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REPORT ON THE RECOVERY OF THE BEČVA RIVER (CZECH REPUBLIC)

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Introduction

The area of the Czech Republic was in past decades loaded by negative influences of the over-exploitation, which has not respected vitally important functions of the landscape. Over one million hectares of soil were drained during 40 years before 1990. In the early fiftieth there were 1 300 thousands of hectares of wetland in the Czech Republic, presently it remains 350 thousands of hectares only. The water utilization, in spite of its permanent deficit within the area of the Czech Republic, reaches an unbelievable high level of 37 % of total sources (Just, 2003).

The milestone in protection of European aquatic ecosystems is implementation of Water Framework Directive (WFD). This directive established the aim of achieving good surface water status in 2015 at the latest. For the purposes of classification of ecological status for rivers these quality elements are given: (i) biological quality elements - phytoplankton, macrophytes, phytobenthos, benthic invertebrates and fish fauna, (ii) hydromorphological quality elements – hydrological regime, river continuity, morphological conditions and (iii) physico-chemical quality elements. It means that when the ecological status of rivers is assessed not only water chemistry parameters have to be taken into account (as was the previous routine) but also biological and hydromorphological characteristics of aquatic ecosystems. This is a very important shift of tendency in watercourse management and protection.

In connection with this fact it is also clear that more attention in planning of river restoration projects is paid to improvement of those hydromorphological conditions of rivers, which has the highest ecological consequences. This report describes rivers regulations in the Czech Republic in the last century and in detail the situation on the Bečva River as an example of natural restoration after a large flood.

River regulations in the Czech Republic

Alterations associated with the water utilization have already been realized in streams and rivers valleys since Middle Ages. It was mainly in connection with a construction of mills, timber-mills and iron-mills. The time of the most extensive technical encroachment to the water environment began by the end of nineteenth century.

Catastrophic floods in ninetieth of 19th century significantly contributed to a development of watercourse modifications related to flood protection. The purpose of these modifications was mainly to drain the water from the landscape very fast. After the flood control regulations, agricultural modifications of small watercourses enabling a function of surface drainage systems came. Streams and brooks began to disappear from the landscape and were replaced by regulated watercourses, canals and drainage ditches. The history of these regulations noticed a few periods of an exceptionally strong activity. Many small watercourses were regulated in thirtieths of 20th century and have been kept in the regulated state till now. The subsequent development was related to introducing of a collective agricultural mass production in 1950s and 1960s. The culmination occurred in 1970s and 1980s. The large surface drainage met with a massive

agricultural chemicalisation, which caused among others also considerable deterioration of water quality (Just, 2003).
Multipurpose impoundments constructed during 20th century primarily affected natural connectivity and dynamics of medium-sized and large rivers. Flood protection, hydroenergetic use, supply with drinking water were managed by structures disrupting river continuum, changing natural flow, sediment transport and thermal regimes in regulated rivers. In combination with straightening and resectioning of rivers the riverine ecosystem was extensively degraded.
First restoration projects in the Czech Republic started after 1990. Their main tools have been Landscape programs of the Ministry of Environment. As a part of the Landscape programs the Program of Recovery of River Systems and the Program of Care for Landscape have been realized since 1992.

Regulation of the Bečva River

Geological, climate and hydrological characteristics of the Bečva River catchment caused periodical flooding of areas around this water course. Flood protection of settlements and cropland by construction of embankments changed the original character of the meandering and anastomosing channel. Major channel changes were carried out in years 1902-1935. Channel cross-sections were modified and reinforced to a trapezoidal shape with the bottom width of 25-35 m, the slope gradient from 1:2 to 1:3 and the cross-section depth of 3 m.
Table 1 shows the proportion of different channel shapes (anastomosed, braided, meandered and straight) on the Bečva River and its two main tributaries (Rožnovská Bečva and Vsetínská Bečva) obtained during the 2nd military mapping (1819-1858) in comparison with the present situation. Whereas the proportion of the straight reaches on the Bečva River accounted of only 25 % during the 2nd military mapping, at present there can be found only straight reaches. As a consequence of the straightening, the river was shortened to only 64 % of its original length.

Tab. 1. Proportion of different channel shapes on the Bečva River and its two main tributaries.

River	Reaches (km) - **year 1858**					**Year 2004**	**Short cut (km)**
	Anastomosed	Braided	Meandered	Straight	Total	Only straight reaches	
Rožnovská Bečva	0.4 (1%)	6.7 (17%)	0 (0%)	31.5 (82%)	38.6	37.4	**1.2 (3%)**
Vsetínská Bečva	5 (8%)	19.8 (32%)	4.7 (8%)	31.5 (52%)	61	58.6	**2.4 (4%)**
Bečva	17.4 (18%)	7.8 (8%)	47.6 (49%)	23.9 (25%)	96.7	61.6	**35.1 (36%)**

Also on both tributaries only straight reaches can be found nowadays. Contrary to the Bečva River, both main tributaries were shortened by just 3% and 4%. It is well understandable as Rožnovská Bečva and Vsetínská Bečva flow throw narrow valleys and naturally there were not many meanders to be cut short.
Before regulations there was a floodplain with forest and meadows. This type of landscape was changed to the species poor landscape with forests and cropland. During planting of the riparian vegetation mainly fast-growing hybrids of poplars were used. Similar as in floodplains of majority of large rivers also in the floodplain of the Bečva River expansionary neophytes have been spread (mainly Reynoutria japonica, Solidago gigantea, Solidago canadensis and Helianthus tuberosus). Despite these negative changes and events many ecologically important landscape elements were preserved.

Fig.1. Comparison of regulated and restored sections near Černotín (photo by V. Syrovátka).

The ecological value of Bečva River catchment is also associated with the fact that with exception of one headwater dam it is not affected by impoundments. Maintenance of this status supported by restoration of channelization effects would recover diversity of habitats for flora and fauna.

The Bečva River is a part of Morava River basin comprising 4000 km of river network. Only about one third is in an acceptable ecological status. Only about 25 % of original forests remain in the areas of this basin, cropland covers more than one half of the floodplains, the urban area amouts to 10 %, original river landscapes and most of main rivers have been regulated and reinforced (Štěrba, 2004).

Catastrophic flood 1997

In early July 1997, the weather was characterized by a shift of a large depression from Britain, Scandinavia and southern France to the Czech Republic and movements of surrounding cloud formations and occluded fronts.

The most widespread flooding at the Morava River basin began on the 5th July 1997, the first substantial flush of floodwater came on the 7th and 8th July. Due to the situation existing in July of that year, a substantional part of rainwater was leaving that area immediately and the run-off coefficient was very high (0.9 or even higher) during the critical days.

1.954 km of the total 3.957 km of rivers managed by the organization Morava Water Basin Authority were affected by the flooding. This flood was the largest one recorded on the Bečva River in the history. The hydrological station Teplice stated the culmination discharge of 950 $m^3 . s^{-1}$ (see Fig. 2). The flood was also exceptional considering its extremely long duration. The discharge of 600 $m^3 . s^{-1}$ lasted for two and half day and the discharge of 400 $m^3 . s^{-1}$ for another three days. Two parameters decide about destructiveness of flood – the size of culmination discharge and the duration time of large discharges. The discharge size decides about water level and velocity. The duration time of large discharges says how long the water influences an affected area. On the duration time depends significantly intensity of scouring.

This flood brought destabilization of the river longitudinal section, substantionally widened the river channel, created huge gravel deposits and formed permanent pools directly in the river channel. The capacity of the new main channel is about Q_1 and riverbanks form the boundary of a new river terrace. New active floodplain has the flooding periodicity similar to the state before regulation.

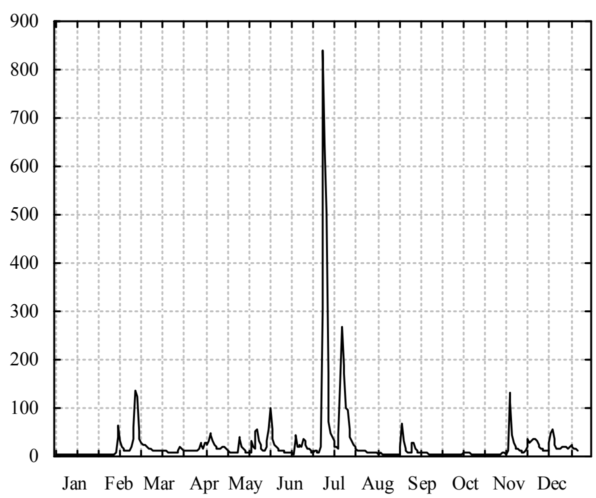

Fig. 2. Mean daily discharges during 1997 ($m^3 . s^{-1}$)

Subsequent development of the Bečva River after the flood 1997

When repairs of flood damages started the Ministry of Environment was very interested in the conservation of new restored ecosystems on the Bečva River. There was a study drawn up where the Bečva River was divided into segments according to recommended treatments (Šindlar, 1997). Five stretches were placed into the category of a priority protection. Based on an agreement between the Water Basin Authority as the Bečva River manager and the Agency for Nature Conservation and Landscape Protection of the Czech Republic it was decided to keep five stretches without any follow-up regulation (Fig. 3). This initial restoration step protected those hydromorphological structures that had been documented from period before the regulation of the river. Hydromorphological studies (Šindlar, 2000) confirmed that these naturally restored sites represent hydromorphological conditions rare in the Czech Republic where the majority of river courses of that type are completely regulated (reinforced, resectioned, straightened, impounded).

The planning process was started with activities combining restoration and flood protection. The protection based on a status of National Nature Reserve is planned for the site Osek. This site together with the other sites should be the part of a bio-corridor of the Territorial System of Ecological Stability with higher than regional importance. It will be important to support a decision process with results of ecological studies. Buying in land around the river that is necessary for the establishment of this bio-corridor is still a very big problem. Another danger is that voices calling for construction of polders or reservoirs as means of flood protection may divert the decision making process from the best way of the river restoration.

Adaptive succession on the Bečva River

At the end of the vegetation season in 1997 it was obvious that the plant succession depends on granular composition of substrate and also on dynamics of moisture regime, mainly on frequency of flooding by higher discharges. Lower gravel bars with fine sandy filling or with a layer of diluvium were characterized by the most extensive vegetation cover (30 - 50%). Contrary to this gravel bars without fine-grained filling or overlay – generally in upper flood corridor – and lower bars often flooding in stripes along the active channel were covered by vegetation very sparsely (to 10%).

It is obvious that as a result of the transformation of the Bečva River channel by flood there was restored the biotope that became extinct due to water engineering regulations at the beginning of the 20th century. It is the biotope of the group of types Saliceta fragilis bounded with gravel-sandy bars (Lacina et al., 1998).

Fig. 3. Location of Bečva River stretches kept for restoration (red bands)

Former practice versus contemporary methods in the river management

Reasons for regulations of river channels in the past years:

- Oversized channel deformation.
- Damage of land round the river.
- More particles in water and subsequent increased sedimentation in lower parts of the river and also reduced channel capacity and that worse flood protection.

Therefore after flood there was performed a study in 1999 to find out if holding those five stretches without following regulation causes some of the negative consequences mentioned above.

The assessment of possible morphological changes of the river corridor was performed using the mathematical model HEC-6. Geometrical characteristics of the corridor, characteristics of the bottom texture and hydrological data had to be input into this model. As results serve information about changes of location of the river bottom, water level and about total amount of particles transported by water in different profiles and time durations of certain discharge.

The study found out:

- Long stretches where only erosion or sedimentation run do not exist, on the contrary these stretches often take turns (with one exception – the site Osek).
- The present channel capacity is very changeable; there are sites below Q_1 but also sites with the capacity more than Q_{50}.

- The flood mostly enlarged the river corridor and thereby also flow capacity.
- Possible future cover of thick vegetation on gravel bars will influence the channel capacity very little.
- There is no expectation of any large and fast shift of upper bank edge and large encroachment into the adjacent land. In the most stressed sites the bank shift will be about 5-10 meters per 10 years.

Restorations focused on large lowland rivers in principle do not exist in the Czech Republic. Removal of regulations of large river systems from headwaters to mouth for the purpose of restoring and reconnecting hot spots of native biodiversity and bio-production has not been accomplished anywhere to date (Stanford, 1996, Gore & Shields Jr., 1995). Therefore it is necessary to solve consequences of floods on large rivers very thoughtfully. Similar conditions as on the Bečva River after the large flood 1997 occurred on the Berounka River after a flood in 2002. The process of natural restoration started earlier by formation of bars and spreading of wood, reinforced banks have been abandoned and this natural restoration was sped by flood very much. A lateral flow over a field following an axis of arm of the river destroyed during long past regulation was present in time of that flood. There sprang up a large erosion line and a few potholes that were left only a little modified and were planted. Costs for a standardization of this natural restoration project are in comparison with usually carrying out restorations very low.

Measures proposed for five restored stretches of the Bečva River:

- Create buffer zones of vegetation along the river in width about 15 meters.
- Adjust river banks to the natural slope and plant with willow cuttings.
- Preserve all hydromorphological structures created by flood in the corridor.
- Let the recessed part of the channel to develop freely.
- Cover the banks in concave curves - where they are most loaded by flowing water -with willow flooring.
- Stabilize parts of bank slopes permanently below water by stone riprap.
- In the long run maximize expansion of the active floodplain to create conditions for accumulation of suspended particles and for stabilization of biotopes in a more stable geomorphologic type – alteration of riffles and pools in gravel substrate.

The flood as a kind of river restoration

The straightening and the resectioning of the channel and the reinforcement of banks performed in the history of the Bečva River reduced natural river-bed evolution, prevented lateral movement of the active channel within the floodplain, reduced the diversity of aquatic and floodplain habitats and isolated the channel from the riparian zone due to the modification of water regime in floodplain. Biodiversity of the riverine landscape was reduced by the loss of the mosaic of species-rich floodplain meadows and wetland habitats. Although residual floodplain forests were maintained, biotopes of softwood forest were affected by changes in the water regime of the floodplain, in particular by a drop of groundwater level (Lacina, 1998). The channel dimensioned to drain floods of medium magnitude (up to 412 $m^3.s^{-1}$) allowed the expansion of cropland to the floodplain, usually near the bank top.
The flood 1997 on the Bečva River reconstituted landscape-scale ecological processes, such as hydrological connectivity and channel migration. At studied sites of the Bečva River the flood created more space for the river, destroyed old embankments and changed the structure of ecotones. All these river changes could be counted to the goals of a river restoration project.

Devastation caused by floods can be considered a welcomed restoration requiring only small further modifications (Tockner et al., 2000, Poff, 2002).

One of the main consequences of the flood is the restoration of spatio-temporal heterogeneity in landscape of the Bečva River. There arose different types of rare habitats at the restored reaches of the Bečva River: (i) marginal pools with organic substrata, sometimes with submerged parts of terrestrial plants (grass leaves, willow branches, stems and roots), (ii) temporarily disconnected pools with different substratum and temperature regime, (iii) main-channel habitats composed of some rare substratum – e.g. tree trunks, branches and roots. The lateral habitats contribute to biodiversity of floodplain river ecosystems and also are important as refugia for macroinvertebrate species and fish during high discharges in the river (Amoros & Bornette, 2002). Thermal heterogeneity, both in space and time, clearly reflects the variety of floodplain water bodies and the complexity of inundation processes (Ward, 1998, Tockner et al., 2000). Thus the removal of regulations as a consequence of flood allows more natural seasonality of flow and temperature, which is important for habitat maintenance and food web energetics (Stanford et al., 1996).

It must be remembered that the flood has been and will be a natural hydrological event (Ward, 1998, Štěrba, 2004, Nienhuis & Leuven, 2001). Flood becomes a catastrophe just in settled flooding areas and in inappropriate modified landscapes. The flood can remodel natural corridors and natural floodplains but can not change their base whereas it can influence regulated corridors and modified floodplains in a crucial way. The flood creates a system of deposits and ruptures and to a large extent restores near natural running of corridors and also transverse and longitudinal sections. As these changes are very valuable and in principle serve as a river restoration we should perform measures after flood very differentially. It means that in built-up areas the protection before damages should be in the first place and therefore there could be prefered restoration of a stable and capacitive channel. In open landscape, conversely, it is necessary to support overflows of flood water into floodplains. When flood waters are drained from the river to prepared areas then it secures not only flood protection but also another useful phenomena – water pollution decrease, fine soil and nutrients retention, infiltration improvement, higher biodiversity, etc. (Štěrba, 2004).

Conclusions

It is very important to finalize the process of integration of five restored stretches on the Bečva river into the bio-corridor of more than regional importance. It calls for helpful negotiations between involved organisations and the Ministry of Environment.

Our research aims mainly at the assessment of how newly created hydromorphological structures influence river macroinvertebrate community in habitat and reach scale. As the channel form depends on the available energy or stream power and on the sediment supply from the catchment upstream or from channel erosion, detailed hydromorphological investigation should precede decision about restoration strategy appropriate for certain conditions. Studies available for Bečva River (Šindlar, 1997, Šindlar, 2000) are helpful for further planning of river restoration. All researches concerning hydromorphology are very useful also in connection with the implementation of Water Framework Directive in the Czech Republic.

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