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Water Retention in River Basins

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Abstract

The paper discusses a broad range of flood control measures designed mainly to increase water retention capacity. It focuses on the main trends in flood control, i.e. on passive flood control and functions of dikes and retention basins. Individual measures are analysed separately with respect to their application in headstream areas and in midstream and downstream tracks of watercourses.

Key words: retention capacity, passive flood control measures, protective dikes, retention basins, hydrological function of peatland

Introduction

With respect to flood control measures applied in the Czech Republic, four main projects falling under the responsibility of the Ministries of Agriculture, Environment, and Transport have been recommended for implementation. Experts from the Faculty of Science at the Charles University could play important roles in designing flood control measures under Project no. 1 – "Flood Prevention" and Project no. 2 – "Agricultural Land Erosion Control".

The key objective of a wide range of flood control measures is to enhance retention capacity of the land. Although individual measures applicable to headstream, midstream and downstream areas are marked by specific characteristics in terms of their selection and flood control impact, river basins should be always considered as whole areas without preferring local or regional interests. The paper looks at measures:
a) applicable to headstream areas
b) applicable to downstream and midstream areas, mainly to the zones delimited by the August 2002 flooding.

1. Main Trends in Flood Control

Upon implementation of remedial measures, it's important to bear in mind that floods are a natural phenomena of river dynamics and that absolute flood control, mainly in extraordinary circumstances, is impossible. We should therefore work on a scaled flood control system integrated into individual zoning or regional plans applicable to particular river basins and their subsections. Such plans should indicate areas exposed to danger when a certain flood control level is surpassed, which would play a significant role in informing the general public as well as industrial sectors. Any remedial measures should be designed to increase or at least maintain current river dynamics while existing natural conditions should be modified as little as possible.

Individual flood control measures suggested in the paper focus on three areas of flood controls:

- Passive flood control;
- Dike construction;
- Construction and renovation of retention basins.

1.1 Passive Flood Control

The main aim of passive flood control measures is to maintain the natural land retention capacity. Out of many possibilities, we recommend mainly the following measures:

- To preserve natural development of flood plains and view them as natural flood areas.
- To take into account flood risks when considering eventual use of flood plains.
- To transfer residential and industrial facilities exposed to frequent flooding to safer parts of flood areas or completely out of flood areas.
- To limit construction and economic activities in flood areas by law amendments – e.g. the *Construction Act*, and to respect existing legislation (the *Water Act*).
- To ensure proper maintenance of water storage areas including existing ponds and pond systems, and to consider renovation of some inused ponds.

In ecological and often in economic terms, actions specified above are often very effective. Flood control measures mostly build on existing retention areas that need to be maintained and in many cases renewed. This applies mainly to wetland renovation.

Out of passive flood control options, a great importance is attributed to large-scale ecological measures slowing down the process of surface runoff and increasing land retention capacity. They involve erosion control of agricultural land, gradual changes of land use structured towards permanent vegetation (replacement of agricultural land with meadows and pastures, planting of fast growing wood species), and spreading of forests typical for particular areas (replacement of spruce monocultures by mixed forests).

Passive flood control measure can be effective only when implemented in harmony with water management and environmental legislation standards.

1.2 Protective Dikes

In the Czech Republic, construction of protective dikes has its own tradition. Numerous dikes are built in flood plains of the Morava and Odra rivers, in the Elbe midstream and downstream areas, or in downstream areas of its main tributaries. Their main objective is to protect residential and agricultural areas.

As recent years have seen an increase in numbers of floods and intensification of their scope, protective dikes are subject to new requirements. Experts have been discussing a new concept of dike line installation, construction methods, prolongation and possibilities of dikes, and the scale of renovation or build-up of existing dikes. Areas where original dikes ceased to play their protective roles provide a broad range of possibilities. However, we should also leave certain carefully selected areas in flood plains free of any flood control measures allowing for a natural water overflow to flood areas.

Plans to renew old and build new protective dikes should respect the following factors:

- Changes in line installation of original dikes should be accompanied by expansion of current flood plain retention areas while putting emphasis on retention enhancement in overall river basins and not only in particular flood plain sections,
- With the exception of watercourses cutting through town residential areas, dikes should contribute to reduction of watercourse hydraulic slopes and growth of the friction coefficient due to larger wetter perimeters and discharge profile areas after flood wave overflow to flood plains. Such measures would slow down water flow and decelerate streams above river bottoms. Protective dikes can also reduce transport of material in longitudinal profiles of watercourses. All of the steps mentioned above would also directly cut down flood wave peaks.
- However, in town residential areas, discharge capacity of watercourses should be further enhanced. In the Otava river basin, this applies mainly to renovation of current and construction of new protective dikes in the towns of Sušice, Horažďovice, Strakonice, Písek, Střelské Hoštice, and Katovice, also to the towns of Strunkovice, Vodňany and Protivín on the Blanice river, and Vimperk and Čkyně on the Volyňka river.
- Construction and renovation works shouldn't undermine the stability of natural ecosystem mechanisms existing between watercourses and flood areas.

1.3 Retention Basins

Flood control can be also enhanced by renovation of old and construction of new retention basins. However, permanent basins built on watercourses always bring about significant changes in natural water ecosystems. The oxygen content becomes depleted and water quality worsens in many respects. Such an environment is favourable for algae, cynophytes and mycrophytes that have many negative effects. Due to biomass sedimentation and nutrients accumulation, oxygen is consumed by prevailing decomposition processes. Changes also affect sediment transport dynamics involving sand and gravel particles sedimenting in retention basins. Thus it becomes difficult for aquatic animals to pass through watercourses in a longitudinal direction. Due to eutrophication problems, construction of retention basins isn't recommended on watercourses of a second-rate water quality.

Retention basins should be planned only after assessment of many factors and shouldn't be enforced unilaterally as flood control measures. If it's evident that renovation of old or construction of new basins will result in enhanced retention

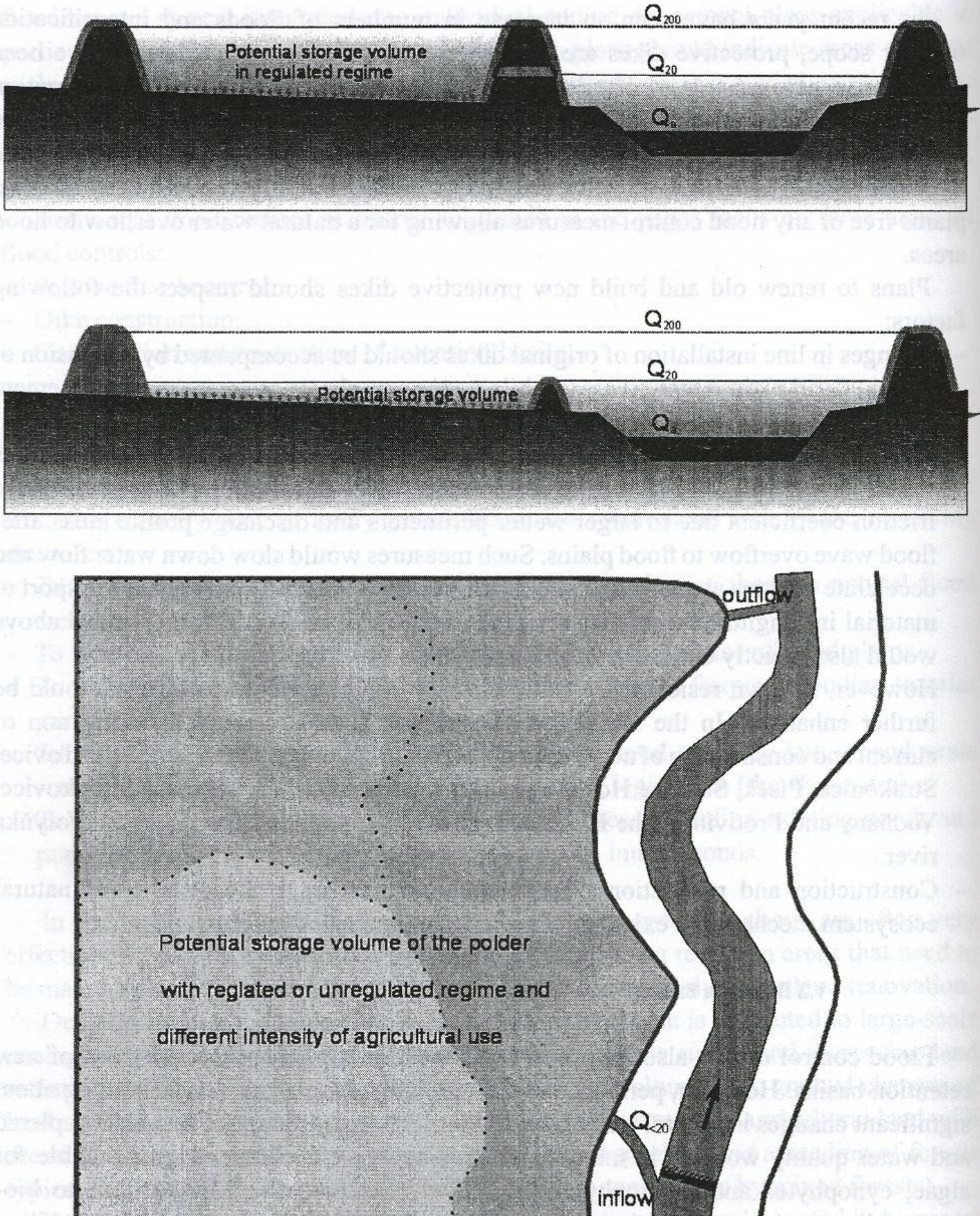

Fig. 1 Scheme of dry polder (author J. Česák)

capacity of river basins, two alternatives should be considered: to build a water basin or a dry (green) polder. Dry storage areas have many benefits. They can be extensively used as pastures, or provide a natural zone for wetlands with bushes and broadleaved forests that improve ecological landscape stability.

On the Otava river, it would be suitable to renew ponds and small basins and clear them of mud, which would increase water accumulation capacity of the river basin. However, this would involve reconstruction of many pond dams. The catastrophic floods in 2002 pointed out to an enormous retention capacity of pond systems that is comparable to the capacity of large river water works.

2. Water Retention in Headstream Areas

To increase water retention in headstream areas of the Vydra and Křemelná rivers and their tributaries, it is necessary to make a thorough analysis of hydrological functions of mountainous peatland and to make an expert assessment of measures currently adopted by the management of the Šumava National Park to control original melioration channels.

Opinions on such issues vary as is evident in literature that was dealing with these questions already in the second half of the 19th century. A detailed analysis of various approaches was made by Ferda (1960). The so called "theory of fungi" stressing the importance of peatland for its significant water storage and discharge regulating capacity was supported already by A. Humboldt, F. Hochstettera, and in the Czech Republic by F. Sitenský (1886).

The group of opponents was enlarged at the end of the 19th and at the beginning of the 20th century and comprised E. Purkyně, C. Hagen, F. Fleischer and others (in Ferda, 1960), and later Schreiber (1927), Dittrich (1936 in Ferda 1960) or Říha (1938). They argued that drainage significantly improves peatland water regime. Their finding was supported by results of other research projects performed in the territory of the Czech Republic in the course of the 50s and 60s in river basins with higher representation of peat. Their relatively large scope was motivated by planned construction of waterworks (Lipno, Orava, Fláje) and the main objective was to assess the impact of peatland on water runoff (e.g. Maňan, Lhota 1953, 1955, Ferda 1960, 1962) and water quality in watercourses and basins (e.g. Novák, 1955, 1959, Onderíková, Štěrbová, 1956, Fiala, Sládečková, 1961).

Results of the works mentioned above proved that watercourses draining peatland areas show significant discharge variations and that the impact of peatland on water runoff balance had been exaggerated. It was found out that winter snow precipitations have a relatively low impact on discharge growth in summer while summer rainstorms play a very significant role in this respect. When raised bogs become full, runoff values grow quickly. During longer periods of draught, peatlands don't play any positive roles in hydrological terms, i.e. they don't feed watercourses. To the contrary, the past research projects stated that hydrological watercourse regimes were improved after draining of peatlands.

Peatlands have a clearly negative impact on water quality in watercourses. Pollution level is related to their scope and cubic capacity in river basins. The problem of pollution is further intensified in water basins located in former peat and fen areas, as in the Fláje waterworks.

In 1959, the upstream area of the Otava river was subject to a large research conducted by the former Research Institute of Melioration in Prague, the Hydrometeorological Institute in Prague (the Central Hydrological Prognosis Services), the Regional Sanitation and Epidemiology Station in Pilsen and other institutions. The main objective was to assess the impact of mountainous peatlands located in the Otava headstream areas on the watercourse hydrological regime and water quality in a planned water basin (to be located in Modrava on the Vydra river or on the Křemelná river downstream track, or in Rejštejn on the Otava river) designed as one of potential sources of potable water for the Pilsen area. Since then such a detailed hydrological research focused on peat hydrological functions in the upstream Otava river basin hasn't been conducted (see Ferda, Hladný, Bubeníčková, Pešek, 1971), however some of the most important results related to the topic of this paper can be used even today:

- Down to the confluence of the Vydra and Křemelná rivers (river basin acreage of 317.305 km^2), hydromorphic soils (classified into two groups marked by peat thickness *up to 50 cm* including the recent vegetation layer and *above 50 cm*) cover an area of 50.17 km^2, i.e. 15.81% of the whole river basin. The best conditions for creation of peat and hydromorphic soils are in the Vydra river basin where peat covers in total 42.08 km^2, i.e. 27% of the whole river basin area (e.g. 40% in the Roklanský stream basin, 36% in the Modravský stream basin, 32% in the Filipohuťský stream basin and 16% in the Hamerský stream basin). In the Křemelná river basin, hydromorphic soils cover only 8.09 km^2, i.e. 5% of the river basin area.
- The above-specified distribution of hydromorphic soils in the river basins of the Otava two main tributaries – the Vydra and Křemelná rivers, seems to influence the hydrological regime of both watercourses (besides other hydrographic and climatic characteristics).

The impact of peatland on the runoff process should be studied also with respect to water quality or the ion content in the periods of low and high discharge. In dry periods, runoff from peatland declines or almost stops, which results in a better water quality in watercourses draining peatland or fed by tributaries cutting through peatland. Such a phenomenon is supported by the results of studies mentioned above (see Ferda et al., 1971) and also recent works (Hruška et al., 1996, 1999, Oulehle, Janský, 2003). If peatlands were capable of increasing discharge volumes in dry periods as claimed by some authors it would have to result in impaired water quality, which is not the case. Hydraulic relations of mountainous peatland to surface watercourses are limited due to specific geomorphological conditions in the Vydra river basin. Watercourses are marked by steep slopes, cut deep into the surrounding relief, and bottoms of their valleys often get under the basal level of peatland located mostly on slopes.

Water quality deteriorates during summer rainy periods or spring snow melting when peat areas are fully saturated by water that overflows to riverbeds. This is proved by changes in the surface water ion composition studied by recent research projects (Hruška et al., 1996, 1999, Oulehle, Janský, 2003).

Studies of the Hydrometeorological Institute performed in the 70s (Ferda et al., 1971) recommend drainage to improve hydrological functions of peatlands. Their conclusions, falling in line with other local as well as international projects, indicate that such measures can significantly lower maximum runoff values as the groundwater level would fall down and thickness of peat surface retention layer would grow. Such studies stress also other positive effects like forest expansion to drained areas.

Currently, objectives applicable to headstream areas of Šumava watercourses have undergone significant changes and functions of its natural ecosystem have been redefined. No waterworks are going to be built in the region and peatland research assessing potential impact on accumulated water quality is no longer needed. Renovation of former drainage channels may now seem anachronistic, but the Šumava National Park is taking completely opposite measures. Blockage of former drainage channels in the area of Modrava fens that has been in preparation for a long time is now under way. Its aim is to increase the groundwater level and to ensure undisturbed and long-term development of natural ecosystems. Such measures are further defended by claims that production of organic matter is of a secondary importance while the main emphasis is put on new findings of botanists and forest experts indicating a higher resistance of waterlogged spruce forests to bark beetles. It is quite clear that current developments won't increase the retention capacity in the Otava headstream area.

Efforts focused on headstream retention capacity enhancement should take into account three factors:

Fig. 2 Broken dike by Roklan forester's house (Photo T. Hrdinka)

- To consider renovation or blockage of original drainage channels. With the exception of peatland-draining channels, blockage of torrents is beneficial for retention enhancement.
- To focus on recovery of vegetation because its degradation by bark beetles also weakens water retention.
- To consider renovation of former accumulation reservoirs that could also play the role of dry (green) polders, reduce flood wave peaks, and catch transported wood. Such small areas can't solve all flood control problems in large regions, but can help reduce flood damage.

All of the issues mentioned above should be discussed by experts in various fields taking into account objectives and priorities of a regional and local significance. Such a discussion could result for example in introduction of suitable landscape elements or gradual modification of land use in areas playing various roles in flood control. However, this doesn't apply to national nature reserves that should be left free of any human interventions.

Enhancement of water retention in catchment areas will help building territorial systems of ecological stability, biocenters, and biocorridors. However, the *Nature Conservation Act*, no. 114/92 Coll. doesn't define the role of territorial systems of ecological stability in terms of flood control and doesn't specify responsibilities of state nature conservancy authorities (Macoun, 1997).

An important role is also attributed to measures aimed at watercourse revitalisation (e.g. higher discharge volumes flowing through riverbeds, introduction of suitable bank stabilising vegetation and its maintenance) and their link to development of territorial systems of ecological stability.

Recommended subjects of further research with respect to assessment of peatland hydrological functions

After more than thirty years, it would be highly desirable to draw on the results of studies conducted by the Hydrometeorological Institute in Prague (Ferda et al., 1971). Current teams could assess peatland hydrological significance under much better conditions than in the past. This is due to a better accessibility of the area, longer time series of monitoring, and modern technology and methods. New projects could also build on first results of a detailed analysis of raised bog lakes (Šumava fens) conducted currently by the Czech Science Foundation under the project "Atlas of Lakes in the Czech Republic". Its output (the project terminates in 2005) should comprise first bathymetric maps of organogenic lakes and specification of their main physical characteristics, and chemical composition. Further projects could study the hydrological regime of peatland and assess various measures designed to increase retention capacity of headstream areas.

3. Water Retention in Midstream and Downstream Areas

Proposed measures apply to areas affected significantly by the 2002 floods. We assume that maximum overflow was identified with sufficient precision by aerial photos and further specified according to registered flood marks.

Fig. 3 Blatenská bog (Photo T. Hrdinka)

In the inundation areas delimited as described above, we suggest *identifying of individual sectors* in terms of flood natural distribution and facilities or areas to be protected. Particular natural and anthropogenic elements can fulfil certain flood control functions. Current use of flood plains outside of town residential areas should be gradually transformed in relation to required changes in the agricultural production structure. This process should involve mainly grassing of arable land areas located in the zones of the August 2002 maximum flooding. Another alternative is to forest such areas by fast growing wood species. Such measures could also further enhance territorial systems of ecological stability. Grass in flood areas could be suitably maintained through livestock grazing. Depressions filled by water during floods should be allowed to develop into natural wetland.

While delimiting zones of different values of protected vegetation, it is also vital to propose specific measures to protect residential centres, individual manufacturing facilities, historical monuments, roads etc. Still, we have to proceed with riverbed regulation, mainly in town residential areas, to increase discharge capacity.

The Rhine river midstream and downstream areas or the Elbe downstream area in Germany have long-term good experience with *dry and controlled polders*. Dry polders at the confluence of the Morava and Dyje rivers had a very positive effect during the 1997 flooding. Dry or controlled polders should be built in certain location of the Otava river basin, mainly on the Blanice and Volyňka rivers. Drawing on the results of a field research, we recommend building a dry polder in Záblatí on the Blanice headstream track to protect the Husinec waterworks by accumulating floodwaters and collecting transported wood. Dry polders allowing for controlled inundation further require construction of drainage channels enabling the outflow of temporarily accumulated floodwaters back to riverbeds after passage of the flood wave.

Flood control measures applied in flood plains also involve *protective dikes*. However, they shouldn't be built close to banks, but rather along residential areas and other facilities requiring protection. Protective dike networks should be designed as comprehensive systems integrating dry or controlled polders.

During the 2002 flooding, most problems were caused by line structures located in flood plains (roads, railways, and embankments). Many of them were badly damaged. Accumulated material (mainly wood from poorly maintained vegetation areas) blocked culverts and bridges, which led to large accumulations of water breaking dikes and barriers and generating damaging flood waves. Such unsuitable line elements preventing flood waves from overflowing into flood plains should be modified or removed.

All of the measures designed to increase the water retention capacity in headstream areas or in flood plains around mid and downstream tracks should be interlinked under an integrated flood control framework (see Buček et al. 1998, Knapp, 2000). Their gradual implementation should be systematic and coordinated by flood management in whole river basins.

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RETENCE VODY V POVODÍ

Résumé

V článku je diskutován široký komplex protipovodňových opatření, jejichž hlavním cílem je zvyšování retenční schopnosti krajiny. Z hlavních směrů protipovodňové ochrany se zvláště věnuje pasivní protipovodňové ochraně, funkci ochranných hrází a retenčních nádrží. Jednotlivá opatření jsou analyzována zvlášť v pramenných oblastech toků a dále na středních a dolních tocích.

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