JOURNAL OF ENVIRONMENTAL GEOGRAPHY
Journal of Environmental Geography 9 (3–4), 1–12.
DOI: 10.1515/jengeo-2016-0007
ISSN: 2060-467X

FLOOD RISK IN SZEGED BEFORE RIVER ENGINEERING WORKS: A HISTORICAL RECONSTRUCTION

Csaba Szalontai

University of Szeged, Department of Geology and Palaeontology, Egyetem u. 2-6, H-6720 Szeged, Hungary
*Corresponding author, e-mail: csaba.szalontai@gmail.com

Research article, received 3 May 2016, accepted 10 September 2016

Abstract

Szeged situated at the confluence of the Tisza and the Maros Rivers has been exposed to significant flood risk for centuries due to its low elevation and its location on the low floodplain level. After the Ottoman (Turkish) occupation of Hungary (ended in 1686), secondary sources often reported that the town was affected by devastating floods which entered the area from north, and a great part of the town or its whole area was inundated. Natural and artificial infill reduced the flood risk to some extent after the town had been founded, but in the 19th century flood risk was mitigated by river engineering and the reconstruction of the town. The town relief was raised by a huge amount of sediment, which makes it difficult to determine the elevation of the original relief as well as the exact flood risk of the study area. However, some engineering surveys originating from the 19th century contain hundreds of levelling data in a dense control point network making possible to model the relief of the whole town preceding its reconstruction and ground infill. Based on these data, we prepared a relief model which was compared with the known data of the 1772 flood peak, from which we deduced that 60% of the town must have been inundated before it was filled up. As there could have been 50-100 cm thick natural or artificial ground infill since the 11th century, the original natural relief can be gained by deducting these data. Based on this deduction, the extent of inundation centuries ago could reach 85%, which means almost total flooding.

Keywords: Szeged, relief, flood, inundation map, settlement history

INTRODUCTION

Szeged was the third most important town in the medieval Kingdom of Hungary, right after Buda and Fehérvár. The town was founded at the mouth of two big rivers (the Tisza and the Maros), so its most important potential was being an ancient junction of trading and military routes. This potential was well-utilised by its inhabitants. The economic and urban development of the town starting in the 11th and 12th centuries resulted in being granted certain privileges by the king, and Szeged became a free royal town by the 14th century.

A common principle in urban geography and in archaeology is that river mouths are one of the most important urban settlement factors. Rivers do not only provide an active connection with other parts of the world, but they also have other important features, for example, according to biogeography, rivers may guarantee tranquillity for the inhabitants of the surrounding area.

The confluence of the Tisza and the Maros Rivers exhibits similar advantages. Their valleys have been important routes connecting the Middle East through the Balkan with the central and the northern parts of Europe, and as such, they made the travel of ancient people and the spread of different economies, raw materials, lifestyles, and material cultures easier. This advantageous geographical situation should have enabled the foundation of significant human settlements at the mouth of the two rivers or the nearby riverside in different archaeological periods, which would also have meant several significant and big archaeological sites. As opposed to this, the lack of archaeological findings and sites points to the fact that the area was mainly uninhabited before the 11th century. Neither archaeology, nor history have researched its reasons in detail so far, the presented ambiguity has not been resolved.

We finished a complex land use evaluation some years ago, which also enabled us to add a new approach to settlement history (Szalontai, 2014). Our findings indicated that the reasons for the area staying unpopulated for such a long time must be connected to the disadvantageous physical geographical features of the Tisza-Maros confluence.

A detailed analysis of archaeological sites and road networks proved that the Tisza-Maros confluence was not controlled by the ancient people directly on the riverside, but from a bit farther away. While the river mouth proved to be rather unfavourable, the water system situated 8 km farther away from the Tisza, which we are going to describe later, provided more favourable conditions. The ancient routes crossing the Carpathian Basin met here, too. By controlling the fords, the confluence of the two rivers could be overseen every period, and the more favourable physical geographical features of these places provided more peaceful life than the river mouth. High flood risk and low elevation were those two unfavourable features that hindered human settlement here the most before the 11th century.

The research of historical floods has been boosted by new findings both in national and international studies for two decades. Climate and environmental history research as well as flood research have gained more and more attention. Our primary aim was to reconstruct floods events by the systematic analysis of primary and secondary sources as well as architectural monuments. In addition, flood-induced environmental, economic, social, architectural, and settlement historical effects and consequences of certain flood sites were studied in detail (Brázdil and Kotyza, 1995; Kiss, 2011; Rohr, 2007; Glaser, 2008).

Our previous researches aimed at identifying and classifying those landscape characteristics of Szeged which help us understand the history of Szeged and its surrounding area. We also intended to provide the basics for the development of a great and comprehensive settlement history of Szeged and its neighbourhood that is based on a new approach developed by the combined efforts of different sciences.

The present study is the continuation of the previous work (Szalontai, 2014a). Our current research questions are the followings: 1) What was the degree of flood risk at the Tisza-Maros confluence and Szeged in the centuries (and millennia) preceding the reconstruction of the town and the beginning of the river engineering works at the end of the 19th century? 2) What was the flood risk extent of medieval Szeged? 3) What influence did it have on the habitation of the area? 4) How often was the area inundated by the Tisza? 4) Where were those higher grounds that remained dry even during floods so they could ensure survival chances? 5) How did all these features influence human settlement?

The above mentioned questions are closely connected to the research interests of archaeology and settlement history as the structure of the inhabited parts of Szeged was basically determined by the connections between surface water and topography. These two features designated those morphological sites that were suitable for permanent settlement. By answering the above mentioned questions, we can identify those places that are suitable for human settlement.

We also aimed at studying why the area of the present-day town was not populated before the 11th century (in the so-called Hungarian Middle Ages), and why there are no such archaeological findings and sites that would signify the presence of permanent or, at least, frequently-populated settlements at the strategic point of the Tisza-Maros confluence. Our previous research proved that the centre of the settlement was not situated along the Tisza before the Hungarian Middle Ages, but it was situated on the high floodplain areas of the water system surrounding the town in an 8-km diameter (Maty-ér/Maty Creek, Fehértó/White Lake, Fertő-láposa/Fertő Marsh, etc.). More significant human settlements were founded on the banks of the Tisza only from the 11th century (Szalontai, 2014b).

Finally, we also aimed at finding out whether there are hills in the area which are usually not affected by floods, but they are so close to the surrounding surface water that they can support life.

STUDY AREA

Szeged is the county seat of Csongrád County, the largest city and the regional centre of Southern Hungary. It is closely situated to the Hungarian-Serbian border, and it is located on the boundary of two microregions: the Southern Tisza Valley and the Dorozsma-Majsa Sand Ridge (Fig. 1). The area is the lowest-lying region of Hungary, its geomorphology is characterised by the relatively small number of macro- and mesoforms (Mezősi, 1984). Its surface forms have relatively small relief (0-2 m/km^2), and they are mainly of fluvial origin. The average relief is between 77-79 m asl, flood-free areas can only be found at a height of 81-82 m asl on the natural levees and the edges of Fehértó. A greater part of the area belongs to the low floodplain of the Tisza, which also surrounds the city of Szeged. The three small islands of the city rise above the surroundings as residual surfaces.

Basically, the hydrography of the study area is determined by the Tisza and the Maros Rivers as well as some smaller streams along the Tisza (Szillér, Jánosér/János Creek, Tápai-ér/Tápai Creek). The River Maros hardly affected the features of the right bank of the Szeged landscape, except when its flood dammed up the water of the Tisza. The Tisza is characterised by two annual floods, which are often likely to last for half a year because they subside slowly. It also means that the land along the river is inundated almost continuously. As the medieval part of Szeged lies in a basin-like area, the somewhat higher ridges along the Tisza prevent floodwater from flowing back into the main river channel, which results in longer floodings. The second important water network around Szeged (Maty-ér, Fehértó, Baktó) has an 8-to-10-km-wide

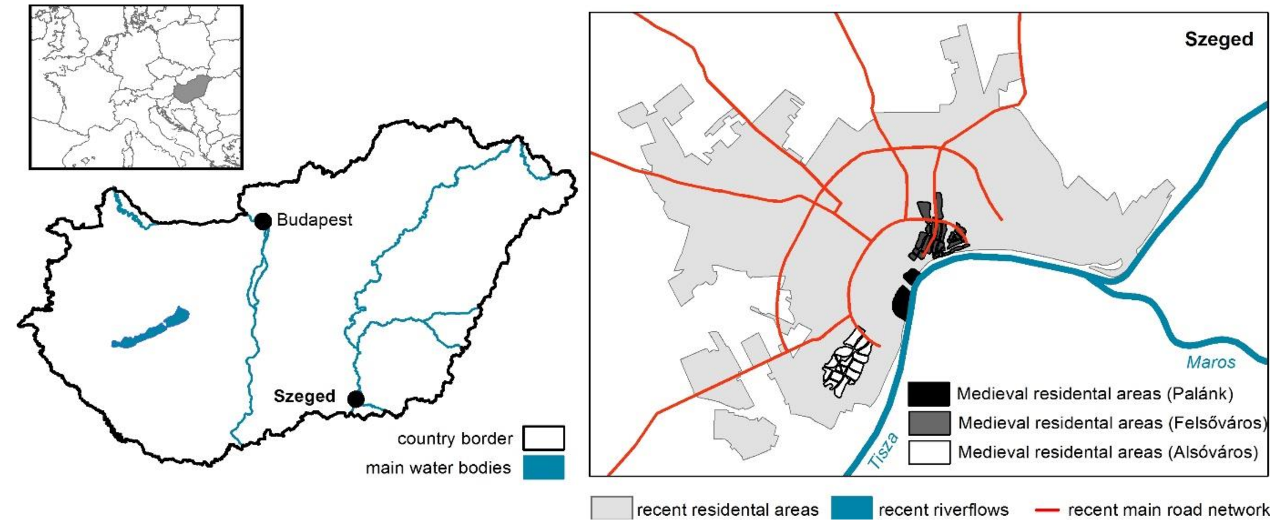

Fig. 1 The location and map of the study area, demonstrating the recent and the medieval residential areas

diameter, and it totally surrounds Szeged. The two water networks have different flood risk characteristics. The Maty-ér, Fehértó, and Fertő-láposa receive water input from the Kiskunság Sand Ridge (Homokhátság) lying between the Danube and the Tisza. This water input includes both surface and subsurface water flows, which fill the pools, basins, and channels along the boundaries of the Sand Ridge. These water flows are slow, static, and of little or no dynamics, they reach the Tisza from beneath Szeged, and they cross the natural stream channels without any obstacles. They have no flood risks in general. This water network is accompanied by unflooded ridges, and the arable lands found here are of the best quality.

As opposed to this, the water network situated on the east is connected to the dynamically changing gauge height of the Tisza, and its parts pose a regular and devastating flood risk due to the two annual floods of the Tisza. The relationship of Szeged and the Tisza is totally different from the usual river-settlement relationship, where every change occurring on the river affects the structure and the safety of the accompanying settlement. Secondary sources documenting floods in Szeged have never reported that the Tisza would have flooded the town by stepping over its banks in the city. Some documents say that the embankment situated on the outer arch of the city-side of the river was washed away, and they also mention that the eastern wall of the fortress standing directly on the riverbank was destroyed by a flood. But there is no data proving that the city would have been totally flooded.

The Tisza always floods the city from the north. The right bank of the Tisza to the north of Szeged is accompanied by a 30-km-long and 2-to-4-km-wide low floodplain which used to carry flood flows downstream. The three small islands where the oldest parts of Szeged were founded are situated on the low floodplain with an average height of 1-1.5 m. Floods usually flowed around these islands: one part of the flood flow passed round from the eastern area of the town, the other part passed round the islands from the north and the west, and they returned to the main channel of the Tisza beyond the town further downstream. In addition, the island of Felsőváros (Upper Town), which is one of the ancient city parts, was divided by several smaller streams which carried water from the low floodplain downstream into the Tisza. These streams also allowed bigger floods to inundate even these older parts of the city. The above mentioned characteristic of the city's location meant a relatively high flood risk, which was further strengthened by unusually high floods.

DATA AND METHODS

Methodology

In order to answer our research questions, we had to reconstruct the hydrographic and geomorphologic environment preceding the land use changes that occurred in the 19th century. By reconstructing the original natural circumstances, we could also get an insight into the circumstances that characterised the different archaeological periods.

A detailed study of the original relief and geomorphology is greatly complicated by the fact that the number of the sources is very scarce, which makes the research object very difficult to investigate. It is obvious that our primary task is not the investigation of historical sources, instead we have to focus on preparing geological surveys/bores that cover the entire area of the city in the greatest possible number, and we have to prepare the model of the original terrain based on these data, and, finally, we have to display historical changes with the help of the so-prepared model. Since such a model is not available for us at present, we are forced to make use of historical data and reconstruct the original relief of the city with the complex analysis of the available historical sources.

Although the historical sources provide useful general information about the structure and the relief of the city, they do not abound with accurate data. Even the great number of available secondary (written) sources (certificates, travel literature, military reports, etc.) do not contain data on topography. In case they do, they usually emphasise the lowland character of the landscape, and they rarely mention the "Öthalom" hills (literally Five Hills) which are residual surface elements with an average of 12-15 meters. The geographical names of the area may contain names with the word "mount", but they are not of morphological origin, they refer to former vineyards. Flood descriptions often mention flood free (dry) islands as well as floods flowing through most of the town without any obstacles.

The research was made further difficult by another characteristic of Szeged. The city was completely destroyed in the 1879 flood, and, during the rebuilding of the city, its residential areas were filled up with a considerable amount of land lifting the relief but also forever concealing any traces of the original terrain. Therefore, in order to investigate our questions concerning settlement history, we have to reconstruct the geomorphology characterising the area before 1879. Then, we will be able to identify those city parts which were inundated or usually dry by analysing flood data.

Filling up the inhabited parts of Szeged and the basins between them with soil was a known practice before the 19th century, which resulted in a gradual decrease in the size of the flooded areas. However, the enormous work that began in 1879 surpassed all previous landscape-changing work and was considered a rare and unique process both in Hungary and in Europe. Its primary purpose was to reduce flood risk, and in order to do so, the ground level of the Downtown area was going to be raised to the height of 822 cm compared to the 0 cm of the stream gauge of the Tisza, which corresponds to 81.92 metres above the Baltic Sea level. There is no doubt, however, that the entire area of the Downtown was not intended to be covered by a homogenous layer. The final version realized was even simpler, in fact, only roads and streets were filled in while the gardens and yards of the houses were no, so there were level differences up to a meter within relatively small distances, such as a house and the street in front of it, which has characterised Szeged since then. So, while the streets are artificially infilled and lifted terrains, the elevation of the gardens and yards of the houses did not change essentially (Kuklay, 1880; Lechner, 2000).

A 3-4-meter-thick or even thicker layer was filled in only into former pools and surface streams, but the entire area is characterized by a 1-2-meter-thick layer (Kaszab, 1987). The thickest infill in the three ancient parts of Szeged can be found in Palánk (City), while the thickness of the infill is not significant in Alsóváros (Lower Town) and

Felsőváros (Upper Town). A new city structure was developed during the reconstruction. The new structure was characterized by a network of boulevards and avenues, all of which lay higher than their surroundings, the ideal infill height was only kept along the road network. As a result, all side streets rise toward the main streets even nowadays.

The natural or artificial lifting of the terrain level of populated areas is not an unknown phenomenon in European towns. It was a well-known practice even in different archaeological periods, which practice resulted in distinctive, interdependent settlements built on each other. It is a natural phenomenon that settlements, especially cities, having been inhabited for centuries or millenia, have several meters thick infill layers (Puskás, 2008). In Moscow, for example, this layer is 2-5 meters thick, but natural depressions may also have a 20-meter-thick infill. Thus, three typical geomorphological forms can be created in cities: excavated (hollow, negative), graded (levelled) and accumulative (cumulative, positive) (Puskás, 2008; Farsang and Puskás, 2009). The resulting infill can be sediment of natural origin, or soil-like material, and can be artificial material (debris, gangue, waste, etc.).

Due to the infill of the city, we have to look for maps that were prepared before the reconstruction. It led us to investigate the topographical data of those handwritten or printed maps that were created before the end of the 19th century, which finally helped us to prepare the topographical reconstruction of the historical town centre. Our previous research did not make use of these maps, although more of these scaled city maps that were prepared before the 1879-1890 city reconstruction contain elevation data. Their importance is also great, because only these maps contain exact data about the original (i.e. preceding the reconstruction of the city) topographical features of the area so they are essential for the topographical reconstruction.

Reducing flood risk was a regularly recurring need and demand in the 19th century Szeged, but to plan this, a general survey of the area had to be done first, with a special attention to surveying elevation. Otherwise it was not possible to start planning river engineering. Thus, the first such map was created in 1830 (Map 1, Buday 1830), but the overall survey took place only a few decades later when, due to the 1879 flood, the destroyed city had to be completely rebuilt (Maps 2-4, Barilari et al., 1879, Heller, 1880, Kuklay, 1879). The consistent and accurate use of elevation data was made easier by 45 iron rods that had been installed as fixed points, and which were intended to promote mapping and rebuilding the city (Map 5, Halácsy, 1879) (Halácsy, 1879; Bertalan, 1884).

After digitizing the maps having been collected during the research, they were georeferenced, then their elevation data were visualized in an EOV system using a GIS program, and they were also recalculated to the present value of meters above the Baltic Sea level (m asl). No compiled city maps depicting the iron rods were made, but each iron rod had a very accurately drawn on-site sketch, which made it possible for us to identify their position as accurately as possible. Therefore, we could locate each reference point and its elevation on the georeferenced city map.

When identifying the original terrain characteristics of the area before the reconstruction and the infill, we also had to pay attention to determine the ground level associated with the elevation data, because elevation data were measured in meters above the Adriatic at the end of the 19th century. The Baltic baseline is 0,675 meters higher than that of the Adriatic baseline, i.e. the absolute values of the Baltic heights are that much smaller than the values of the Adriatic heights. There was one independent reference point in Szeged, to which all architectural plans were aligned: it was the 0 point of the stream gauge of the Tisza River (73.70 m asl) (Vágás, 1991). The reason why it is important to emphasise 0 as a reference point is that, for example, when giving the thickness of the infill layer, this thickness was given compared to the 0 point of the stream gauge. Six meters of infill does not mean six meters of soil, it means that compared to the 0 reference point of the Tisza, the level of the terrain was lifted with 6 meters. That is, the Tisza 0 point + 6 m + 74.37 m above Adriatic sea level -0.675 m = 79.7 m above Baltic sea level.

After the terrain reconstruction, the collected elevation data were compared to the peak values of the floods, then by depicting them on a map we were able to locate those areas which were more likely to be inundated when a higher flood occurred. To do so, we utilized the flood data which were less influenced by landscape-changing human activities. It means using those data which originate from the time when floods occurred in a natural (non-engineered) riverbed, flood control works did not hinder flood flow, and floodwater returned to the original river channel naturally. These requirements are necessary because archaeological and historical flood risk cannot be compared to such floods of which causes or flow were influenced by significant human activities. Therefore, useful and credible data can only be gained from the times preceding river engineering. Thus, we used the data of the 1772 flood as our standard flood level data, which peaked with 630 cm (80 m asl above the 0 point of the Tisza stream gauge in Szeged). It was not the biggest flood Szeged had to suffer, but it was one of the last floods which was neither caused nor influenced by human activities, and there were accurate data on the highest flood level. There were bigger floods in the 18th and 19th centuries (1851: 80.61 m), and there were even higher average flood peaks between 1772 and 1850 (80.11 m asl), but we deliberately underestimated the extent of the potential risks a little bit (Fig. 2).

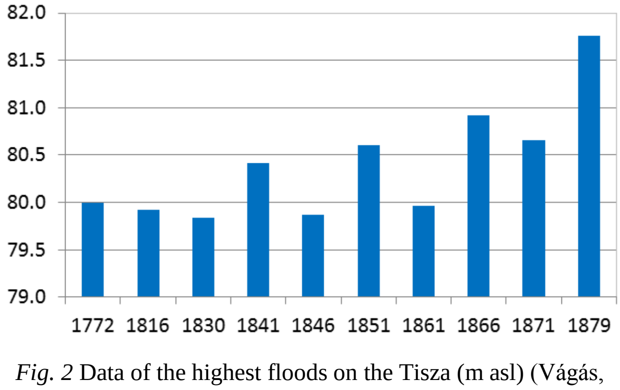

Fig. 2 Data of the highest floods on the Tisza (m asl) (Vágás, 1991)

We carried out the following analyses with the data of the studied maps. We indicated the elevation data on the original and the georeferenced maps one by one. We divided the measured points into 3 groups on the basis of the highest flood water level in 1772 (630 cm over the 0 point of the Tisza stream gauge = 80.00 m asl):

- inundated points;
- saturated points, which are situated 20 cm higher than flood level;
- flood-free (dry) points.

Subsequently, we performed the same process, but we subtracted 50 cm from the 19th century elevation data assuming that it equals with the amount of natural infill of the area between the 11th and the 19th centuries. Based on these data, we divided the elevation data into three groups again.

Finally, we simultaneously visualized all data of the five maps by copying them into one file, then we carried out the above mentioned classification again. We also carried out an analysis where we calculated with a 100-cm-thick infill since the 11th century settlement. In order to provide easier orientation, we indicated the contemporary major road network (avenues and boulevards) as well as the earliest settlement structure of Szeged on the original map.

The detailed description of the applied historical maps

Map 1 (Buday, 1830) is one of the most accurate and detailed maps from the first half of the 19th century, which depicted the outline of all surface water on the town structure, and both the height of water level and that of the walking level were given everywhere. The data were given in Viennese feet / inch units, and the then highest flood peak data of the year 1770 were also given in the same units. A total of 70 elevation data were recorded, 44 of which were numbered. Data measured in the streets, on the water level of Eugenius Ditch and its trench are also included in the elevation data (Fig. 3a,b).

Map 2 (Barilari et al., 1879) depicts the entire area of the city, its street network, street names, all houses, and the data of 203 measured points. The survey was carried out mainly during and after the flood receded. Slope calculations

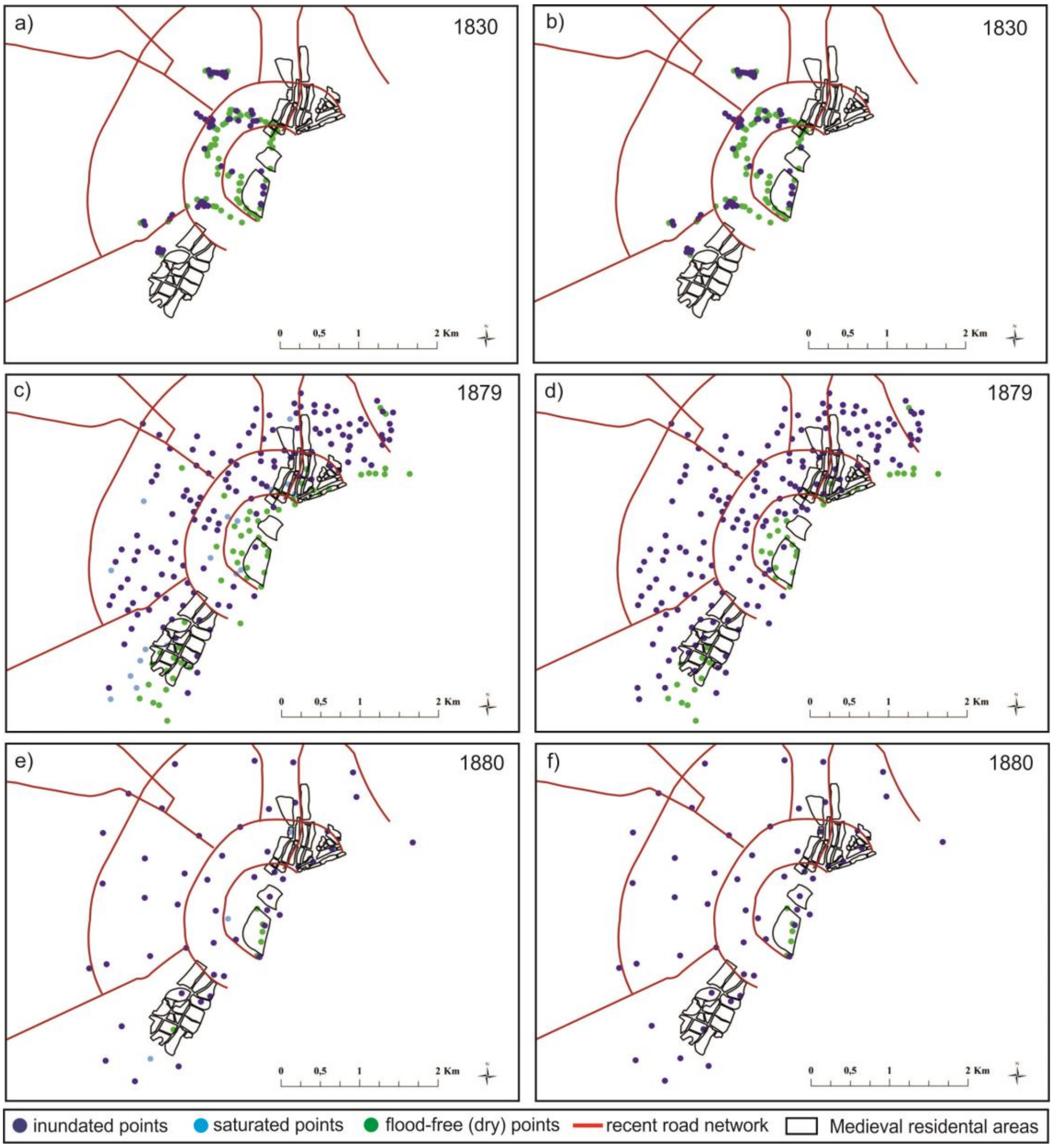

Fig. 3 Location of inundated and flood-free points in the city a) on the basis of Buday (1830); b) on the basis of Buday (1830), calculated with 50 cm infill; c) on the basis of Barilari et al. (1879); d) on the basis of Barilari et al. (1879), calculated with 50 cm infill; e) on the basis of Heller's map depicting boring sites (1880); f) on the basis of Heller's map boring sites (1880), calculated with 50 cm infill

were done in the inner area of the city to determine elevation differences, and the elevation layer plan of the city was developed on the basis of these calculations (Kulinyi, 1901). Elevation values were given compared to the 0 point of the Tisza stream gauge (Fig. 3c,d).

Map 3 (Heller, 1880) depicts the ground-plan of Szeged as it was before the flood. The works were organized by B. Kuklay, a royal assistant engineer appointed to help the Royal Commissioner of Szeged, and B. Zsigmondy engineer, who also evaluated the data (Bertalan, 1884). There are 63 boring points on the map, which were drilled with augers between April 4, 1879 and December 15, 1880. Measuring points were designated to gather data about the entire area of the city, but first of all the three major city parts, especially the central squares. Additional data were collected on such sites which had hydrographic, topographic, or town-planning importance (e.g. Mars Square and vicinity). The map also includes the drilling profile of the "Geological Cross-section of Lajos Tisza Boulevard artesian fountain 1: 2500" as well as the section drawings of the "Geological layer plan of the Royal town of Szeged". The eight sections have scales, the elevation of the surface (above the Tisza 0 point marked with a line and text as well) is also written on the surface (e.g. +6.75) (Fig. 3 e,f).

Map 4 (Szeged, 1879) depicts the entire area of the city, street network, street names, all buildings and land lots. Areas covered by water were indicated with blue colour. Elevation values were given compared to the 0 point of the Tisza stream gauge. The data come from the 1879-survey of Kuklay, in which a total of 110 points were measured. In several cases, it happened that he measured at the same location as the data indicated on Map 3 (e.g. at the two corners of the same street), but the values did not correspond to each other. As a point definition of these places is no longer possible, we treated both values as authentic and included them into our database (Fig. 4a,b).

Finally, Map 5 (Halácsy, 1879) depicts the points (87 pieces) that were placed out for triangulation in order to help mapping and rebuilding the city, among which 45 pieces were cast iron rods and 42 were marked wooden posts (Halácsy, 1879; Bertalan 1884). The iron rods were marked with Roman numbers from I to XLV, and each of them had two designated elevation data: one indicated the elevation above the 0 point of the Tisza stream gauge, the other one indicated meters above the Adriatic (Fig. 4c,d). A number of outskirt points were also designated by elevation data. The work was carried out in July-August 1879, when the city was still partly inundated, and there were lots of ruins.

Each rod and post had an own data sheet which contained a few lines in handwriting about their exact location, the property where they were placed out or they were the closest to, and each property was marked with the number of the respective rod or post. In addition, a 1: 1000 scale sketch was also prepared depicting all of the important landmarks, rods, and posts as in a plan.

We continued to survey the extent of flood risk on the basis of the maps mentioned above. We know a lot of floods from the history of the city, so we have to classify the area as having high flood risk on the basis of its historical data already. However, only a detailed analysis of the data can answer the question whether it was always true for the entire city or there were dry, flood-free spots in the flooded area.

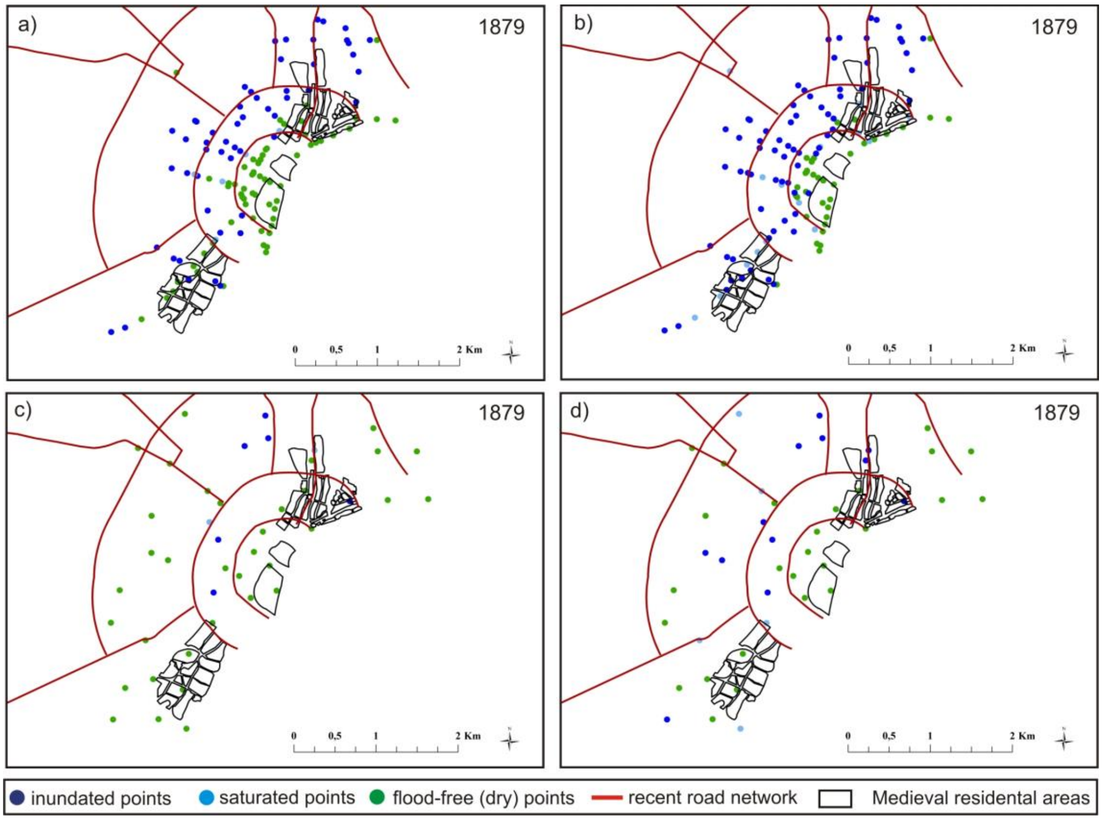

Fig. 4 Location of inundated and flood-free points in the city a) on the basis of Kuklay's map (1879); b) on the basis of Kuklay's map (1879) calculated with 50 cm infill; c) location of inundated and flood-free points in the city based on the number of iron survey posts a) based on Halácsy's map (1879); d) on the basis of Halácsy's map (1879), calculated with 50 cm infill

RESULTS

The topography of Szeged

Those anthropogenic activities that shape the downtown area of contemporary Szeged have been present for nearly a thousand years. Landscape transformation is likely to have begun in the early settlement times when people started to change the terrain in order to securely possess central areas. It was not a major influence on the landscape back then because it was not a primary goal to change the functioning of the natural environment. The inhabitants' will to adapt to nature was still stronger than the force to change the environment.

The second phase is the post-Ottoman city-forming period when two types of landscape changing activities took place. First, there was a conscious and significant reconstruction of the city structure (e.g. building Eugenius Ditch which was a fortification system around the inhabited parts of the city). Second, there was an increasing demand for more and more area which also facilitated stronger landscape changing activities. This period had a stronger impact already but it had little impact on the landscape and topography yet. However, former depressions around the islands were started to be infilled, and the surface of the islands was also subject to levelling.

In the third phase, the settlement structure became stable by the middle of the 19th century, and, in addition to the already existing landscape changing activities, the city experienced a significant external impact in the form of recurring floods of the Tisza River. Hundreds of houses collapsed in the inundated city, and after the flood retreated, the ruins were certainly used locally for grading, for example, or for levelling elevation differences. The 1867 flood had the greatest influence on the city: this period saw the reconstruction and the infill of the city's inhabited areas to reach the ideal level as well as the infill of the inner part of the city.

By analysing the database of the five maps previously described, we can see that the elevation values varied between 77 and 83 m asl (Fig. 5) by the 19th century. One of the outstandingly high data among the 83 m asl values definitely refers to the height of a flood control dam, so it is not a relevant data.

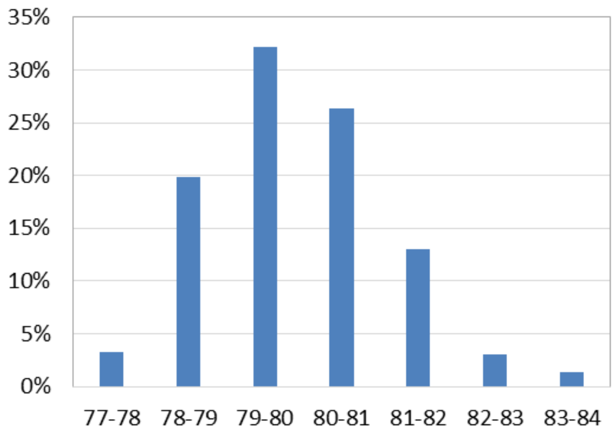

Fig. 5 Height distribution of the survey points (m asl) in the database

Only a few data were included in the extreme range, 55.24% of the points were shorter than 80 meters (the flood peak of the Tisza was 80 meters in 1772). If we also add those data which are in the high-risk data range of 80-81 m, then we can see that a significant part of the city, i.e 81.59 % of the measured points can be found under the critical 81 m asl. The highest values (above 82 m asl) typically occur in a narrow stripe along the Tisza, which values clearly indicate initial bank dikes and natural levees. In addition, these high values often appear along the Eugenius Ditch (an earth trench built as fortification at the end of the 17th century) too. The mean of all points is 79.85 m asl (Fig. 6).

Unfortunately, the elevation data of Map 1 cannot be used here as its lowest points indicate such channels and pools that were either temporarily or permanently covered by water. The purpose of its creation was not the levelling of the city, but the survey of the water-filled pools, therefore the measuring points do not show the relief of the city. The highest points of the survey can be found either along the Tisza or on the city side of Eugenius Ditch, which points designate artificial dikes along the water.

The results correspond to the known data of the topography of the city well. Earlier reconstructions (Reizner, 1899; Kaszab, 1987; Blazovich, 2002) reached the same essential conclusion. J. Reizner proved very early that Szeged was founded on those three islands which we knew as Palánk (City), Alsováros (Lower Town) and Felsőváros (Upper Town) later. He was the first to utilize scientifically the results of the drillings that had been carried out 20 years earlier, and he evaluated the data not only from a geological point of view, but also in terms of settlement history.

Topographic data (Fig. 7) also show that the different parts of the city and the area between them were divided into several small pools that were permanently covered by water (called as "csöpörke" in Szeged). They were regularly filled with water during floods, and it took a long time for them to dry up completely, so it was very difficult to utilize the suitable parts of the islands.

All three islands are residual surfaces located directly on the riverfront. Their slightly higher surfaces by the river can be defined as narrow natural levees which are characteristic of meandering channels (Kohán, 2003; Molnár, 2011). The edges of the islands that are farther away from the Tisza gradually sink toward the direction of the lower terrains, so the area beyond the islands becomes deeper, and closed pools do not let flood water flow back to the river. Those parts of the city that are situated even more distant from the Tisza may lie even deeper, the elevation difference may reach up to 1-2 meters compared to the levees.

This drainless area character was the reason for the 1879 flooding to downflow so slowly; it took a half year to get rid of the water in the inhabited parts of the city, and even then steam pumps had to be used. But this nature was the cause of another common phenomenon: several-day-long rainfall could cause serious aerial floods in the city (Lechner, 2000).

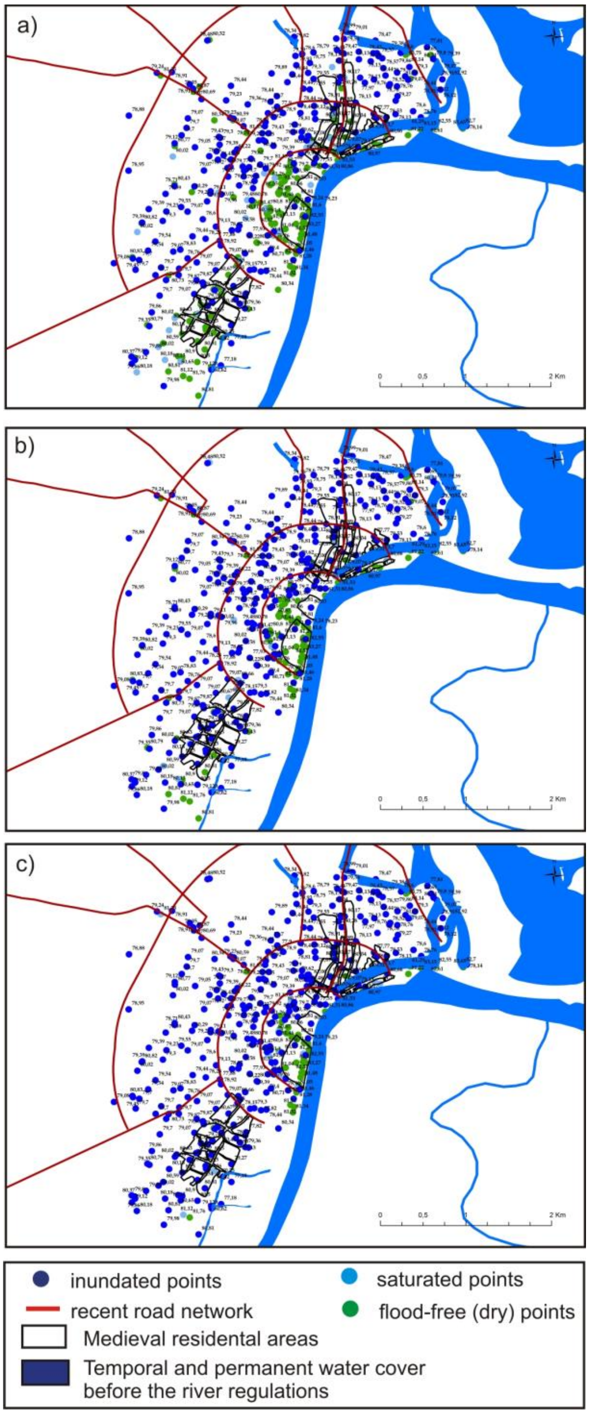

Fig. 6 Location of inundated and flood-free points a) on the basis of all height points depicted on the map; b) calculated with 50 cm infill; c) calculated with 100 cm infill

The geomorphological features of the islands were also different. The middle island (Downtown) was the highest of the three islands. Other parts of the city which are usually situated farther away from the central part of Felsőváros (Upper Town) lie lower than the rest of the city. Obviously, it also means that these parts of the city were inundated first when flood waves from the north arrived. Present day Rókus and Makkosháza are also characterized by lower terrain, but they were not inhabited in the Middle Ages. A significant part of Alsóváros (Lower Town) is also considered to be low-lying save its southern end where the elevation of the surface reaches that of the Palánk (Fig. 7).

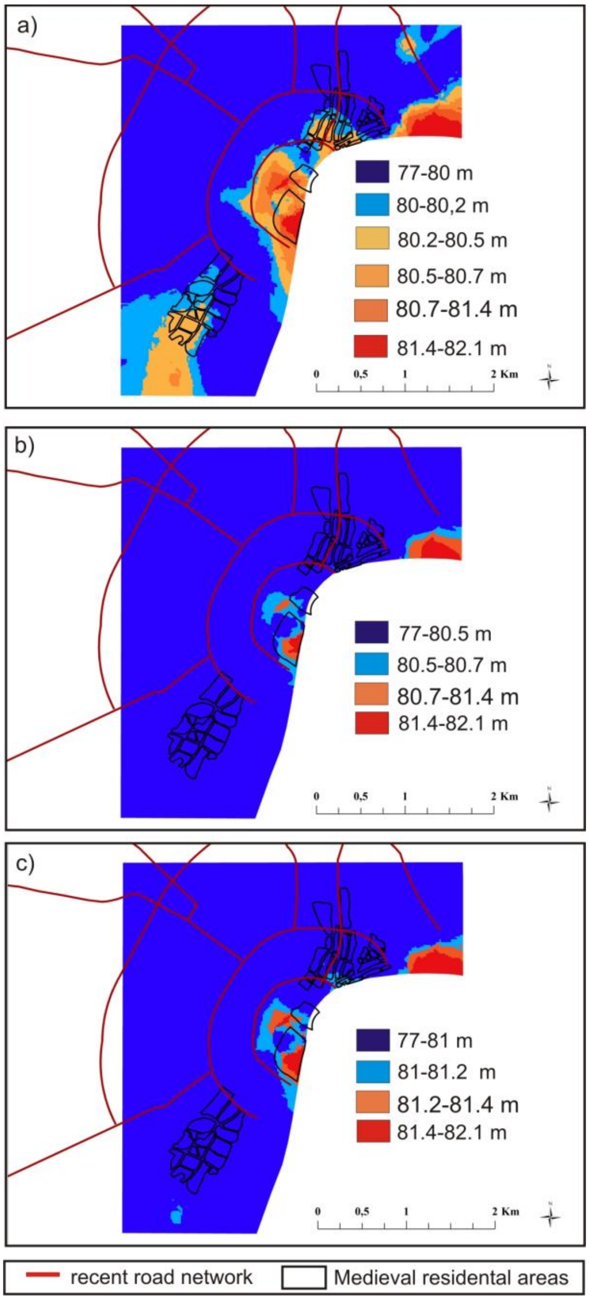

Fig. 7 Relief models of Szeged before the great flood a) on the basis of map data; b) calculated with 50 cm infill; c) calculated with 100 cm infill

Flood risk of Szeged

According to scientific literature, flood-proof settlement level is marked at 6 meters above the 0 point of the Tisza stream gauge (Nagy, 1957), which is 79.70 m asl in the case of Szeged. For this reason, the research assumes that prior to 1879 those parts of Szeged which lay below 77.32 m asl were hardly habitable, while large areas of the city lay either at or below 75.32 m asl (Vágás, 1991).

The newly processed data clearly show that a high flood would not inundate about half of the city by the end of the 19th century. However, it is clear that it could hardly have been valid in previous centuries or millennia, and already in the early Middle Ages the city had very high flood risk. If we do not take the 50-100 cm thick infill originating from urban planning into account, the elevation of the measured points reduces, and, therefore, the number of inundated points greatly increases.

These data and results spectacularly demonstrate that the low-lying terrain of Szeged, which characterized the city before the reconstruction, meant extremely high flood risk, and virtually the entire territory of the city was equally affected. However, this risk continues to grow if remember the simple fact that it is not just inundation that causes damage, but also those seemeingly dry city parts are greatly affected where the soil is saturated from beneath, furthermore the waves caused by the wind could also pose further damages on the dry surfaces. Flood damage does not end at the water level, however, we had to define damaged area in our present study so we considered those area damaged which lay 10 to 20 cm above the highest flooded water level. Saturated areas also become totally useless, life is limited here for a while, too. So, if we examine flooded and saturated areas together, an even higher proportion of the inhabited parts of the city is affected by the flood.

Visualizing the processed data on a map meant important new results, as it was the first time that we could assess the extent of flood on the basis of accurate figures (Fig. 6-7). However, if we subtract the values of the assumed 0.5-1 meters thick infill layer from the data gained from the map analyses, it is even more clearly visible which parts of the city were affected by a high flood.

This result also indicates that in climate cycles similar to the 18t^{h} and 19th centuries the extent of inundated areas might have been the same. It also became clear that before the foundation of the town, 86% of the measured points was certainly inundated when a higher flood occurred on this low-lying terrain, which was due to the absence of a thick, either natural or artificial infill layer (Fig. 8). It means an almost total inundation actually.

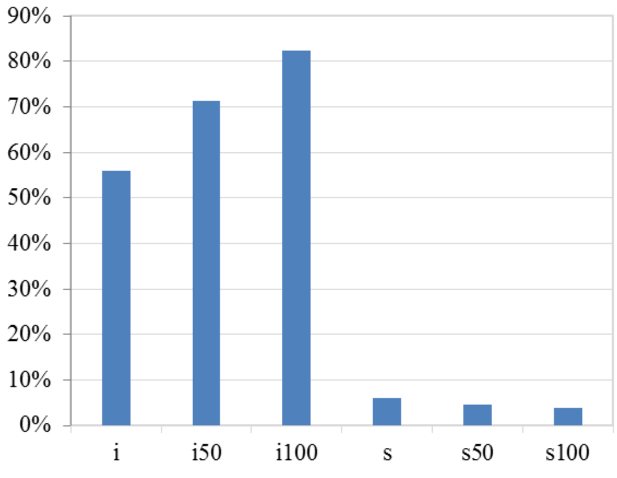

Fig. 8 Normal inundation extent of the points in database (i: inundated, s: saturated), as well as calculated with 50 cm infill (i50, s50) and 100 cm infill (i100, s100)

The reliability of our method can be checked easily. We marked the elevation points on the inundation map of the 1879 flood, and they obviously indicated a total overlay with the inundation of the city which means that our results are correct (Fig. 9).

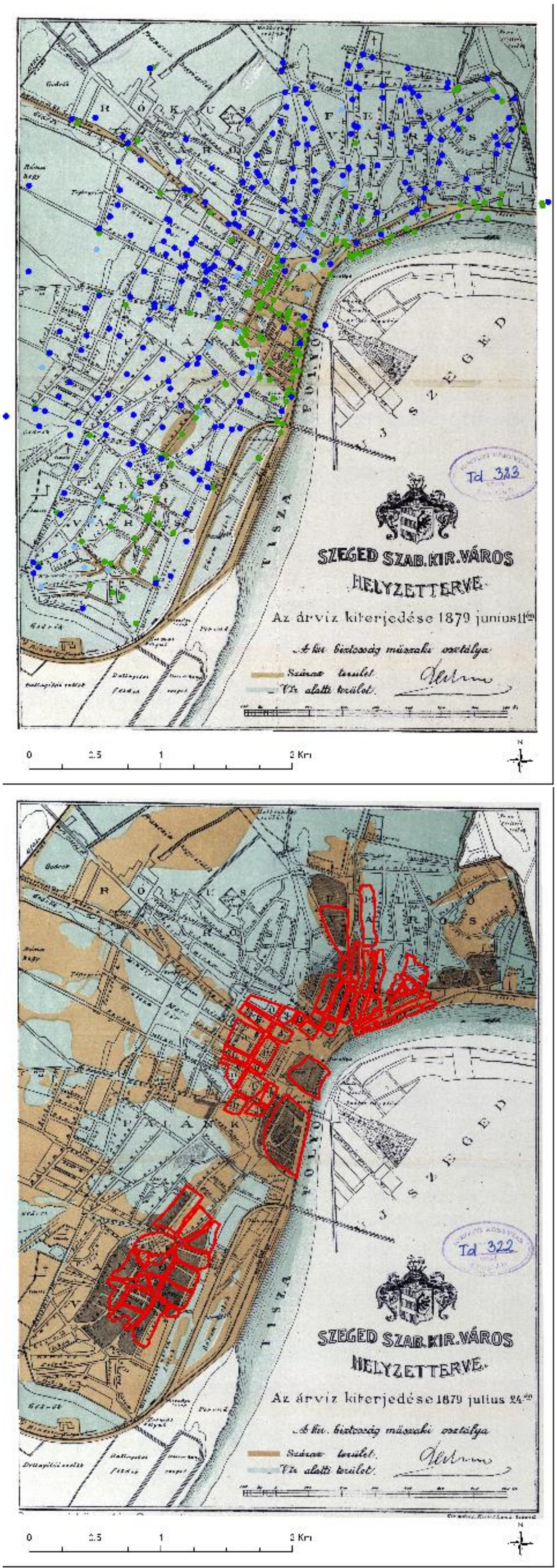

Fig. 9 a) Location of the studied points on an inundation map dating from 11 June 1879 (Action Plan, 1879); b) Medieval city structure on an inundation map dating from 24 July 1879 (Action Plan, 1879)

Since the primary purpose of our present study was to analyse the flood risk of the study area during a much longer time period, we must also emphasize that the highest flood was compared to the levels measured in 1879. In addition, we also found data that supports our hypothesis that the elevation of the original terrain was different centuries ago, or, for example, in archaeological times. Unfortunately, we do not have precise and useful drilling data about it, but if we presume that a minimum of 50-cm-thick layer was formed at certain measuring points, we must be close to the truth. I. Puskás measured a 50-cm-thick layer in the former fortress, which was formed before the 19th century, and there are other excavation proofs of 50 to 100 cm thick infill layers from other parts of the city, which layers originated in the Middle Ages or the modern era (Puskás, 2008). We cannot find as thick an infill layer in an empty room inside of a fortress as in residential areas, there are no ruins of former buildings there, no sign of purposeful infill, and floods were not able to deposit a significant amount of mud due to the fortress walls. Based on these observations and data, we are right to presume that there was a minimum of 50-cm-thick infill from the foundation of the city to the end of the 19th century. Moreover, even higher values, up to a 100-cm-thick infill, are also likely to have occurred, but we must also emphasize that it still has to be researched in the near future.

We cannot finish our investigation without commenting on the real destruction of the flood. The earliest measured data about the flood peak of the Tisza in Szeged originates in 1770 (Buday, 1830). Although there are older secondary sources describing the devastating effects of major floods, they do not contain any accurate data about flood peaks. For this reason, we do not know where the flood peak of the Tisza was before the 18th century. It is certain that the end of the 18th century was characterized by a cooler and more humid climate both in European and Hungarian history, which meant that river flow rates must have increased and resulted in higher floods. However, it also means that drier climate periods (e.g. the Roman Age, or the 10th to the 13th centuries) witnessed smaller floods, which also reduced the high flood risk of the city.

As to settlement history, the most important issues concerning the Tisza are related to the floods. The most important settlement historical issue of the frequently flooded areas was the population's ability to adapt to the changing stages and discharges of the river, to what extent they were able to use the excess water of the floods, or how they could mitigate flood damage (Molnár, 2011). The Tisza has two characteristics that distinguish it from other large rivers. One of them is that the river floods the low floodplain already at middle water level surface elevation, and its environment is gradually flooded. The other one is that the two annual flood cycles make life unbearable along the Tisza due to the elongated time of river downflow and slow drying out of the flooded areas (Fig. 10). It has been made even more difficult by the fact that the populated area of the city is of basin-like, and the slightly higher ridges along the river prevent the free flow of flood water from the deeper pools that are farther away from the river. So the whole process takes much longer than elsewhere. Flood damage, isolation and all negative effects are extremely important in terms of settlement history, because they complicate life as well as land use (Kiss, 2011).

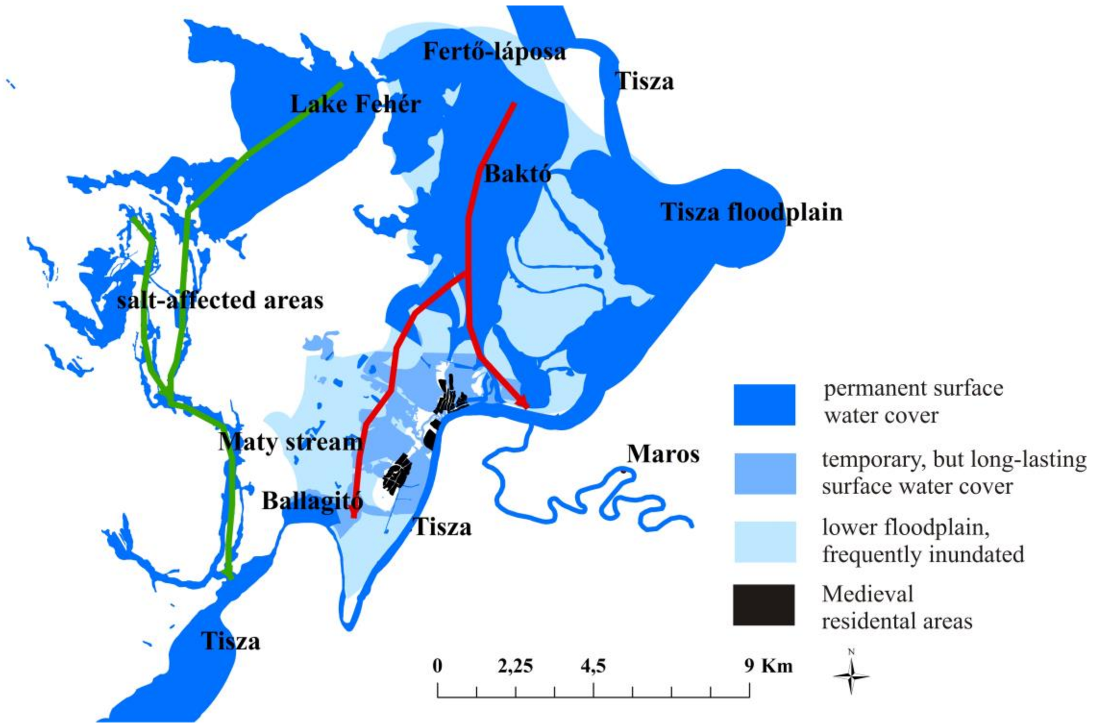

Fig. 10 Map of the catchment area of the river-system in and near Szeged, and map of the permanent and temporary surface water cover before river engineering (Szalontai, 2014b). Green arrow: waterflow from the Kiskunság Sand Ridge (Homokhátság) without flood risk; red arrow: Tisza floods posing significant flood risk and damages

It cannot be accurately determined which areas were flooded in Szeged and in its vicinity. We know about a flood that reached even the pool of Fehértó from the west (in 1801), but floods usually inundated the areas that lie to the east of the highway leading to Csongrád today. In the late Middle Ages, of all populated areas it was the northern part of the city, Felsőváros (Upper Town) that experienced the most floods or was directly threatened by them. Nevertheless, it was also common that Alsóváros (Lower Town) was also flooded, for example in 1712 (Reizner, 1899), when the flood arrived from the north and inundated the inhabited parts from that direction (Fig. 11)

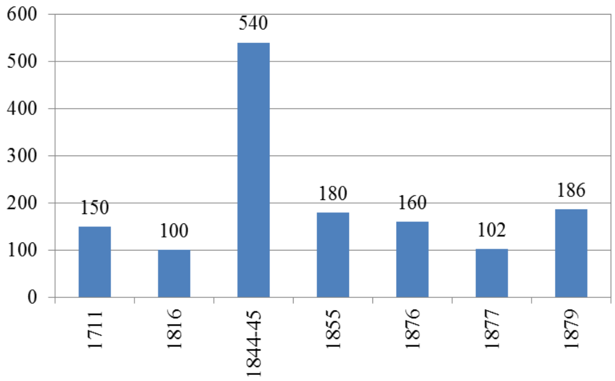

Fig. 11 Length of inundations (number of days) (Vágás 1991)

From landscape assessment point of view it is also important to know where were dry surfaces where the inhabitants could move in case of a flood inundating the whole city. It is known that in 1689 and in April 1712 the whole city was inundated except for Palánk due to the earth trenches. In these cases the surrounding vineyards and the "Öthalom" hills were surely dry, which could be approached by boats (Reizner, 1899; Kardos, 1979). In 1770 Szilléri hills, the highest situated small island (79.5-80 m) were also inundated, which meant that all other lower-lying areas were flooded for that time and the loess-covered "islands" were also inundated. Engineering maps from 1830 demonstrate that these flooded areas extended to the Öthalom hills and Ballagitó areas; water covered low-lying arable lands, thus, the city was fully surrounded by Tisza floods from the north.

If we study the flood exposure of Szeged, we have to take into account another important aspect. Today we can state precisely where there used to be streams, pools in the populated parts of the city (Szalontai, 2014a). These surface waters were not of temporary nature, but permanent, their riverbed was always visible and meaningful to the community, as long as it was not concealed (or destroyed) artificially. Their long-lasting (sometimes persisting for centuries) presence is best proved by the fact that street and ground-plot structure was developed in harmony with the then-present subsurface water bodies, and thus the people living there adapted to their channels and water influx.

But what is even more surprising is that not only the permanent hydrological elements trace out the possible settlement sites, but temporarily flooded areas as well. We can come to this conclusion also when we overlay the medieval town structure to the city map that was prepared five months after the great flood. In 1879, the deepest parts of the city were still covered by floodwater in July, after the March flood. These areas indicate those pools which were characterized by temporary inundation before the river was engineered. It can be noticed very well that these pools almost completely surround the earliest parts of the city, and they literally complement the blank spaces between the separated units.

These urban wetlands were not built in with houses and remained empty until the 20th century. Their single city structure utilization was the building of Eugenius Ditch after the Turkish occupation as the southern end of the ditch was built by using these wetlands and pools as a security system. The stream that once ran along the northern wall of the former fortress had similar effects on the settlement structure, as there was a large wetland there that separated the two parts of the city for centuries, and this situation did not change over time, not even after losing the border fortification role it previously had.

The low-lying areas were not inhabited, and they were usually swamplands with recurring inundation. The area is likely to have had aquatic or hydrophobic plants as the predominant vegetation. In the modern era, they were low-lying arable lands (so-called "nyomásföldek") which served mainly for grazing.

It is a complex water system, which received significant flood water supply on each occasion when the inhabited parts of the city were flooded. Its pools are likely to have always been filled with water. Due to the significant water supply of these pools, their infill or drying out became significantly difficult, which can also be considered as flood damage, similarly to the physical destruction caused by water.

CONCLUSION

Concluding the results of our study, we can say that, compared to the 19th century city, the inhabited parts of Szeged were situated on lower-lying terrains for centuries or millenia before the foundation of the city. For this reason, particularly during periods of cooler and wetter climate, the Tisza floods coming from the north inundated the entire area of the later city. The flood covered the low floodplain and the low-lying basins to be filled with water, thus creating an actual sea around the city with several kilometers of diameter. This huge amount of water made life as well as entering or leaving the settlement impossible. These conditions significantly limited the location of residential areas and therefore before the Hungarian Middle Ages the center of settlement was found farther away from the banks of the Tisza, and not along it, on the flood-free areas of the surroundings.

The 10th and 11th centuries were characterized by a gradual warming, and the coming drier climate (medieval climate optimum) significantly improved this unfavorable hydrological feature, and must have reduced flood risk to a great extent (Lamb, 1982; Rácz, 2001). These changes led to the possibility of using the economic benefits of Maros salt trade to start the development of the city, which finally turned Szeged into one of Hungary`s most important and flourishing cities.

References

Bertalan, A. 1884. Szeged szab. kir. város földrajzi és meteorológiai viszonya. (Geology and meteorology at Szeged) Szeged. 70 p. (In Hungarian)

Blazovich, L. 2002. Városok az Alföldön a 14–16. században. Dél-Alföldi évszázadok 17. (Cities of the Great Hungarian Plain in the 14th-16th centuries) Szeged. 271 p. (in Hungarian)

Brázdil, R., Kotyza, O. 1995. History of Weather and Climate in the Czeh Lands I (Period 1000–1500). Zürcher Geograpische Schriften 62, Zürich. 260 p.

Farsang, A., Puskás, I. 2009 A talajok sajátosságai a városi ökoszisztémában — Szeged talajainak átfogó elemzése. (Soil attributes in urban ecosystems – The detailed assessment of soils in Szeged) *Földrajzi Közlemények* 133, 397–409. (In Hungarian)

Glaser, R. 2008 Klimagesichte Mitteleuropas. 1200 Jahre Wetter, Kilma, Katasrophen. Darmstadt, Primus Verlag, 227 p.

Halácsy, S. 1879. Szab. kir. Szeged városa beltelkeiben háromszögitett elsőrendű főalappontok kiszámításának jegyzőkönyve (Report on the calculations on the main geodesic points in Szeged). Szeged, kézirat. Somogyi Library (in Hungarian)

Kardos, I. 1979. Szeged árvízvédelmei rendszerének kialakulása az 1879. évi katasztrófa előtt és után. (Flood protection in Szeged before and after the flodod in 1879). *Hidrológiai Közlöny* 59, 252–260. (in Hungarian)

Kaszab, I. 1987 Építésföldtani összefüggések Szeged és környéke felszínközeli üledékeiben. (Engineering Geology of near-surface sediments of Szeged and its neighborhood).Budapest. 113 p. (In Hungarian)

Kiss, A. 2011. Floods and Long-Term Water-Level changes in Medieval Hungary. PhD dissertation. Budapest. 323 p.

Kohán, Z. 2003. A tradicionális középkori ártéri gazdálkodás geomorfológiai környezete (Geomorphological environment of traditional (medieval) floodplain farming). *Földrajzi Értesítő* 52, 5–21. (In Hungarian)

Kuklay, B. 1880. Talajfúrások Szegeden. (Soil surveys in Szeged)Kézirat. 4 p. (In Hungarian)

Kulinyi, Zs. 1901. Szeged új kora. A város újabb története (1879–1899) és leírása.(The new history of Szeged (1879-1899) Szeged, 690 p. (In Hungarian)

Lamb, H. H. 1982. Climate, history and the modern world. London and New York. 387 p.

Lechner, L. 2000. Szeged újjáépítése. (The reconstruction of Szeged) Reprint, Szeged. 92 p. (In Hungarian)

Máté, Zs. 1989. Szeged XIV. századi helyrajza. (Szeged in the 14th Century) TCsMT 14, 5–75. In Hungarian

Mezősi, G. 1984. Szeged környékének negyedkori és recens felszínfejlődésének néhány kérdése a részletes geomorfológiai elemzés tükrében. (Quaternary and recent surface development int he vicinity of Szeged based on a detailed geomorphological assessment) In: Az Alföld gazdaságföldrajzi kutatásának eredményei és további feladatai. II. Természeti környezet. Békéscsaba 1984, 203–212. (In Hungarian)

Molnár, S. 2011. Environmental historical research of floodplain management demonstrated through two sampling sites on the Great Plain of Hungary. PhD Theses, University of Szeged, 125 p.

Nagy, M. 1957. Szeged földrajzi energiái és a város hatásterülete. (Geographical energies and the affected areas in Szeged) A Szegedi Pedagógiai Főiskola Évkönyve, 137–170. (In Hungarian)

Ozsváth, G. 2003. Három, a közelmúltban visszakerült 19. századi kéziratos Szeged térkép. (Újabb malomadatokkal). (Three maps recently became avaiable from the 19th century on Szeged-including new mill data). MKCsM 2002 (Szeged 2003), 81–93. (in Hungarian)

Puskás, I. 2008. Urban soils:complex evaluation and classification of soils in Szeged. PhD Theses, University of Szeged, 153 p.

Rácz, L. 2001. Magyarország éghajlattörténete az újkor idején (Climate history of Szeged in the Modern Age). Juhász Gyula Felsőoktatási Kiadó, Szeged. 303 p. (In Hungarian)

Reizner, J. 1899. Szeged története I. (The history of Szeged) Szeged, 398 p. (In Hungarian)

Rohr, Ch. 2007. Extreme Naturereignisse im Ostalpenraum. Naturerfahrung im Spätmittelalter and am Beginn der Neuzeit. Köln-Weimar-Wien, Böhlau Verlag, 201–398.

Szalontai, Cs. 2014a. The role and significance of the Maty creek and the connected hydrological system in the settlement history of the vicinity of Szeged. PhD Theses, University of Szeged, Doctoral School of Earth Sciences, Geoarcheology, Szeged, 131 p.

Szalontai, Cs. 2014b. Két víz között. Hatalmi és stratégiai központ váltás Szeged környékének településtörténetében. (Between two floods. Political and strategic centre changes int he settlement history of the vicinity of Szeged). In: Horváth, G. K. (ed.) Vízhasználat, vízszabályozás és társadalom a 13–20. századi Magyarországon. Balassi Kiadó, Budapest, 37–78. (In Hungarian)

Vágás, I. 1991. A Tisza szabályozása. (River regulation works of the River Tisza) In: Gaál, E. (ed.) Szeged története 3/1. 1849–1919, Szeged, 133–139. (In Hungarian)

Maps

Buday 1830. Buday Mihály város főmérnök által jegyzett térkép Rajzolat melly Sabad Kir. Szeged várossának belsőbb részeiben található Motsáros víz állásoknak házhelyekre való felosztását mutattya. 1830. Magyar nyelvű, színes kéziratos térkép. Mérete: 950x600. Méretarány: 2” Bétsi hüvelk=100 öl. (Ozsváth, 2003; Szalontai, 2014) MFM jelzet nélkül.

Barilari et al. 1879. Situation de la ville de Szeged. Szeged szab. kir. városának átnézeti vázlatrajza. Másolva és kiegészítve a k. biztosság műszaki osztálya által. Barilari, P. Gros, L. Jacquet, L. Waldorp, J. Kozlowski, Th, Szegeden 1879. évi július havában. Magyar és francia nyelvű kőnyomatos árvízvédelmi térkép. Méret: 78x122 cm. Méretarány: 1:7200. MNL S068 V Ny (Részlet).

Heller 1880. Szeged sz. kir. város Földtani réteg-terve. A Tisza 0 pontja alatt 4 méter mélységben képzelt vízszintes metszet. Plan géologique de la ville de Szeged. Coupe horizontale prise au niveau duzéro fleuve de Tisza. Heller Lajos mérnök térképe. 1:10000. 1880. Sk Td 329, Td 381 (Kuklay, 1880).

Kuklay 1879. Szeged szab. kir. városának átnézeti vázlatrajza. A jelenlegi városi lejtmérési adatok. 1879. Másolva és kiegészítve a k. biztosság műszaki osztálya által, Szegeden 1879. évi július havában. Endrényi Lajos nyomdájából. Mérték 1”=100 méret 33,5x42 cm. CsML T102, Sk Td 319, Tm 343, Tm 73, Tm 74.

Action Plan 1879. június Szeged szab. kir. város helyzetterve. A kir. biztosság műszaki osztálya által. Mértékmérővel. Sk Td 323a

Action Plan 1879. július Szeged szab. kir. város helyzetterve.. A kir. biztosság műszaki osztálya által. Mértékmérővel. Sk Td 322

Abbreviations

CsML Archives of Csongrád County /Csongrád Megyei Levéltár/, Szeged

MFM Móra Ferenc Museum /Móra Ferenc Múzeum/, Szeged

MNL National Archives of Hungary Magyar/Nemzeti Levéltár/, Budapest

Sk Somogyi Library/Somogyi Könyvtár/, Szeged