood danger assessment

is the result of method of Risk Matrix in the first step. It represents categories of threatened areas in floodplains by colored scale (Říha et al, 2006).

These categories allow suitability assessment of contemporary or future land use and recommend type of future use for areas with each level of danger.

This procedure is possible to use in the landscape planning or proposal of measures for the reduction of adverse consequences of flooding.

The exact specification of the danger for individual municipalities is stated in the following table:

<table>
<thead>
<tr>
<th>Danger $R$</th>
<th>Category of Danger</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R \geq 0.1$ or $IP \geq 2$</td>
<td>(4) High (red color)</td>
<td>It is not recommended to either allow new or extend recent build-up area, where people or animal can live. For recent build-up areas suggest such flood protection, which will reduce risk to acceptable level.</td>
</tr>
<tr>
<td>$0.01 \leq R &lt; 0.1$</td>
<td>(3) Middle (blue color)</td>
<td>Development is possible with some restrictions resulted from detailed analysis of potential flood threat. Build-up of sensitive objects (e.g. hospitals, schools, fire station etc.) is unsuitable there. It is not recommended to extend recent build-up area.</td>
</tr>
<tr>
<td>$R &lt; 0.01$</td>
<td>(2) Low (orange color)</td>
<td>New development is possible. Estate owners have to be informed about potential flood threat. Sensitive objects have to be protected against flood.</td>
</tr>
<tr>
<td>$p &lt; 0.0033$ ($N &gt; 300$)</td>
<td>(1) Residual (yellow color)</td>
<td>Flood protection is solved by long-term planning of land use zoning focused on especially sensitive objects (health care institution, historical objects etc.).</td>
</tr>
</tbody>
</table>
**Flood Risk Map**

Flood Risk Map combines information about danger and vulnerability of objects and activities in floodplain. Landscape vulnerability is represented by objects and activities which are occurred in landscape.

For each of the land use classes are determined value of maximal acceptable risk:

<table>
<thead>
<tr>
<th>Acceptable risk</th>
<th>Recommended land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) High (red)</td>
<td>Water area; Parks and open space, gardens, woods; Arable land, meadow, pasture land</td>
</tr>
<tr>
<td>(3) Medium (blue)</td>
<td>Sport and recreation</td>
</tr>
<tr>
<td>(2) Low (orange)</td>
<td>Residential; Public services; Transportation and utility; Industrial and manufacturing; Agriculture (structures)</td>
</tr>
<tr>
<td>(1) Residual (yellow)</td>
<td>Sensitive structures (health care institutions, fire departments, historical landmarks, etc.)</td>
</tr>
</tbody>
</table>

**Flood Risk Map** shows areas where maximal acceptable risk is exceeded. The reached values of the flood danger in the corresponding color scale are indicated inside each such shown area. These zones have to be reviewed in term of risk management (possibility of risk reduction) and a Flood Risk Management plan has to be establish for them.

**Conclusion**

The Methodology of flood risk mapping was agreed as a guide in the calls of Grants from the Operational Program Environment for Water Management Infrastructure and the Reduction of Flood Risks (Area of Intervention - 1.3 The reduction of flood risks). These investments support to enhance the mapping data on flood hazards and flood risks with specified outputs at the national and regional levels in areas which were chosen in the phase of Preliminary Flood Risk Assessment.

Financed by Ministry of the Environment of the Czech Republic (project Flood risk maps followed from flood hazard in the Czech Republic (2007-2011) and the Cohesion Fund - Technical Assistance of Operational Programme Environment.)