Journal of Env. Geogr. Vol. III. No. 1-4. pp. 25-30

CHARACTERISTICS OF THE FLOW REGIME ALONG THE REGULATED TISZA RIVER REACH DOWNSTREAM OF TISZAFÜRED

Bezdán, M.[1]

[1] VIZITERV Consult Kft, Budapest, Hungary

Abstract

In this paper, an attempt is presented at clearing the reasons of some uncommon flow phenomena observed over the Tisza reach downstream of Tiszafüred, and at pointing to the practical significance of the results obtained. Over six hundred thousand daily stage data were selected from the more than six million (!) water level data, registered from 1876 to 2009 (on the gauges between Tiszafüred and Novi Bečej (Törökbecse)). Taking the data of ground water wells into consideration, the conclusions arrived at are believed to be of interest to theoretical fluvial hydrologists, yet also to river engineers engaged in designing and operating (when needed) flood control schemes.

Key words: low-water, high-water, ground water, hysteresis function, water level drop, backwater, barrage, permanence

INTRODUCTION

The comprehensive reclamation project conceived by Pál Vásárhelyi and implemented under the management of Károly Herrich has changed flow conditions of the River Tisza and those of the tributaries substantially. Flood peaks rose by 3 to 4, and low waters dropped by 2 to 3 metres in the bed, which was shortened by 32 % of the original length. The steeper slope has increased the average flow velocities river $\sqrt{1,6}$ = 1.26 times at medium stages. The coincidence pattern and extent of interaction with the tributaries have also undergone changes (Vágás 2007).

Owing to drainage accelerated by roughly 26% in the main river and to the loss of storage space in the severed oxbows (Vázsonyi 1973), the spring and early summer flood waves travelled downriver faster and were followed by longer arid summers and longer low water periods. After up to 20 to 40 rainless days, most of the flow consists of groundwater drained by the river (Szalay 2000). Groundwater is depleted further by withdrawals for human uses (Csatári et al. 2001, Völgyesi 2005, 2009), thus lowering the ground water table (Rakonczai 2006).

The project has started hydrologic processes, which conflicted with traditional laws of fluvial engineering, and which failed to explain several of the phenomena and processes actually observed. These include the dropping low-water levels (Iványi 1948, Dunka et al. 1996, Konecsny 2010), the changes in the ground water table and the flow regime of rivers (Rónai 1985, Tóth 1995, Tóth – Almási 2001, Rakonczai 2001, Bozán – Körösparti 2005, Völgyesi 2005, 2009, Pálfai 2005, 2011, Szalai – Lakatos 2007, Marton 2010), the rising high-water water levels and the effects of the barrages (Koncz 1999, Stegăroiu 1999, Schmutz et al. 1995, Giesecke – Mosonyi 2005). More recent studies have attributed these to changes in the state of the flood bed flanked by the levees (silting and vegetation growth) and in the channel geometry (Nagy et al. 2001, Schweitzer 2001, Gábris et al. 2002, Sándor – Kiss 2006). Without intending to question the potential local significance of these effects, the hydrological phenomena dealt with below (viz., flattening flow profiles, effect of barrages and the actual hydrologic interactions between the recipient and the tributary rivers, as well as the ground water) are considered more general and substantial in nature.

Flood waves starting form the Upstream Tisza have been observed repeatedly to overtake each other before entering the middle reach. Some of such flood waves have been observed more recently to split again on the lower reach. Backwater, respectively drawdown, by the major recipients has been offered as explanation for these phenomena (Vágás 1982). The flood waves entering from the tributaries Maros and Hármas-Körös may coincide with rising or falling stages in the recipient Tisza River and raise, or lower the peaks of the latter. The actual stage in the Danube, the ultimate recipient, may also back up, or draw down the Tisza water level and even start a peak spreading upstream in the Tisza River. Such random flood waves may become perceptible as the cause of important changes in the flow regime in the Tisza River, owing to the extremely flat slope of the latter. The discharge measurements of growing frequency over the past decades have revealed that together with the gauge reading, the slope of the surface profile must also be allowed for when estimating the actual discharge (Dombrádi 2004).

The 133 years long record of flows and floods in the River Tisza has revealed that the normal velocity and direction of flow differ markedly from the velocity and direction of the flow registered during the flood peaks (Vágás – Simády 1983). The flow velocity is determined normally by the discharge, bed- and surface slope conditions of the river in accordance with the conventional laws of hydraulics, whereas the velocity of the flood peaks depends highly on the actual backwater and/or drawdown caused by the tributaries, or the main recipient (the Danube). The peak stage may spread upstream against the direction of flow over long river sections. Flood waves starting over the upper reach have been observed repeatedly to flatten over the middle, or lower reach, before entering the Danube. Although more in-depth studies on the aforementioned phenomena have been started but recently, their correlation seems obvious.

The general opinion of Huszár (1985), Bogdánfy (1906), Erdős (1920), Tellyesniczky (1923), Korbély (1909), Iványi (1948), Lászlóffy (1982), Vágás and Simády (1983) was that not all flood waves travelling down the River Tisza, but only some of them peaked earlier at upper gauging stations than one of the downstream ones, and ended "regularly" at the mouth to the Danube. An appreciable number of Tisza floods were affected on one of the middle or lower sections (not necessarily the same in every case) by backwater of a flood on the Danube or one of the Tisza tributaries – especially the rivers Maros or Körös Rivers, or drawdown in the case of their recession, so that the peak occurred earlier at the lower gauging station than at one of the upstream ones.

A hydrological phenomenon observed long ago on the Tisza River is the hysteresis loop, viz., a curve displaying the discharge of a flood wave versus the corresponding stage (Bogdán-ffy 1906, Korbély 1937, Németh 1954). Its substantial feature is a peak stage residing over the same section for a longer period of time (several days). As a consequence of these irregularities the relationships based on steady flow velocity and surface slope are limited in their validity and usefulness.

OBJECTIVES

The aim was to identify and offer theoretical and practical solutions to issues as yet not fully cleared in the Tisza River section downstream of Tiszafüred. Over six hundred thousand daily stage data were selected from the over six million water levels registered from 1876 to 2009 (on the gauges between Tiszafüred and Novi Bečej (Törökbecse).

The more specific objective was to correlate streamflow and progress of flood waves, to analyse their likelihood along the river section and in time, their statistical characteristics and to discover the hydrological and geographical reasons leading to their occurrence in the Tisza section downstream of Tiszafüred and to identify those considered extraordinary relative to other rivers.

An attempt was made at shedding new light on areas of scientific interest believed to merit further study in order to improve flood control measures by drawing on lessons learned during floods of recent decades, and made possible by latest advances in computerised analysis. The impact of the tributaries and the main recipient – the Danube – on the Tisza was the most important question, which has not received adequate attention thus far. Surface profiles in river networks comprising tributaries and recipients are prominent areas in this respect. In such networks the distinction between the velocity of river flow and that of the flood peak is believed important enough to study more in depth. The phenomenon of flood peaks spreading opposite to the direction of flow is believed unique in global fluvial hydrology.

Accelerated drainage in the wake of the Tisza Valley Reclamation Project has depleted the water resources also along the Tisza reach downstream of Tiszafüred. The extent thereof in periods of low precipitation was demonstrated on the basis of the data of ground water level detection that had started in the beginning of 1930's.

Weirs were studied for their impact on groundwater, river flow and water regime.

METHODS AND AREA OF ANALYSIS

Tisza water levels registered daily after regulation from 1876 up to 2009 on the gauging stations between Tiszafüred and Novi Bečej (Törökbecse) were processed. Surface slopes were determined as the difference in water levels registered simultaneously on two adjacent stations and divided by the distance between the respective stations. The surface slopes determined in this way were then evaluated statistically. The following river sections were studied: Tiszafüred, Taksony, Tiszabő, Szolnok, Martfű, Tiszaug, Mindszent, Csongrád, Algyő, Szeged in Hungary, and Novi Kneževac (Törökkanizsa), Senta (Zenta), Novi Bečej (Törökbecse) in Serbia. The gauge readings were divided into metre-ranges and the slopes obtained were entered in the appropriate range. The 133 years long record was also subdivided into periods.

The daily surface profiles of the Tisza were plotted and the annual lowest-, mean- and highest stages were identified. Any change over time in these water levels was examined for events and interference with the life of the river, which have actually or potentially affected the flow regime.

The annual duration of water levels below the gauge "0" and above the "600 cm mark" was noted, as well as the actual duration in the higher-than 600 cm range of the major flood waves. The flood waves travelling normally downriver, that is peaking successively at each gauging station and showing no backwater evidence were analysed. The temporal changes of the annual low level in the groundwater observation wells were compared to the low stages in the rivers. A few flood-loops were plotted making use of the scarce streamflow measurements and the corresponding gauge readings. For the same cases the conventional gauge relation curves were also drawn.

REVIEW OF THE FINDINGS

By detailed scrutiny of the over 130 years long record of river stages in conjunction with over 80 years of groundwater readings, with due allowance for human interferences in the catchment, as well as for changes in rainfall pattern, the following conclusions have been arrived at:

The major drop of low-water levels over the Martfű–Mindszent Tisza section is attributable to the substantial reduction of the runoff from, and exhaustion of, the storage opportunities in the Körös catchment. The major drop has taken place in two steps: In the 1841-1842 low-water period considered relevant for setting the elevation of the "0"point of the gauges, the combined flow in the three Körös branches was large enough to feed the Tisza section involved, so that the gauge readings were higher. Subsequent developments in the Körös catchment have depleted the low-water yield and thus reduced the discharge to the Tisza materially. The reduced low-water discharge from the Körös catchment has flattened the former bulge on the low-water surface profile on the affected section (*Fig. 1*).

The low-water surface profiles react promptly to changes in the tributary discharges. Reduced inflow from the Körös catchment has reduced the low-water streamflow in the recipient Tisza downstream of Csongrád. This, in turn, has allowed more pronounced effect of the backwater caused by discharge of the tributary Maros. As the consequence thereof, the surface slopes decreased from the Maros mouth upstream as far as Csongrád. On the other hand, upstream of the Körös mouth the surface slope became steeper again, because the low inflow from the Körös causes no backwater in the Tisza (Bezdán 2010a, 2010b).

Completion of the Tiszalök Dam in 1957 and of the Eastern Main Canal in 1965 has relieved dry-weather water shortage in the region and raised low-water flows in the river section studied. Additional supplies to the region were channelled from the Kisköre Dam and the Western Main Canal. The low-water surface profiles became even smoother thanks to the backwater of the Novi Bečej Dam (1976).

Flood waves travel downriver with different surface slopes. The average slopes on the various sections were calculated from widely scattered data. In terms of percentages the differences are formidable and play a significant role in changing the water levels. When compiling stage forecasts, local distribution of rainfalls must also be allowed for (Bezdán 2010a, 2010b).

Except for river sections impounded also at low-water, surface slopes become steeper with falling depth. At mean water the surface slope is flatter than at low water. The cause of this phenomenon is that downstream of the mouth of a tributary, the discharge thereof is added to that of the recipient Tisza, the water level in the latter rises with a steep surface slope. On the other hand, upstream of the mouth the flow in the recipient is backed up, the water level is raised, while the surface slope becomes flatter and may assume even negative values. Over the section affected peaking is delayed and an inverted flood loop occurs. Such reversed flood loops develop on river section(s) upstream of backwaters. Immediately downstream of tributary mouths normal flood loops may be expected. In cases where the backwater effect of the recipient, or a tributary, or a weir extends upstream beyond the mouth of a recipient, the sense of the flood loop downstream of the mouth will depend on the actual discharge of the tributary (Bezdán 1997, 1998, 1999, 2008, 2010a, 2010b).

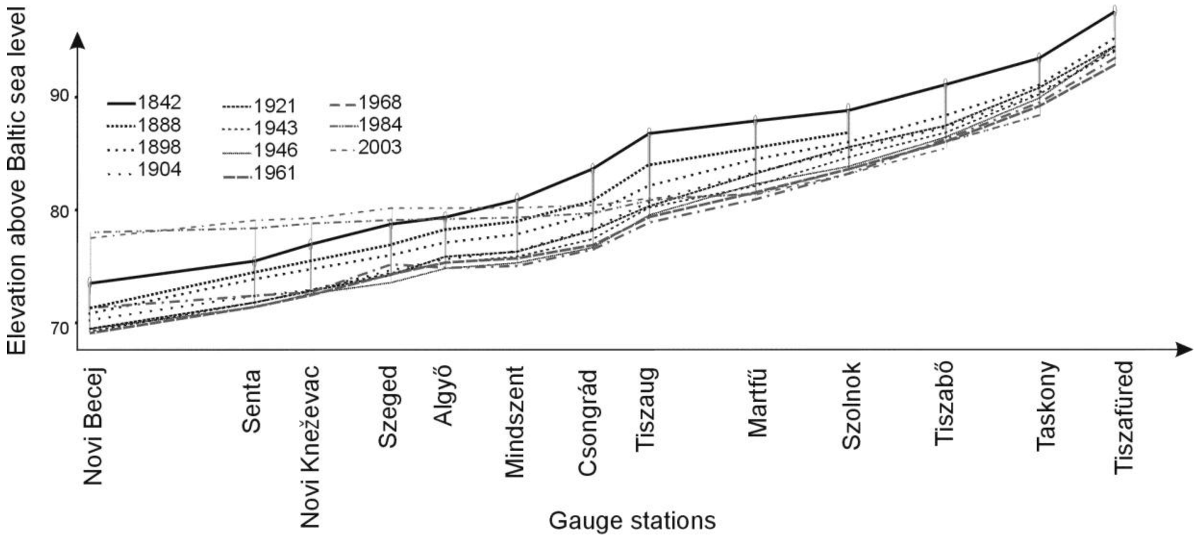

Fig. 1 Surface profiles of lowest low-waters in the years indicated

Over 70% of the Tisza flood waves were backed up by one of the tributaries or the Danube during the 1876 to 1975 period. More than 90% of the flood waves peaking with stages above the 600 cm range belonged to this category. Since the Novi Bečej Dam was commissioned in 1976, backwater has raised 80% of the flood waves and 95% of those with overbank stages. Conveyance of virtually all high floods is affected also by the fact that these are under the combined influence of two or more tributaries and since 1976 also of the Novi Bečej Dam. The most often backed up river section in the high-water ranges are those between Tiszaug and Algyő. Since the dams were commissioned, flood waves were backed up repeatedly along these sections. Flood waves peaking within the banks in the pre-dams period were backed up by the Danube beyond Szeged in 25% of the cases, this percentage having grown to 48% since the Novi Bečej Dam started operating. Of the overbank floods backed up beyond Szeged, 25% were registered before 1976 and 20% thereafter. This information is of paramount interest in forecasting and fighting floods. The number of flood waves peaking in “reversed order” decreases with distance from the river causing them. The number of peaks attributable to the Danube backwater decreases with distance from the Tisza mouth, but owing to the clearly undistinguishable simultaneous influence of the Körös and Maros tributaries, the relationship is not a straightforward one. The unbalanced distribution of the occurrence of all “reversed” flood waves may be influenced by the possibility of interference between several gauging stations (Bezdán 1999, 2008).

Owing to backwater from the recipient, some flood peaks occur upstream of the mouth of a tributary. Thus 40% of the Tisza flood waves since 1876 and peaking at all gauging stations terminated upstream of Senta. This figure is 54% for flood waves peaking above the 600 cm mark. Since 1976, when the Novi Bečej Dam started operating, 58% of the flood waves terminated at one of the stations upstream of Senta, whereas formerly this figure was 28%. Of the flood waves peaking in the higher-than 600 cm range those advancing farthest downstream occurred most frequently between the stations Martfű and Szolnok during the 1876-1975 period. After 1976 most flood waves peaked latest along the Martfű, Tiszaug and Mindszent section. For the apparent “retardation” of the Tisza flood waves described by several authors, random changes of the actual hydrologic conditions in the catchment are believed responsible, rather than spontaneous, or artificial hydromorphological changes in the river bed. This information should be remembered when contemplating levee reinforcement projects (Bezdán 1999, 2002).

During the 1976-2009 period, over the Tisza sections influenced by dams and weirs the low-water surface slopes decreased, while their statistical scatter widened. The high-water-slopes, on the other hand, became steeper with a narrower scattering range (Bezdán 2010a, 2010b).

Downstream of the Kisköre Dam commissioned in 1973 the lowest low-water levels dropped until the year 2009 by more than 100 cm at Taskony, 50 cm at Tiszabő, 20 cm at Szolnok and 10 cm at Martfű, Parallel thereto, the duration of low water levels has grown.

Novi Bečej (Törökbecse) Dam commissioned in 1976 has created a backwater reach extending normally upstream to Csongrád (in the range of lowest low-waters up to Tiszaug) and raising the low-water level at Tiszaug by 55 cm, at Csongrád by 105 cm, at Mindszent by 150 cm, at Algyő by 170 cm, at Szeged by 200 cm, Novi Kneževac by 270 cm, at Senta by 300 cm, while at the dam itself by 385 cm on the average. This means that at lowest low-water the average readings on the same gauging stations became -240, -135, -25, 50, 70, 140, 205 and 270 cm, respectively. The dam has thus actually eliminated low-waters in its vicinity, reducing flow velocities virtually to zero.

Releases of low and medium flows are thus completely controlled by the dam. This implies at the same time that the channel along the backwater reach has no influence any more on the flow regime and functions actually as an impounded system, which stores the water until it is released as scheduled by the dam operator (Bezdán 1994).

Upstream of Kisköre Dam the lowest backwater level has increased by more than one metre since the nineties. Silting has raised the lowest backwater by 30-50 cm also upstream of Novi Bečej Dam. The water levels at high flows are influenced by the dams and weirs, as well as by the discharges of tributaries. Kisköre Dam influences the flow regime by the water stored behind it in that any arriving flood wave spills over a raised water level rather than over a low one, changing the original conditions. Flood levels may then be raised substantially downstream as far as the southern national boundary, especially in then event of simultaneous flood discharges from the aforementioned two major tributaries (the Maros and the three Körös branches).

At times of major flood waves, the backwater upstream of the Novi Bečej Dam merges the former gauge relation curves as far upstream as Tiszaug. Traces of the historic gauge relations are difficult to recognise even at times of high Maros floods. This means that river flows are controlled by the Novi Bečej Dam also during high-water periods, in that releases depend on the conveying capacity of structure. The arriving flood flows are thus necessarily stored and raise the water level in the limited flood-bed volume enclosed by the flood levees up to the Kisköre Dam. The rate of release at the mouth depends not necessarily on the rate of the original inflow, but on the conveying capacity and hydrologic state of the recipient streambed comprising the dam. During the pre-dam period the traditional gauge relation curves have clearly revealed any backwater and substituted the flood loops representing the stage-discharge relation and offered partial compensation for the scarcity of discharge measurements (Bezdán 1994).

Besides backwater, dams are prone to raising also the groundwater table. Owing to the local topography and soil conditions, this impact is especially pronounced in the surroundings of the Novi Bečej Dam, where the groundwater never sinks below a certain elevation. Higher groundwater under large areas in low-water periods has reduced the water absorbing capacity of the soil relative to the former, natural conditions. Infiltration from the storage ponds built in the elevated parts of the catchment has also raised the groundwater table. The resultant impact consists of shorter low water periods and longer duration of medium- and high waters. The lowest water tables sustained by the dams are also higher than those prior to the construction of the storage ponds, which prevent the groundwater from sinking below a certain level even in dry periods. Flood waves entering the Hungarian reaches from the headwaters encounter drastically changed conditions, in that backwater raises base water levels in the rivers possibly without higher streamflow rates controlled by dams.

CONCLUSIONS

Any statistics of water levels, sediment transport and channel morphology compiled on the Tisza River will be necessarily misleading without allowance for the fact that dams cause fundamental changes in hydrologic and sediment transport processes alike. This is why however long historical records and such created after the commissioning of dams must be considered separately.

Csongrád Dam postponed repeatedly, would be an important link in the canalised Tisza River. In a sequence of dams in which the backwater of a downstream one extends to the tailwater of the one upstream, silting in the headwater and erosion in the tailwater are much less pronounced than in more loosely spaced schemes. Yet the river strives to attain equilibrium conditions so that high rates of sediment transport are attenuated gradually. According to experiences gained thus far, dams change the flow regime, raise the low-, medium- and high water levels, reduce flow velocity and cause silting.

Over the Tisza reaches downstream of Kisköre Dam frequent and occasionally conspicuous natural and man-made backwaters (caused by the Körös and Maros tributaries, the Novi Bečej (Törökbecse) Dam and the Danube) raise strong doubts as regards the effectiveness of emergency reservoirs upstream. Higher levels of safety against floods of higher peaks and longer durations would be achieved by raising and strengthening appropriately the existing defences.

Acknowledgement

The author is grateful to László Márfai (OVK), Tiborné Göldner (OVK), Miklós Lázár (ATIKÖVIZIG), Brandenburg Róbert (ATIKÖVIZIG), László Márfai (jun.) (ATIKÖVIZIG) and József Szalai (VITUKI) for help in collection of data, and to Levente János for the ardous work of processing the data. I am also indebted to Dr. János Rakonczai for advice and scientific support.

References

Bezdán M. 1994. Teljesítőképességi elemzés az algyői belvízrendszer példáján. *Hidrológiai Közlöny* 74/6: 381-383

Bezdán M. 1997. A vízhozam és a vízállás különleges kapcsolatai a Tisza vízjárásában. *Hidrológiai Közlöny* 77/3-4: 197-202

Bezdán M. 1998. Kölcsönhatások a Tisza-vízgyűjtő folyóin. *Hidrológiai Közlöny* 78/4: 247-249

Bezdán M. 1999a. Árhullámok előfordulása a Közép- és Alsó-Tiszán. *A Magyar Hidrológiai Tárasaság Vándorgyűlés Kiadványa*. Miskolc: MHT. 14-21

Bezdán M. 1999b. A Tisza balparti mellékfolyóinak hatása az árhullámokra. *Hidrológiai Közlöny* 79/2: 89-99

Bezdán M. 2002. Árhullámok befejeződése a Közép- és Alsó-Tiszán. *Hidrológiai Közlöny* 82/2: 123-126

Bezdán M. 2008. A folyó-vízszín természetes duzzasztásának és süllyesztésének hatásai a Tisza középső és alsó szakaszán. *Hidrológiai Közlöny* 88/1: 9-26

Bezdán M. 2010a. A vízszín-esések alakulása az Alsó-Tiszán. *Hidrológiai Közlöny* 90/5: 29-36

Bezdán M. 2010b. A Tisza Szolnok és Szeged közötti szakaszának vízszín-esése. *Hidrológiai Tájékoztató* 2010: 65-66

Bogdánfy Ö. 1906. A természetes vízfolyások hidraulikája. Budapest: Franklin Társulat. 250 p

Bozán Cs. – Körösparti J. 2005. Földárja a Dél-Alföldön. *Hidrológiai Közlöny* 85/3: 7-13

Csatári B. et al. 2001. A Tisza-vidék problémái és fejlesztési lehetőségei. Fejlesztési program. Kecskemét. Online at: http://www.alfoldinfo.hu/tisza/tiszakotet.html

Giesecke J. – Mosonyi E. 2005. Wasserkraftanlagen. Planung, Bau und Betrieb. Berlin-Heidelberg: Springer Verlag. 830 p

Dombrádi E. 2004. Vízhozam- és vízállás- idősorok analízise a folyómeder állapotváltozásainak kimutatására. *Hidrológiai Közlöny* 84/4: 57-60

Dunka S. – Fejér L. – Vágás I. 1996. A verítékes honfoglalás. A Tisza szabályozás története. Budapest: Vízügyi Múzeum, Levéltár és Könyvgyűjtemény. 215 p

Erdős F. 1920. Tisza-szabályozás. *A Magyar Mérnök és Építész Egylet Közlönye* 54: 5-11

Gábris Gy. − Telbisz T. − Nagy B. − Bellardinelli E. 2002. A tiszai hullámtér feltöltődésének kérdése és az üledékképződés geomorfológiai alapjai. *Vízügyi Közlemények* 84/3: 305-322

Huszár M. 1985. Vízrajzi értekezés a Körösvidékről (Hungarian edition of the Latin work, written in 1823). Gyula: Körösvidéki Vízügyi Igazgatóság. 63 p

Iványi B. 1948. A Tisza kisvízi szabályozása. *Vízügyi Közlemények* 30/2: 131-159, 30/3: 271-304 and 30/4: 398-435

Koncz J. 1999. Mit üzen Ausztria keleti szomszédjainak a Freudenaui Dunai Vízerőmű felavatása alkalmával? *Hidrológiai Közlöny* 79/3: 161-163

Konecsny K. 2010. A kisvizek főbb hidrológiai statisztikai jellemzői a Berettyó folyón. *Hidrológiai Közlöny* 90/4: 31-40

Korbély J. 1909. Az árvízjelzés, tekintettel a Körösök és a Berettyó vízjárására, valamint a Tisza szegedi és csongrádi vízjárására. *A Magyar Mérnök és Építész Egylet Közlönye:* 30-73

Korbély J. 1937. A Tisza szabályozása. Debrecen: Nemzeti Könyv- és Lapkiadó Vállalat. 25 p

Lászlóffy W. 1982. A Tisza. Budapest: Akadémiai Kiadó. 610 p

Marton L. 2010. Alföldi rétegvizek potenciometrikus szintjeinek változása. *Hidrológiai Közlöny* 90/2: 17-21

Nagy I. – Schweitzer F. – Alföldi L. 2001. A hullámtéri hordaléklerakódás (övzátony). *Vízügyi Közlemények* 83/4: 539-564

Németh E. 1954. Hidrológia és hidrometria. Budapest: Tankönyvkiadó. 662 p

Pálfai I. 2005. Földárja, az Alföld sajátos hidrológiai jelensége. *Hidrológiai Közlöny* 85/3: 15-18

Pálfai I. 2011. Aszályos évek az Alföldön 1931–2010 között. In: Rakonczai J. (ed.) Környezeti változások és az Alföld. A Nagyalföldi Alapítvány kötetei 7. Békéscsaba. 87-96

Rakonczai J. 2001. A környezeti változások hatása az alföldi táj átalakulására. Magyar Földrajzi Konferencia 2001. CD edition.

Rakonczai J. 2006. Klímaváltozás – Aridifikáció – Változó tájak. In: Kiss A. – Mezősi G. – Sümeghy (eds.) Táj, környezet, társadalom / Landscape, environment and society. Szeged: SZTE. 593-601

Rónai A. 1985. Geologica Hungarica. Az Alföld negyedidőszaki földtana. Budapest: Magyar Állami Földtani Intézet–Műszaki Könyvkiadó. 446 p

Sándor A. – Kiss T. 2006. A hullámtéri üledék-felhalmozódás mértékének vizsgálata a Közép- és az Alsó–Tiszán. *Hidrológiai Közlöny* 86/2: 58-62

Schmutz St. – Mader H. – Unfer G. 1995: Funktionalität von Potamalfischaufstiegungshilfen im Marchfeldkalasystem. *Österreichische Wasser- und Abfallwirtschaft* 47/3-4: 43-58

Schweitzer F. 2001. A magyarországi folyószabályozások geomorfológiai vonatkozásai. *Földrajzi Értesítő* 50/1-4: 63-72

Stegăroiu P. 1999. Vízilétesítmények hatása folyók vízjárására. *Hidrológiai Közlöny* 79/1: 19-22

Szalai S. – Lakatos M. 2007. Éghajlatváltozás, éghajlati érzékenység. *Hidrológiai Közlöny* 87/5: 29-32

Szalay M. 2000. Az Alföld felszíni vízkészlete. In: Pálfai I. (ed.) A víz szerepe és jelentősége az Alföldön. A Nagyalföld Alapítvány kötetei 6. Békéscsaba: Nagyalföld Alapítvány. 96-104

Tellyesniczky J. 1923. A Tisza-völgy árvizei és árvízmentesítése. *Vízügyi Közlemények* 5/1: 10-21

Tóth J. 1995. A nagy kiterjedésű üledékes medencék felszín alatti vizeinek hidraulikai folytonossága. *Hidrológiai Közlöny* 75/3: 153-160

Tóth J. – Almási I. 2001. Interpretation of observed fluid potential patterns in a deep sedimentary basin under tectonic compression: Hungarian Great Plain, Pannonian Basin. *Geofluids* 1/1: 11-36

Vágás I. 1982. A Tisza árvizei. Budapest: VÍZDOK. 283 p.

Vágás I. 2007. Második honfoglalásunk: a Tisza-völgy szabályozása. *Hidrológiai Közlöny* 87/3: 30-38

Vágás I. – Simády B. 1983. Az árvízi előrejelzés fejlesztésének Szegeden kialakított módszerei és eredményei. *Vízügyi Közlemények* 65/3: 347-368

Vázsonyi Á. 1973. A Tisza-völgy vizeinek szabályozása. In: Ihrig D. (ed.) A magyar vízszabályozás története. Budapest. 281-370

Völgyesi I. 2005. Mennyit termelhetünk a felszín alatti vízkészletekből? *Hidrológiai Közlöny* 85/5: 20-24

Völgyesi I. 2009. Ökológiai vízigény, vagy megfelelő talajvízszintek. *Hidrológiai Közlöny* 89/5: 53-56

á