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FLOODPLAIN REHABILITATION SCHEMES: EXAMPLE OF THE KAPOS FLOODPLAIN, HUNGARY

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Abstract

The restoration of rehabilitation of channelized rivers can only be successful if the establishment of a close-to-natural new channel is accompanied by a complex rehabilitation of the floodplain. Floodplain rehabilitation necessitates the assessment of present-day hydromorphological and landscape ecological conditions and the rehabilitation potential of the geomorphologically identified floodplain segments. The paper presents an example a rehabilitation measures from Hungary: the floodplain of the fully channelized Kapos River of low discharge with virtually no active floodplain and poor landscape connectivity on the protected floodplain. However, along some sections, in the embayments, where the floodplain is broader, there is opportunity to implement rehabilitation measures and reach the objectives of the EU Water Framework Directive for rivers in modified state. A scheme for channel and dyke relocation is proposed – without details of the engineering implementation.

Keywords: floodplain rehabilitation, rehabilitation potential, river regulation, dyke relocation, Hungary

1. INTRODUCTION

Worldwide a wealth of books and papers have been produced by geomorphologists, hydrologists, engineers, ecologists and their joint teams on problems of river channel and floodplain restoration or rehabilitation (Manci, K.M. 1989; National Research Council 1992; Sear, D. 1994; Kondolf, G.M. 1995; Hey, D.L. & Philippi, N.S. 1995; Brookes, A. & Shields, F.D. Jr. 1996; Fennessy, M.S. & Cronk, J. K. 1997; Kauffman, J.B. & Beschta, R.L. 1997; Macdonald, K.B. & Weinmann, F. 1997; Theiling, Ch. 1998; Wissmar, R.C. & Beschta, R.L. 1998; FISRW 1998; U.S. Department of Commerce 1998; Tockner, K. et al. 1999; Zöckler, C. 2000; ECRR 2001; Bratrich, C. et al. 2002; Buijse, A.D. et al. 2002; Clarke, S.J. et al. 2003; Hulse, D. & Gregory, S. 2004; Hohausova, E. & Jurajda, P. 2005; Kline, M. 2007; WWF International 2010). As a theoretical background to the issue the classical concept of 'design with nature' (McHarg, I. 1995), which also includes landscape ecological aspects, can be detected. In addition to bringing planning in harmony with natural processes, sustainability is another foremost requirement – as it is a basic requirement for planning in general.

2. FLOODPLAIN REHABILITATION APPROACHES

Some concepts in floodplain management has to be clarified. The *recovery potential* of a river-floodplain sytem means the potential development of seminatural conditions within a perspective of 50–100 years, including the factors which hinder this development. Recovery potential is either natural or enhanced (supported by human interference – National Research Council 1992). *Restoration potential* means the re-establishment of the natural (usually pre-regulation) conditions of the fluvial system transformed by human activities (Cairns, J. 1991). If there is no chance to perfect restoration, it is more advisable to talk about *rehabilitation potential* (Wolters, H.A. et al. 2001).

Recently such topics have been particularly intensively studied in the United States (see e.g. National Research Council 1992; Fichenich, J.C. 2006), Australia (see e.g. Rutherfurd, I. et al. 1998; Koehn, J.D. 2001; Brierley, G.J. & Fryirs, K.A. 2008) and increasingly in Europe too (Tockner, K. et al. 1999; Tockner, K. & Stanford, J.A. 2002).

The alternatives of restoration/rehabilitation are referred into one of three groups (Smith, M.P. et al. 2008): *'no action'*, *passive* or *active intervention (Table 1)*. The 'no action' alternative means that the channelized river is capable of restoring its close to natural conditions without any human assistance. In this case the recovery potential is assessed as high. From such a strategy, however, it cannot be expected that a fully natural state is restored – not even on the very long term.

With passive rehabilitation the river is influenced to counteract the external effect and to restore the previous state without direct intervention into the fluvial system. The difference between the two kinds of approaches can also be formulated in the following way: active rehabilitation aims at 'products' (creating landforms and vegetation assumed to be more favourable), while passive rehabilitation strives at generating processes which are expected to lead to favourable conditions later in the future (Richards, K.S. et al. 2002).

Table 1 Comparison of the three rehabilitation approaches (modified after Smith, M.P. et al. 2008)

general approach	*strategy*	*example*	*recovery potential*
'no action'	no intervention in the hope of natural recovery, i.e. that the river itself obliterates the consequences of minor disturbances	disturbances of natural origin (such as floods) lead to an equilibrium state over the long run	high
passive	after implementing flood control measures, the free response of river channel is allowed and promoted	purchasing land in the riparian zone by the state to secure space for meander development	medium
active	correction of the alignment of the channelized river in order to establish a stable channel, incorporating passive procedures	new channel alignment, bank reinforcement using natural methods but allowing space for the 'fine tuning' of flow pattern	low

The passive procedures include legal regulations, for instance, prohibition of urban development on the floodplain or declaring the floodplain a nature conservation area. These are proper measures to prevent further deterioration and to promote natural recovery. In most of the rehabilitation projects first passive and then auxiliary active ('hard' or 'soft engineering') interventions are implemented locally in order to assist the river channel reach the desired equilibrium as soon as possible. Even rivers which require intensive active interventions may have a high restoration potential if, for instance, the conditions are favourable for the design of the meander belt (sufficient space is available).

In the *empirical method* of channel restoration the equations of hydraulic geometry, the knowledge on channel pattern (Leopold, L.B. & Wolman, M.G. 1957) and geometry (Williams, G.P. 1986, 1988; Simon, A. 1989) are widely utilized. The transfer of the revealed relationships to different environmental conditions, however, can be a source of major error. Less input data are needed for the *analogue method*. It is essentially the shaping of the river to be restored after the model of another river in a (more) natural, 'healthy' state. In this case the slope, channel material and riparian vegetation of the reference river is the model for the design of rehabilitation (see e.g. Rosgen, D.L. 1998). To find optimal references, however, is far from being an easy task. When *analytical methods* are chosen for planning rehabilitation, physical equations and computer modelling at various spatial and temporal scales are employed. Their disadvantage is that they do not reflect real conditions and, therefore, the application of empirical and analogue methods is not superfluous. As a general rule, the more natural recovery processes are allowed to operate (Smith, M.P. et al. 2008) and the more floodplain rehabilitation measures are incorporated (in a holistic approach), the more successful the rehabilitation process will be. From an *ecological* viewpoint the most imprtant *tasks* in river rehabilitation are (Brookes, A. & Shields, F.D. Jr. 1996):

- to create a flood hydrograph close to the natural;
- to restore the riparian zone and the floodplain ecological network as perfectly as possible;
- to restore the matrix of the floodplain with the minimum active human intervention;
- to remove obstructions from the way of meander development.

3. A method for rehabilitation potential assessment

The *River Styles® method* is a qualitative, mostly non-parametrical approach to stream typology (Brierley, G.J. & Fryirs, K. 2005). Instead of a quantitative evaluation it only provides guidelines for river and floodplain surveys. It assesses the capability of rivers for adjustment (Downs, P.W. 1995), the appropriate response to environmental changes over historical times (which is a rather limited interval in Australia) and the recovery potential of channels and floodplains (Brierley, G.J. & Fryirs, K. 2005). The final objective is to select the most appropriate solutions for the repair of riverine environments and habitats.

A central criterion of classification is the *valley confinement* of channels, a fundamental control of channel adjustment (Fotherby, L.M. 2009). Further criteria are the shape of the valley cross-section; channel slope and pattern; floodplain width, continuity and landforms; grain size distribution of alluvia and other channel and floodplain properties.

A great advantage of the River Styles® approach is – even though it was elaborated so far away from Europe – that it harmonizes with the European Union's Water Framework Directive (European Commission

2000), which identifies good, medium and poor hydromorphological conditions compared to reference reaches. This method is more than a template for describing rivers – it is a useful tool to investigate channel and floodplain development.

In addition to the assessment of the rehabilitation potential, a rehabilitation proposal should include all measures which serve the restoration of the floodplain into close-to-natural conditions (Buijse, A.D. et al. 2002 – *Fig. 1)*. (Here rehabilitation measures are only treated from landscape ecological aspects, no engineering details are concerned.)

In the case of the channelized rivers of Hungary the term rehabilitation potential can only be used with some restriction (Lóczy, D. 2011). It is assumed that the rehabilitation potential varies with the hydromorphologically established segments of the floodplain. Therefore, the floodplain rehabilitation potential is to be assessed segment by segment. The need for particular passive modifications or active interventions which could serve best the purposes of flood control and habitat preservation (or re-creation) was identified. (Obviously, the improvement of navigation conditions is not relevant for small rivers of low discharge.)

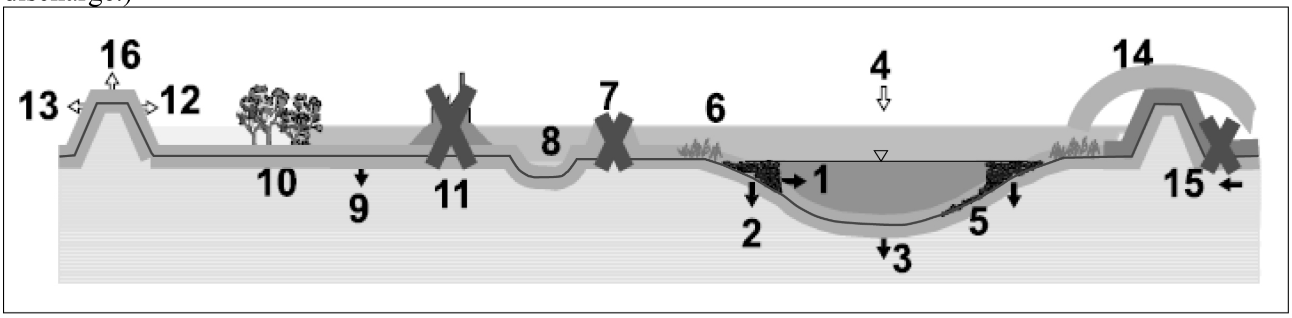

Fig. 1 Possible rehabilitation measures along regulated lowland rivers to facilitate navigation, flood protection and to improve ecological conditions (source: Buijse, A.D. et al. 2002; Fig. 7). 1 = narrowing of the main channel; 2 = lowering of groynes; 3 = dredging; 4 = redumping of sediment; 5 = permanent channel cover; 6 = creating natural bank; 7 = removing summer embankment; 8 = digging a secondary channel; 9 = lowering of the embanked floodplain; 10 = nature development, spreading natural biota; 11 = removing of raised areas; 12 = dyke reinforcement; 13 = dyke repositioning; 14 = water retention (outside the high-water channel); 15 = obstructing lateral inflow; 16 = dyke raising

A recent report on the rehabilitation of the floodplains of the Danube and its tributaries (WWF International 2010) restricts its scope on rivers with catchment areas larger than 4000 km^2. At the same time, satisfactory conditions for the floodplains of large rivers can only be secured if those of the smaller tributaries as well as their catchments are also in good state (ECRR 2001). The most efficient way of *runoff retention* is the afforestation of the barren slopes of small catchments and the same applies to sediment retention too (Dietrich, W.E. & Dunne, T. 1978; Mander, Ü. et al. 1997). In the international literature – naturally, in addition to the restoration of the river channel – the following objectives are set for catchment rehabilitation:

- creating connectedness measurable by landscape ecological indicators;
- the identification of reference sections;
- the establishment of proper vegetation cover;
- increasing biodiversity and
- several social goals (for instance, land ownership clarification).

As a general rule, regular inundation has to be accepted as a natural state of floodplains to which land use has to be adjusted. The most appropriate land use in waterlogged areas is grassland economy (meadow) (Kaliczka, L. 1998).

4. CASE STUDY: REHABILITATION POTENTIAL OF THE KAPOS FLOODPLAIN, HUNGARY

4.1. The Kapos River and its floodplain

One of the two drainage basins which lie entirely on Hungarian territory is the medium-sized catchment of the Kapos River. It covers 3,295.4 km^2 in the Outer Somogy Hills region (*Fig. 2)*. The trunk river is 112.7 km long, a 5th-order stream (after Strahler, A.N. 1957) at confluence to the Sió Canal (the outflow of Lake Balaton to the Danube). Water discharge is low, mean flow is ca 7 m^3 s^{-1}. The topographical *floodplain* (without that of the tributaries) extends over 104.2 km^2, which makes up 3.3 per cent of the total catchment area. (It is interesting to note that, according to U. Schwarz [2011], the Danube floodplain is also

3.3 per cent of the drainage basin!) On the territories of three counties (Somogy, Baranya and Tolna) the river is fed by 27 right-bank tributaries and 28 left-bank tributaries of relatively permanent flow. It has only a single fourth-order tributary (the Koppány River) and three third-order streams (the Surján and Orci Streams and the Baranya Canal). The confluence of the Kapos River with the Sió Canal is at river kilometre 79 of the Sió, the outflow of Lake Balaton and a tributary of the Danube.

Valley density is highest in the Mecsek segment of the Kapos catchment, but its values are also high in the Zselic Hills and along the Koppány River (8–10 valleys km^{-2}) and interfluvial ridges are not wider than 150–200 m (Völgy Hangja 2009). The *asymmetry of topography* is also reflected in the alignments of tributary valleys on the northern and southern valley sides. The hill ridges along the Koppány River rise to 300 m elevations, but the Southern Outer Somogy Hills along the Kapos River is a flat loess-mantled hill plateau of ca 150 m elevation, dissected by broad and bowl-shaped dry valleys (called 'derasional valleys' in Hungarian geomorphological literature). As a consequence of neotectonic evolution, for the floodplain the alternation of broader sections *(embayments)* and narrow *gaps* separating them are characteristic.

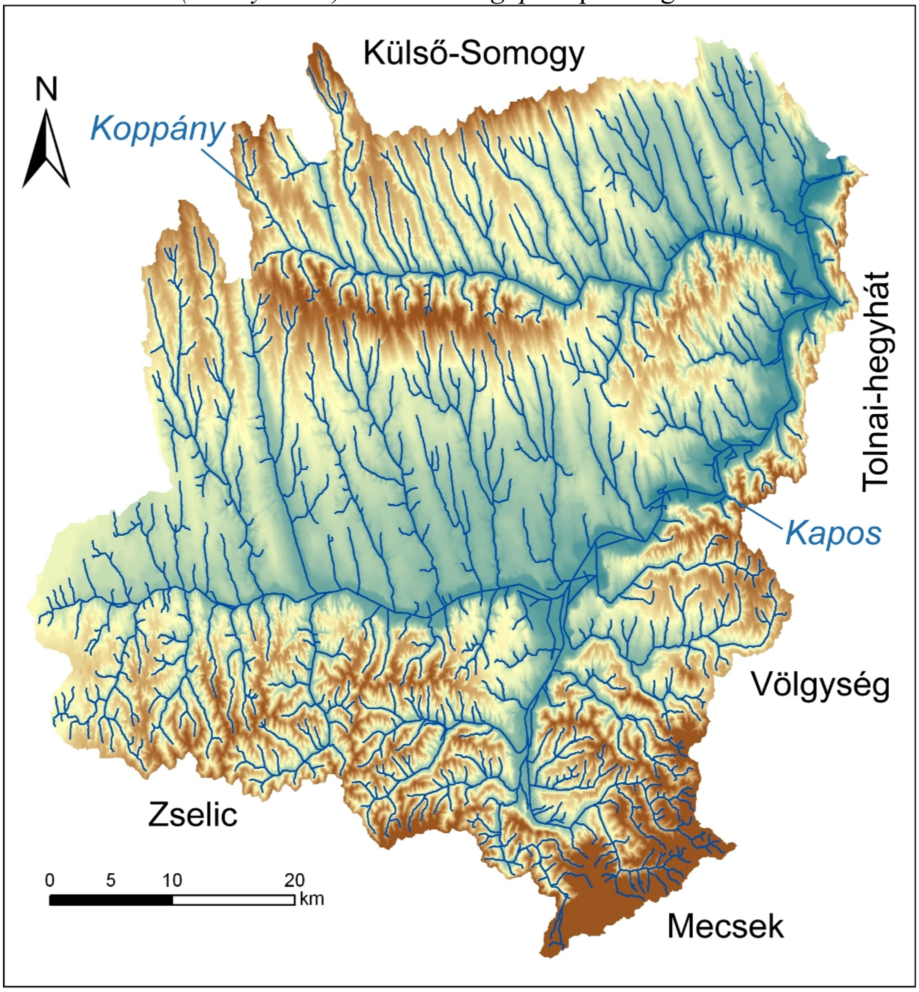

Fig. 2 The catchment of the Kapos River in Southern Transdanubia, Hungary

4.2. Rehabilitation issues in the Kapos floodplain

For the rehabilitation of small watercourses and their floodplains Hungarian water management experts formulate the following *principles* and *practical tasks* (Bognár, Gy. 1989):

- creating close-to-natural shape of channel banks and riparian habitats;
- grassing of the freshly ramparts (for securing erosion control before the roots of tree vegetation fully develop);
- planting saplings of high-growth native trees, such as willows and alders, downslope from the upper third of the rampart in order to increase slope stability, the proliferation of bushes and the separation of the riparian zone from areas of intensive agriculture.

The findings of the hydrogeomorphological assessment of the Kapos floodplain (Lóczy, D. 2011), however, clearly point out that the problem is much more complex and a more careful planning of rehabilitation measures is necessary.

An environmental protection report with land use analysis from nature conservation aspect with feasibility study (Gergely, E. et al. 2000) has been prepared for the Kapos catchment, but it mostly neglects the floodplain. Although the proposals below may be too ambitious compared to the financial resources available for environmental protection in the region, some of their details may be worth considering and implemented on the long run. The main rehabilitation goals are summarized in the following points:

- The floods of 1999, 2005 and 2010 underline the importance of *flood control,* which necessitates *water management* (water retention) investments and *land use* changes.
- The improvement of the *landscape pattern* of the floodplain could contribute to the establishment of a well-developed ecological network, providing connection to the Balaton-Boronkamellék ecological corridor in the west, towards the east, in the direction of the Danube floodplain (units of the Danube-Drava National Park) and towards the north, the Koppány Valley. The rehabilitation of the buffer zones (which were found to be fragmented in the landscape ecological investigation) would improve the now unsatisfactory *water quality* (meeting the requirements of the EU Water Framework Directive).
- Floodplain economy (arable farming, fisheries and possibly also earthy peat and muck excavation) could be harmonized with nature conservation considerations.

The conclusions drawn from both the hydrogeomorphological studies (the description of embayments and gaps, valley and floodplain asymmetry, channel reconstructions) and landscape ecological assessments help the achievement of the above goals.

In the international literature the measures necessary for the implementation of river and floodplain rehabilitation plans are outlined from hydrological (for instance, Brookes, A. 1996), ecological (Clarke, S.J. et al. 2003) or combined (Wolters, H.A. et al. 2001) approaches. Authors are convinced that the identification of floodplain segments by morphometrical parameters (Lóczy, D. et al. 2012) is also relevant in the planning of rehabilitation measures: the character of the floodplains segments strongly influences the required optimal combination of interventions *(Table 2).* In the densely built-up upper (Kaposvár–Dombóvár) section the opportunities for any transformation are rather limited, but much more favourable downstream, in the broad embayments, where the floodplain rehabilitation potential is higher. The proposal could refer to alterations in the following properties:

- river mechanism (geomorphic action), alignment (channel relocation, excavation of new channels, filling up ditches), which may involve the rearrangement of transport lines, too;
- dyke relocation further away from the river;
- flooding of backswamps and oxbows;
- land use change, introduction of new crops and less intensive modes of cultivation.

Table 2 Options for channel and floodplain rehabilitation measures in the individual floodplain segments of the Kapos River (by Lóczy, D.)

number	*floodplain segment (river km)*	*character of floodplain segment*	*rehabilitation potential*	*codes of necessary interventions (see Fig. 1)*
I.	112.7–109.2	narrow valley without floodplain	high	6, 10
II.	109.2–86.4	gradually broadening, ever more continuous floodplain	low	6, 9, 10, 11, 12, 15
III.	86.4–68.7	partially confined floodplain, gaps at short intervals	medium	6, 7, 8, 10, 13
IV.	68.7–49.5	partially confined floodplain of fluctuating width, gaps at medium-length intervals	high	6, 7, 8, 10, 11
V.	49.5–28.2	hardly confined floodplain, broad embayments, narrower gaps at longer intervals	very high	4, 7, 8, 10, 11, 13, 14
VI.	28.2–0	partially confined floodplain with gaps at short intervals	medium	3, 4, 5, 9, 12, 16

The assessment of the rehabilitation potential shows that the rehabilitation proposals should focus on floodplain segments IV and V, where a combination of a range of interventions is expected to improve the ecological conditions of the floodplain.

4.3. Outline rehabilitation plan

The starting point for proposals to reduce flood hazard (for instance, Gergely, E. et al. 2000) is *channel rearrangement* along the Kurd section. This kind of intervention would also improve landscape pattern. In order to reach a *good ecological state* (European Commission 2000) in the segments of the highest rehabilitation potential, a comprehensive transformation of the floodplain is needed. This transformation is either induced or fully executed by human action (passive or active rehabilitation approach).

As it was mentioned above, creating new Kapos channel sections requires space and it is only feasible in the broadest embayments. In the gaps, because of the existing infrastructure and built-up areas of villages, the present channel has to be retained. Studying the map with the reconstructed channel and floodplain conditions *(Fig. 3),* it is visible that before regulation the Kapos used to be an *anabranching river* in the broader embayments. From a purely geomorphological viewpoint, the establishment of several more or less parallel, meandering channels would be an optimal solution for the restoration of drainage pattern. This can be achieved through taking advantage of partly the infilled channels still traceable in microtopography and partly the 19th-century regulation plans (Beszédes, J. & Herman, J. 1829). The side channel concept by Beszédes could also fall into this category. The *canals along the floodplain margin*, with courses similar to natural channels, could develop into true channels and fulfil the following *functions*:

- They could conduct away the flash floods generated on tributary streams (which could also be dangerous as attested by the May 2010 events).
- They could distribute among themselves the flood discharges from the Upper Kapos River.
- They could isolate the main channel from the non-point pollution of agricultural (or accident) origin.
- They would raise groundwater levels and ensure better water availability even in dry spells.
- This way, the survival of vegetation in the critical marginal zone could be secured, through establishing links with the main channel, landscape pattern in the floodplain could be repaired and a landscape of high diversity created (see Tockner, K. et al. 1999) even if the agricultural character of the landscape were maintained.

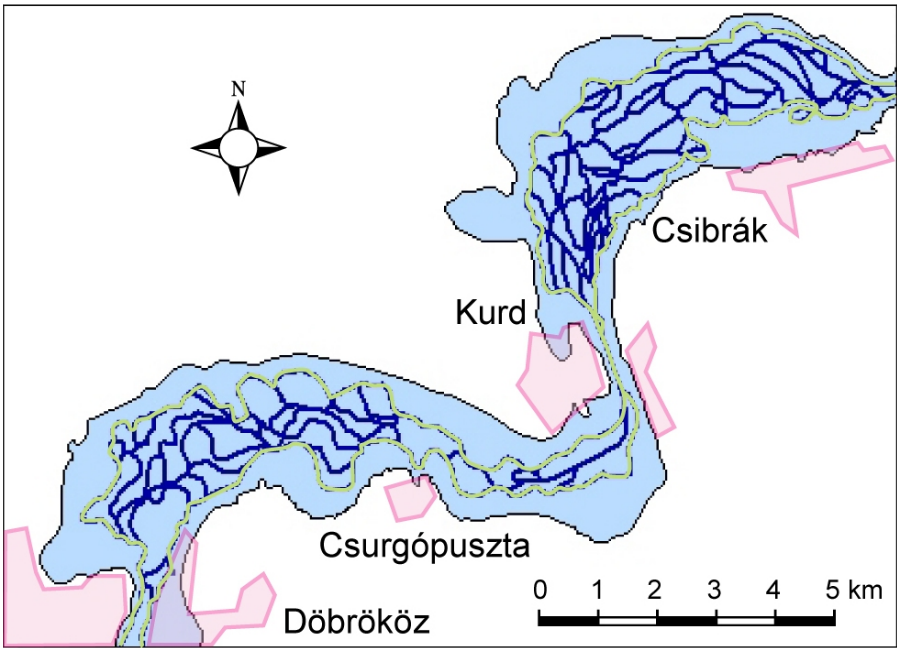

Fig. 3 Detectable paleochannels on one segment of the Kapos floodplain

The present study is not concerned with the engineering solutions needed for the implementation of rehabilitation plans but it can be remarked that – although the excavation of new channels is an expensive element of the plans – the sale of the extracted earthy peat, highly demanded by horticulturalists, could cover part of the costs.

For the purposes of extending the active floodplain and thus reducing the summit levels of flood waves in Western Europe the *relocation* of flood-control dykes further *away from the channel* (in the German literature: Deickrücklegung) is already applied as a solution (Clarke, S.J. et al. 2003; ECRR 2001, 2008). (Since this procedure is one of the most cost-effective and debated, as a matter of course, this cannot be called a routine intervention.) In Hungary, the Amended Vásárhelyi Plan for the reduction of flood hazard on the Tisza River and its tributaries is also based on the same principle, i.e. the (only temporal) *extension of the active floodplain*. This kind of solution has a great area demand, but, at the same time, serves the protection of agricultural land (Bognár, Gy. 1989).

Planning floodplain rehabilitation on the reach between the villages Döbrököz and Csibrák is made more complicated by the railway line, which cuts across the middle part of the right-bank floodplain. Along a ca 4-km long section the railway should be relocated to the very margin of the valley *(Fig. 4)*. The reason for this is partly to allow more space for rehabilitation measures and partly to reduce the risk of dyke breach at a site where the railway crosses and old channel filled with decomposed peat liable to further compaction. Its additional benefit would be the creation of a complex channel system (close to the pre-regulation conditions) and of a *wetland* of 1500 hectares area in the bottom level of a backswamp. The length of the river reach affected by the proposed dyke relocation is ca 7 km on the left bank and ca 10 km on the right bank along the Döbrököz reach and 3 km and 4 km, respectively, along the Kurd–Csibrák reach.

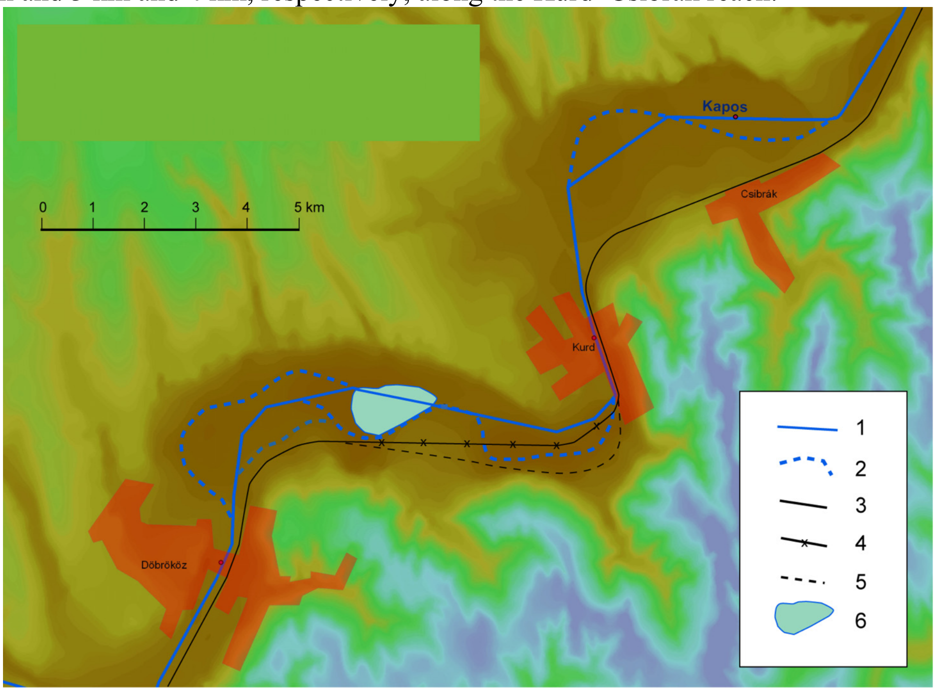

Fig. 4 Floodplain rehabilitation proposal (channel alignment) for the Döbrököz and Kurd–Csibrák embayments of the Kapos floodplain (by Lóczy, D.). 1 = the present river channel; 2 = proposed new channel reaches; 3 = existing railway track; 4 = railway track to be removed; 5 = proposed new railway track; 6 = proposed constructed wetland; 7 = built-up area

Following the great river regulations and even in the period between 1960 and 1980 an impotant objective of water management was the increase of arable land (by 25–30 per cent) and formation of large agricultural fields (up to 300 ha area) (Bognár, Gy. 1989). Since the late 1980s the requirements of environmental protection, nature conservation and landscape ecology has been coming to the fore.

Relying on the findings of landscape ecological and land evaluation assessments (Lóczy, D. 2011), intensive agricultural cultivation in the marginal zone should be replaced by complex riparian vegetation zones, which is capable of functioning both as a buffer zone and an ecological corridor. At the Koppány confluence the flood and excess water hazard is so high that in land use nature conservation has absolute priority over agricultural production. Arable farming should retreat to areas where excess water hazard is very low. (This is not only important in order to prevent yield losses but also to preclude the spreading of invasive plants on moist soils after periods of high precipitation. In the Kapos floodplain common ragweed *[Ambrosia artemisiifolia]* and common wormwood *[Asclepias syriaca]* present the greatest danger.)

The efficiency of the riparian zone should be enhanced by its complex structure, i.e. to be built up of strips of trees, bushes and grasses (Forman, R.T.T. & Godron, M. 1986). It is particularly important to divide arable fields from the dykes (the active floodplain) by a riparian zone of complex structure with the necessary width (at least 30–50 m), capable of fulfilling complex ecological functions. Referring to the ecological role of floodplains, for ensuring proper habitats for birds, many reptiles and amphibian species, however, this buffer width is not sufficient. From this aspect, a minimum 100 m wide buffer zone of close-to-natural vegetation should be desirable around the newly established constructed wetlands.

4.4. Long-term impacts of floodplain rehabilitation

The proposed changes in floodplain land use could be felt even on the short run. Floodwater retention would be enhanced and flood hazard reduced. New opportunities would open for recreation with attractions such as floodplain sections with high visual value, water surfaces and valley gaps. In the backswamps arable farming would be replaced by meadows connected to the ecological network and gallery forests would line river channels and ditches (Gergely, E. et al. 2000). With improving connectivity and landscape diversity indicators floodplain biodiversity could also be enhanced and the nature conservation function strengthened. Arable (or possibly organic) farming would be restricted to higher-lying, terrace-like surfaces with minimum excess water inundation hazard and very favourable soil properties and water availability (Gergely, E. et al. 2000). In arable fields of poor productivity cereal growing is to be gradually replaced by the cultivation of energy plants or horticultural crops, while the lowest-lying tracts could be used as grasslands or forests – with regard to landscape ecological consideration.

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