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Strategy or disaster

Flood prevention related issues and actions in the Tisza River basin

FERENC SCHWEITZER[1]

Abstract

Changes in land use of the lowland landscape along the Tisza River have largely been shaped by processes that took place after flood control and regulation measures of that river. As a result fluvial accumulation has either been eliminated or restricted to the flood plain. At present human settlements extend to some segments of the low flood plain threatened by flood hazard. The amended Vásárhelyi Scheme focuses on raising embankments and extension of flood plain. Floods called the attention to problems that have to be solved, such as the stability of levee slopes. To prevent slope slumps it would be reasonable to start studies on flood control embankments in order to reveal sections endangered by an extreme water pressure during floods.

Key words: geomorphology, flood hazards, flood plains, Tisza River Valley

Rising from the Northeastern Carpathians, Tisza River flows into the Danube after covering 946 km. The catchment of the Tisza (157,186 km^2) opens up toward the W and SW. Within its 700 km long section across the Alföld (Great Hungarian Plain), the water level remains below 100 m a.s.l. Along the middle and lower reaches in the plain its valley is asymmetric: geomorphologically it flows in a trough-shaped depression upon its low flood plain.

Tisza River emerged in the Late Pleistocene and initially it crossed the plain with its tributary Szamos (Someş) eastward from its present-day channel. Its terraces of Pleistocene age are to be found in the latter regions. The river had been attracted to its present-day position by the Holocene depressions located east and north of Nyírség, the recent depression of Jászság and by the Szolnok–Titel trench. Its meandering channel changed frequently until the completion of water regulation, which were performed according to the concept of Pál Vásárhelyi. The flatland is rich in microrelief forms as evidenced by the presence of cut-off meanders, double and triple channels (*Fig. 1*). Masses of water provided by floods stepping out on the left bank between Tiszadob and Tiszafüred, flowing across

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[1] Director, DSc, Geographical Research Institute, Hungarian Academy of Sciences, H-1112 Budapest, Budaörsi út 45. E-mail: schweitf@mtafki.hu

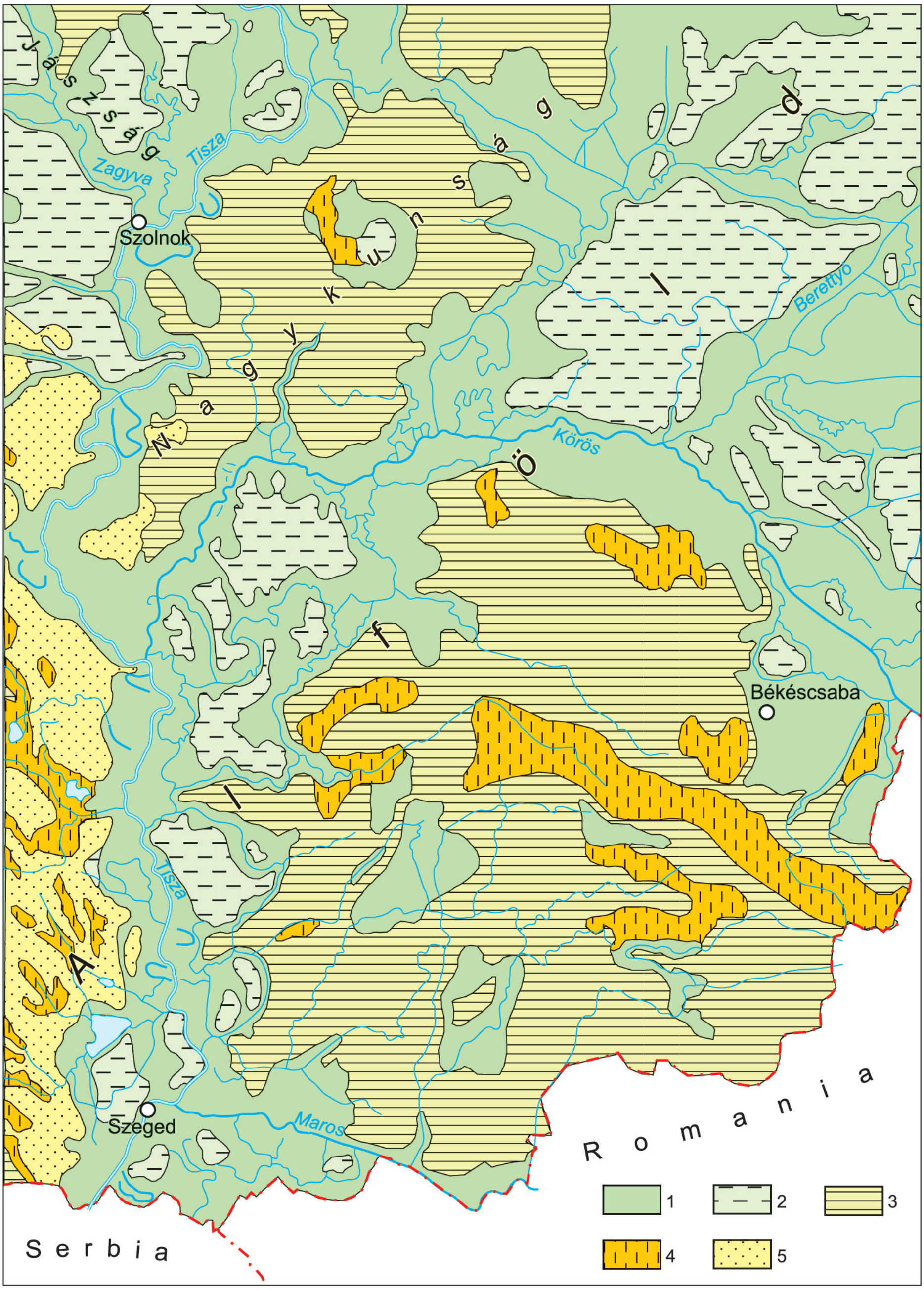


Fig 1. Relief types in the southeastern part of the Alföld. – 1 = low flood plain; 2 = low flood plain of poor drainage; 3 = flood-free lowland (high flood plain); 4 = low alluvial fan covered with infusion loess; 5 = slightly rolling sandy lowland

swamps and transported by the Hortobágy stream reached the Berettyó marsh situated 30–35 km away. The shallow (30–40 cm deep) water and the swamps once formed part of the extensive wetland within the Tisza drainage basin. Hortobágy stream flows north to south in a ca 10–12 km wide clayey channel, filled up with 8–10 m thick fluvial–alluvial sediments down to its tributary to Körösök. This minor valley used to be the track of the great floods; by now the area lying deepest within the Nagykunság and Hortobágy regions has been silted up.

Nowadays huge masses of water originating from heavy rainfalls in the mountain frame and surging up in the plain create emergency situation during high stages. They cause floods of long duration and make large areas waterlogged in the Tisza valley.

The settlements along the rivers of the Alföld were located in the so-called high flood plain, which had not been inundated even during the most devastating floods. The ancient Tisza and its tributaries had flooded huge areas in the plain, a considerable part of which was occupied by marshy areas and backswamps (*Fig. 2*).

The idea of the regulation of the Tisza River had been raised for the first time during the reign of King Matthias Corvinus, in the second half of the 15th century. It was he who issued the first decree that levees must be erected in order to protect the land. The basis of water regulation was created much later: the Habsburg Emperor Francis II emanated a law in 1807 encouraging the organisation of associations aimed at flood control and water regulation.

As a result of mapping of the Tisza between 1834–48 led by Sámuel Lányi it had become obvious that high water endangered 854 settlements in 18 counties, among them even some of those, which were located on the high flood plain and hitherto had not been inundated. It was a token of the low flood plain being silted up.

As a consequence of forest clearance, rough grazing and land cultivation along the river and probably enhanced by mining and quarrying activities within the drainage basin, runoff had increased and together with the risen high water levels they posed a serious threat for human settlements. To protect the towns and villages, linear infrastructure and agricultural land the Tisza Valley Association was organised in 1846 under the guidance of Pál Vásárhelyi. It also pursued planning, co-ordination and implementation of activities on flood control and water regulation.

Construction of a system of embankments along the Danube and Tisza rivers and tributaries also involved the construction of artificial channels, cutting off meanders and reclamation of swampy areas through the operation of drainage canals. These measures have been and still are considered one of the most radical contemporary interventions in the natural conditions of Europe. These measures were taken for the solution of tasks set by the socio-economic demands of the time.

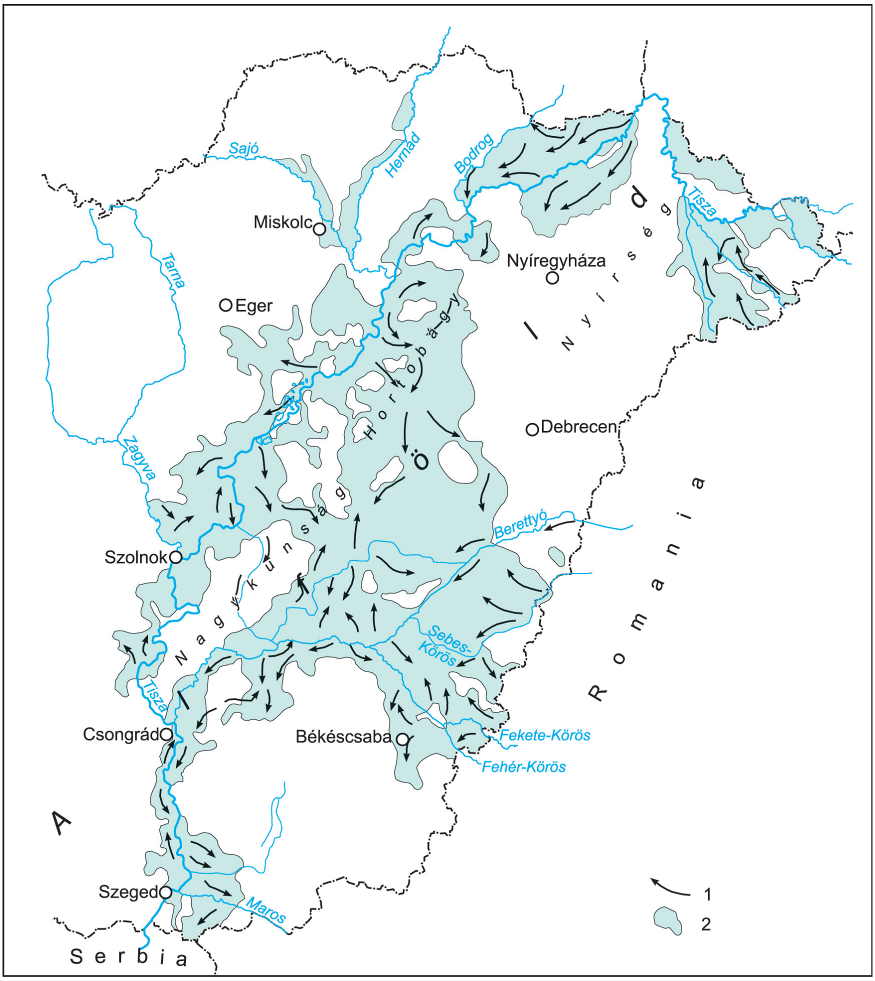


Fig. 2. Waterlogged areas in the Tisza valley prior to water regulation (Ihrig, D. 1952). – 1 = outlet of water from the river channel and direction of currents; 2 = inundated areas

As it is well known, initiation of water regulation along the Tisza was the merit of Count István Széchenyi and implemented partly according to the plans elaborated by Vásárhelyi. These activities were based on the hydrological law of Vásárhelyi, the validity of which for the middle stretches of great rivers had been recognised internationally. For instance, flood control and water regulation of the Middle Rhine and Mississippi valleys were executed on its basis.

What was the main point of this law? Vásárhelyi's attention was drawn by the facts that during mean water the Tisza is in equilibrium and does not build sandbars. He had come to the conclusion that effective measures on regulation are only feasible if:

a) the river is shortened by cutting through the braided channels (meanders),

b) floods provide a rapid drainage (travel time) similar to that of mean water which means that between channel width and depth of floods there should be an identical ratio as between those of mean water.

Taking into account the above considerations, Vásárhelyi calculated the average distance between the embankments, and found it to be 750 m (changing between 500 and 1900 m depending on local factors). This caused serious commotion among the concerned public because close embankments could involve higher levels of floods with a growing hazard of the failure of dikes. This uncertainty and panic mood had been the reason why the Italian engineer Pietro Paleocapa had been invited as an expert. It was he who proposed the system of flood protection applied for the Po River i.e. shaping of a wide flood bed to be inundated by the great floods and of inner dikes along the river to hold back the lower summer floods.

However this system has a defect of its own: due to silting up of the flood bed by high waters year after year, the levels of floods rise as well. Nowadays the Po filled up its flood bed to an extent that low water of the river flows higher than the roofs of the houses in Ferrara.

From this short historical review it becomes clear that the optimum extension of the flood bed between dikes and levees has been a controversial issue since the time of Vásárhelyi and Paleocapa. So was the number of meanders to be cut through. Vásárhelyi planned 102 meanders to cut off, whereas Paleocapa found it necessary to shorten the channel by 15 meanders. Thus the river had been shortened (from 1420 to 977 km) whereas the stream gradient increased and the character of beds of low and medium discharge slightly shifted toward the upper reaches. Rivers leaving mountain and hill regions suddenly acquire lower section character owing to an abrupt fall in stream gradient. In natural conditions sediment load of watercourses accumulates in alluvial fans (in a way the Nyírség or the Maros fan emerged) but it has recently been enforced to deposit in relatively narrow flood beds between the levees.

The Tisza and tributaries have always been rich in sediment load. Even the most ancient settlements situated on high flood plains were inundated sometimes because the low flood plain in their surroundings had been silted up.

Natural sediment transport probably has grown with the progressing urbanisation and during 150 years of flood control the process of silting up and relief evolution of flood beds with the emergence of point bars accelerated.

The updating of maps along the Tisza started in 1974 but later it was postponed. Preparation works called attention to the process of silting up (Sass, J. 1981). Nevertheless, filling up of the flood bed and formation of point bars had been neglected up to the turn of the millennium. It might sound absurd, because Vásárhelyi's concept was a controversial issue, just on the basis of this problem. Though some experts did take into account the rise of high water stages on the flood plain pressed by the embankments, the rate of sedimentation was underestimated. Nowadays this has led to a situation when the embankments need to be raised regularly and if the present conditions are going to survive, this problem is here to stay (*Fig. 3*).

According to the measurements and joint mapping activities of the Geographical Research Institute HAS and KÖTIVIZIG, the flood bed of the Tisza river at Szolnok has been silted up in a thickness of 200–240 cm since the water regulation measures. During the same period the flood plain of the Körösök has raised by 160–180 cm. The 5, 10 and 13 cm thick sediment layers accumulated by the floods of the past years or decades are clearly discernible (*Figs 4* and *5*). Based on VITUKI (1983) data each flood of the Tisza between 1976 and 1983 left an average 30 cm thickness of deposits, in spite of the mitigating effect of the Kisköre water reservoir. During the great flood of spring 2000, 14 cm thick sediment was deposited upward Szolnok.

This process will lead to the situation when flood waves occur higher than the level of the low flood plain prior to flood control measures, which used to be inundated regularly. E.g. now the Tisza does not flow along the deepest line of the valley but upon a silted up flood bed so once it steps out to the flood plain, the return of its water to its elevated channel is made impossible. It seems the same is happening to the Tisza and its larger tributaries as it has occurred to the Huang He in China or to Po River and its environs in Italy (*Fig. 6*).

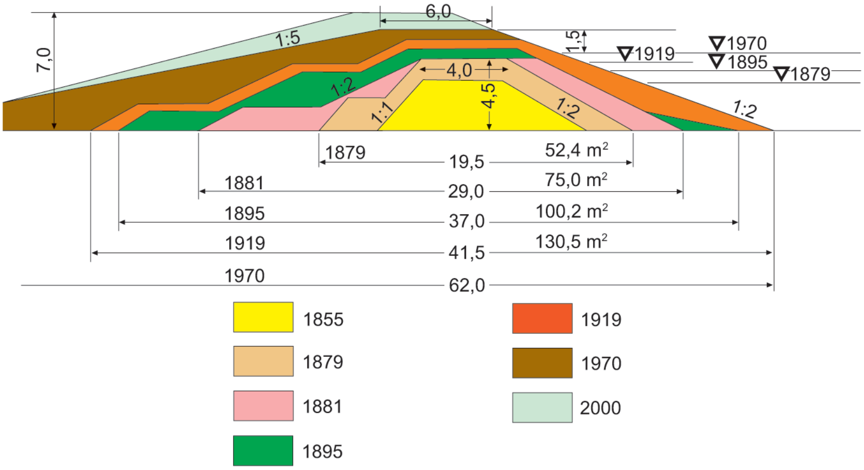
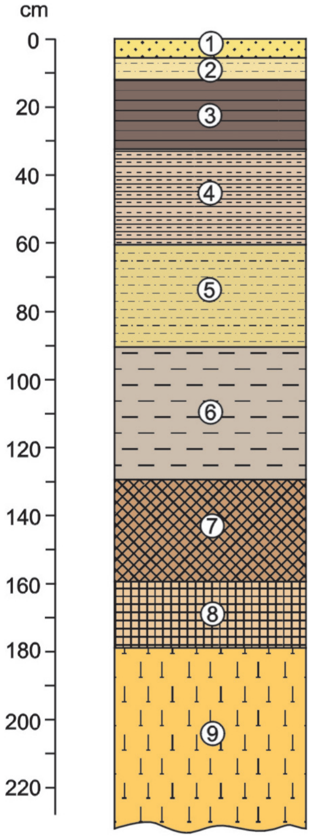


Fig. 3. Rising of the embankment along Tisza (Schweitzer, F. 2000)



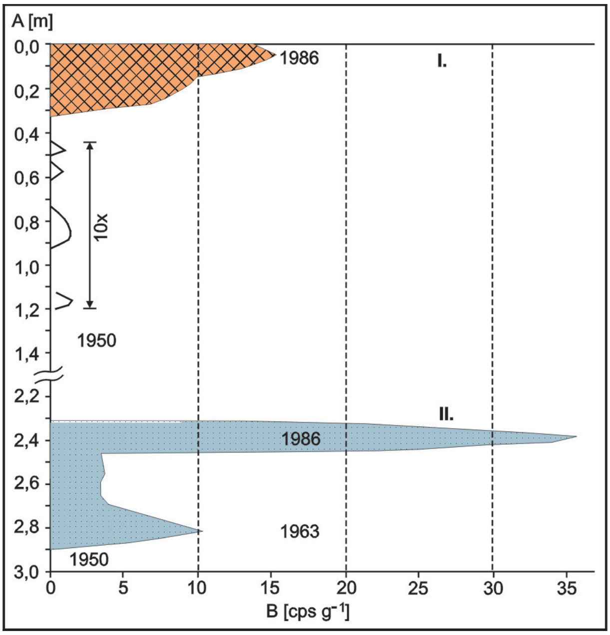


Fig. 5. ^{137}C distribution in the sediments of (floodway) point bar (I.) and Marótzugi-Holt-Tisza (abandoned meander, II.), after Braun, M.–Dezső, Z.–Hadady, Gy. 2001. – A = depth; B = ^{137}Cs activity concentration; 10x = tenfold magnification

Fig. 4. Profile of the flood bed sediment sequence along the Körös River in Takácszug. – 1 = grey micaceous sand; 2 = grey silty sand; 3 = dark brown clay; 4 = stratified silty clay; 5 = grey silty fine sand; 6 = grey fine sandy silt; 7 = greyish-brown hydromorphous soil; 8 = hydromorphous soil formed prior to flood control measures; 9 = infusion loess (Schweitzer, F. 1999)

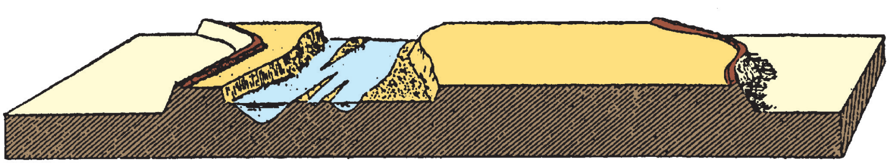


Fig. 6. Bloc-diagram showing silting up of the channel of Huang He, China (after Cholnoky, J. 1900). The initial height of the embankment was 14 m and the flood bed was filled up to 11.5 m. The distance between the dikes was ca 11 km (Schweitzer, F.–Nagy, I.–Alföldi, L.)

An extreme rate of silting up of flood beds is described in the book written by Jenő Cholnoky entitled 'The land of dragons' (1900, p. 293) in relation with the Huang-he at Kaifeng. He writes: "I approached the big river from the large settlements stretching at the mountain foothills and reached it on 13th January. The height of the embankments is14 m but the river filled up the channel so that they are only 2.5 m higher above the flood bed. Terrible situation! No wonder that the failures of the dikes along the Huang He are so devastating!" (

It is widely acknowledged that in 1999 and 2000 dike failures could be prevented along several sections of the Tisza and its tributaries in the Great Plain only with the involvement of enormous material expenditures and human effort. However, in 2001 in the Bereg environs a dike failure occurred at Tarpa (*Fig. 7*). On the map compiled by Ihrig, D. (1952, *Fig. 2*) the most critical places and the extent of the waterlogged area can be seen.

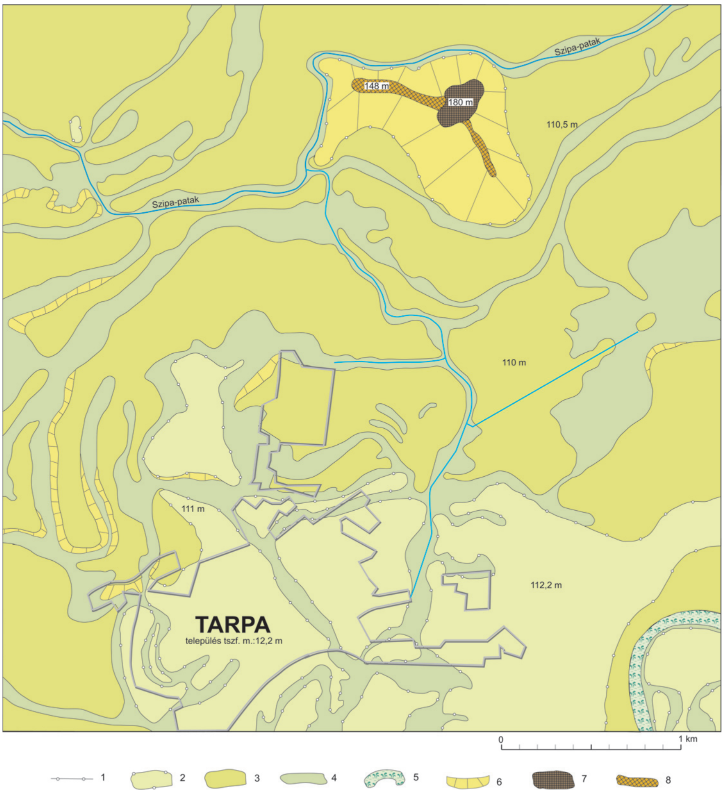


Fig. 7. Geomorphological sketch of the environs of Tarpa (comp. by Balogh, J. 2001). – 1 = rim of the high flood plain; 2 = high flood plain; 4 = filled up former meander; 5 = cut-off meander, waterlogged; 6 = slope, undistinguished; 7 = higher summit level between 160–180 m; 8 = lower summit level between 140–150 m

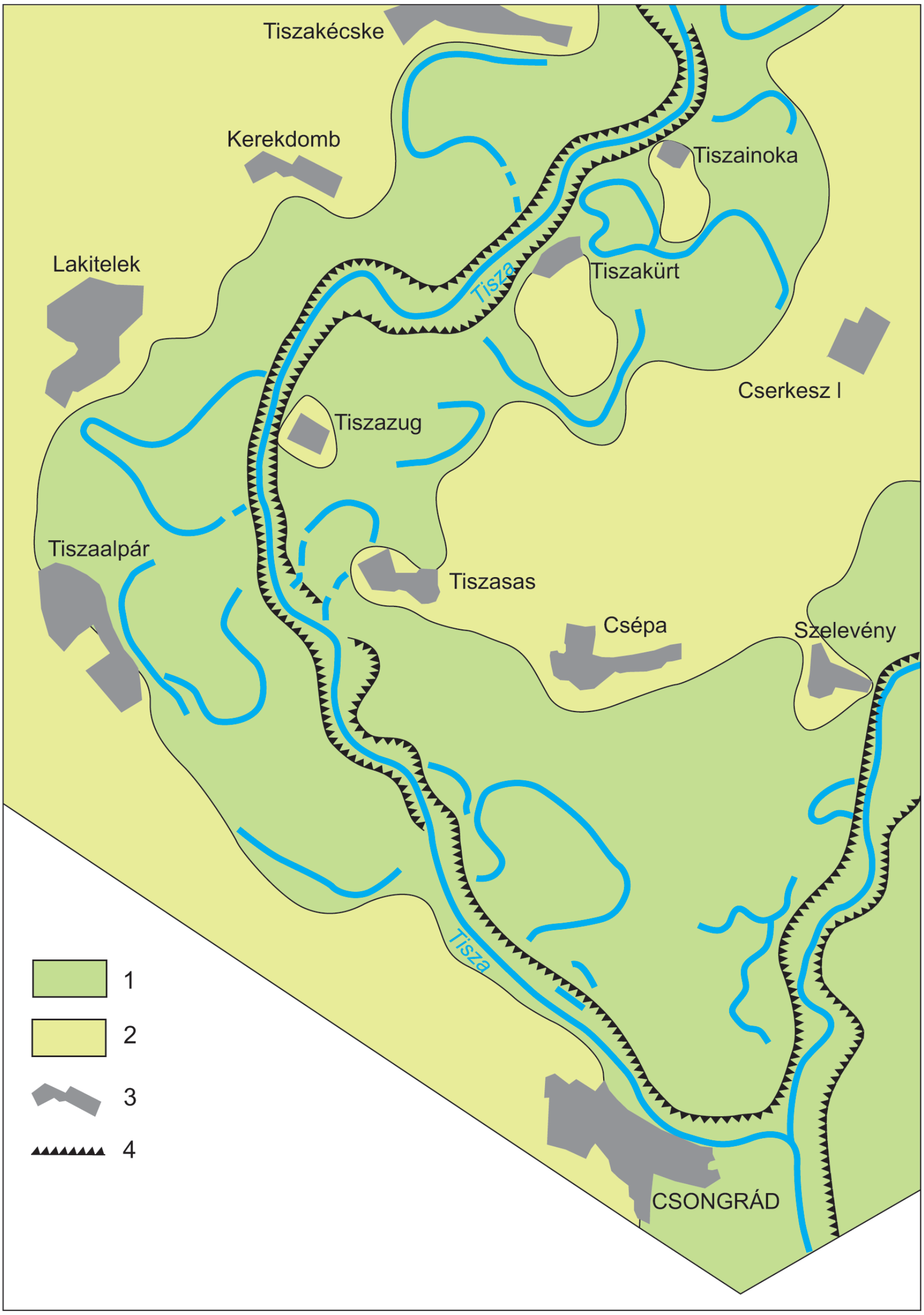
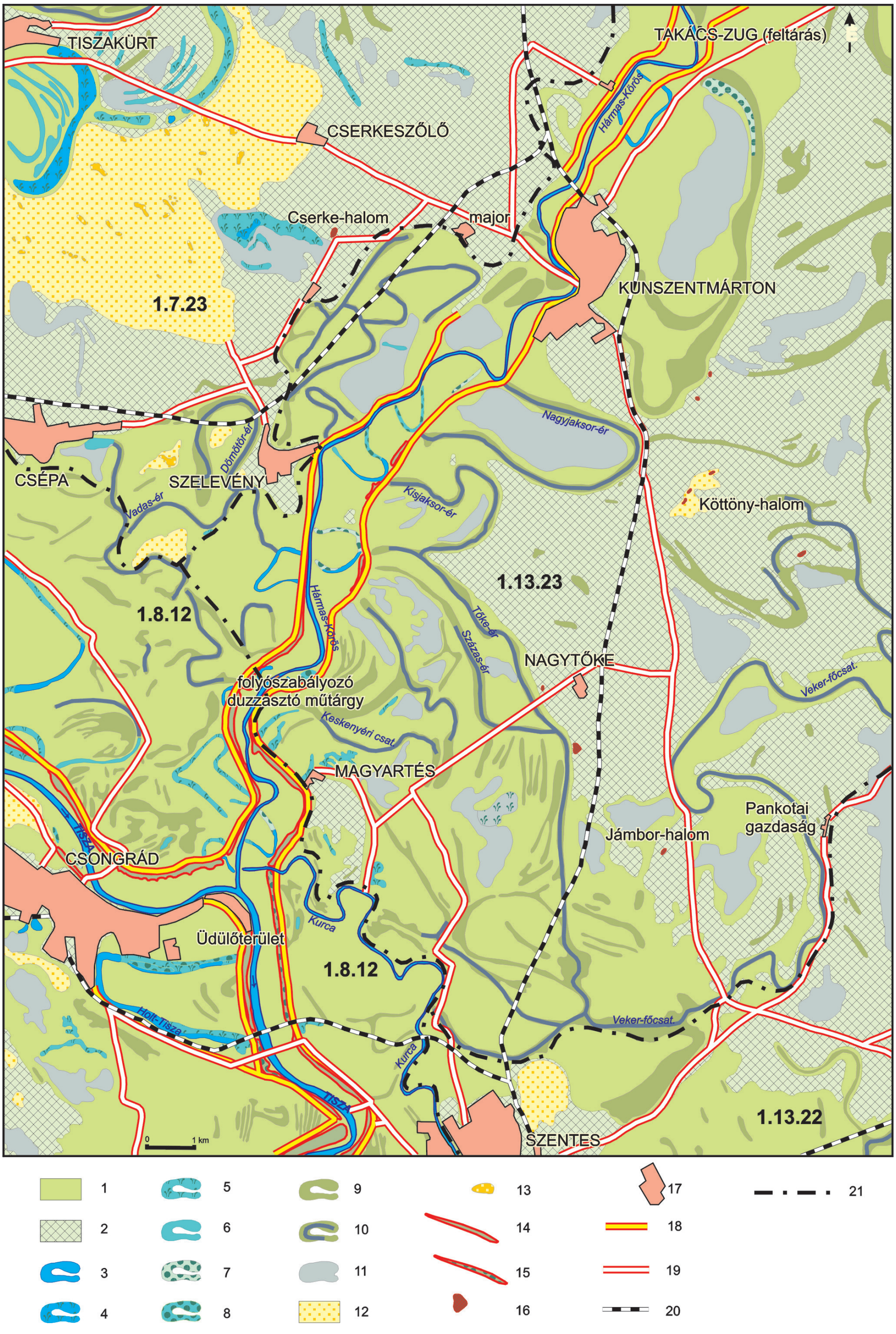


Fig. 8. Geomorphological sketch of the section between Tiszakécske and Csongrád. – 1 = low flood plain; 2 = high flood plain; 3 = settlement; 4 = embankment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Nagyjaksor-ér
Dömötör-ér
CSÉPA
SZELEVÉNY
Vadas-ér
Kisjaksor-ér
Köttöny-halom
1.13.23
1.8.12
Hármas-Körös
Tőke-ér
Százas-ér
NAGYTŐKE
Veker-főcsat.
folyószabályozó
duzzasztó műtárgy
Keskenyéri csat.
MAGYARTÉS
Pankotai
gazdaság
Jámbor-halom
TISZA
CSONGRÁD
Üdülőterület
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No chance must be given to what occurred repeatedly in the 20th century (1919, 1925, 1940, 1948, 1970, 1974, 1998, 1999, 2000) that the high water reached or overgrew the crest of dikes and levees. The latter were constructed for a probability of the occurrence of the highest floods once in 50 years. Owing to the silting up of the flood bed they are either to be raised time and again (which has been the practice so far) or it must be completed by another solution.

The opening of the flood bed in places where the emergency storage is allowed by geomorphologic, economic and social geographical conditions and by the infrastructure would contribute to the revival of quasi-natural conditions (Schweitzer, F. 2001, *figs 8* and *9*). The construction of detention reservoirs is considered part of the amended Vásárhelyi Scheme (Váradi, I.–Nagy, I. 2002, *Fig. 10*). Also this could provide solution for a nation-wide strategic problem because emergency situations threaten the security of life and property of nearly 1.5 million people. To counterbalance a permanent rise of flood levels dikes and levees must be enforced and raised periodically. As it was the case during the high water stages of the Tisza in 1999 and 2000, a system of more than one hundred years' age is slowly improved at the price of incredible human effort and material means. The question however is if the whole system is able to meet the security requirements during the forthcoming centuries.

Large hydrological schemes must be supported with huge investments and they are to serve for long duration; their substitution is highly expensive and time consuming. Along the Körösök a very narrow (50–70 m wide) flood bed was left during water regulation in the late 1800's (Alföldi, L. 1999). It continues into the 150–200 m wide flood bed on the Transylvanian part of the valley. This funnel-shaped configuration has resulted in a bottleneck and led to frequent dike failures, threatening with piping and extension of waterlogged areas during each flood. To prevent this hazard either flood beds should be broadened along the Hungarian section or the dikes must be relocated (*Fig. 8*).

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Fig. 9. Geomorphological map of the outlet of Körösök to the Tisza (comp. by Balogh, J. 2001). – 1 = low flood plain; 2 = high flood plain; 3 = cut-off meander, intermittently waterlogged; 4 = cut-off meander, permanently waterlogged, with reed-sedge vegetation; 5 = cut-off meander, intermittently waterlogged, with reed-sedge vegetation; 6 = filled up former meander, intermittently waterlogged; 7 = filled up former meander in flood-plain gallery forest; 8 = filled up former meander in flood-plain gallery forest, intermittently waterlogged; 9 = filled up former meander cultivated as cropland; 10 = = filled up former meander, drained; 11 = alkaline, waterlogged flat; 12 = wind blown sand; 13 = sand dune. Man-made landforms: 14 = row of pits on the flood bed (for dike construction); 15 = row of pits for dike construction with gallery forest coverage; 16 = kurgan; 17 = flood levee; 18 = highway; 19 = railway; 20 = settlement; 21 = boundary of natural microregion; 1.7.23 = Tiszazug; 1.8.12 = South Tisza Valley; 1.12.22 = Csongrád plain; 1.13.23 = Körösszög

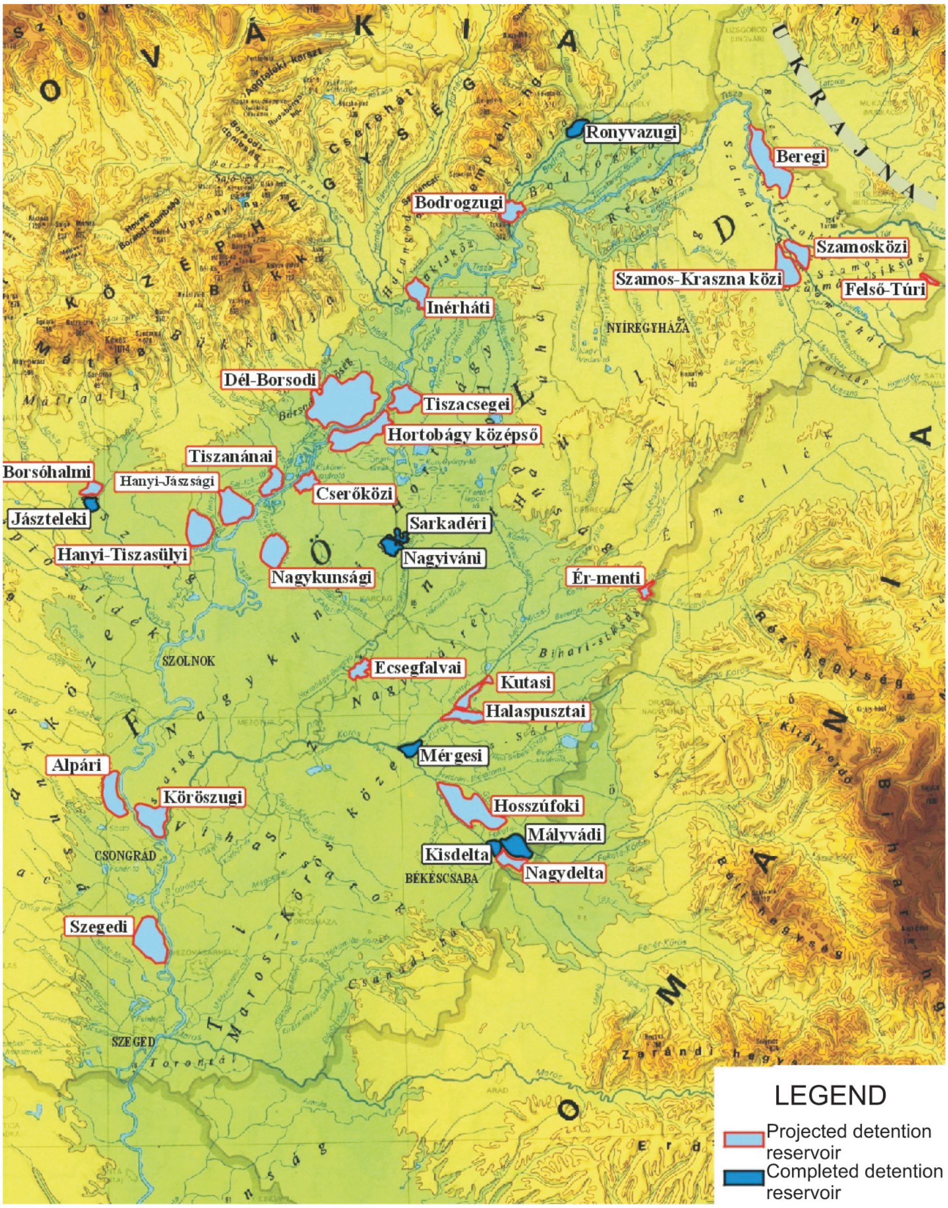

Fig. 10. Detention reservoirs in the Tisza Valley according to the amended Vásárhelyi Scheme (Váradi, I.–Nagy, I. 2002)

Further development of the Vásárhelyi Scheme (2002) is aimed at the lowland storage of water transported by floods (*Fig. 10*) Another opportunity is the enlargement of flood beds up to the geomorphological levels of the high flood plains (*figs 8* and *9*). This solution would contribute to the safe flood control and improve the biological habitability of the landscape if on the protected side (low flood plain) reservoirs of integrated use (accommodating abandoned channels) were constructed. These storage facilities as organic part of the natural environment (e.g. Bodrogzug, Köröszug, Tiszanána, Cserőköz) would play the ecological role of the swamps of past centuries. The realisation of similar schemes is the responsibility of academic research. The temporal perspective of these investigations is some hundred years. 150 years ago Pál Vásárhelyi outlined a nearly perfect scheme meeting the contemporary demands, yet leaving behind quite a number of problems to be solved in the near future. In the first step a number of questions must be answered by scientific research which have been outlined by the author in an earlier study (Schweitzer, F. 2000):

– Studies on the evolution of the Tisza valley over the past ca ten thousand years with mapping of buried and current channels and their intersections, since the latter pose a piping water hazard;

– Exploration and measurements of the rate of silting up of the flood bed, a survey of changes having taken place since flood control and water regulation measures; measurements on pollutants transported from the catchment area to the flood bed and accumulated there; clearing out if sediment accumulation is uniform over the different parts of the flood bed and if there is a proven relationship between the distance from the dike and the rate of sedimentation;

– Mechanism of the evolution of point bars and natural levees and their relationship with the silting-up process over the flood bed;

– Investigations into historical changes of forest coverage of the mountainous sections of the drainage basin of the Tisza and its tributaries;

– Mapping and evaluation of the configuration of high flood plain (high bank) and levees; study on the opportunities to extend flood bed, in some places elimination of embankments, function of which could be taken over by high banks in the future; or (as an alternative) construction of levees in more distant areas, investigations into the storage capacity of the extended flood bed;

– Geoecological-geomorphological investigations over the flood plain and flood bed aimed at the rapid conduit of floods and at an adequate storage of excess waters;

– Adequate treatment of the vegetation spreading over the flood bed. The gradient of the channel along the middle reaches of Tisza is 3 cm per one km and the current of water is slowed down by the emerging thick shrub;

– Economic and social geographical studies.

In the Tisza Valley the length of embankments of primary and secondary categories is 1320 km, to this 119 km high bank section is added making up 1439 km as the total length of flood levees. In the course of the river regulation measures the length of the Tisza was reduced from 1420 km to 977 km. At present the 600 km long Hungarian section of the river is flanked by 1085 km long embankment.

If raising of crests of dikes is to enjoy priority, it will have to be executed in the future more frequently than previously, owing to the intense silting up of the flood bed.

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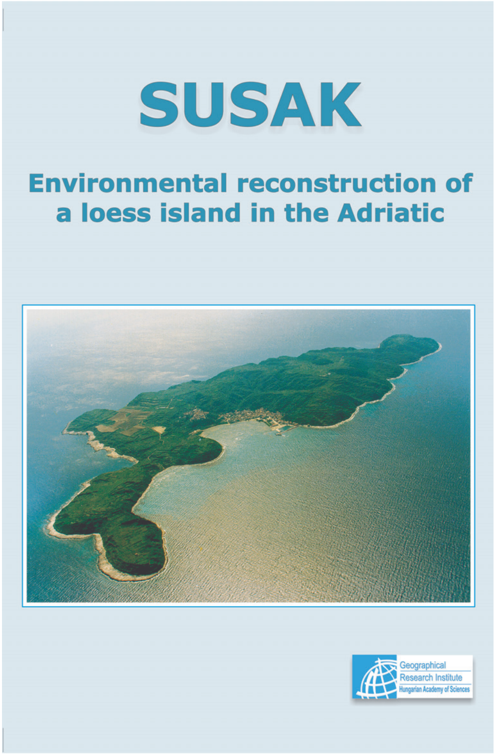

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