MAPPING EXCESS WATER INUNDATION INDUCED HAZARD AND ITS IMPORTANCE IN HUNGARY

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Abstract: Excess water induced inundation is a specific feature of the Hungarian Lowland. This type of flooding is associated with considerable damage in agriculture, in urbanised area and in transport infrastructure. The protection against excess water steadily has received similar importance as protection against fluvial floods. The experience of recent years suggest that excess water defence systems consisting drainage canal networks, hydraulic structures, pumping stations and reservoirs do not need contemporary requirements. Water management and land use planning need a new strategy, while in the process planning and decision making application of state of the art excess water hazard maps should play an important role. EU- Flood Management Directive underlines the necessity to compile flood hazard maps including regions with excess water induced inundation.

Key words: excess water, inundation, flood hazard mapping, flood protection, flood management

1. Introduction

Owing to physical geographical conditions of Hungary excess water or water table induced inundation represents a major type of flood hazard beside the usual riverine floods endangering a lowland regions. This type of hazard represents a major problem with only a few international parallels. Excess water causes damages in agriculture, urban areas and also in transport infrastructure. Mitigation and defence against this specific type of inundation requires major spending at the national level. A system of drainage canal network, pumping station and excess water reservoirs was created in the 20th century. The experience of the last 60 years indicate that the given system and the applied defence strategy is not sufficient. There are natural and social reasons for the given inadequacy and there is a need for a new comprehensive strategy. Mapping of excess water endangered lands, knowledge of the extend and frequency of flooding is a needed for water management and land use planning and also for sake of elaboration of the new strategy.

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2. Excess water inundation hazard in Hungary

Around one quarter of the Hungarian territory belongs to low lands with difficult flow conditions where natural drainage is nearly blocked. Defence against excess water is aimed at the mitigation of damage induced by snowmelt, rainfall waters and groundwater rise. The existing defence infrastructure consists drainage canal networks and reservoirs in 85 local systems covering 44510 km^2 (see Fig. 1 and 2). Some of these systems are transboundary ones linked or serving neighbouring countries. The systems from the point of view of running and maintenance can be subdivided into state run main canals (11600 km) pumping stations (with total capacity 815 m^{3}s^{-1}); flood association and community run canals (17900 km); farm and other private canals (13000 km).

The design capacity of these systems is sat to drain inundation with 10-year return period within 15 days. Specific drainage flow is sat in the range 0.010-0.078 m^{3}s^{-1} km^{-2}.

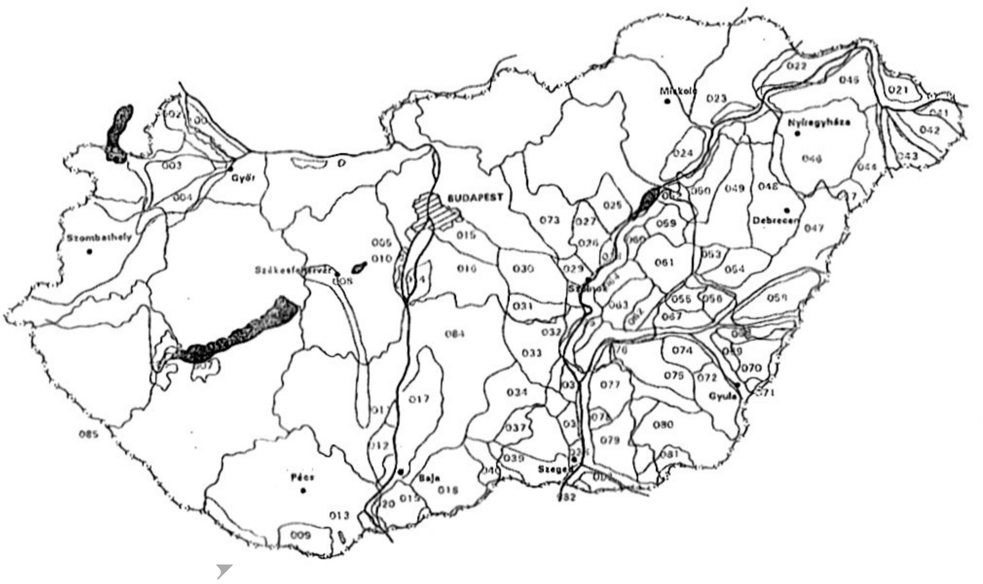

Figure 1. *Excess water defence systems in Hungary.*

As a result of a construction of defence systems the territory endangered by excess water inundation has been reduced since 1940, from the original 6000 km^2 done to 500- 1000 km^2 in 1980s (fluctuating within wide ranges depending on water input). This positive turn was reversed by extreme events in 1999- 2000 and 2006 when inundated area reached 4400 and 2400 km^2, consequently.

Causes of excess water inundation are manifold, composed together by natural environment and anthropogenic factors.

Natural and environmental conditions: Unevenly distributed in time and space precipitation maxima; Air temperature; Soil conditions; Depression type morphology; Small slopes; Limited possibilities to conduct drain water gravitationally owing to high water levels in receiving streams in extreme situation; Coincidence of excess water and riverine floods.

Anthropogenic factors: Changing lot sizes where not followed by construction of new drainage canals; Improper land use patterns; Improper agricultural technologies; Absence of maintenance of drainage canals and hydraulic structures.

Figure 2. *Excess water sensitive regions in Hungary.*

Following the political and economic changes in the early 1990s land ownership underwent substantial changes. This process concerned almost 60000 km^2 of arable land and modified the size and structure of agricultural lots. Consequently water management systems and hydraulic structures did not correspond to the new conditions.

Flood risk associated with excess water can be defined as the consequence of natural and man- made factors of flood generation in a situation when inundation potentially evolves damage or harm to certain type of economic activity. The analysis of excess water related flood risk should include investigation of its nature and frequency, the exposure, sensibility and vulnerability of endangered objects. In terms of natural characteristics the above can be assigned to the annual probability of saturation by water or inundation of the given piece of land. It is important to note that flood risk is not a natural attribute and can be understood only in human perspective which is linked to the society (Fig. 3).

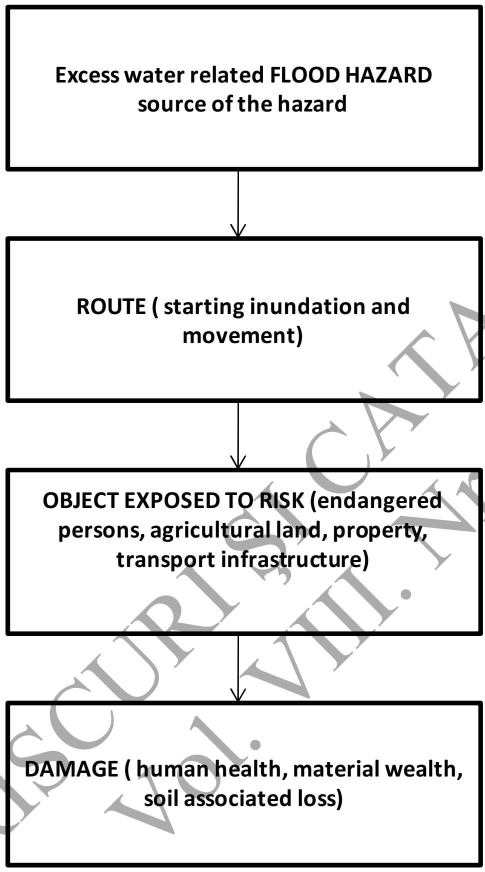

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Figure 3. *Logical sequence of the hazard- risk route.*

Excess water induced risk can be reduced by mitigating either the hazard or the vulnerability. Technical measures reducing the frequency of excess water related inundation consequently lessen flood risk. Regulation of land use and implementation of pro active flood defence measures can change exposure and vulnerability of a community towards excess water related flood risk.

3. The frequency of excess water inundation and damages induced in Hungary

The harmful impact of flooding appears in the form of direct and indirect damages. Impact in crops, buildings and the cost of defence activity belong to the category of direct damages. Deterioration of soil structure and loss of nutrients and other harmful changes induced by water saturation belong to the group of indirect damages. The frequency and scale of these damages are to be investigated.

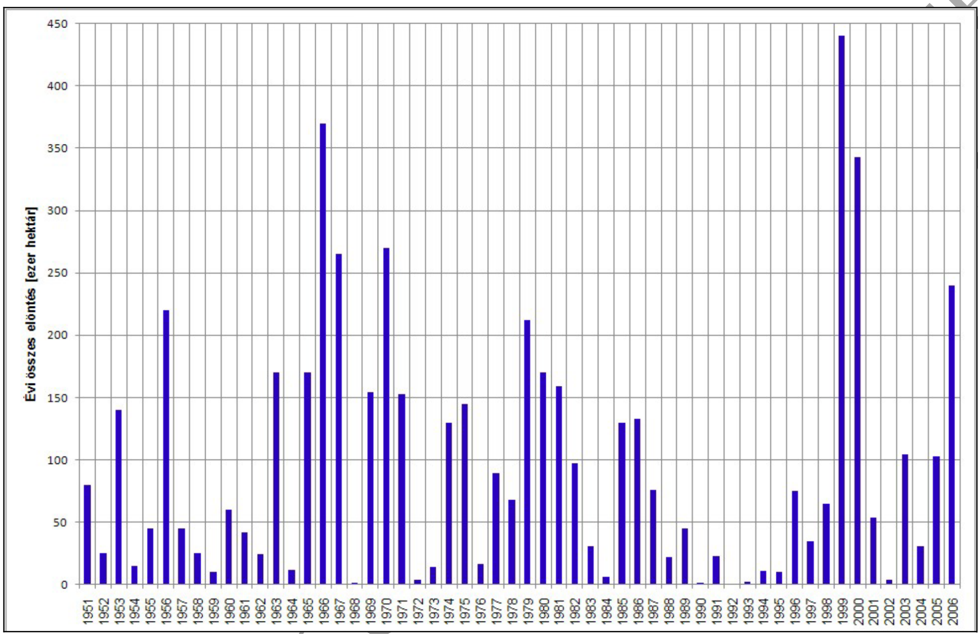

Figure 4. *Anual extend of excess water induced inundation in the period 1951- 2006 in Hungary [thousands of hectares, ·10 km^2].*

Excess water inundation happens almost every year in Hungary. The severity of flooding can be characterised by a single figure, the maximum extend of inundation. The investigation of the period 1951- 2006 indicate that there are 17 years with excess water flooding within an average 20 year. Out of the mentioned 17 years 6 are slightly, 3 moderately, 4 extensively, 3 very extensively and 1 extremely flood prone. Annual extent of flooded areas for the given period is shown on Figure 4.

Results of frequency analysis of the return period and the extent of annual inundation are given in Table 1. Results of the fitted probability distribution are listed.

Table 1. Probability of excess water induced inundation (Pálfai, 2006)

Annual probability [%]	Return period [year]	Annual extent of inundation [km^2]
50	2	610
20	5	1760
10	10	2700
5	20	3620
2	50	4800

Investigation of damages is a much more complex issue. Changes in protection and defence techniques and the system of prices had to be taken into consideration. Damages are defined by the extent, duration and seasonality of inundation. Naturally inundation induced damages in the growing season are much higher in agricultural crops. A simplistic approach has been applied, the year 2006 given as very extensively inundated was taken as basis and damages in other years were calculated proportionally to the inundated area. The total damage composed of agricultural, urban and other damage (cost of flood defence against excess water was also added) was estimated at 35 thousand million HUF (about €130 million) in 2006. The given analysis resulted 315 thousand million (€1170 million) total damage for a average 20 year period, while the resulting mean annual damage is estimated at 16 thousand million (€ 60 million). (Pálfai, 2006)

4. Mapping of excess water inundation in Hungary, history and recent developments

The importance of mapping excess water induced flooding was recognized several decades ago, land use planning, protection of inbuilt areas and agricultural land required such type of information.

- Excess water hazard was estimated in 1950s by using data on soil, relief and climatic conditions of low land catchments.
- The set of hazard map compiled in the late 1970s (scale 1:100000) utilized information on flooded area.
- As a step towards further development the previous maps were combined with the analysis of soil properties influencing excess water generation. As a result, series of 1:100000 maps indicating soil type related excess water hazard were compiled in the early 1980s. Four categories of hazard were indicated: none; low; moderate; high.
- Based on the 1961- 1980 inundation maps of the Hungarian Lowland a new method of mapping was elaborated which utilized the survey of excess water

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flooding and frequency data. Excess water frequency map in the scale of 1: 500000 was compiled in the early 1980s covering all low land regions in Hungary.

- Modern technology, GIS techniques have been applied since early 2000s. The impact and interactions of geological, morphological, hydrographical, soil, hydrological, land reclamation and climatological factors influencing the generation of extreme excess water events have been investigated since 2001 at pilot areas.

Nowadays the main aim of excess water hazard maps is to integrate most of the information needed to create flood risk maps specific for excess water and flood risk management plans. Consequently excess water hazard maps have to contain parameters like the extent of inundated area, duration of inundation and outflow reducing the total volume of excess water (drainage, evaporation, infiltration). To meet main requirements towards flood hazard mapping appropriate modelling tools are to be used (rainfall runoff, 1D and 2D hydrodynamic models). The first steps have been already made by a research consortium composed by VITUKI Environmental Protection and Water Management Research Institute, Budapest and two departments of the Budapest University of Technology and Economic Science (BME) working on the project "Hydrological and hydraulic methodological bases of flood hazard mapping". Among other requirements the project is aimed at the creation of tools for the production of output prescribed for EU- member countries in the "Flood management directive" accepted on the 23d October 2007. While the project is aimed at overall flood hazard a specific features of low land regions and excess water induced inundation are also considered. Impact of climate change, present state of the system of flood protection, the influence of flood defence activities and the role of land use changes are taken into account.

Besides meeting the requirements of the Flood Management Directive specific conditions of Hungary should also be considered, like water management related factors listed below:

- Forecasting of excess water, assessment of excess water volume and inundation extent;
- Maintenance of the drainage canal network, organisation of excess water related flood defence;
- Regular checking of hydraulic structures, planning and design of system upgrading;
- Operation of excess water protection systems;
- River basing management plans for excess water influenced catchments;
- Land use development including optimal planning and subdivision of agricultural lots, rehabilitation of wetlands.

All of the above aspects need information on the extend duration and frequency of excess water induced flooding.

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