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REHABILITATION POTENTIAL OF THE DRAVA RIVER FLOODPLAIN IN HUNGARY

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Abstract
In Hungary river rehabilitation projects affect the Danube, Tisza and Drava Rivers. The lower Drava is part of the Danube-Drava National Park and extensive areas are included in the Natura 2000 system. By-channel revitalization interventions are under way but a complex rehabilitation should not only cover the active floodplain, but the entire morphological (flood-free or protected) floodplain and requires detailed assessments of its hydromorphological and ecological reference conditions. Our research intends to supplement the hydromorphological survey with monitoring and more detailed assessment of floodplain conditions along the Hungarian Drava River from the viewpoints of water availability, soil conditions, vegetation and nature conservation. A large-scale programme, called Ancient Drava project, has been launched to counter the unfavourable climate change trends (gradual desiccation of the floodplain) and the social implications (e.g. deteriorating regional employment and income conditions) The project envisions major transformations in water management and land use of this region, and has numerous implications for regional development. Out investigations are meant to assess the benefits expected from this project. A central research task of ouir research is to estimate the performance level of fundamental ecosystem services at environmental flow conditions.

Keywords: Regulated river, floodplain, floods, drought, oxbows, water recharge, Hungary

1 INTRODUCTION

As a consequence of river regulation and land drainage measures on the one hand and the impact of global climate change on the other, the alternation of floods and drought periods became typical of the environment of the Hungarian Drava floodplain. Extremities in water availability strongly effect the quality of life of the local population, also suffering from the adverse influences of socio-economic changes in the last decades. In the autumn of 2012 physical geographers of the University of Pécs launched a research project with the principal purpose to assess the potentials of the physical environment after the completion of floodplain rehabilitation. *Rehabilitation potential* is defined as the opportunity for the simultaneous performance of as many as possible of floodplain ecosystem services. Ecosystem services are grouped as provisioning services (harvestable goods); regulating services (maintaining natural processes and dynamics related to biodiversity, land, water and air); carrying, cultural and supporting services (MEA 2003; Slootweg et al. 2010). The main ecosystem services in floodplains include flood protection, groundwater replenishment, sediment and nutrient retention, water purification, resilience and recovery of river ecosystems after accidents, biodiversity/habitat, river-floodplain products (wood, fish, game, reed), cultural values, recreation and tourism, and climate change buffering capacity (WWF International 2010). Sometimes restoration is used as a synonym for rehabilitation. *Restoration potential*, however, covers the opportunity for more ambitious water management projects and means the re-establishment of the natural (usually pre-regulation) conditions of the fluvial system transformed by human activities (Cairns, 1991). *Recovery potential* after some human intervention into the life of the river refers to the re-creation of seminatural conditions which potentially develop within a perspective of 50–100 years – at least in a geomorphological sense (Fryirs & Brierley 2013). In general, recovery potential is not relevant for regulated rivers.

2 THE HUNGARIAN DRAVA RIVER AND ITS FLOODPLAIN

The Drava is an important tributary of the Danube. Its length is 720 km and total catchment area is estimated between 40,150 and 41,810 km^2, of which 6,160 km^2 (ca 15%) lies in Hungary (236 to 70.2 river kilometre), where it is a border river with Croatia (except for a 29-km section) (Sommerwerk et al. 2009; VKKI 2010). (Although for historical reasons the international border does not follow the thalweg of the present river channel.) As opposed to the upper Alpine catchment of high relief, consisting of gorges and a narrow floodplain, the lower catchment in the Carpathian Basin is mostly of hilly and lowland character with a wide floodplain (of which ca 486 km^2 belongs to Hungary), bordered by high bluffs in shorter sections, and elongated shape, open to the east. The latter circumstance has important implications for precipitation conditions (see e.g. Kiss et al. 2013). For instance, in 2010, a year with extremely humid weather, no significant flood was measured on the Lower Drava River. The climate of the catchment is characterized by winter drought (January to March), wet summers (Atlantic influence in June-July) and autumns (Mediterranean influence in October-November) (Lovász 1972). Higher discharges in the period April to June are due to snowmelt in the southern ranges of the Eastern Alps. Average precipitation on the Hungarian catchment is around 720 mm and runoff is 435 mm, but the influence of this inflow on the water regime of the Drava is much more limited than that of the Alpine catchment. The climatic conditions are reflected in equable annual and monthly river regime, where only moderate variations are observed. Due to global warming, the duration of river ice has been considerably reduced: in the 1930s the river was commonly frozen for 28-30 days, while in the 1990s only for 2-3 days. It was almost free of ice cover in the 21st century. However, in the winter 2013/14 record amounts of snow (5.9 km^3) accumulated on the Alpine catchment by 27 February (National Water Management Service).

2.1. Hydromorphology

Since the assessment of rehabilitation potential focuses on the floodplain rather than on the Drava channel, the parameters of the latter are only briefly presented here. In Hungary the mean *discharge* of the river is 496 m^3s^{-1} at the Barcs gauge, with long-term (1901-2000) low flow 190 m^3s^{-1} and high flow 1,433 m^3s^{-1} (for the Drávaszabolcs gauge, where hydrological observations began in 1936, the same parameters are 525, 220 and 1,365 m^3s^{-1}, resp.) (OFTE 2007). (The considerable difference between discharges measured at the upper and lower river gauge is explained by floodplain storage during flood waves.) The highest flood discharge was 3,070 m^3s^{-1} at Barcs (recorded on 19 July 1972), while lowest ever discharge in December 2001-January 2002. High daily fluctuation in water level results from the peak-time operation of the Dubrava hydroelectric plant in Croatia. It amounts to 110-130 cm at Őrtilos, 50-70 cm at Barcs and 30-40 cm at Drávaszabolcs. (The dams on the Austrian and Croatian sections of the river created artificial conditions and make the selection of reference sites for rehabilitation extremely difficult.)

2.2. Active floodplain

The Drava is a regulated river with active floodplain on the section from 140.8 to 70.2 rkm. Minimum *width* of the active floodplain is 80 m, while maximum width is 1,800 m. On the average floodplain width is 650 m, which compares with the 3,500 m average width and 14,500 m maximum width of the morphological floodplain, which includes the active floodplain and the former, now flood-protected, floodplain outside the levees. The sheer width of the floodplain could be reckoned as a major factor in the assessment of rehabilitation potential (Lóczy, 2013). The vegetation of the active floodplain of the Hungarian bank is softwood forest plantations and subordinately wet meadows, mostly in the vicinity of oxbows (Ortmann-Ajkai et al. 2003).

2.3 Oxbows

Due to the common anastomosing channel pattern, the active floodplain of the Drava River abounds in *by-channels*. The South-Transdanubian Water Management Directorate surveyed 20 of them and found them in a progressed state of siltation (OFTE 2007). Three of the by-channels have already been revitalized, i.e. they were dredged and flushed through after their closures being (partially) removed. A relief of 2-3 m is typical of the morphological floodplain. The total number of channel reaches of the Drava (beyond the flood-control levees) which were *cut off* through natural processes in historical times or artificially in the course of river regulation originally amounted to 18, but most of them has been completely infilled and shows no water surface today. In 2014 eight of them are registered as oxbow lakes (Table 1). Eutrophication rapidly reduces the depth and open water surface of oxbows. The utilizaton of oxbow lakes is mostly for angling and they are also important plant species and bird refuges (Pálfai, 1998).

Table 1 Major oxbow lakes in the Drava floodplain (updated after Pálfai, I. 1998)

Oxbow	Lake	Length (km)	Width (m)	Depth (m)	Open water surface (hectares)	Settlement
Cún-Szaporca	Kisinc	1.3	100	1.0	20	Szaporca
	Kishobogy	0.6	50	0.5	6	Szaporca
	Szilhát	0.6	80	0.5	6	Cún
Majláth-puszta	Majláth-puszta	1.8	40	0.5	4	Kisszentmárton
Bresztik	Bresztik	1.5	70	0.8	1.9	Drávasztára
Verság	Verság	1.3	60	1.0	7	Piskó
Matty	Matty	1.2	100	1.2	10	Matty
Matty Old Drava	Hótedra	1.1	40	1.5	4	Matty

3 THE ANCIENT DRAVA PROGRAMME

The ongoing research also serves as a baseline survey for a large-scale rehabilitation scheme, the so-called ”Ancient Drava” Programme. Beginning to be implemented in late 2013 for the Ormánság, the lower floodplain segment of the Hungarian Drava, an economically and socially disadvantaged region, the Programme affects 43 settements on 45,000 hectares of land and will cost close to EUR100 million. By 2020 it is envisoned that the rehabilitated wetlands will attract ecotourism (for instance, anglers), improved water supply will allow irrigated agriculture and local inhabitants to earn their living from traditional economic activities.

Authors are convinced that the project can only be successful if the plans of water recharge are prepared in view of the rehabilitation potential of the floodplain, which serves as the basis to judge the success of rehabilitation (Jähnig et al. 2011). Drawing on the experience from their previous investigations in the Kapos River floodplain (Lóczy 2012, 2013), authors are surveying the present-day (baseline) hydrogeological, hydromorphological and landscape ecological conditions of the floodplain with special regard to oxbow lakes and attempt to estimate the rehabilitation potential of the floodplain. Here two crucial segments of the complex water recharge network are highlighted: the Korcsina canal (joining the Drava at 119.9 rkm – Fig. 1) and the Fekete-víz stream. At present the Fekete-víz is in connection with the main channel at 83.1 rkm and 76.7 km, but according to the plans it will recharge the Cún-Szaporca oxbow (Fig. 2), which will be linked to the river at 88 rkm.

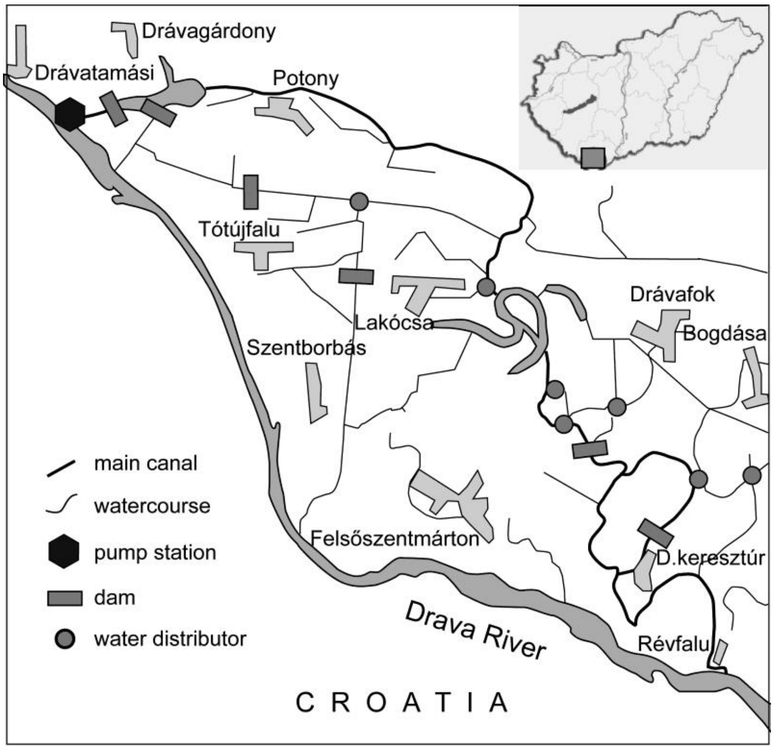

Figure 1 Detail of the water recharge scheme in the upper Ormánság section of the Hungarian Drava floodplain (after OFTE 2007)

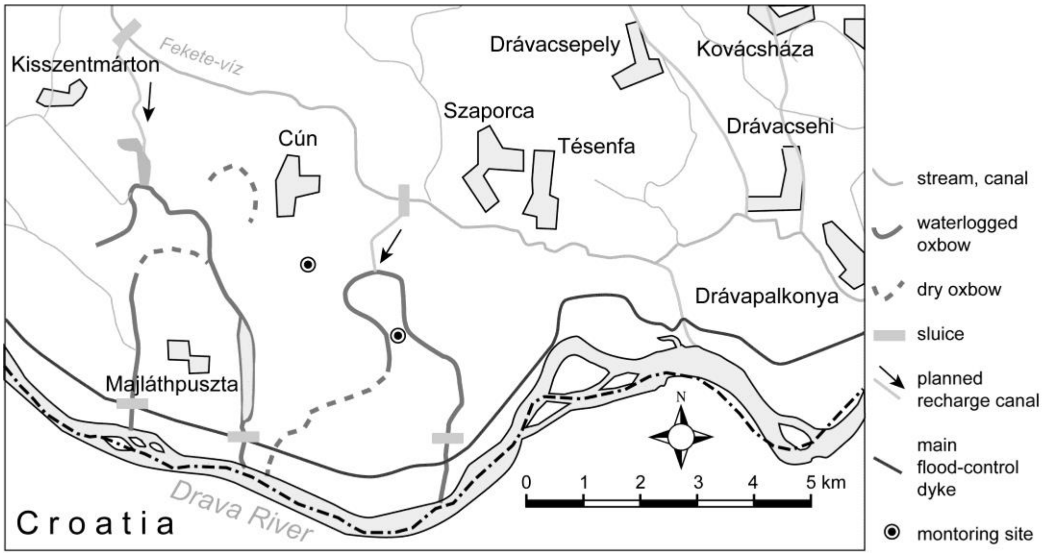

Figure 2 Projected water transfers the Majláth-puszta and Cún-Szaporca oxbow study areas

Water replenishment in the upper Ormánság is based on water transfer along the 44-km long canal system named after the *Korcsina* Stream. At higher water levels gravitational flow is possible through a sluice built into the flood-control levee and water recharge will affect 81 km^2 area. The canal is also suitable to collect excess water from the inundated floodplain and conduct it to pumping stations, where it is discharged to the channel. In gravitational operation the conduction capacity of the Korcsina canal is 5.5 m^3s^{-1} and in pumping 1 m^3s^{-1}. The bottom width of the canal is 1 m and its average slope ranges from 0.054% on the upper section to 0.014% on the lower. For six kilometres the canal follows the course of a triple oxbow system. This solution is meant to promote groundwater recharge for agricultural, forestry and nature conservation purposes.

The 23-km long *Fekete-víz* canal system collects runoff from the southern Baranya Hills through the streams Pécsi-víz and Okor. Its bottom width is 3.0 m, slope ranges from 0.023 to 0.038%. Parallel to the canals 5-7 m high levees serve flood control since floods on the Drava may impound stream flow. This recharge system supplies water to one of our study areas, the Cún-Szaporca oxbow (see later).

The Ancient Drava Programme has complex objectives (AQUAPROFIT 2010). It is an ambitious regional development programme, which outlines conditions to be reached through future development and involves a wide range of measures to this end. A central chapter of the programme is a *landscape management plan*, which paves the way to the restoration of some of the traditional and environment-friendly economic activities widespread before river regulation. Behind this plan lies a new water governance strategy, which allows groundwater replenishment, the irrigation of 5,000 hectares of agricultural fields and the establishment of 700 hectares of open water surfaces. The Programme also includes revitalisation interventions on seven by-channels of the Drava River and the rehabilitation of oxbows now with poor connectivity with the main channel.

The implementation of the Ancient Drava Programme depends on a series of preconditions and some considerations are *critical* in this respect. Among them, the retention of floodwater through the revitalization of old meandering channels together with their riparian vegetation is of fundamental significance. Environmental/ecological flow is to be ensured by the construction of bottom weirs and flood gates. According to landscape ecologists (Lehmann et al. 1996; Lantos, 2005) land management and landscape pattern should be adjusted to the water supply realized by the recharge system, while the scheme primarily intends to meet the water demand of large-scale farming.

Floodplain *afforestation* is regarded by planners as a biological tool for water retention. A total of 3,296 ha of irrigated forests are planned. In addition, the energy plantations which serve to supply the Pécs power plant with fuel also need appropriate groundwater levels. However, this benefit of floodplain forests has not been proved by research on forest water budget (for Hungary see e.g. Móricz et al. 2011). Evapotranspiration from the forest canopy usually represents a much greater moisture loess than the gain from the increase of infiltration and reduction of runoff. The water supply of the floodplain would strongly depend on whether *environmental flow* could constantly be ensured. Pumping would raise the costs of recharge to unacceptable levels. A debated issue concerns the future ecological conditions in oxbows in response to feed-*water quality*. Water recharge would also involve *land use conflicts*, which are difficult to resolve on scientific basis. Similar conflicts may arise between subsistence and market economy, family farms and large-scale industrial farming.

4 STUDY AREA

The lowest-lying sections of the Drava floodplain, next to the channels of the Drava and its tributaries almost entirely consist of silty deposits and hardly suitable either for intensive cultivation or human settlement. The main floodplain features are oxbows and other abandoned channels with natural levees and scroll bar systems, backswamps and to the north flat-topped elongated blown sand dunes of west to east strike, locally called 'ormány' (tusk), which gave the name of the Ormánság region.

Two abandoned channel beds, now oxbow lakes, had been selected for investigation. The Majláth-puszta oxbow is a 6-km-long cut-off from the times of 19th century regulations with a relatively deep and intensively used lake (Table 1) and swamps to the east and extensive softwood forests in the west. The Cún-Szaporca oxbow, a 257-hectare nature reserve since 1969, is a water fowl sanctuary within the Danube-Drava National Park (Závoczky 2007) (Table 1; Fig. 2). The oxbow was cut off through natural process some centuries before river regulation, but it had communication with the main channel during flood stages, until 1975, when a new alignment of flood defence line and the Kisinc sluice was built. In the cases of both lakes water inflow from the direction of the Drava, however, is irregular and insufficient to prevent decay. The oxbows are bordered by softwood willow forests, hardwood ash and oak forests, inserted in the matrix of intensively used agricultural fields.

5 METHODS

The ongoing research intends to supplement the hydromorphological pilot survey of the Drava and Mura rivers (FLUVIUS 2007) from the viewpoints of major ecosystem services associated with surface and groundwater availability, soil conditions, vegetation and biodiversity. After identifying the components of the floodplain rehabilitation potential, as conceived in a recent report for the Danube (WWF International 2010), an integration of hydrogeomorphological and ecological properties is planned (Meitzen et al. 2013).

The assessment of restoration/rehabilitation potential covers the study of floodplain landforms (size, shape, configuration, connectivity), landscape pattern, vegetation, land use from the aspects of the maintenance of protected areas and performing various ecological functions (ecosystem services) (WWF International 2010; Waidbacher & Schultz, 2005). Floodplain connectivity is studied from hydrological and ecological (biodiversity) aspects (Tockner et al. 1999, 2010). Eventually, we intend to find an answer to the question whether the Ancient Drava Programme successfully fulfilled its tasks.

Landforms (first of all oxbows) are evaluated for their flood retention potential (Lóczy, D. 2012, 2013) and water availability for aquatic and riparian vegetation. Special attention is devoted to the seasonal dynamics of wetlands, critical elements of landscape pattern, and the naturalness of vegetation (Dénes & Ortmann-né Ajkai 2006; Ortmann-Ajkai et al. 2012). The interactions between landform, groundwater dynamics and vegetation conditions are studied in detail in seasonal dynamics in order to establish opportunities for the required surface and subsurface water replenishment and estimate its spatial extension. The techniques employed cover the processing of archive water budget data, field monitoring of groundwater conditions, well testing and soil profiles analyses, in the future supplemented with remote sensing survey of land use and vegetation dynamics.

Groundwater recharge regulation as a principal ecosystem service is central in our investigations. In the past century dropping groundwater table negatively influenced forest growth, primarily the valuable oak stands (Lehmann et al. 1996). After the implementation of revitalization plans by the water management authority, a rise in groundwater levels should ensue. It is open to debate to what extent the artificially raised water level of the oxbows would affect the groundwater table in adjacent areas since this requirement contradicts the goal of retaining water in the oxbow bed. The two groundwater monitoring stations are in operation since September 2013 and meant to reveal the influence of higher water levels in the oxbows on the water budget of the immediate environs. Well tests were performed to estimate the extent of subsurface communication between the oxbow and the Drava channel.

The opportunities for the restoration of macrophyte vegetation can be assessed through habitat classification using the Floodplain Index (Waidbacher & Schultz 2005) and the rating of connectivity based on the indicator plant system (Janauer et al. 2012). The processing of survey data (Ortmann-Ajkai et al. 2003; Dénes & Ortmann-né Ajkai 2006) is under way.

6 RESULTS AND DISCUSSION

In this first phase of research, the accumulated monitoring data does not yet allow final answers to the questions asked at the onset of the project. The flood retention function of the studied oxbows is hindered by the low-capacity of the outdated sluices and the siltation of the oxbow lakes. The merging of the individual lakes in the Cún-Szaporca oxbow would create a higher capacity for water storage (on ca 50 hectares) and a more extended habitat at the same time. Even if this engineering intervention is implemented, because of the complex fluvial sequence, the oxbow lake will not be able to raise groundwater levels regionally. Infiltration and soil moisture content monitoring indicates rapid responses to local impacts such as heavy rainfalls and snowmelt (in February 2014) (Fig. 3). In contrast, the preliminary results of groundwater observations show that in the environs of the oxbow groundwater flow heavily depends on the water stage of the Drava (Fig. 4), but at low water groundwater flow is invariably directed towards the river channel (particularly from Lake Kisinc, where the water level is up to 1 m above the groundwater table). Low waters are increasingly common as a consequence of the subsidence of the Drava basin and the incision of the river channel. The clogging (biofilm development) of the oxbow bed may adversely influence groundwater flow. Well testing indicates that with a 3-m deep fluvial sequence of highly variable grain size under the oxbow bed, 15 days are needed for 0.5-m drop in water level. As far as water recharge in the drought months (July and August) are concerned, the calculations of water deficit by the water management authority are based on precipitation observations at Pécs. If the Szaporca rain gauge is accepted as basis, the resulting values, 0.17 $m^3 s^{-1}$ for July and 0.14 $m^3 s^{-1}$ should be increased by ca 15%.

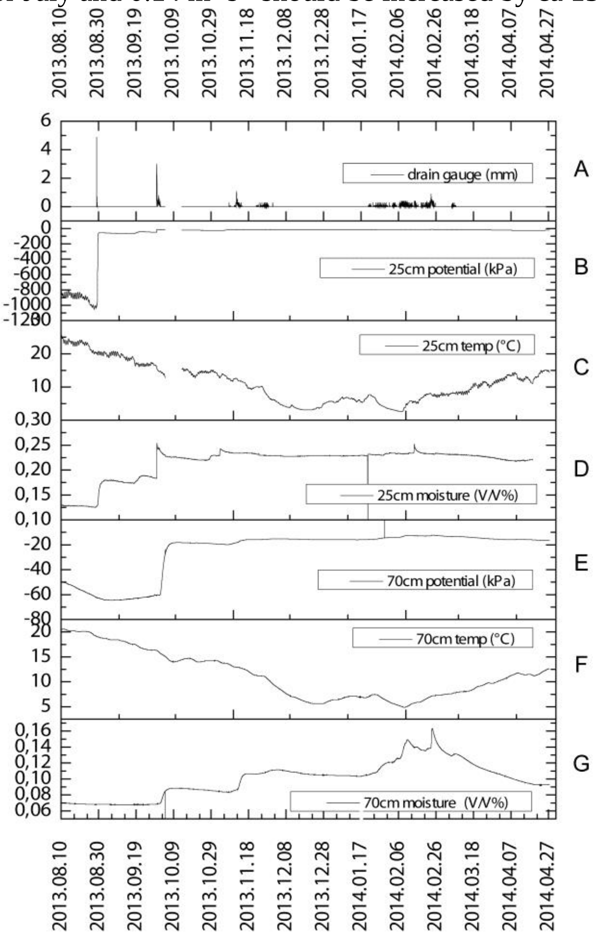

Figure 3 Results of groundwater monitoring at the Cún-Szaporca oxbow. A – 30-minute infiltration (mm); B – water retention potential at 25 cm depth (kPa); C – temperature at 25 mm depth (°C); D – soil moisture content at 25 cm depth (V/V%); E – water retention potential at 70 cm depth (kPa); F – temperature at 70 mm depth (°C); G – soil moisture content at 70 cm depth (V/V%)

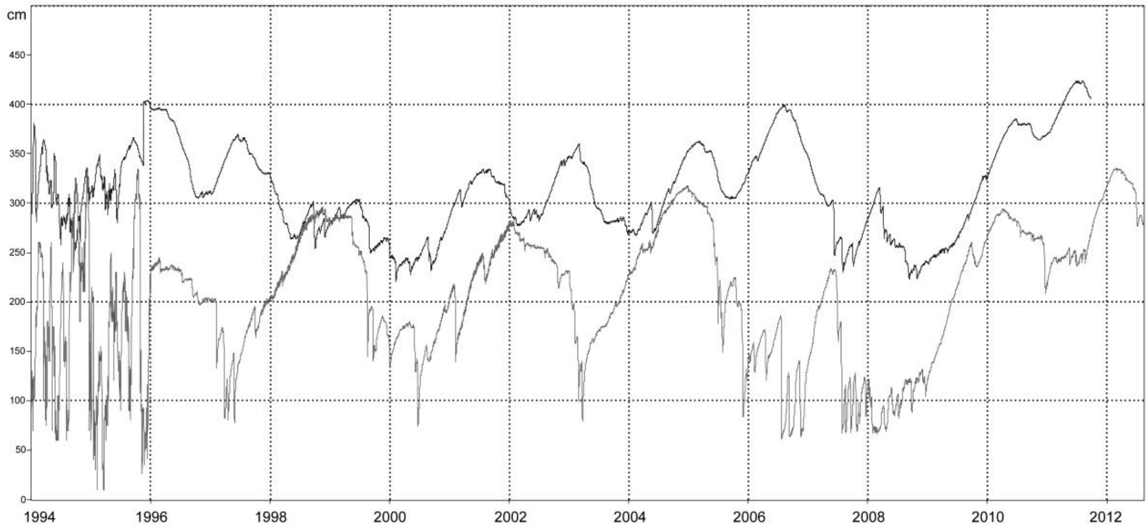

Figure 4 Groundwater table levels at Drávaiványi, in the morphological floodplain of the Drava River (lower curve), and at Drávafok, on a sand mound, at 8.5 km distance from the channel (upper curve)

7 CONCLUSIONS

No final assessment of the rehabilitation potential of the Hungarian section of the Drava River is possible at this stage of research. The water recharge of the studied oxbows has to be strictly regulated as the inflow of too great amounts of water may be disastrous for the riparian ecosystem of the oxbows. The precise estimation of environmental/ecological flow values is critical for success and constitutes a separate part of the project. Although exceptionally high-water stages on the Drava River may last as long as 200 days (as in 1999) for most of the year (particularly in July and August), water recharge will only be possible for limited periods, but lake levels could be impounded through engineering solutions and thus ensure favourable groundwater levels at least in the immediate environs of the oxbows. The construction of the water replenishment system to the Cún-Szaporca oxbow started in late 2013. When it is completed, the first signs of impact will be observed in the water budget of the floodplain. The long-term benefits of the Programme, however, will only be observed when it is assessed to what degree the rehabilitation potential of this floodplain segment with regard to surface and groundwater, vegetation and land use conditions, performing a wide range of ecosystem services, is realized.

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REFERENCES

AQUAPROFIT 2010, *Ős-Dráva Program – Összefogással az Ormánság fellendítéséért (Ancient Drava Programme: Joint Action for Development in the Ormánság).* Executive summary. AQUAPROFIT Zrt., Budapest, 29p. [in Hungarian]

Beca 2008, Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels. *Report prepared by Beca Infrastructure Ltd for New Zealand Ministry for the Environment*, Wellington

Cairns, J. 1991, The status of the theoretical and applied science of restoration ecology. *The Environmental Professional*, **13,** 186-194.

Chovanec, A., Waringe, J., Straif, M., Graf, W., Reckendorfer, W., Waringer-Löschenkohl, A., Dénes, A. & Ortmann-né Ajkai, A. 2006, A Dráva baranyai holtágai 2. Vegetáció-térképek (Oxbows of the Drava River in Baranya county 2: Vegetation maps). *Natura Somogyiensis*, **9,** 27-38. [in Hungarian]

FLUVIUS 2007, *Hydromorphological Survey and Mapping of the Drava and Mura Rivers.* FLUVIUS, Floodplain Ecology and River Basin Management, Vienna, 140p.

Fryirs, K.A. & Brierley, G.J. 2013, Geomorphic analysis of River Systems: An Approach to Reading the Landscape. Blackwell, Oxford, 360p

Jähnig, S.C., Lorenz, A.W., Hering, D., Antons, C., Sundermann, A., Jedicke, E. & Haase, P. 2011, River restoration success: a question of perception. *Ecological Applications,* **21,**6, 2007-2015.

Janauer, G., Hale, P. & Sweeting, R. 2003, Macrophyte inventory of the river Danube: A pilot study. *Large Rivers* **14,**1-2, 229p.

Janauer, G.A., Schmidt-Mumm, U. & Reckendorfer, W. 2012, The macrophyte – floodplain habitat relationship: indicator species, diversity and dominance. *Scientific Annals of the Danube Delta Institute,* **18,** 43-48.

Kiss, T., Blanka, V., Andrási, G. & Hernesz, P. 2013, Extreme weather and the rivers of Hungary: rates of bank retreat. In: Lóczy, D. (ed.): *Geomorphological Impacts of Extreme Weather: Case Studies from Central and Eastern Europe*. Springer, Dordrecht, 83-98

Lantos, T. 2005, Markóc településfejlesztési koncepciója (Concept for the settlement development of Markóc). Manuscript. Markóc

Lehmann, A., Papp, T., Szappanos, F. & Varga, D. 1996, Élőhelyfejlesztés vízgazdálkodással a Dráva árterén (Developing habitats through water management in the Drava floodplain). *Erdészeti Lapok,* **131,**5, 150-151. [in Hungarian]

Lóczy, D. 2012, Floodplain rehabilitation schemes: example of the Kapos floodplain, Hungary. In: Gâştescu, P., Lewis, W. Jr. & Breţcan, P. (eds): *Water resources and wetlands.* Conference proceedings, 14-16 September 2012, Tulcea, Romania. Editura Transversal, Târgovişte. 71-80.

Lóczy, D. 2013, *Hydrogeomorphological-geoecological foundations of floodplain rehabilitation: Case study from Hungary*. Lambrecht Academic Publishing, Saarbrücken. 382p.

Lovász, Gy. 1972*, A Dráva-Mura vízrendszer vízjárási és lefolyási viszonyai (Hydrography and runoff in the Drava-Mura water system).* Akadémiai Kiadó, Budapest, 158p.

MEA 2003, *Millennium Ecosystem Assessment. Ecosystems and Human Well-being: A Framework for Assessment.* Island Press, Washington, D.C.

http://www.millenniumassessment.org/en/products.aspx

Meitzen, K.M., Doyle, M.W., Thoms, M.C. & Burns, C.E. 2013, Geomorphology within the interdisciplinary science of environmental flows. *Geomorphology,* **200,** 143-154.

Móricz, N., Berki, I & Rasztovits, E. 2011. A Nagyalföld erdeinek állapota és hatásuk a talajvízszintre (State of forests in the Great Hungarian Plain and their impact on groundwater levels). In: Rakonczai, J. (ed.): Környezeti változások és az Alföld (Environmental change and the Great Plain). Nagyalföld Alapítvány, Békéscsaba, 119-126. [in Hungarian]

OFTE 2007, *Ős-Dráva Program. Vízügyi műszaki terv (Ancient Drava Programme: Water Management Technical Plan).* Ormánságfejlesztő Társulás Egyesület, Sellye. 172p. [in Hungarian]

Ortmann-Ajkai, A., Czirok, A., Dénes, A., Oldal, I., Fehér, G., Gots, Zs., Kamarásné Buchberger, E., Szabó, E., Vörös, Zs. & Wágner, L. 2003, Dráva holtágak komplex állapotértékelése (Complex baseline survey of the Drava oxbows). In: Hanyus, E. (szerk.): *Az EU Víz Keretirányelvének bevezetése a Dráva vízgyűjtőjén (Introduction of the EU Water Framework Directive).* WWF Hungary, Budapest. 68-79. [in Hungarian]

Ortmann-Ajkai, A., Lóczy, D., Gyenizse, P. & Pirkhoffer, E. 2013, Wetland habitat patches as ecological components of landscape memory in a highly modified floodplain. River Res. Aplic. DOI: 10.1002/rra.2685

Pálfai, I. (ed.) 1998, *Magyarország holtágai (Oxbows in Hungary).* Közlekedési, Hírközlési és Vízügyi Minisztérium, Budapest, online version: http://www.holtagak.hu [in Hungarian and English]

Slootweg, R. & Mollinga, P.P. 2010. The impact assessment framework. In: Slootweg, R., Rajvanshi, A., Mathur, V.B. & Kohlhoff, A. (eds): *Biodiversity in Environmental Assessment*. Cambridge University Press, Cambridge, 87-124.

Sommerwerk, N., Hein, T., Schneider-Jacoby, M., Baumgartner, Ch., Ostojić, A., Siber, R., Bloesch, J., Paunović, M. & Tockner, K. 2009, The Danube River Basin. Chapter 3 in: Tockner, K., Uehlinger, U. & Robinson, Ch.T. (eds): *Rivers of Europe*. Elsevier, London, 59–112

Tockner, K., Lorang, M.S., Stanford, J.A. 2010. River flood plains are model ecosystems to test general hydrogeomorphic and ecological concepts. *River Research and Applications,* **26,** 76-86.

Tockner, K., Schiemer, F., Baumgartner, C., Kum, G., Weigand, E., Zweimuller, I. & Ward, J.V. 1999, The Danube restoration project: species diversity patterns across connectivity gradients in the floodplain system. *Regulated Rivers: Research and Management,* **15,** 245-258.

VKKI 2010. *Vízgyűjtő gazdálkodási terv. Dráva részvízgyűjtő (Drainage basin management plan: the Drava partial catchment).* Vízügyi és Környezetvédelmi Központi Igazgatóság, Budapest. 162p. [in Hungarian]
http://www.vizeink.hu/files/Reszvizgyujto_VGT_Drava.pdf

Waidbacher, H. & Schultz, H. 2005, The Floodplain Index – a new approach for assessing the ecological status of river/floodplain-systems according to the EU Water Framework Directive. *Large Rivers* **15,**1-4, 169-185.
http://www.boku.ac.at/hfa/forschung/graf/publications/large_rivers.pdf

WWF International 2010, *Assessment of the restoration potential along the Danube and main tributaries.* Working paper for the Danube River Basin. Final Draft. World-Wide Fund for Nature,Vienna, 60p.
http://assets.panda.org/downloads/wwf_restoration_potential_danube.pdf

Závoczky, Sz. 2007, Szaporcai Ó-Dráva-meder (Old Drava bed of Szaporca). In: Tardy, J. (ed.): *A magyarországi vadvizek világa (Wild waters in Hungary)*. Alexandra, Pécs, 348-353. [in Hungarian]