THE EFFECT OF THE EXTREME WEATHER EVENTS EXERTED ONTO THE GROUNDWATER LEVELS WITHIN THE KALOCSAI-SÁRKÖZ AREA

J. SZALAI[1], *GY. NAGY*[2]

ABSTRACT. – The effect of the extreme weather events exerted onto the groundwater levels within the Kalocsai-Sárköz area. The effect of the past years' extreme weather events was reflected by the variation of the groundwater levels, too. However the changes showed significant differences considering the areas. The year 2012 was characterised by the fact that the groundwater level changes appeared in areas for which there was no such example in the past decades and due to which absolute minimum levels had formed by the autumn of 2012. Simultaneously due to the fast increase of the water-level that occurred in spring of 2013 there were absolute maximums in the neighbourhood of some monitoring wells. The Kalocsai-Sárköz area does also belong to this category. This phenomenon drew the attention to the fact that regarding a small area with such specific features like the Kalocsai-Sárköz there is a new risk factor compared to the experience of the past decades: this is the extreme variation of the groundwater level. Thus it is a must to perform a complex analysis of the groundwater level, with an approach and methodology of taking also into consideration the environmental variables and the background factors.

In the thesis we are presenting the results obtained when revealing the connections between the variation of the environmental variables and background factors as well as the time-series of the groundwater levels.

Key words: alluvial plain, groundwater, monitoring well, environmental variables, background effects, risk

1. Introduction

Our study area, the Kalocsai-Sárköz is located on the left side of the Danube, in the South-western flange between the Danube and Tisza rivers (Alluvial Plain Along the Danube, Dunamenti-síkság), (Hajdú-Moharos & Hevesi 1999, Szalai, 2011.). It is 240 km long, stretching from Vác as far as the Southern

[1] General Directorate of Water Management/Országos Vízügyi Főigazgatóság, Budapest, e-mail: szalai.jozsef@ovf.hu, paleohidrologie@gmail.com

[2] Lower Danube Water Authority/Alsó-Duna-völgyi Vízügyi Igazgatóság, Baja. e-mail: nagy.gyorgy@aduvizig.hu

country border, in a width of 20-25 km, narrowing both in the northern and southern areas, forming a plain of alluvial deposits, in the southern part of the Danube plain (Figure 1). Its current limits are partly natural, on the west it is delimited by the Danube, on the east by the western flange of the Hátság, and partly it can be delimited by geographical and geological features. (Some sources (Marosi & Somogyi, 1990.) consider that the Madocsa area situated on the right bank of the Danube does also belong to the Kalocsai-Sárköz region. However due to its separation we did not consider this area within the study.)

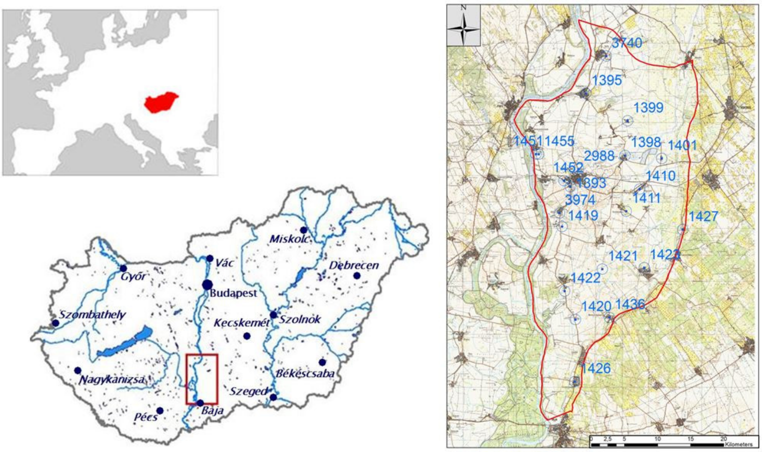

Figure 1. Location of the area of case study, the Kalocsai Sárköz, and the groundwater monitoring network of it.

The Sárköz area situated at the southern flange of the Danubian plain is wedged between the Szekszárd Hills, the Danube-Tisza Interfluve ("Homokhátság") and the Bácska Plain between the Danube and Tisza rivers. The first appearance in a document from 1459 mentions it as "Sarkez" (Vályi, 1796.). In Hungary, the areas being close to the river estuary and delimited by the water flows were usually separated by the word "köz" (meaning in-between) added to the smaller water flow. In this area the name of Sárköz and the Kalocsai-Sárköz derives from the Sárvíz (former Sár) river flowing into the Danube at Báta, being one of the significant tributaries of the Danube. This water flow is also mentioned by the sources cited by Ortvay as Sarwezy, Saarwyze, Sarvizi, Saar fluvius (Ortvay, 1882., Kiss, 1988.).

Péter Treitz characterised the hydrographical situation as follows: "The Danube forms two branches under Pest. One branch went toward the west and at the edge of the shifting sand got to the current main flow at Baja." This statement is backing the opinion saying that the name of Sárköz – as a geographical name – should mean the area closed by the Sár and the Danube, within the Danube and

Tisza rivers, where the river is meandering along the western flange of the Hátság. Due to the shifting to the west of the main bed of the Danube the river divided the area into two parts, but the morphological and hydrographical features kept remaining similar. The area parts can be differentiated according to their names (Tolnai- és Kalocsai-Sárköz).

József Pataki says: "In country there are many areas named Sárköz. The people called the watery areas closed by the rivers as such, and still do, and usually using the name of the smaller river. Parallel with the Sárköz in the South-eastern part of Tolna county there is the Sárköz of Pest county, on the other side of the Danube. In Szatmár county and the Csallóköz there is another area called similarly." (Pataki, 1954.).

2. Forming of the Kalocsai-Sárköz

The forming of the Kalocsai-Sárköz was caused by two important factors: one of them is the crust motions, the other one is the Danube that is changing its bed due to the crust motions. During the mid-pleistocene age due to the crust motions the Danube changed its flowing direction toward the east in the Kisalföld (Small Hungarian Plain) then it entered the Alföld (Great Hungarian Plain) through the Visegrád gorges where it continued its way toward the south-east (Pécsi, 1959., Bulla, 1962., Neppel et al. 1999., Lóki, 1999.). The process of building the cone of alluvial deposits was influenced by repeated crust-motions: due to the sinking of the eastern flange of the Trans-Danubia region (period of the würm ice-age) the already formed fan-like deposit-cone changed the flowing direction of the Danube, and the bed drifted gradually to the west, covering the south-western part of the current Homokhátság.

At the beginning of the Holocene the warming-up and the rather rainy weather resulted a significant increase of water yield. In the Sárköz area the river formed a wide, meandering bed with many islands on the loose sediment, and the entire region was restructured several times by the multi-branch river when the flood was passing through. The status that remained almost till the present days is shown properly in the work of Mátyás Bél ("*Notitia Hungariae novae historico geographica*", appeared in 1735) through the map of Solt county (prepared by Sámuel Mikoviny) where the Danube meanders, the ramifications, the islands and the swamp can be identified properly.

Until the very present days the Danube and its tributaries played an important role in forming the region's geographical forms. This was caused primarily by the fact that the Danube carried the pebbles originating at the Upper Danube (Felső-Duna) to the Uszód area. The pebble layer embedded at the bottom increased significantly the stability of the bed. The change of the bed-shape took place through drifting erosion, by separating the banks the bed was widening and islands were forming. However under Uszód the stability of the bed moderated significantly due to the change of the bed-material, which formed the entwined system of the curves and branches, which is proved also by the hydrographical features of the Sárköz region from before the systemisation.

The river section between Budapest and Baja was also characterised by the fact that there were frequent ice-dams causing huge damages, similarly to the frequent floods. The current structure of the water system is the result of the regulations that started in the 19th century and ended in the 20th century (cutting the curves, building the dams, regulating the river-bed, draining the swamp).

3. Geomorphological characteristics of the study area

The 1050-km^2 (being 950 km^2 without the Madocsa region) Kalocsai-Sárköz plain has an altitude of 88.5-112 m above sea level, sloping gently toward the south and south-west. Regarding the surface there are significant differences between the northern and southern parts as well as between the western and eastern parts, too.

The characteristic geographical forms of the plain's northern part are the terrace remnants and the lower flood-areas. The terraces are built by clay-sand and shifting sand, the flooded areas are built by fine-grain alluvial deposits. Under the surface forms there is a pebble layer down to the Uszód area, with a variable thickness (Pécsi, 1959., Bulla, 1962., Neppel et al. 1999., Mezősi, 2011., Szalai & Nagy, 2012.).

To the south, the perfect plain is covered by water-damming muddy and clayey deposit in the lower flooded areas, the upper flooded area is covered by mud, sand and at some points there is shifting sand of alluvial origin.

The tied and abandoned bed areas and the areas without flowing exits are quite specific. The latter ones gave way to wide lakes whose significant part does still exist but the majority is losing its water during the dry season. The southern area is characterised by the accumulation of the fine-grain alluvial deposit, at some points one can find pebbles from the Trans-Danubian region.

The geographical forms of the region's western flange and their materials were formed primarily by the Danube floods until the water structures were finished. The eastern flange was influenced by the waters carrying the fine deposits and they filled up the shallow and dry lakes and the bed-remnants that still exist.

4. Soils and land-use of the Kalocsai-Sárköz

The major part of the Kalocsai-Sárköz area is formed by adobe (73%). The sandy adobe is not spread uniformly, its proportion is 12%. In the eastern and northern flanges and scattered in some sectors there are various sands, whose proportion is 3%. In some wedged areas there is clayey adobe, too (8%). There is peat (4%) in a narrow longish north-southbound area, along a bed-section of the Danube valley's main canal (Dunavölgyi-főcsatorna) which can be considered the remnant of the Danube's former abandoned bed that is sort of filled-up. (In the region there is a favourite bathing spot with a similar origin. It is the Lake Szelidi (Szelidi-tó), east of Dunapataj.)

Based on the genetic types the soils of the region show a specific zoning: in the band being close to the Danube, widening to the west and south there are alluvial soils. When going to the east in the southern part of the region there are meadow soils at an increasing rate, then there is humus sand and drifting sand on the left bank of the main canal and the western flange of the Homokhátság. The central area of the region is characterised by the meadow chernozem soil. The northern part of the region is considered to be the area of the solonchac-solonetzic, and slightly to the south and in the depth there is the salty meadow chernozem. Almost parallel with the bed of the Danube valley's main canal (Dunavölgyi-főcsatorna) there are meadow soils, and to the south there are plain-swamp soils.

The current utilisation of the region can be analysed based on the CORINE maps. A certain part of the area that became flood-free after the systemisation works was used for agricultural purpose which means arable lands. As accordingly the non-irrigated arable lands are characterising almost the entire region. In addition the proportion of the meadow-pasture, in the north-east the natural lawn and meadow is more significant. There are bigger and consistent forests mostly in the Danube's area, in the south-western flange of the region and in some minor sectors.

The sandy areas of various sizes are used for grape-growing mostly. In the bed-remnants that are still not filled up there are swamps and peat-marshes. Their shape is following the curves of the former river bed.

5. Groundwater regime of Kalocsai-Sárköz

The groundwater motions of the Kalocsai-Sárköz area is shown by using the data that were collected between 1951 and 2013 and by taking into consideration two west-east sections. In order to assure the comparability we used the curves recalculated for the altitude above sea level at an identical height domain.

The majority of the water levels measured in the monitoring wells of the northern section was in the 86-92 m interval above sea level (Fig. 2). The effect of the drought of years 2011 and 2012 was visible significantly, especially in connection with the water levels measured in the 001401 Öregcsertő monitoring well: in 2012 there was an absolute minimum, and in spring of 2013 there was an absolute maximum because of the rainy weather.

The second section within the southern area has three monitoring wells only (Fig. 3). Their variation domain is between 87-91 m. The curves are characterised by the significant decrease that took place in 2000 and the accurate measuring of the maximums of year 2010 was not possible due to the structural features of the measuring devices installed in the wells.

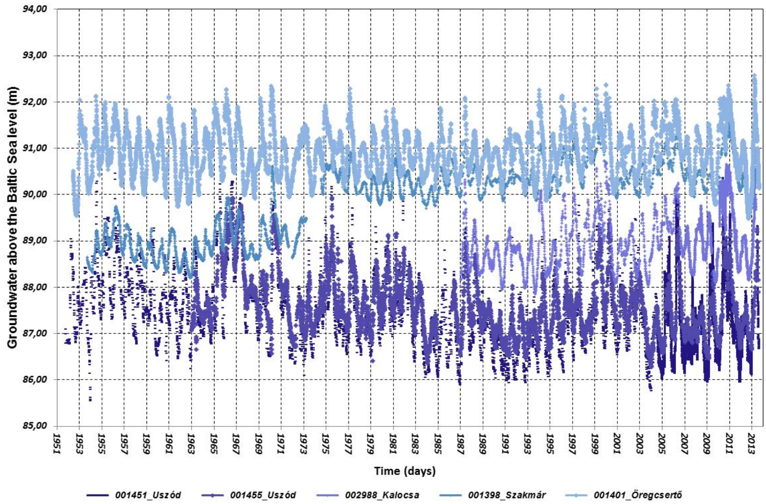

Figure 2. The time-series of the monitoring wells of the first cross-section, on the north part of the area.

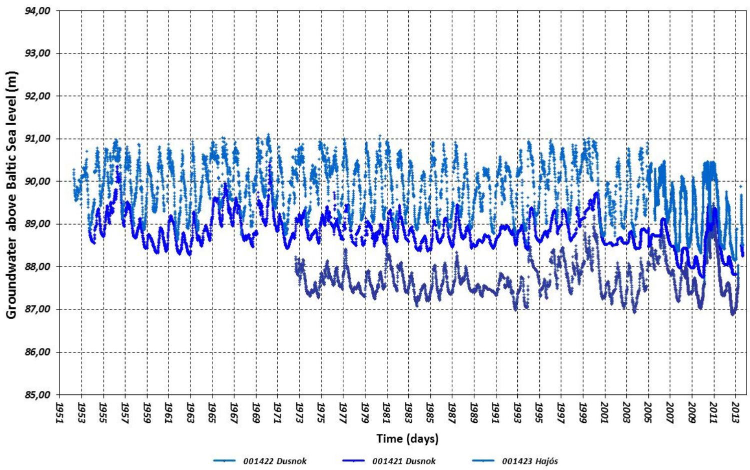

Figure 3. The time-series of the monitoring wells of the second cross-section, on the south part of the area.

6. Effects of the environmental variables on groundwater level

The groundwater motions of a certain area are formed by the hydro-meteorological and other background factors and the environmental variables. The former ones appear as accidental short-term (precipitation) effects, while the modification of the environmental variables can be relatively short during a flood, but it can also be prolonged, even a century-long due to forestation or water system management. (Probably the groundwater holding layer, the geological medium can be considered the least changing element of the environmental variables.) In our approach the environmental variables include the regional features that characterise the physical surroundings of the monitoring well respectively they describe the variation on the long run. (The majority of the vast changes is due to human intervention – forestation, landscaping, building up.)

It is known that the motions of the groundwater – besides other environmental variables - are also influenced by the cover of the surface. The effect of the forestation that took place decades earlier in an experimental site and was based on local measurements in an experimental area – named after Imre Komlósi, formerly operated by the wind up Water Resources Research Institute (Vízgazdálkodási Tudományos Kutató Intézet, VITUKI) at Méntelek, near Kecskemét city – could be proved clearly. The measuring of the effect exerted by the various surface covers onto the groundwater is a time consuming and expensive task. In order to reveal the changes that took place throughout the decades or centuries there is need for collection of additional information.

6.1 Overview maps from the 18th century

The military surveys can be considered "databases" suitable for the national review that were created more or less based on uniform principles, and their utility was increased and spread significantly by the space-IT developments. It is a favourable condition that one of the objectives of mapping consists of identifying and recording the geographical forms that are important from warfare perspectives (e.g. watery, difficult areas, forests, geographical forms). The timely change of the latter ones can be followed along the pages of the later surveys, similarly to the changing and differentiation of the landscape (the road system becomes more and more complex), becoming something created by man (landscaping and water structuring, forestation, surface mining, industrial sites, appearance of big cities) can also be monitored.

Basically within the Kalocsai-Sárköz area it was the water structure that changed the early features of the landscape, and it became a flood-free area leaving behind the intertwining, flooded wetland shown in the map of Sámuel Mikoviny with a system of inner water-canals and permanent water-beds. The changes that occur in the neighbourhood of the surface-water perceiving wells can be evaluated based on the details with identical scales of the maps of the survey made in various moments.

Regarding the revealed maps made about the Kalocsai-Sárköz we did not try to present all of them because some of them presented the main features of the region but contextually they could be considered as drafts only.

Figure 4. Map of Solt county (left) and detail of a map from 1763 (right)

Mátyás Bél – in his work "Notitia Hungariae novae historico geographica", that was published in 1735 – is presenting the map of Samuel Mikoviny showing the Solt county (Fig. 4, left). The magnified details show clearly the Danube meanders, the still live and abandoned branches, the surrounded islands respectively the deep swamps.

The picture in the right side shows the Kalocsai-Sárköz area based on a map created in 1763 (Papp-Váry & Hrenkó, 1989.), (Fig. 4, right). Analysing the contextual details of the map it can be stated that the area keeps having an intertwined water system, but differing form the Mikoviny map that was made decades earlier the sectors situated in the northern higher flood-free area show a definite texture. This shows probably the areas that are used for agriculture after the region has again been populated. The map is special in the way that in the drawing situated in the bottom right corner one can see the person characterising the region of that time: the fisherman-hunter.

6.2 Military surveys

The military topographical maps occupy a special position in the history of the Hungarian cartography. Their geo-referred versions – besides their aesthetical value – are the static data sources of the past environmental variables that can't be lacked when looking for answers within the water management.

Within the 1st military survey the sections at scale 1:28800 created in Hungary based on the surveys of years 1782-1785 are still free of projections, their inaccuracy can be significant, thus the identification of some objects may not be that easy. The presented details clearly show that the two defined churches („Karátsony-Templom", „Tsornoi-Templom") are probably free of floods, they were constructed on a small hill jutting out of the watery area (Fig. 5, left).

The 2nd military survey ordered in 1806 by Emperor Franz I. „Zweite oder Franziszeische Landesaufnahme", in the Hungary of years 1819-1869 was created at a scale of 1:28800. During the creation of the sections they applied the Cassini sectioning and projections (keeping the angle and distance, with parallel and perpendicular section limits). Due to the characteristics – meaning the distortions of the map sections - this projection system is not that accurate. (The spherical and plain lengths were not corrected.) The surface forms of the surroundings of the monitoring well show clearly the position of the bed-remnants, dead-ends and watery areas (Figure 5, right). During the landscaping works of the section that was made between 1858 and 1860 there are some constructions around the probing well. Their environmental effect still can't be considered significant.

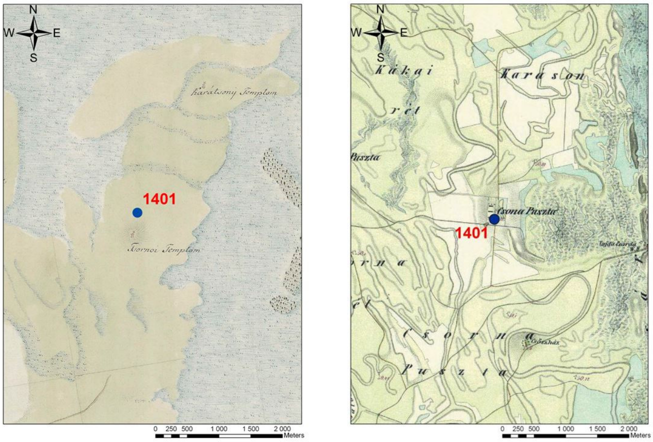

Figure 5. Surroundings of the groundwater monitoring well 001401 Öregcsertő at the time of 1st and the 2nd military surveys

The 3rd military survey started after the introduction of the metric system (1871), thus the surveying scale – differing form the earlier versions – is 1:25000 that is still used in case of the military topographic maps. The survey took place for the entire Hapsburg Empire, with a uniform sectioning, thus the distribution of the map-sections covering the historic Hungary's area can be shown in one sheet. The division of the surveying and projected maps is related to the geographical grade system, meaning that the sectioning was not adjusted to the surveying maps but the starting point consisted of the sectioning of the general map with a scale of 1:200000 because the covered area is a grade-trapezoid (1°x1°) (Jankó, 2007.). The surveying of Hungary and the Partium region took place between 1872 and 1884, within a relatively short period. Regarding the geographical forms and the road system there is no significant deviation from the earlier version, however the improved accuracy is striking (Fig. 6, left).

Unfortunately the planned, namely the 4th, military survey was interrupted in Hungary, only the surveying of the Tatra Mountain was finished. Naturally the need for the maps that can be used widely increased by time, thus - as a prompt solution – the sheets of the 3rd military survey were "cleaned" from the military contents, and they were made available for the civil users, too. Between the left and right parts of the map there is a significant similarity, but even the difference is evident. The geographical forms are almost identical, but the plain elements are partially identical with the original contents, the accelerating change since the surveying is measurable.

The changes of the military maps characterise the status from before establishing the perceiving system, thus the effect of the change of the environmental variables onto the groundwater can be estimated only since the measurement data are missing. It can be supposed that the drainage resulted a certain reduction of the underwater quantities. However based on the maps it can be considered that in the neighbourhood of the selected 001401 Öregcsertő monitoring well neither the surface cover nor the area utilisation changed significantly (Fig. 6, right).

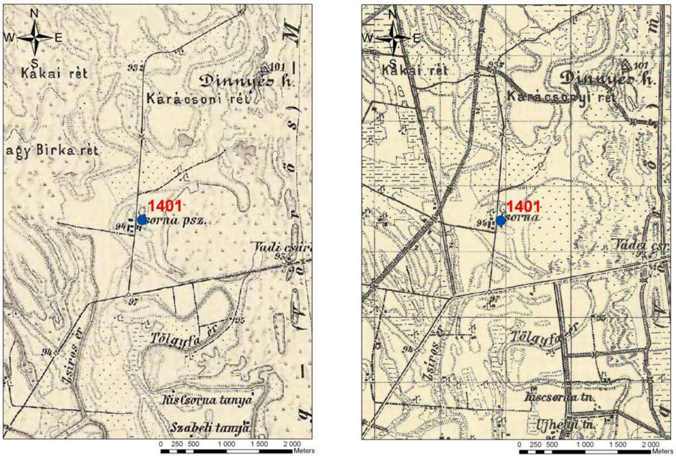

Figure 6. Surroundings of the groundwater monitoring well 001401 Öregcsertő at the time of 3rd military survey and at the early 20th century.

6.3 Maps from the second part of 20th and the beginning of 21st century

The introduction of the Uniform National Projection System (Egységes Országos Vetület, EOV) – forming the base of the Uniform National Mapping System (Egységes Országos Térképrendszer, EOTR), being currently in practical use – took place in 1975 which is based on a sunk angle-keeping cylinder projection with an oblique axis. The base surface is the rotating ellipsoid (IUGG-67) accepted in 1967 by the International Union of Geodesy and Geophysics (IUGG). This map could be used and referred to for decades as the so-called statutory map being the most accurate one.

The topographical map with a scale of 1:10000, considered confidential for long proved to be useful through its accurate presentation and detailing. The possibilities – besides the qualification – were delimited by the transportation difficulties and damaging of the paper material. The sheet readers were a significant step in switching form the traditional data carriers. The new digital maps are available and used electronically mostly, usually only the results of the operations are appearing on paper, and quite often they do not appear at all.

In the part presenting the surroundings of the 001401 Öregcsertő monitoring well the hydrographical elements, the use of the area and the geographical forms are catching the attention. It can also be stated that near the scattered vineyards there are solitary trees only (Fig. 7, left). The neighbourhood is characterised by the grassy colours that formed in the former watery areas. These areas were used by the sheep in the period when the map section was prepared.

The development of the cartographic tools and methods then the appearance of space IT as a new and stand-alone area, changed the everyday use of maps. We are presenting two possibilities as follows.

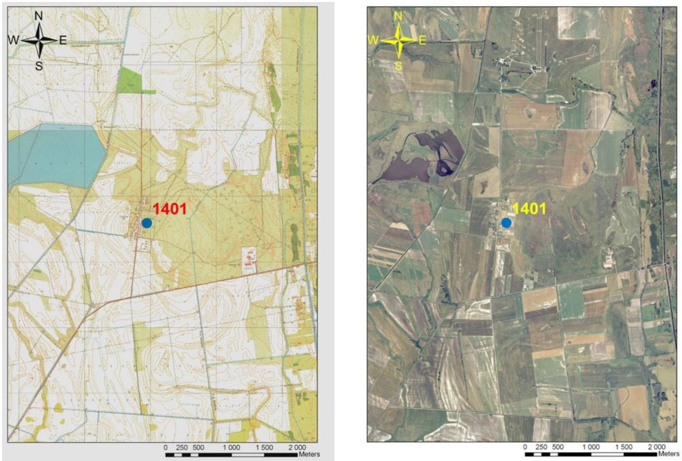

Figure 7. Surroundings of the groundwater monitoring well 001401 Öregcsertő in the second part of 20th century, and on the aerial photo of MADOP.

The cutting seen in the right side of the figure (Fig. 7) was made within the National Ortophoto Programme (Magyarország Digitális Ortofotó Programja, MADOP). Within the program in 2000 there were airborne pictures taken of the entire country. The pro-gram also included the preparation of the raster portfolio containing the geographical forms, hydrographical and plain drawings based on the analogue topographical EOV maps-sections that were prepared earlier between 1970 and 2000.

The picture shows clearly the houses, the agricultural areas, the hydrographical and other line elements. The majority of the former watery areas are used now, during the dry summer of the pictures the wet meadows were mown, which is clear in the picture. The brownish specifically patterned area situated north-west from the well is a fishpond, a remnant of the old water-world.

Naturally there are space-IT systems that are prepared for other purposes and can be used for the evaluation. One of them is the Agricultural Lot Identification System (Mezőgazdasági Parcella Azonosító Rendszer, MePAR), evaluated by the Institute of Geodesy Cartography and Remote Sensing (Földmérési és Távérzékelési Intézet). The MePAR maps' background is currently assured by the ortophoto taken at the airborne photographing base of 2007-2010 which makes it suitable or monitoring the timely modification of the environmental variables (http://www.fomi.hu/portal /index.php/ projektjeink/ mepar).

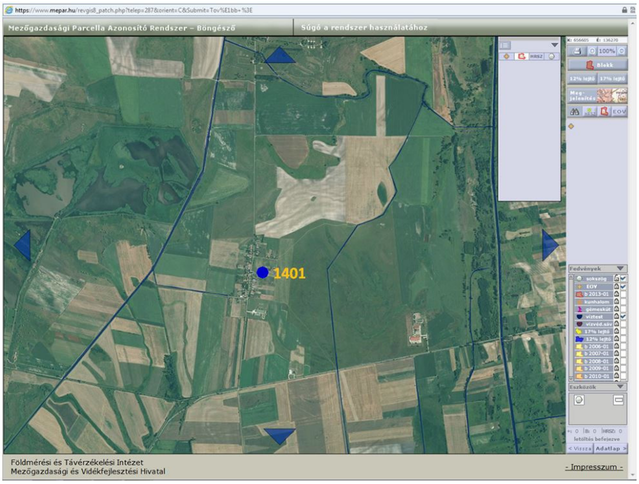

Figure 8. Surroundings of the groundwater monitoring well 001401 Öregcsertő in the MePAR System
(Source: **https://www.mepar.hu/revgis8_patch.php?telep=287&orient=C&Submit=Tov%E1bb+%3E**)

The figure shows the surroundings of the 001401 Öregcsertő monitoring well based on the monitor-photo of the search that took place in the MePAR Browser (Fig. 8).

7. Effects of background factors

The task of naming of the background factors that influence the groundwater motions is usually easier than the calculation of the strength of their effect, meaning the comparability. The solution of these tasks requires mathematical tools. In simple situations the satisfactory result can be supplied by the correlation calculation, too. The definition of the weight of several background factors may require the application of geo-mathematical tools, too.

7.1. Effect of the Danube River

When considering the background factors that influence the groundwater motions within the Kalocsai-Sárköz area we are presenting the supposed effect of the Danube's motions, the precipitation and the water-level of the canal.

The effect of the Danube's water motions can be shown visibly through the 001451 Uszód and 001455 Uszód monitoring wells. The selected period is between January 1, 2010 and December 31, 2012 (Fig. 9).

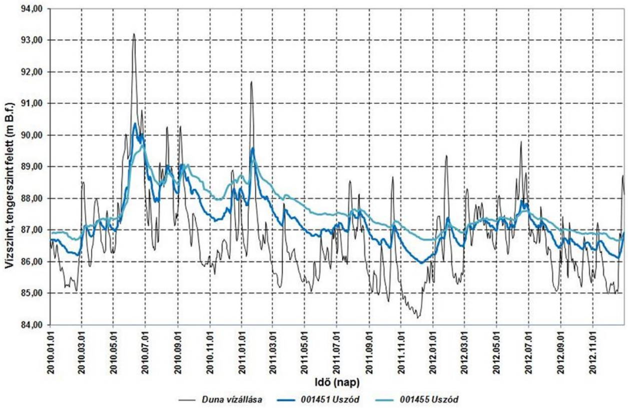

Figure 9. Changes of the water level of Danube and the groundwater monitoring wells near the 1523,2 rkm

The selection of this period was justified mostly by the extreme hydrological situations. The figure is showing the timely variation of the Danube's water level at river km 1523,2 through the values calculated by using the data of the 000549 Paks and 000550 Dombori water gauges and also based on the measuring data of the two groundwater monitoring wells. It can be stated that the water motions of these two wells established at a relatively short distance from the Danube's bed and the variation of the Danube's water level have similar timely features. Primarily the arrival of the flood waves is followed by significant change of the level of the groundwater. The passing of the flood waves is shown by a relatively fast decrease of the Danube's water level which is followed by the change of the groundwater's level with a significant delay.

This statement was supported by the result of the correlation calculation aiming at the definition of the strength of the connection between the Danube's water level and the variation of the groundwater changes. The result of the calculations gave a value that was smaller than expected regarding the strength of the connection.

7.2 Effect of the precipitation

Even the precipitation can be considered among the background factors that influence the groundwater motions, where the space and timely variation of the precipitation – in case of the favourable geological circumstances -, especially in the areas with high level of groundwater can cause intensive and significant increase of the groundwater (Fig. 10).

Within the Kalocsai-Sárköz area the precipitation measuring takes place at the 004370 Öregcsertő-Csornapuszta station. The figure is showing the timely variation of the precipitation between August, 2010 and April, 2013 as well as the levels of groundwater measured at the 001398 Szakmár, 001399 Kalocsa and 001401 Öregcsertő monitoring wells.

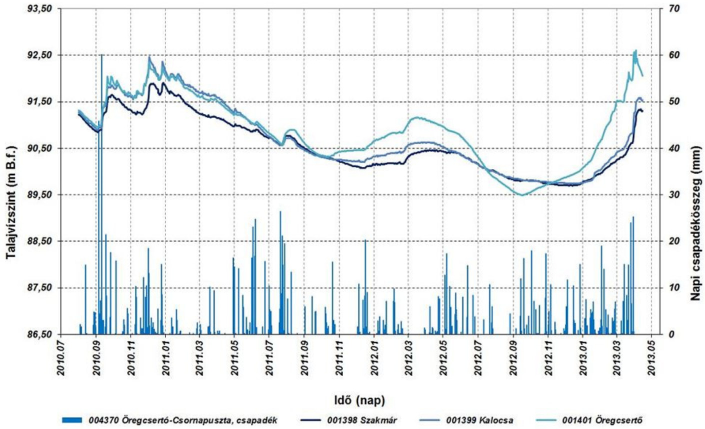

Figure 10. Effect of the precipitation on the groundwater level in the cross-section at Öregcsertő.

It can be stated that the geological structure of the area does not make it possible – not even in case of significant amount of precipitation – to experience an extreme change of groundwater as a result of a quick infiltration process.

7.3 Another background factor: excess water

Regarding the background factors the effect of the canals of the excess waters can't be disregarded. Within the Kalocsai-Sárköz area in the neighbourhood of the Öregcsertő-Csornapuszta region the possibilities are favourable from the perspective of evaluating the effects because it is possible to measure the precipitation, the level of groundwater and the level of the nearby canal of excess water.

8. Conclusions

The weather extremities of the past years influenced the variation of the levels of groundwater. The timely and space distribution of the occurred variations showed different features for each area and region. In some areas there were features that differed from the changes experienced earlier. One of the areas is the Kalocsai-Sárköz. At this low level (considering the sea level) there was an absolute minimum in 2012 which justified the thorough analysis of the causes of the phenomenon.

These analyses aimed at registering the background factors and environmental variables that influence the soil water's motions – and with special regard to the latter ones – aiming at their timely variation. Besides the collection of the hydrographical data measures in the area the valuation of the timely variation of the environmental variables took place based on the maps presenting the Kalocsai-Sárköz area. As an example we presented the variation of the 001401 Öregcsertő monitoring well's environment.

Regarding the variables of the environment of the 001401 Öregcsertő monitoring well and based on the presented map-details it can be stated that the settlement structure of the region did not change significantly. The most significant modification of the influencing factors was caused by the canals of the permanent excess waters established due to the water management, the significant decrease of the proportion of the permanent and temporary open-water surfaces (increase of the proportion of the surfaces that became drier) and the increase of the agricultural lands that also can be considered a consequence, which involved the necessary modification of the plan coverage. All these influencing factors may also have modified the geological medium at certain extent.

The analysis of the timely variation of the groundwater motions and the precipitation showed that the effect of the precipitation of high quantity arriving in a short period is less significant. However the joint effect of the big precipitation quantities following each other within a short period is causing a significant increase of the groundwater level. During the lasting drought periods – as shown in summer of 2012 – there is a significant decrease of groundwater level. The extremely high temperature measured in the past weeks – during this summer – and the lack of precipitation caused again a significant decrease of the groundwater level.

Based on the analyses it can be stated that within the Kalocsai-Sárköz region and regarding the weather extremities the lasting lack of precipitation and the extreme temperature can be considered strong risk factors which is damaging the agricultural production and the still remaining wetlands. The increase of the level of the groundwater occurring during the extremely rainy weather may cause agricultural damages, however it is supporting the regeneration and sustaining of the water-needing communities.

REFERENCES

1. Bél, M. (1735), *Notitia Hungariae novae historico geographica*. Bécs, Ausztria. (Forrás/Source: http://dfg-viewer.de/show/?set%5Bimage%5D=21&set%5Bzoom%5D=default&set%5Bdebug%5D=0&set%5Bdouble%5D=0&set%5Bmets%5D=http%3A%2F%2Fdaten.digitale-sammlungen.de%2F~db%2Fmets% 2Fbsb00077450_mets.xml)
2. Bulla, B. (1962), *Magyarország természeti földrajza*, Tankönyvkiadó, Budapest.

3. Hajdú-Moharos, J. & Hevesi, A, (1999), *A kárpát-pannon térség tájtagolódása. Pannon Encyclopaedia Magyarország földje* (Pannon Encyclopaedia The land that is Hungary – geology, geography and cartography of Hungary and its surroundings) Karátson, D., pp. 274-284. Kertek 2000 Publishing House, Budapest, Hungary, ISBN 963-85792-3-4.
4. Jankó, A. (2007), *Magyarország katonai felmérései 1763-1950.* Argumentum. (A Hadtörténeti Intézet és Múzeum könyvtára sorozat) ISBN 9789634464334
5. Kiss, L. (1988), *Földrajzi nevek etimológiai szótára I-II*., Akadémiai Kiadó, Budapest, 1988. ISBN 963-05-4567 5.
6. Lóki, J. (1999*): A dunai Alföld*, In: Pannon Encyclopaedia Magyarország földje (Pannon Encyclopaedia The land that is Hungary – geology, geography and cartography of Hungary and its surroundings) Karátson, D., Kertek 2000 Publishing House, Budapest, Hungary, pp. 298-299. ISBN 963-85792-3-4.
7. Marosi, S. & Somogyi, S. (szerk.) (1990), *Magyarország kistájainak katasztere*. MTA Földrajztudományi Kutatóintézet. ISBN 963 7395 09 1.
8. Mezősi, G. (2011), *Az Alföld természeti képének kialakulása*. In. Rakonczay J. (szerk.) 2011: Környezeti változások és az Alföld. A Nagyalföld Alapítvány Kötetei 7. – Nagyalföld Alapítvány, Békéscsaba. pp. 15–24. ISBN 978 963 85437 8 3
9. Neppel, F.; Somogyi, S.; Domokos, M. and the experts of the cooperating Danube Countries (1999), *Paleogeography of the Danube and its cathment*. A hydrographic monograph. Follow-up volume V. The riverbed conditions of the Danube. Part 2, Regional cooperation of the Danube Countries in the Framework of the International Hydrological Programme of UNESCO, Published by VITUKI Rt., ISBN 963 511 128 2
10. Ortvay, T. (1882*), Magyarország régi vízrajza a XIII-ik század végeig I–II*. Budapest, M.T. Akadémia Könyvkiadó-Hivatala.
11. Papp-Váry, Á. & Hrenkó, P. (1989): *Magyarország régi térképeken*. Gondolat/Officina Nova, Budapest, 106. pp. ISBN 9632822633
12. Pataki, J. (1954): *A Sárköz természeti földrajza*. Szekszárd.
13. Pécsi, M. (1959): *A magyarországi Duna-völgy kialakulása és felszínalaktana (Genesis and surface morphology of the Hungarian Danube Valley,* (in Hungarian). Földrajzi Monográfiák, Vol.3, Akadémiai Kiadó, Budapest,
14. Szalai, J. (2011), *Changes of the ground water regime in the area located between the rivers Danube and Tisza*. Riscuri şi Catastrofe, An X., Vol. 9., Nr. 2./2011. pp. 227-236. Universitatea Babeş-Bolyai, Facultatea Geografie, Cluj-Napoca,
15. Szalai, J. & Nagy, Gy. (2012), *A Duna-Tisza köze talajvízjárásának alakulása az elmúlt évek hidrometeorológiai eseményeinek tükrében.* A Magyar Hidrológiai Társaság által rendezett XXX. Országos Vándorgyűlés dolgozatai. ISBN 978-963-8172-29-7.
16. Vályi, A. (1796), *Magyar Országnak leírása, Buda*. (Forrás/Source: http://www.arcanum.hu/fszek/lpext.dll/?f=templates&fn=mainh.htm&2.0) Magyar Országos Levéltár, Budapest).