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EFFECTS OF POLDERS ON THE COURSE OF FLOODS IN THE WATERSHED OF THE TICHÁ ORLICE RIVER

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Abstract

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Polders show an important water-management function in the flood-control protection of watersheds. The course of actual floods in recent decades and effects of the water works on flood flows have proved the suitability of the construction within integrated flood-control measures in particular watersheds of the Czech Republic. To determine the transformation effect of flood-control measures in watersheds mathematical modelling is an important method, which is used not only in the preparation and design of retention areas but also in dealing with the flood protection of towns and villages. Easy verification of other measures in watersheds is also useful. Their implementation can be thus prepared for the future or it is possible to back off the intentions. In our case, a fact is advantageous that the model is operated in the workplace of the Elbe Basin water-management dispatching centre, which is compatible with assessed polders in the partial Elbe watershed, namely in the Tichá Orlice watershed and its partial Třebovka watershed. The polders assessed are situated on the Třebovka stream, which is the largest tributary of the Tichá Orlice river. These dry reservoirs and the increased protective function of the Hvězda pond affect runoff from about 80 km^2. Within research activities, possibilities were studied to obtain necessary retention areas in existing small water reservoirs. It became evident that the only realistic solution was to increase protective functions of the pond Hvězda. Its present total retention space of 1.4 million m^3 can be increased only by 0.35 million m^3, however, in combination with the sophisticated lay-out of a new emergency spillway and outlet the whole retention space can be used much more effectively. To obtain other retention areas localities were found out in the whole upper watershed of the Třebovka stream, which fulfilled requirements for placing the adequate capacity of polders. Subsequent modifications of the Třebovka channel in the most endangered villages and towns and their capacity design according to transformation effects of selected reservoirs and measures, determination of their effect and comparison with profiles on the Tichá Orlice are the content of the paper.

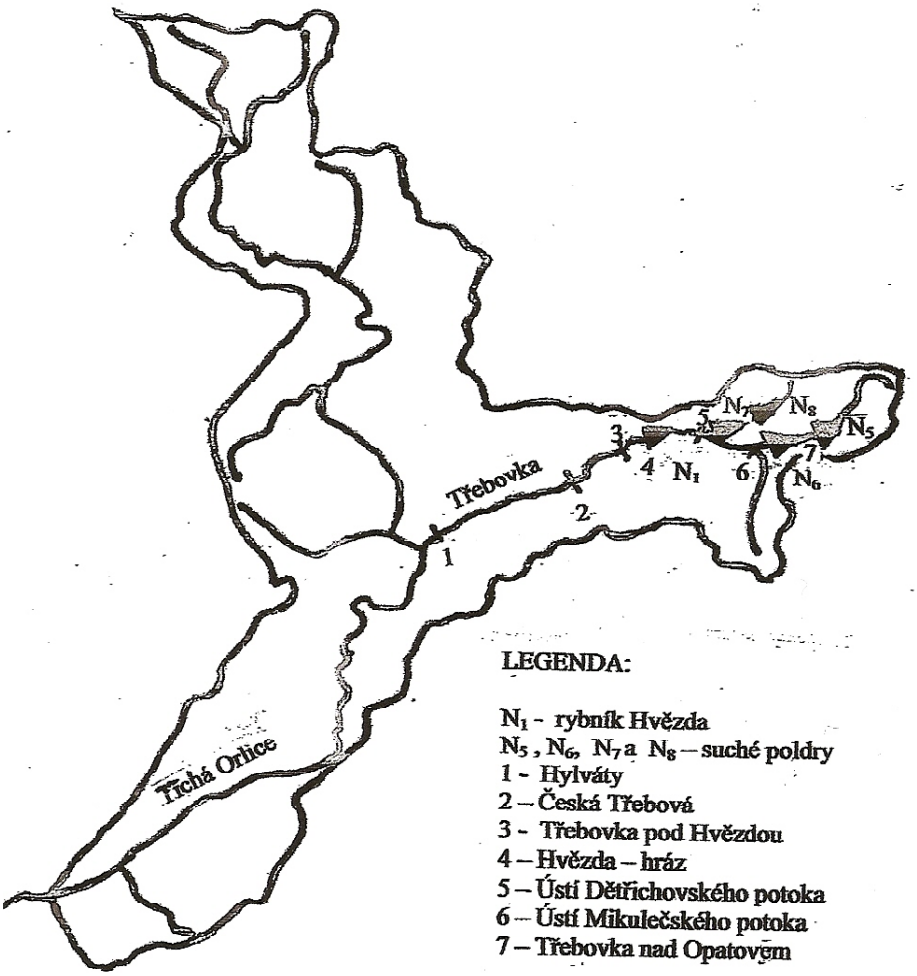
floods, flood-control protection, flood transformation, polders

In recent years, high waters caused extensive floods and damages on the large part of our territory. In 1997 and repeatedly in 1998 and 2002, the most extensive floods and thus also damages occurred on estates occurring in the watershed of the Tichá Orlice river, a left-hand tributary of the Elbe river in Hradec Králové. In a number of profiles, particularly in the watershed of the Tichá Orlice, hundred-year flows were reached or even exceeded, the passage of which through the territory showed the vulnerability of the urban and village built-up area inducing an appropriate response of inhabitants aimed at the increased flood-control protection of towns and villages.

Immediately after the floods, restoration of the river channels damaged by the floods was started as well as the preparation of system flood-control measures. The study results in the proposal of integrated measures including, among others, the creation of retention areas for the transformation of flood flows. In the upper part of the river watershed, the system of dry reservoirs (polders) with an important transformation effect for the whole watercourse has been designed.

MATERIAL AND METHODS

In the Třebovka watercourse, the largest tributary of the Tichá Orlice river, four dry reservoirs and the increased protective function of the existing pond "Hvězda" affect runoff from an area of about 80 km^2. In Fig. 1, the Tichá Orlice watershed with selected profiles is demonstrated. The following regulations of the Třebovka river bed in the most endangered villages and towns were dealt with according to transformation effects of the polders and just description of these measures, determination of their effects and comparison with profiles on the Tichá Orlice river are the content of this paper.



1: *A scheme of the Tichá Orlice river showing selected comparative profiles (N1 – the Hvězda pond, polders: N5, N6, N7, N8. Profiles:, 1 – Hylváty, 2 – Česká Třebová, 3 – Třebovka below Hvězda, 4 – Hvězda dam, 5 – the mouth of the Dětřichovský potok stream, 6 – the mouth of the Mikulečský potok stream, 7 – Třebovka nad Opatovem)*

Within the study, a possibility was monitored to obtain necessary retention space in existing ponds. It has appeared that the only realistic solution consists in the increased protective function of the Hvězda pond (Hydroprojekt, a. s., Praha, 2001). Its total retention space 1.4 million m^3 can be increased only by 0.35 million m^3, however, in combination with the sophisticated lay-out of a new emergency spillway and outlet it is possible to use the whole retention space more effectively.

This design will provide a marked transformation effect without major negative impacts on the built-up area of Opatov occurring up the river. To obtain other retention areas, suitable localities, which fulfilled requirements for placing polders of adequate capacity were found out in the whole upper watershed of the Třebovka stream. Four polders were designed, namely two on the Třebovka stream (N_5 and N_6) (Hydroprojekt, a. s., Praha, 1999) and two on its right-hand tributary, the Dětřichovský potok stream (N_7 and N_8), In Tab. (I), (Hydroprojekt, a. s., Praha, 2000). Through these measures, the total retention capacity of 3.2 million m^3 is created in the polders including the reconstructed pond Hvězda. At present, all polders are already in operation. Activities associated with adjustments of the pond Hvězda have been also finished.

I: *Main parameters of polders in the upper watershed of the Třebovka stream*

	Polder N_5	Polder N_6	Polder N_7	Polder N_8	Pond Hvězda
Dam type	earth-fill homogenous	earth-fill homogenous	earth-fill homogenous	earth-fill homogenous	earth-fill homogenous
Dam crest elevation (m a.s.l.)	469.00–469.10	455.50–455.60	442.50–442.60	456.50–456.60	424.50–424.60
Level elevation	468.32	455.04	442.09	456.13	422.30
Volume (10^3 M3)	618	422	258	176	3502
Emergency spillway elevation (bezpečnostního přelivu	467.70	453.90	441.20	455.10	420.40
Polder bottom elevation	460.30	447.60	434.00	446.60	-
Maximum height of the dam (m)	8.8	8.5	9.5	9.6	9.0
Dam crest length (m)	290	153	92	80	190
Bottom outlet diameter (m)	1	0.5	0.8	0.8	2×0.6
Length of the crest of weir of the emergency spillway emergency spillway (m)	9	9	8	8	15
Outlet intake elevation (m a.s.l.)	461.00	448.00	435.50	449.10	414.85
Slope gradient -upstream	1:3.7	1:3.4	1:3.4	1:3.4	1:2.5 to 3
- downstream	1:2.2	1:2	1:2	1:2	1:2.2
Maximum inflow (10^3 M3)	18.1	9.7	16.5	16.6	36.0
Transformed runoff (10^3 M3)	8.7	9.3	15.1	16.3	15.75

All polders mentioned above were designed by the HYDROPROJEKT, a. s. consulting company. Inevitable engineering/geological surveys proved that the selected profiles fulfil requirements for the construction of homogenous earth-fill dams. Functional structures and the dam body are designed almost identically in all polders with minor modifications according to specific conditions and required transformation effects.

The dam body – a homogenous earth-fill dam from local materials with 0.1 m elevation in the highest place to eliminate expected settling. Compaction was carried out at prescribed layers and by means of the prescribed number of passages. The upstream face of the dike is lined by stone pavement above the level of permanent damming up and then covered with humus and sown. The downstream face is covered with humus and sown from the level of a toe drain up to the dam crest.

Bottom (flood) outlet – the intake part created by a concrete-steel shaft with a crest of weir on the level of the permanent damming up is placed in the lowest point at the upstream heel of a dam. The whole intake part is protected by a steel rack catcher. The intake part is connected with a downpipe, which leads in a stilling basin. In walls of the basin a regulating steel plate is inserted.

Safety spillway and a chute – the concrete structure of a side emergency spillway is lined by stone. The spillway is connected with the chute bed. The trapezoidal chute bed is lined by quarry stone with transverse stabilization concrete sills.

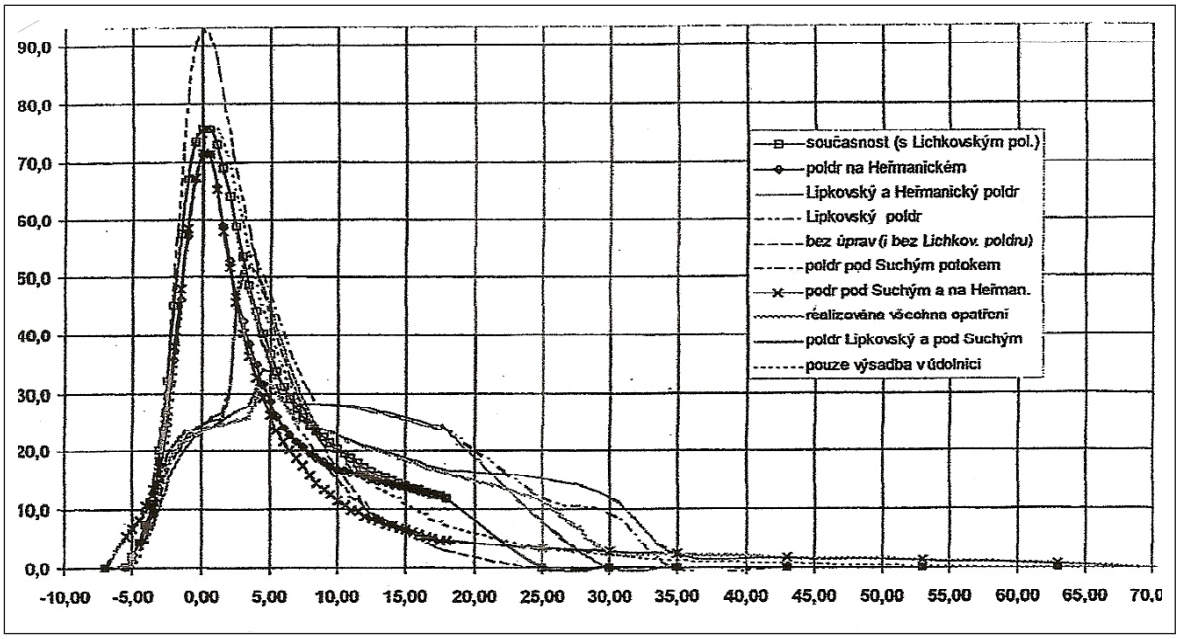
RESULTS

Transformation effects of proposed measures

The system of retention reservoirs situated in the upper part of the Třebovka watercourse brought a certain transformation effect, the size and range of which were treated locally for particular reservoirs in the course of preparation and designing work. Moreover, in case of the Třebovka stream, with the estimation of transformed flows downstream the watercourse (a tributary to the reservoir Hvězda).

Results of the hydrotechnical assessment of the system of polders on the Třebovka stream show that the culmination flow Q_{100} can be significantly reduced only by polder No. 1 (Hydroprojekt, a. s., Praha, 2000), while effects of other polders are negligible. Considerable reduction of the volume of a flood wave occurs, however, in the intake to the Hvězda pond (Doležal 2001), which is a very important effect of the system of polders. Therefore, it was possible to reduce design parameters of the pond in

a plan for its reconstruction as compared with outputs from research results, particularly retention volume necessary to achieve the target transformation effect. Transformation effects of the system of polders and of the reconstructed pond Hvězda are evident from diagrams in Fig. 2. Thus, due to the system of retention reservoirs in the watershed of the upper Třebovka, it is possible to reduce the Q_{100} flow by more than 40 m^3. s^{-1} and to catch virtually the whole wave volume.



2: *Transformation effects of polders on the Třebovka stream*

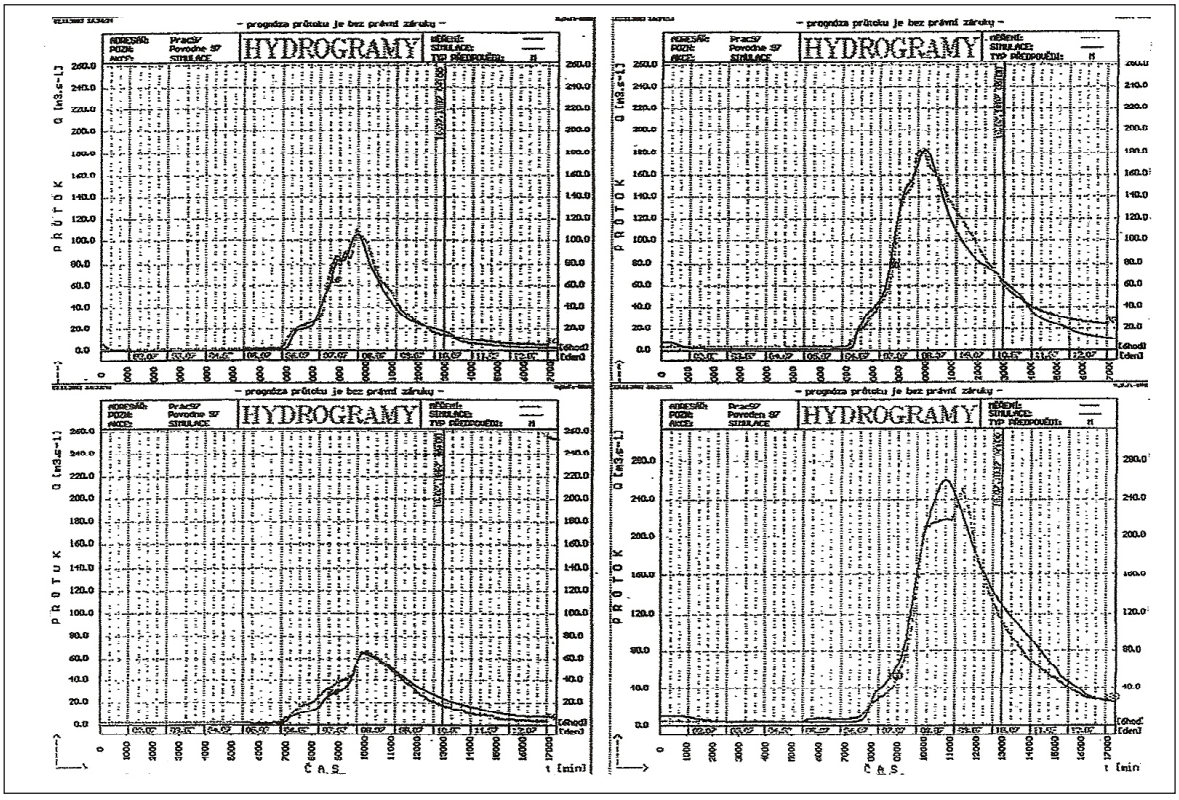
By means of the HYDROG (STARÝ, M., 2002) mathematical distributed model compiled by Doc. Ing. Miloš Starý, CSc., determination of effects was dealt with in selected river profiles (ie, particularly in villages lying on the Třebovka stream) on the basis of comparing the simulated courses of flood waves without the intended reservoirs and simulated courses of flood waves considering all already constructed or really intended new reservoirs.

The mathematical model HYDROG (STARÝ, M., 2002) is suitable for continuous simulation, operational predictions and the operative control of runoff from a watershed (reservoirs can occur in the watershed) from rainstorm or regional precipitation or runoff caused by meeting the snow cover. The HYDROG program models a precipitation/runoff process. It means that the only input (at the given initial condition of the system) is the time and area distribution of precipitation over the watershed. These data serve for modelling the whole process and hydrographs of floods in the arbitrary selected flow profile are an output of the process in the stream network. A flood situation in July 2001 was used as an calibration episode for the Tichá Orlice river. At that time, most part of the automatic measuring network of rain-gage stations necessary for the model operation was already available.

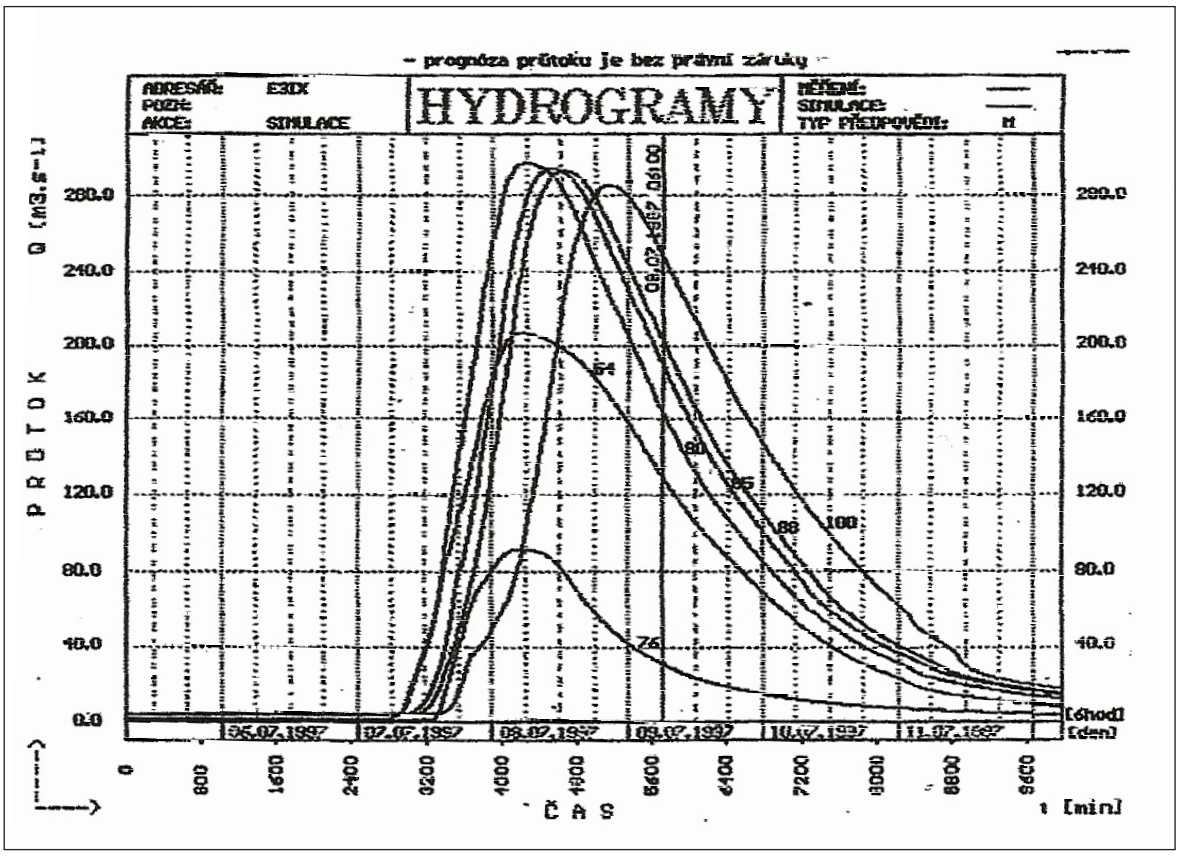
At the Třebovka stream, the transformation effect of the existing Hvězda reservoir became markedly evident and culmination flows in profiles below the pond ranged about Q_{50}. In 1997, an automatic rain-gage network of the present type did not exist. Therefore, it was necessary to carry out replacement by other stations in a number of cases and to perform hour distribution of these totals according to the nearest stations where these data were available. Calibration coefficients remained the same as in the calibration flood situation. Fig. 3 shows the comparison of measured and modelled flows in selected specific profiles.

It was proved that if precipitation fell in central or lower parts of the watershed precipitation in upper parts of the watershed was not markedly preceded, the transformation effect of reservoirs propagated downstream was evident in central and lower parts of a watershed. Results obtained proved quite unambiguously the high transformation effect of the set of proposed measures, which resulted from the fall of culmination flows in the set of selected profiles situated in the river network (see Fig. 4).

In the Třebovka stream, increasing the capacity of the natural or modified bed was gradually designed virtually in all villages and towns occurring along the watercourse. Above the pond Hvězda, it is in Opatov, downstream in Třebovice, Rybník, Česká Třebová and Dlouhá Třebová. In all cases, designs were carried out for flows obtained from transformation effects of all measures in the watershed.



3: *Comparison of measured and modelled flows during the flood of 1997*



4: *The Třebovka stream profiles*

DISCUSSION

Operation experience with newly constructed polders are minimal so far. It refers mainly to operation maintenance because marked increasing the water level in reservoirs has not occurred yet. Most of dry reservoirs cannot be subject to check operation because damming up the reservoirs is not realistic from technical (bottom outlet without a closure) and hydrological (flows) aspects. Implementation of technical-safety supervision is the special part of operation activities. It is a complex of activities, which should reveal possible disorders in their initial stage and thus prevent the origin of disorders of serious character. Fitting up the dams corresponds to their construction, importance and information potential of a quantity measured. In earth-fill dams, it mostly means only the measurement of deformations. Intensive fluctuation of the water table, namely up to extreme values appears to be the most unfavourable loading of the dam body as well as the zone of footing bottom and its effects on the water work will be possible to evaluate only in the realistic situation. Polders are special-purpose technical facilities to retain certain part of the flood wave volume, to decrease culmination flows or at least their time shift. They are very important from the point of view of reducing flood damages, which has been proved by this study.

CONCLUSION

It is possible to say that polders satisby their basic flood-control water-management function and purpose. The course of actual floods and affecting the water flow by these water works have confirmed justification and suitability of the polder construction within integrated flood-control measures in special-interest localities.

Present experience from the several-year use and operation of the water works proves, however, important, permanent and extensive operational denands. They withdraw considerable part of working capacities of the watercourse manager. Moreover, a fact that it refers to water works where there is only minimum stable damming-up, a certain rate of unforeseeable behaviour of the water work occurs when, in the course of time, various changes can appear due to biological, geological, hydrological and other factors.

SOUHRN

Vliv poldrů na průběh povodní v povodí Tiché Orlice

Poldry mají v protipovodňové ochraně významnou vodohospodářskou funkci. Průběh dosavadních povodní v posledních deseti letech a ovlivnění povodňových průtoků těmito vodními díly potvrdil oprávněnost a účelnost výstavby v rámci komplexních protipovodňových opatření v jednotlivých povodích České republiky.

Pro stanovení transformačního účinku protipovodňových opatření v povodích je významným prostředkem matematické modelování, které se uplatňuje nejen při přípravě a navrhování retenčních prostorů, ale také řešení povodňové ochrany sídelních útvarů. Výhodou je rovněž snadné ověřování dalších opatření v povodích, jejichž realizaci je tak možné do budoucna připravovat nebo od těchto záměrů ustoupit.

V našem případě je výhodou skutečnost, že model je operativně provozován na pracovišti vodohospodářského dispečinku Povodí Labe, což je kompatibilní s posuzovanými poldry v dílčím povodí Labe, konkrétně v povodí Tiché Orlice a jejím dílčím povodí Třebovky.

Posuzované poldry leží na Třebovce, která je největším přítokem Tiché Orlice. Tyto suché nádrže a zvýšená ochranná funkce stávajícího rybníka Hvězda ovlivňují odtok z cca 80 km^2. V rámci studijních prací byla nejprve sledována možnost získání potřebných retenčních prostorů ve stávajících malých vodních nádržích. Ukázalo se, že jediné reálné řešení je zvýšení ochranné funkce rybníku Hvězda. Jeho stávající celkový retenční prostor 1,4 mil. m^3 lze zvětšit jen o 0,35 mil m^3, avšak v kombinaci s důmyslným uspořádáním nového bezpečnostního přelivu a výpustí lze mnohem efektivněji využít celý retenční prostor. Pro získání dalších retenčních prostorů byly vyhledány lokality v celém horním povodí Třebovky, které splňovaly požadavky na umístění přiměřené kapacity poldrů.

Následné úpravy koryta Třebovky v nejohroženějších obcích a jejich kapacitní řešení podle transformačních účinků vybraných nádrží a opatření, následné stanovení jejich účinku a porovnání s profily na Tiché Orlici, jsou obsahem tohoto příspěvku.

povodně, protipovodňová ochrana, transformace povodní, poldry

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