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Lead author	**János Tamás**, GWP CEE - University of Debrecen, Hungary **Attila Nagy,** GWP CEE- University of Debrecen, Hungary
Contributing authors	**János Fehér,** GWP CEE, Hungary **Stelian Nistor,** GWP, University of Oradea, Romania **Erika Budayné-Bódi**, University of Debrecen, Hungary **Bernadett Gálya**, University of Debrecen, Hungary
Peer-reviewer	**Branislava Matić**, Jaroslav Černi Water Institute, Serbia

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1. Preface

In cities, the formulation and compliance with sustainability considerations have so far been the basis of social and economic development. In the near future, a climate change and adaptation will result in challenges that have not been experienced before and should be prepared in time. Cities represent an increasingly important part of the integrated watershed management, with their considerable size, population size, economic background and expected high living standards of the population. The purpose of these case studies is to present the principles described in the guideline in practice through two examples of important cities in the Tisza watershed. Between the two cities, there is a long-standing historical, cultural and economic connection, which is hoped to complement a water sensitive blue and green city visions and practices. The selection criteria of the two cities were to be similar in number, size and economic development of the population. At the same time, however, they are different in hydrological terms, so that the solutions to different facets can be provided to decision-makers. Debrecen is situated on the plan, which is poor in surface waters. Its potable water source is groundwater.

Oradea lies in the valley of Crisiul Repede, with significant water reservoirs from the river, which cannot be found in Debrecen. Oradea's main water source is the river crossing the city, which had caused significant flood risk before it was regulated.

Both cities are affected in the same way by the impacts of climate change, the main characteristics of which are the increase of frequency of extreme flashfloods, dry periods and other extreme weather events. There are many similarities in urban structure of both cities. The inner historical core area is surrounded by a suburban area with huge concrete blockhouses, which are interrupted by green parks.

However, while the river is the axis of the Oradea's city structure, the same is not found in Debrecen, which lies on the junctions of the great eastern commercial roads. In both cities, it is increasingly important to combine urban landscapes and environmental noise caused by transport as well as to mitigate air pollution and noise pollution. The important goal is to increasingly close the urban hydrological cycle and improve the quality of the outlet city water.

In both cities, there is a very important tourist and therapeutic role of the thermal waters, as well as the problem of thermal water reutilization. In many areas, the two cities can learn from each other and perhaps with common thinking it will be easier to find solutions to urban hydrology.

In the two cities prevails the traditional urban water management approach of accepted technical solutions for rapid drainage of surplus waters in the urban drainage network. At the same time, the role of water retention and storage increases mainly by the green methods.

In many cases, besides traditional engineering approach, the historical hydrological statistical reference data source used no longer provides reliable results for design of new types of the often real-time interventions.

That is why SMART city technologies have the role of intelligent measuring in the water supply system. Of course, no details of this complex subject can be depicted and therefore the authors sought to evaluate the key areas.

The materials of the two cities are not presented in the same scale for many similarities in order to avoid repetitions. We refer to several reference materials from which the interested person can learn many more details. The collection, evaluation and editing of the materials were done primarily by researchers from the University of Debrecen and the University of Oradea, but their work was supported by a number of city experts, citizens, whose names list would be long but whose work was appreciated by the authors. The authors express their hope that many of the settlements in the Tisza River Basin will benefit from the lessons learned from the following publication, contributing to sustainable management of our water resources.

The Essential Messages of the Case Studies:

- The development of both cities depends on both quality and quantity of available water resources. However, policy makers are still not aware of integrated urban hydrology methods, therefore there is no strategy focusing on these specific tasks so far. Preparing such strategies would be essential.
- The sustainability of water resources is indirectly covered by various strategies, such as the climate adaption strategy, which does not disclose the relationships of hydrological elements and therefore the decision-making processes are often fragmented, moreover occasionally eliminating each other's effect, for instance in the case of drainage systems and water storage facilities.
- Cities can be considered greater local river basins having a spectacular effect on surface waters (e.g. in Oradea) or on groundwater reservoirs (e.g. in Debrecen). However, some basic information about the catchment area, such as its size or its infiltration properties, is not entirely available to the relevant authorities.
- The impact of urban microclimate on both urban river basins can be clearly demonstrated. At the same time, conventional engineering data (e.g. runoff values) would require continuous review due to climate change and urbanization. This would require the development of monitoring systems and measurement methods, for instance ground weather radar installed in Oradea to yield benefits. Ground radar provides good opportunity to measure high-energy hail and tornado storms accurately.
- There is a strong correlation between population and water quality but urban planning should favor rather the maintenance of water instead of the general drainage practice applied so far.
- There are no quantitative problems in cities yet, but there are many water quality risks, especially in historical abandoned industrial sites.
- The urban green corridor is key to urban water management practices, e.g. in flood management or in rain harvesting. The problem, however, is that there is no uniformly recommended good practice. After sample projects, they often do not continue and do not build upon each other.
- Cities have a key role to play in water supply and wastewater treatment in central waterworks, apart from their own territory, in the 25-30 km agglomeration area. This is advantageous for operational efficiency, but its cost-effectiveness is unclear yet.
- A typical example of a city with low-water, non-permanent water streams is Debrecen where no monitoring network was built, since its streams have no significant impact on the waters of the catchment area, but by more conscious water management a much more important role in urban water management can be reached (flash flood, blue corridor).
- The Crisul Repede section of Oradea is hydro-morphologically modified, therefore the migration of aquatic animals is limited. The weirs have negative effect on local species by limiting free longitudinal fish migration if are not equipped with functional passage systems. The need for directional flow connectivity of rivers represents an essential condition of the Water Framework Directive approved by the European Communities and, therefore, should be applied to all streams containing migratory species, but optimal solutions highly depend on local aquatic environmental conditions.
- The flood risk of the Oradea impacted area is relatively small in comparison with other Romanian rivers. Urban flood management includes pre-flood, flood emergency and flood recovery activities. Within the framework of flood surveying, satellite images can provide up-to-date geographical information, which is helpful during different phases of the flood management.
- Storm water is a significant source of pollution and therefore introduction of the concepts of source control, flow attenuation and treatment in natural and artificial biological systems is important. Preventive actions for hydrological adverse impacts are always simpler and cost-effective compared to damage management. There are many preventive solutions, but they need to be adapted to the local hydrological situation. It is important to introduce them and to provide financial support to local people.
- The Natural Water Retention Measures aim at restoring and maintaining water related ecosystems by natural means. They are Green Infrastructures intended to maintain and restore landscape, soils and aquifers

in order to improve their natural properties, the environmental services they provide, and to favor climate change adaptation and reduced vulnerability to floods and droughts

- Quantitative risks stated for sustainable groundwater abstraction in 90’s and drinking water sources were threatened in Debrecen. Nowadays, with a decrease in demand for tap water, the water yield has also declined and water use has become more sustainable.
- The function of the applied GIS groundwater model is to evaluate data layers and to provide a new type of information to the end user, and has, therefore, proved to be particularly suitable for the vulnerability study of aquifer zones.
- Strategic goals of geothermal energy are as follows: to develop efficient methods for the use of geothermal heat for direct use and/or electricity production by environmentally friendly use, in particular concerning protection of underground drinking water resources.
- The combined natural gas and geothermal district heating system has the best economic performance in Oradea. One of the best uses of geothermal energy is the bath where it can be used for balneological treatments or for recreational purposes. However, in terms of water quality, the high salt content of the effluent is problematic, but in the case of Oradea enough diluent water is available.
- A secondary pollution in the pipe network and leakage losses are continuous problems in the drinking water network. This can be reduced with the introduction of a real time smart measuring system.
- The amount and quality of wastewater is highly dependent on the status of the canals, the level of water supply, urban structure and characteristics, and on the component of water outlet. In conventional combined channels a significant amount of sediments can be gathered where a flash flood can occur besides significant leakage loss. Separated system channels are oversized. It also causes a constant odor problem with high persisting costs.
- High-capacity aerobic WWTP produces a large amount of sewage sludge, so it is necessary to manage it efficiently in the future.
- The operation of WWTP is apparently similar, but the specific energy consumption significantly differs based on applied technology and management. It would be important to introduce an energy audit to measure efficiency. High treatment energy costs can be significantly reduced by sustainable energy resources (biogas, solar energy) or through the newly introduced recycling technology (e.g. struvite).
- The role of the Tócó creek is not significant in the current VGT (RBMP for Hungary). However, such temporary watercourses have significant importance in the urban water management system, although hopefully the new VGT practice will also pay more attention to solving the IUHM problems. By a new revitalization process, a real fresh watercourse should be developed that can be applied to solve critical water scarcity (e.g. irrigation, industrial water).
- From the decision support point of view, the approach of the Shared Vision Planning, presented in the JOINT Tisza project, was the baseline. The goal of the Shared Vision Planning is to improve the economic, environmental and social outcomes of water management decisions. The Shared Vision Planning facilitates common understanding of a natural resource system and provides a consensus-based forum for stakeholders to identify trade-offs and new IUHM options with a lot of computer based modelling.
- The methods presented are suitable for supporting effective data acquisition and urban water balance modelling and for reducing decision uncertainty. Urban hydrology analyses are influenced by precise, digital urban models in 2D and 3D. Remote sensing technologies (spectral image processing) are able to cover large urban areas at low price and represent a quick solution for an area. Product processing is partly or entirely automated, performed by this remote sensing method. Their disadvantage is that interpretation requires time and professional knowledge.
- A capacity of knowledge building is critical for all tasks and it would be useful to accelerate the applied research and knowledge transfer among the actors.

2. Case Study for the City of Debrecen

Introduction to the City of Debrecen

Figure II.1. The crest of Debrecen

Debrecen, a town with county rights, the second largest city in the middle of the Northern Great Plain Region and Hajdú-Bihar County, on the eastern border of the European Union, is placed on the Great Plain (Figure II.1.). In terms of territorial relations it can be highlighted that Debrecen is located at the meeting point of three regions (Nyírség, Hajdúság and Hortobágy), while the inner and outer areas of the city lie at the border of Hajdúság and Nyírség. The largest eastern part of the city, stretching to the valley of the Tócó creek, belongs to the South-Nyírség Region. This small landscape is an alluvial cone plain, which is a flat area in the neighborhood of Debrecen, covered by a thin layer of shifting sand. Beyond the Kondoros watercourse, special forms of parabola dunes appear as well. This field has special morphological characteristics of being horizontally divided by north-northeast and south-southwest valleys. These used to be marshy, waterlogged areas, which blocked the east-west traffic. There is a southwest slope in the South-Nyírség part and adjacent landscape due to Debrecen's surrounding laying in a shallow. The southwestern part of the city is more likely to be classified as the Hajdúhát microregion, which contains a loess-cover, formerly alluvial cone- shaped plain. At Hajdúhát, in the north-west direction of Debrecen, in the direction of Józsa, the surface level raises and reaches an altitude of 165.7 m above Csegei-halom (Csegei-mound). The southern part of the city reaches the territory of South Hajdúság, which is a flood-free place, with many slightly waved, alluvial cones, covered by loess slurry.

Other interior areas that belong to Debrecen such as an agglomeration ring are the places of suburbanization processes (from this point of view, the most important places are the following: Józsa, Pallag and Ondód) (Figure II.2.).

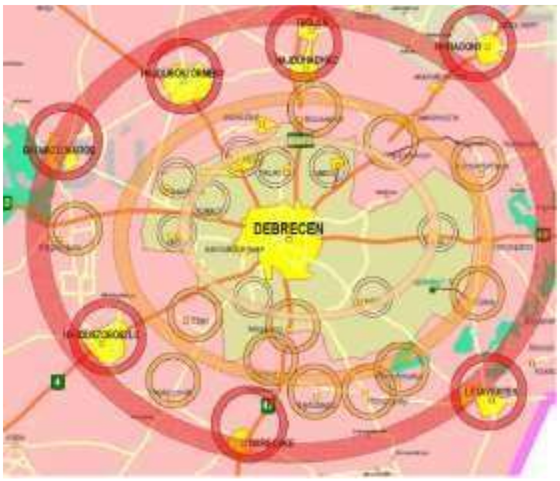


Figure II.2. Agglomeration zones of Debrecen[1]

Next zone is the internal agglomeration (Nagyhegyes, Ebes, Hajdúszovát, Mikepércs, Sáránd, Hajdúbagos, Hosszúpályi, Monostorpályi, Újléta, Nyírmártonfalva, Hajdúsámson és Bocskaikert). In addition, an external agglomeration settlement ring has already started to be formed (Hajdúböszörmény, Balmazújváros, Hajdúszoboszló, Derecske, Létavértes, Hajdúhadház, Téglás és Nyíradony). The Central Statistical Office defines the agglomeration zone of Debrecen as a metropolitan settlement of Debrecen (with the following members : Debrecen, Bocskaikert, Ebes, Hajdúbagos, Hajdúsámson, Mikepércs, Sáránd, Újléta, Vámospércs).

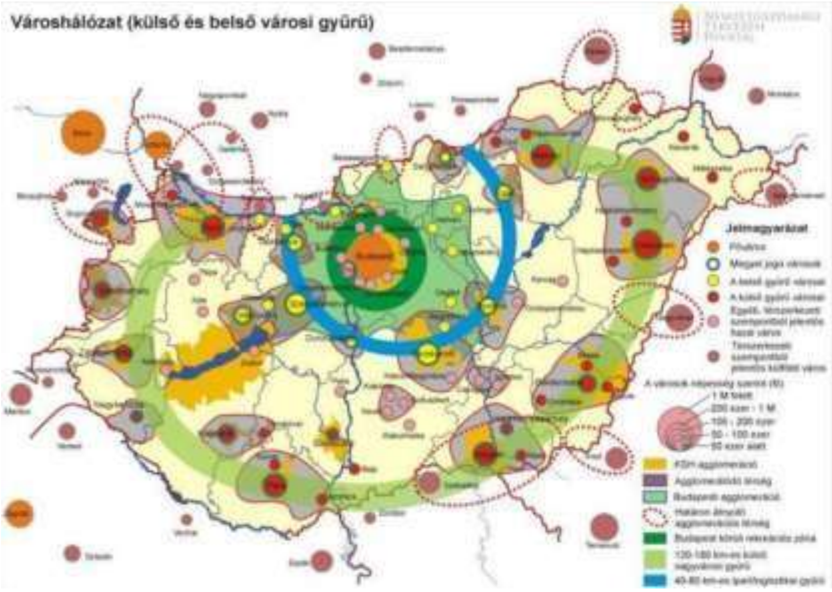


Figure II.3. Centers and peripheral agglomerations in Hungary[2]

Debrecen is one of the most important regional centers of the Hajdú Bihar county, the North Plain region and Hungary. It has the role of an economic center as well as a center of education, science and culture with macro-regional importance (Figure II.3.).

Due to hydrographic conditions, there is a duality at Debrecen. On one hand, there seem to be poor surface water resources. On the west side of the town there are many similar stream water resources with low runoff like the Tócó stream (Figure II.5.), or on the east side for example the Kondoros stream, which runs to the Berettyó River and the Hortobágy River and partly to the south (Figure II.4.). Low runoff, high environmental impacts and pressures result in poor water quality.

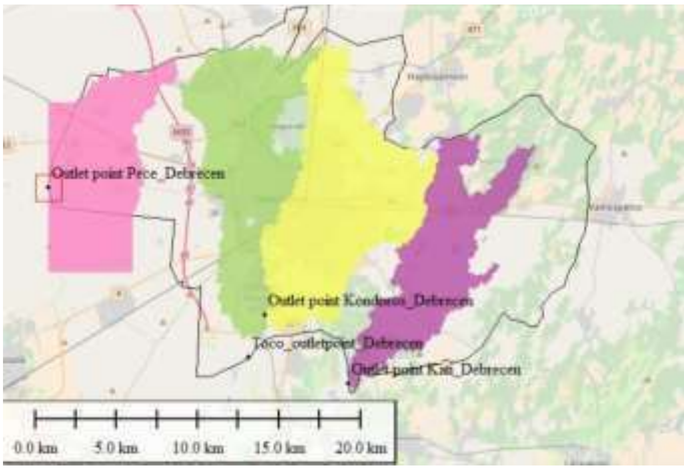


Figure II.4. Main watersheds of Debrecen from west to east: Pece, Tócó, Kondoros, Kati waterflows (owner-edited hydrological map

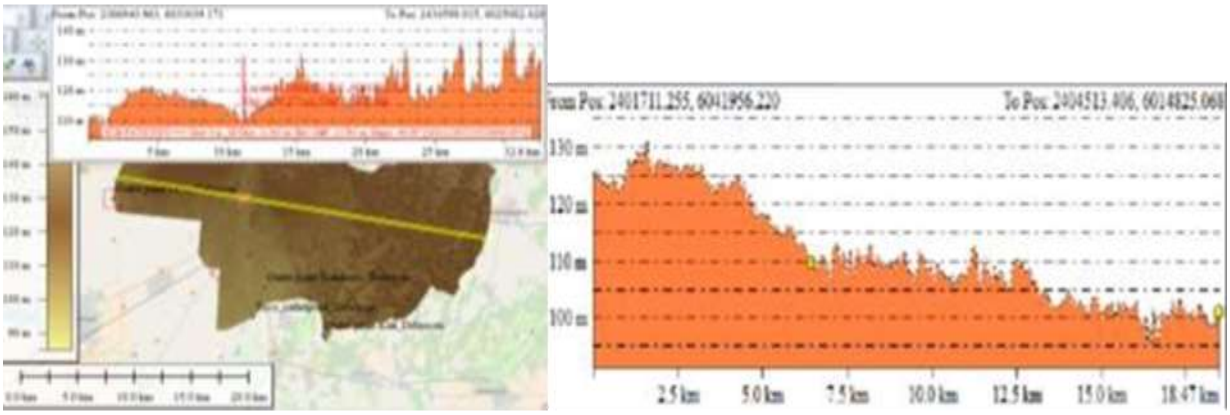


Figure II.5. DEM section where city center is the relative deep part (marked with red cross on DEM) NS direction- Tócó cross section and WE direction (owner calculation)

However, Debrecen is rich in groundwater resources suitable for several water use purposes. These groundwater resources have an important role in drinking water supply. Moreover, mineral water with a temperature of 70 °C and high microelement content is utilized for recreational and balneological purposes exploited by drilling.

In spite of the metropolitan characteristics of Debrecen, there is a 30 % rate of forest area that has high importance (this is a total administrative area, including peripheral area). This provides a healthy urban climate, recreational opportunities (Nagyerdő, Erdőspuszta) and optimal drainage and infiltration conditions. During previous centuries, Debrecen has continuously expanded its forest land until it reached today's total area of about 15,000 hectares. In the eastern part of the city, at Erdőspuszta, the rate of forests reaches 50 %, which is much higher than the average. In the northern and eastern part with gardens, there is a 3 km thick forest buffer zone. The most important forests are at the following places: Monostori-forest, Nagyerdő, az Apafai- forest, illetve Dombostanya-, Nagycsere-, Haláp-, and Bánk forest, as well as the Paci- forest.

Urban climate

Urban microclimate

As was emphasized in the Manual for Knowledge Development Tools and Knowledge Transfer in Urban Hydrology of the Joint Tisza project book, the cities on the northern hemisphere have on average by 2°C higher temperature, 12% less solar radiation, 8% more clouds, 14% more rainfall, 10% more snowfall and 15% more thunderstorms annually compared to the conditions of rural environments. [3],[4] .

Detailed analysis of the Urban Heat Island (UHI) in Debrecen was discussed by several authors (Figure II.6.)[5], [6], [7]. They have concluded that larger differences are detected between the UHI intensity values based on satellite and ground time series measurement in winter than in summer. Mean UHI intensities are compared along the characteristic cross-sections of urban surface in the north to south direction. In Debrecen, the UHI intensity determined from satellite (MODIS) data is 3-6°C in February. In summer, the differences of UHI intensity values are smaller, not exceeding 0.5°C and 1.5°C in Debrecen.

If we study the UHI Debrecen time series analysis, this deliver more important details for the impact of building development density and the occurrence of different types of artificial surfaces with UHI. Urban parks, especially if irrigated and with covered fountains (for example, the Nagyerdő district), may represent an 'oases effect', because they are anomalous moisture sources in an otherwise dry area. These have a significant impact on local micro climate. In the eastern sector of Debrecen, the detached and semi-detached houses with gardens are dominant; the ratio of the artificial surface cover is between 25% and 50%. Near the geometrical center of the city, in the downtown, the ratio of the artificial surface cover is highest (60-80%) and the average distance of the buildings is lowest, but the highest buildings cannot be found there.

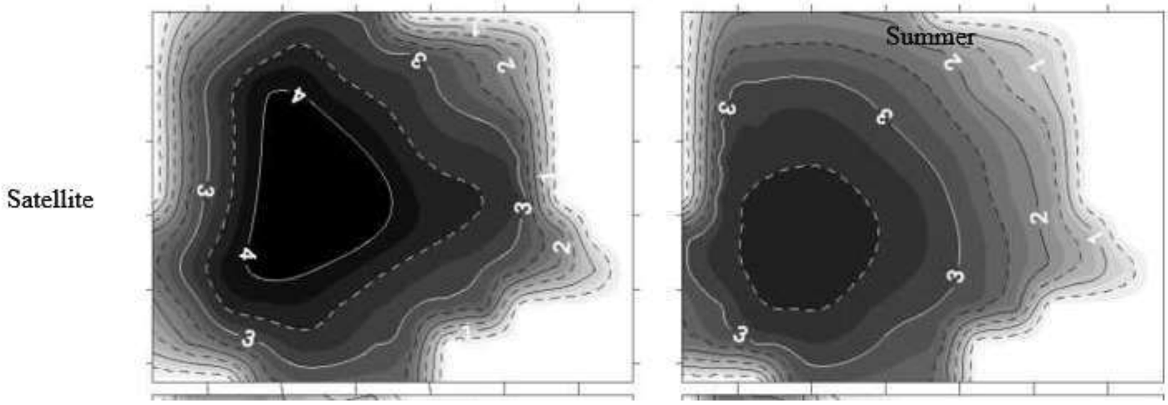


Figure II.6. Mean urban heat island structure of Debrecen-based satellite measurements, 2002-2003, winter and summer[8].

In the western sector there are large housing estates of Debrecen with 10-14 story buildings. The ratio of the artificial surface cover is not very high (40-60%), but there are the most extensive vertical active surfaces. Since the houses are built in N-S rows, the distance of the buildings in that direction is minimal (only a few meters) and they form quasi-homogenous active surfaces oriented to the east west. In the N-S direction the imbalance is more visible than in the E-W direction. In the south there is the industrial belt of the city, where the ratio of the artificial surface cover is between 60 and 80%. On the other hand, in the northern sector there is the forest of "Nagyerdő" (Great Forest) with an extensive urban park forest (1.75 km2) with sports-grounds, the stadium, the amusement park, the zoo, the clinics and the campus of the University of the City.
Most places there have not clear borders between the impervious city surface and its environment: the density of the buildings decreases very gradually because flakes of detached houses with gardens alternate with extensive green areas. The UHI peak is missing and the city center and its neighborhood takes the shape of a broad and very flat "plateau". In the eastern sector of the city intensities increase gradually towards the center because the built up density grows gradually as well. The forest of Nagyerdő in the north is the coolest part of the city. The highest horizontal gradients (0.5°C/300 meters) were found there. This is in harmony with the spatial pattern of the distribution of natural and artificial surfaces. In the urban part of the "Nagyerdő" forest, the ratio of artificial surface cover is under 30%. It is bordered by low intensity residential areas, the campus of the University of Debrecen and the clinics of the city. In the north it is connected to the trunk of the forest outside the city and for this reason it behaves like a cold fringe of that: it is colder than its urban environment by 0.5- 0.8°C annually on average. The spatial pattern is primarily determined by the build-up characteristics of the city and can be highly modified based on the city regulation plans.

Climate change and other adverse effects on urban microclimate

Debrecen (47.5ºN, 21.5ºE) is located in the north-eastern and in the south-eastern part of Hungary at 120 m above sea level, respectively, on a flat plain. Debrecen does not have any larger river. Here is the border of a moderate cool and moderate warm climate so the area is moderate dry, some places dry and with water shortage. The annual sunshine hours are around 2,000 hours and the average annual temperature is between 9.6-9.8 ° C. Rainfall distribution is quite varied, while the annual precipitation is between 550-600 mm. Prevalent wind directions are NE, N. The area is poor in surface water bodies, in the city there is only the Tócó creek with low water quality and low water yield, which has quite an importance in a geological historical development process by flowing across the Nyír water valleys. With regard to Debrecen's average monthly temperatures, it can be said that the coldest month is January, while the hottest is July. The average temperature range of the year is 22.3 ° C. Debrecen's average annual rainfall is 540 mm, the summer term is wetter, while the winter term is drier. The least rainfall falls in January-March and the wettest month - with nearly two and a half times the amount - is June.

In Debrecen, the annual amount of sunny hours averages 1960 hours, but year on year they show great variability. It is possible to observe the typical annual course of the sunshine, with summer months having the maximum (250-270 hours per month), while in the November-January period it has the minimum (50-70 hours per month).

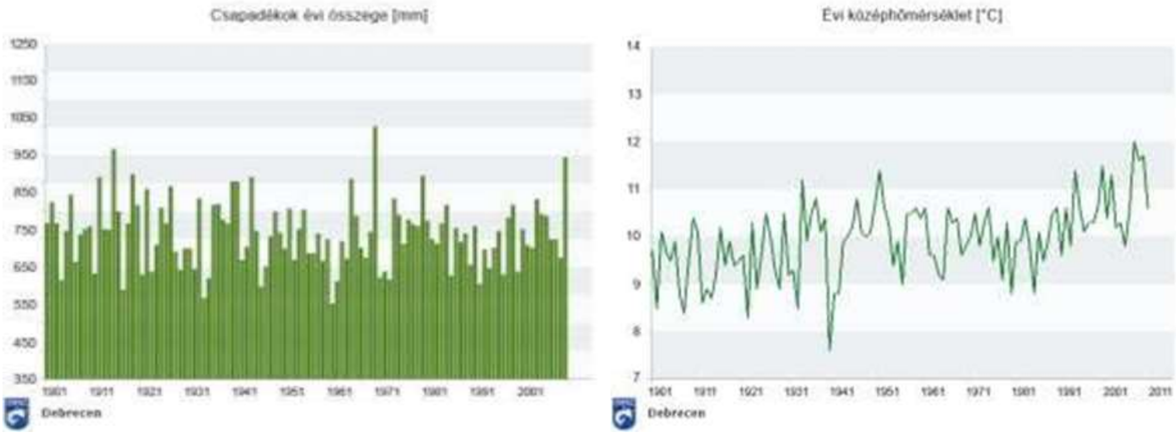


Figure II.7. Annual precipitation and temperature in Debrecen city (OMSZ)

Analyzing the data of the last one hundred years or even just the last 20-30 years, it can be stated that the average temperature of the city and its surroundings is rising, while rainfall and the number of extreme weather events increases (Figure II.7.).

According to the data of 110 years, the amount of daily precipitation in Debrecen is higher than 10 mm at least on 5 days and on average on 16 days per year. Within one year, a rainfall phenomenon with more than 20 mm occurs at least one day/year, but on average for 4 days/year. The number of days with precipitation over 20 mm has slightly increased, which also shows an increase in the intensity of rainfall events. Of course, significant differences can occur between the years, as the precipitation of over 20 mm can be more than double the annual average. The daily maximum precipitation also increased by nearly 10 mm from 33 mm between 1900-2010, reflecting that the number of extreme weather events increases (Figure II.8.).

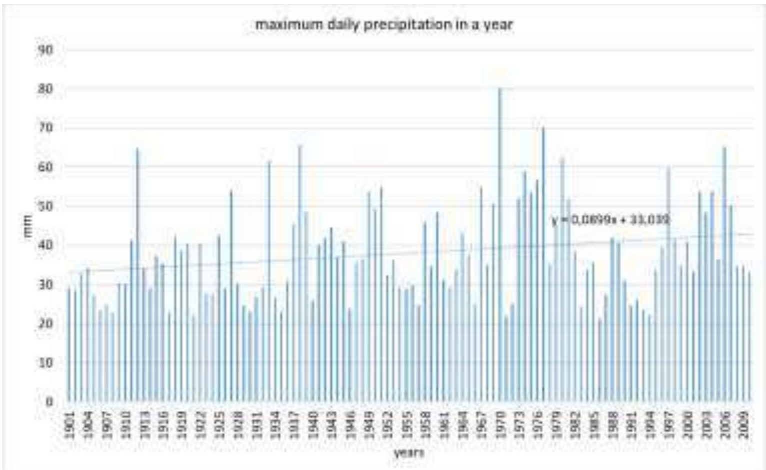


Figure II.8. Changes of the maximum daily precipitation within the 110-year interval (OMSZ)

The alteration of the maxima of monthly precipitation data show that the highest amount of daily precipitation (between 55-80 mm) is in the late spring, summer and early autumn period. This means that with the unchanged annual precipitation, more extreme precipitation phenomena are expected (Figure II.9.).

Figure II.9. Flash floods cause more serious damage to infrastructure and green environment of the Debrecen city (Photo: Tamás)

The precipitation intensity shows higher uncertainty of the spatial forecast as it concentrates in smaller areas, but with more heterogeneity in the city.
The frequency of the daily precipitation above 20 mm also increased during the 110 years, based on the precipitation probability curves for the occurrence of precipitation of above 20 mm. Whilst the probability of a 30 mm daily precipitation was 25.74% between 1900-1930, it increased to 31.45% in the period of 1980-2010 (Figure II.10.).

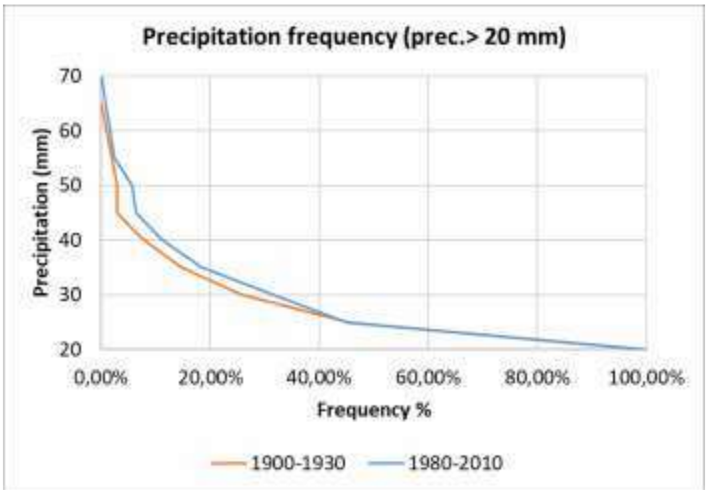


Figure II.10. The frequency of daily precipitation above 20 mm in the period of 1900-1930 and 1980-2010 (owner calculation)

In case of urban water drainage and management precipitation with 1 (47.8 mm / h), 2 (73 mm / h), 4 (97 mm / h) or 10-years (131 mm / h), probability can be considered standard, if the time of concentration is less than 180 minutes[9].

Storms are also significant in terms of precipitation intensity (Figure II.11.). The examples of precipitation phenomena with precipitation intensity exceeding the thresholds described previously were provided by the meteorological station of the University of Debrecen. The peak intensities measured on 05/06/2008 exceeded 380 l/(s.ha) (140 mm / h) but on 16/08/2010 it reached 550 l/(s.ha) (200 mm / h). The recurrence interval of these precipitation intensities was 13 (05/06/2008) and 50 (16/08/2010) years based on the data of Wisnovszky (1984)[10], Sali (1993)[11] . In addition, when calculating with 140 mm/h intensity, 22 mm fell down in a period of 9.5 minutes on 05/06/2008, the recurrence probability of which is 3.7 years, based on the relative prevalence of maximum precipitation[12]. Therefore, in such cases even well-designed drainage systems cannot drain precipitation effectively, therefore increasing the risk of flashfloods or excess water and floods. In addition to significant financial damage, these phenomena may cause health hazards in unified channels. For this reason it is important to work as accurately as possible in the design, to work with the most approximate data representing real situations and to revise the design methodology.

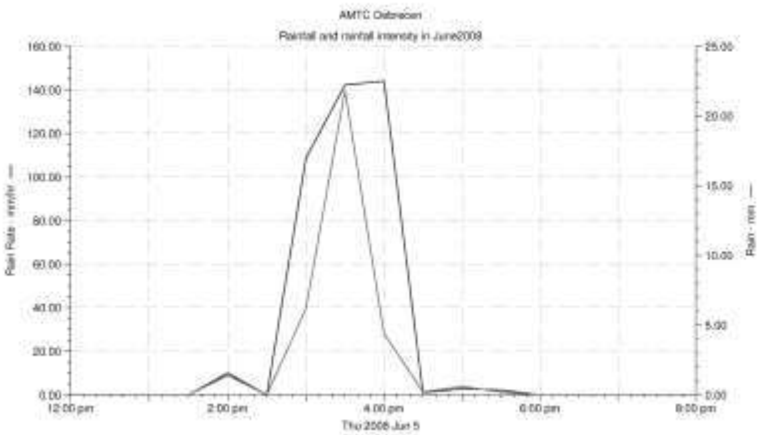


Figure II.11. 10 minutes of moving average rainfall data at the University of Debrecen (owner calculation)

Several climate change studies were conducted in the Debrecen region, among others, by the National Meteorological Service. Based on the 110 year interval dataset from 1901 to 2010, the hottest years occurred in the last decade of the last century and after the start of the new millennium. The three hottest years were in 2008, 2009 and 2007, respectively.

The number of days below 0°C decreases annually by 0.3 days, which means a reduction of 32 days in 110 years examined. At the same time, the number of heat days increased, averaging 14-16 days compared to 1981.

In the future, based on climate models (ALADIN-Climate, REMO), the average temperature will increase more than the national average in Debrecen, the number of days with temperature below 0 °C will decrease, while the number of heat days is expected to increase.

With respect to precipitation, in national terms modelling shows that in the 21st century, we can expect a decrease in summer and spring periods and more rainfall in winter periods, while rainfall intensity will increase throughout the year - but most of all in autumn. In addition, an increase in continuous dry periods is likely in summer and increase in rainfall intensity will occur in all seasons except for summer [13] .

Different drought indices are used for the characterization of drought with different goals around the world. The Hungarian Drought Index (HDI) expresses the prevalence of drought and supports preventive activities. Based on the meteorological data, the time series calculation basically relies on soil moisture measured at 3 levels in the soil root zone (Figure II.12.).

Figure II.12. Operational drought and water scarcity measuring network capable of forecasting water scarcity in a root zone[14]

A large number of standard meteorological stations (ca. 300) will also be suitable for irrigation planning in green areas of the nearby cities.

Urban hydrology water balance

The main objectives of urban hydrology are to manage urban water cycle in a sustainable fashion by taking into account both surface and ground water, flooding and impacts on waterway erosion and to maintain or return the flow regime as much as possible back to its natural level. It is also important to protect and restore, if possible, water quality (for both surface and ground water) and conserve water resources, as well as to enhance urban landscape and amenity areas by incorporating storm water management measures, which offer multiple benefits, in the landscape. One of the most common calculation methods is the water balance equation calculation, which can be determined for the Debrecen city as follows:

$$P_r + P_s + P_{mp} + Sw_{inf} + R_{off} + D_{in} + Th + Ir + Drin \\ = D_{out} + Ev + Tr + Dp + W_w \pm S_{res} \pm S_{Wet} \pm S_{soil}$$

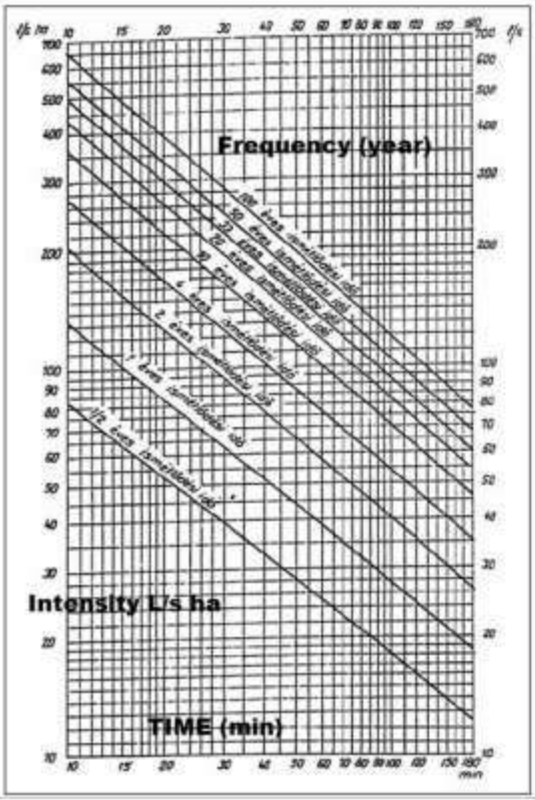
P_r –Rain
P_s –Snow
P_m- Micro precipitation
S_w –Inflow surface water (rivers, creeks)
R_{off}- Runoff
D_{in}- Drainage inflow
T_h – Thermal water
Irr – Irrigation

D_{out} - Drainage outflow
Ev - Evaporation
Tr- Transpiration
D_p- Deep percolation
W_w- Waste water
S_{res}- Reservoir
S_{wet}- Wetlands
S_{soil} – Soil water capacity

The rainfall-runoff (R-R) evaluation

The calculation result of the runoff factor in a rapidly changing urban environment can only be accounted with high uncertainty. One of the most important inputs for urban hydrological models (e.g. Rational Method) is the rainfall data. The Rational Method can only be applied at watersheds smaller than 200 ha with less than 15-minute collection time and with low water logging, where permanent precipitation intensity can be assumed[15]. Permanent precipitation intensity can be defined based on IDF intensity-duration-frequency curves[16].

Intensity-duration-frequency (IDF) curves at a location are one way of presenting rainfall data available at a location by statistical analysis. Frequency refers to the probability that a storm of a given magnitude will be equaled or exceeded in a given year and is equal to the reciprocal of the return period in years. IDF curves provide average rainfall intensities corresponding to a particular return period for different durations. IDF curves are calculated and defined in Hungary by the Montanari equation (Figure II.13.).



recurrence interval (year)	a mm/h)	c (-)
1	47,8	0,69
2	73,0	0,71
4	97,0	0,72
10	131,0	0,72
20	158,0	0,73
33	180,0	0,74
50	202,0	0,74
100	238,0	0,75

Figure II.13. IDF curves on a logarithmic scale and IDF numerical values in Hungary[20]

The disadvantage of the hypothesis of permanent rainfall intensities is that the variability of precipitation is not taken into account. Consequently, it doesn't allow more accurate scaling. Rainfall, which is constant in time, has linear correlation. As a result, in the first third of the event, precipitation height is far below the "pro rata temporis" quantity. Consequently, it is required to rethink the planning of precipitation modelling (Figure II.14.).

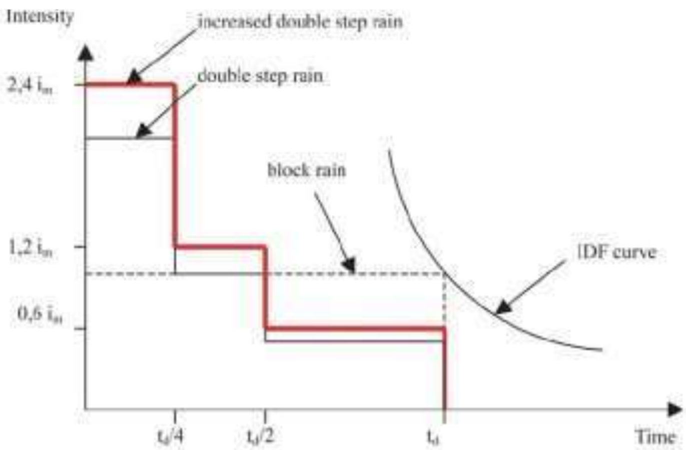


Figure II.14. Increased double step design storm[20]

It becomes clear from observations that in case of short duration rainfalls (relevant for urban drainage), the first half of the duration is preponderant, as 70-80% of the total rain falls during this period[17]. This "advanced characteristics" of real storms should be taken into consideration when determining design storms[18].

Furthermore, the nowadays seemingly unavoidable tendency of climate change must be considered. As a result of these changes, the frequency of extreme events will expectedly increase (extremization) and this will manifest, in terms of urban water management, in both increasing intensity and amount of rainfalls. The design storm should reflect this phenomenon.

Based on the Hungarian database, the so-called "accelerated intensity" profile contains the effect of climate change, which is an increased double step design storm depending on the duration time, shown by Figure II.20. However, to calculate curve values, an appropriate spatial/time monitoring system implementation is required. It would be ideal to set up a ground short-range radar calibrated by the installed precipitation network. In order to predict the development of short localized rainstorms, which follows the abrupt development of a cumulonimbus, high spatiotemporal resolution monitoring of meteorological phenomena is required. The University of Debrecen is implementing a Dual Polarimetric Doppler Weather Radar that can simultaneously transmit and receives horizontally- and vertically-polarized radio waves. It is capable of computing the movement velocity of nimbus, as can be obtained from the Single Polarimetric Doppler Weather Radar using horizontally-polarized radio waves, as well as precise precipitation intensity. The comparison test shows that the radar and the disdrometer measure the same dynamics in the rain event with high ground resolution.

Urban Water System Evolution

Surface waters

The Debrecen city is poor in surface water with only some streams flowing through urban watershed. In the western part of the city, the Tócó, in the eastern part of the city, the Kondoros, and Kati as well as Pece, small watershed, cover the north-western part. Pece and Kati have low flows, and non-permanent water when water ecology collapsed or was seriously disturbed.

The Tócó creek, as a permanent water flow, was at the beginning of the last century the western boundary of the inner city, and nowadays, with the expansion of the city, residential areas and industrial areas are surrounded by many places. Kondoros is in contact with fewer residential areas, but the city's new housing development has already crossed the Kondoros line. The recipient of rainwater from the western part of the city and the treated waste water of Debrecen is the Tócó creek.

The Tócó valley is situated at the meeting point of two landscapes, with their characteristic features. Clayey sand and clay fine-grain dominate near the surface, which is reflected in varying thickness. Geological maps prepared in this area show the location of the Tócó stream in Debrecen, the relations of the two landscapes, as well as the role of the Tócó stream.

The Tócó creek flows at the border of Hajdúböszörmény (Bodaszőlő), Zelemér (Figure II.21.). It is believed that the present-day Tócó Valley was the seat of a great riverbed in the Upper Pleistocene era in the Northeastern Carpathians. When the larger rivers left the basins, smaller streams emerged in the abandoned basin, so the Tócó could be formed, which in the Ice Age, 25 and 10 thousand years ago separated the Nyírség hills by the Hajdúsági loess, laying at the boundary of the two surface geological formations.

, more Several water mills had operated on the Toco creek in the middle age, but nowadays it is often completely dry in the summer, while threatening urban areas by flash floods.

The current length of Tócó is 25,940 meters. Its total catchment area is approximately 174 km^2. The recipient is the 60+900 section of the Kösely Main Canal. Permissible inland excess water flow in the upper section is 0.42 m^3/s (23+563-25+940 sections) with the highest inland excess water flow of 6.00 m^3/s (5+000 to 11+274 sections). The Tócó Canal operator between the 0 + 000 - 4 + 200 sections and the 24+500 - 25+940 sections is the Transboundary Water Directorate, and since 1992, between 4+200 - 24+500 sections it is the Debrecen County Law City Council. Tócó is the main recipient of the rainwater collected by the city's sewerage system,

both as a recipient of the separated western part of the town, and as a recipient of sewage and rainwater purified by sewage purifiers collected by the combined system drainage system that is still in operation in some parts of the city.
The water is occasionally burdened with great intensity waters coming from the Kishegyesi Road (13+674 section) and the Southern line (11+720 section) streams. Tócó is also the recipient of the city's purified sewage (10+978 sections).
The 7th main collector (7-0-0) starts at the northern end of the Egyletkert Street and passes through the Gázvezeték Street and continues to the end of the Egyletkert Street (Figure II.22.). Turning westward, it crosses a meadow and proceeds to the Kanális Street. Here, it is joined by the 72 collector, and then it passes through the Kanális Street to the airport and then enters the Tócó watercourse. The main collector is a mostly unpaved ditch with a 1:1 slope and 1.0 m bottom width. A section of the main collector crosses the entrance to the airport with a Ø1.0 concrete culvert and then becomes a lake, a fire-water reservoir at the airport and passes through an overflow into the closed canal under the airport parking area and then again becomes open ditches, the Tócó- ditch. The main collector is strongly planted with vegetation and is heavily muddy. It has only a fraction of its actual water capacity.
Based on the survey and calculations, which were made in 2011 for the system capacity monitoring, under the access road of the airport arriving to the culvert there was a yearly return precipitation that results in the flow of 1215 l/s, while the water delivery capacity of the culvert is 772 l / s and the closed canal section under the airport parking space has a water delivery capacity of less than 653 l / s.
Additional bottlenecks in water transport after the closed phase, passing through the airport are the present condition of the course of the Tócó-ditch leaving the area of the airport, and the culverts on it with a water transmission capacity of 701-1397 l / s (Source: Péter Lovas, Plan No .: D-0511/2011).
From the previous data, it can be seen that a hydrological situation can occur annually, so that the pre- airport culvert retards the arriving waters, and the transmitted waters cannot be guided further by the culvert under the parking. In this part of the city, in the 7-0-0 drainage basin there are currently several unbuilt areas, the utilization of which is expected to be continuous, thus increasing the proportion of built surfaces, resulting in an increasing amount of water to be drained.
It would create a different hydraulic situation if the city would pollute and cleanse the currently sunken and vegetated fields. In this case, water could flow up to 2127 l / s from the city.
Already in the city area it would be expedient to keep the effluent from the Epreskert and Tégláskert, so that they are delayed for further guidance. Of course, in this case too, the bottlenecks would cause a problem. In addition to the current conditions, the drainage of the area is further complicated by the fact that the water level in the recipient section, in the Tócó (8 + 725 sections), is greater than 105.6 mBf although the water level corresponding to the calculated maximum water flow in the given section is 105.3 mBf. (Water level data cannot be provided more accurately because the hydraulic dimensioning of the given section is based on the course geometry and state of the water permit.)

Shallow groundwater

The level of shallow groundwater (hereinafter groundwater) underneath the city has a varied picture of morphological conditions. The groundwater flow direction is S-SW, which can be influenced locally by human activity. The deepest resting groundwater level is located in the north, northeastern part of the city, here is not uncommon to have the 8-meter resting water level either. The highest level of ground water can be measured near the Tócó Valley, in the western and southwestern parts of the city. Here the resting groundwater level is only 1-2 meters, but there is also a near water level at ground level. The regulating effect of the Tócó groundwater level can be clearly demonstrated by approaching the watercourse. In the eastern and central part of the city, the ground water level of 5-6 meters is characteristic.
Groundwater is poor and of bad quality throughout the city due to human activity. This is due to the fact that household wastewater discharges that have occurred over the last decades due to lack of sewer network can

be identified. The upper groundwater layer has high nitrate, phosphorus and nitrite content. The drinking water supply of the city is basically based on the utilization of deeper groundwater and the water that used to be cleaned is provided from deeper (100-140 meters) layers. Nearly one fifth of the drinking water consumed by the city is purified surface water from the Eastern Main Canal.

Urban structure – Land use/Land cover

In the case of urban hydrological analyses, the rate of surface sealing to the entire river basin is a very important parameter, which mainly affects the ratio of infiltration and runoff. In habitats, there is close correlation between population density and surface sealing ratio. There is an intensive raise in sealing parallel to the population density increase until 120 persons/hectare. Above that value, sealing has slightly increased. Above 150 persons / hectare it becomes entirely constant (approximately at 65 %). This statement is valid only for urban areas. However, in the case of industrial and commercial part of the town, where population rate is nearly zero, the sealing rate is over 70-80 %. It can be seen, in the case of Debrecen that it has been expanded at arable land, forest, and water surfaces, changing the run-off in poor surface water areas.
Different parts of the city play various roles in the hydrological system (Figure II.15.). However, studies focused on water regime analyses from this point of view hadn't been made yet. So this is the first time that the effects of this process are estimated and evaluated, as will be shown in this publication, by strategical plans.

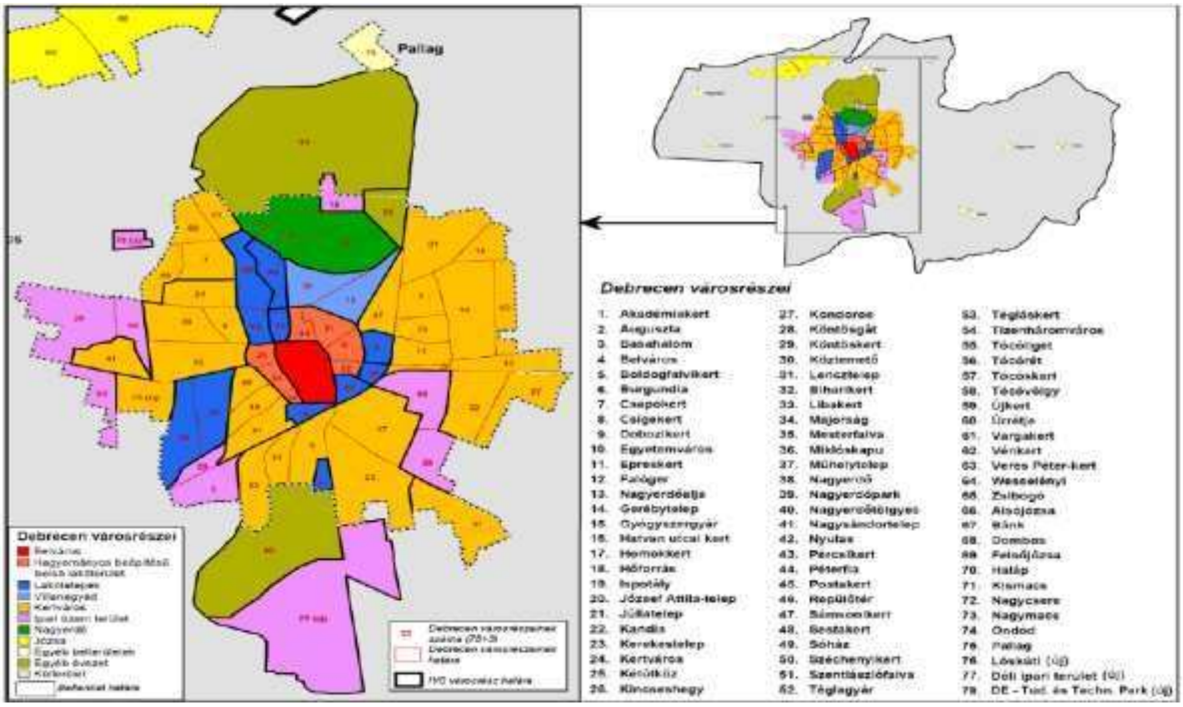


Figure II.15. Different parts of Debrecen[1]

Downtown

In the last decades, the population of this town part has declined above average and aged. The number of houses and built-up areas has increased. The population of the city tends to travel significantly to the city center and roads connecting the city's east-western and north-southern parts of the city (or at least affecting it) cause a high level of environmental pollution, thus causing rainwater pollution by cars. There are considerable parking problems in the city center as well. Over the past few years, several underground garages have been built in the city center, which could modify the free flow of groundwater. In this part of the town ,a coherent green surface system, which promotes better microclimate can be found only in few cases. Unfortunately, not enough attention has been paid to this problem in recent investments. To improve the microclimatic conditions, fountains can be only a local solution. However, these are operated by purified water with drinking water quality. In addition, they use remarkable energy sources. Recycling of rainwater in this part of the city would have significant potential.

Traditional city area

This part of the town involves the ring around the city. From the point of view of built-up characteristics, it looks like a small-town area divided by condominiums and residential areas. In the Mesterfalva part the rate of low-comfort level houses is nearly 25 %, while in the northeastern part the rate is 13 %, while a more favorable indicator has a positive trend in the Kandia district. The economic functions of the traditional built-up areas are not so significant, along with two major construction companies in the western part of the city. The lack of adequate green spaces in this part of the town is also a problem and an extremely low level of street network in the inner areas has to be highlighted as well.

Residential area

The residential part of the town mainly lies at the western side of Debrecen. In addition, these areas can be found at former suburbs built in 70’s and 80’s ((Libakert, Ispotály, Sóház, Dobozikert, Sestakert, Újkert, Tócóskert, Tócóvölgy, Wesselényi). The parts of the Tócó valley, Wesselényi and Epreskert were built in the 90's and the panel structure has changed to the condominium form. Similarly to other towns in the country, council estates in Debrecen are also becoming more and more problematic due to the impoverishment of the population and partly to due to the deterioration of these buildings. The renovation process has already started, but housing stock is very significant with the number of approximately 31,000. The area is characterized by significant residential water consumption and waste water production. The quality of the environment is better in the built-up areas, so there could be the opportunity to collect and utilize local rainwater and to create urban gardens. Infiltration of pervious surfaces should be advanced to reduce flash flood submergences.

Exclusive residential area

The exclusive residential area of the town is located in the north of Debrecen, south of the Great Forest Park, and consists of the Great Forest and the Great Forest down part. Until 60’s the town district of Nagyerdő used to be characterized primarily as the upper class district with family houses, while the Great Forest down part was characterized by family houses. Over the last decades it has become more favorable to build condominiums in the Great Forest district. However, in the northern and central side of the Great Forest down district, the housing estates occupy a relatively large area. The accessibility is great by public transport: the tram plays the most important role, the bus in the western parts, while the trolleybus in the eastern part plays an additional role. The large private green area contributes positively to the microclimate, where it is possible to extend rain-harvesting solutions and link green space management as well.

Garden suburb

Garden suburb, the so--called Kertváros part, represents the other large part of population after building the estates. In spite of the residential area, here the population had been continually growing between 1990 and 2000 and thanks to its family house characteristics, the population rate is so much lower here. The U-shaped part of the town comprises of several districts. The southwestern garden suburbs include Széchenyikert, Postakert and Vargakert, the parts of the southern garden suburbs consist of the Tégláskert, the

Boldogfalvikert, the Kerekestelep and the Homokkert and the eastern garden suburbs include the Juliatelep, the Thermal Springs, the Csapókert, the Sámsonikert, the Gerébytelep, Péter Veres garden, Kincseshegy, Pércsikert, Biharikert and Kondoroskert. The south-eastern garden suburbs comprise the Lencztelep, the Northeast Garden, the Akademiakert, the Nyulas, the Tócóliget and the Úrrét, the Western Garden Köntöskert, the Csigekert, the Garden City, the Hatvan Street Garden, the Nagysándortelep and the Lóskút part of the town (the latter is located at the border of the Tócóvölgy residential area and the industrial brickfield area, built in recent years). In the garden suburb part of the town several major residential park investments have been carried out and the population increase has been observed. These include the Tócóliget area (the Liget residential park), the Mediterranean residential park (Csigekert), the Főnix residential park and the Fészek residential park (Lóskút district). At the same time, a number of commercial units (for example Baumax, Euronics, Diego, TTL) have been set up in the easy access areas, which used to be unbuilt fields. Especially the traffic on the Sámson road, which is one of the fastest growing suburbs of Debrecen, also includes traffic flows from Hajdúsamson. Traffic problems occur in Tócóliget, which was built in the first decade of the new millennium, and in Úrrét, which extended to the north. In these areas, the level of built-up density is very variable so that unique precipitation handling solutions can be applied from this aspect.

Industrial area

The Northern Industrial Park district includes the TEVA-BIOGAL Pharmaceuticals Plan in the Great Forest.

The western industrial area core consists of two main industrial parks. The Western Industrial Park is a brownfield industrial park with a 100% occupied area of 30 hectares, with 90 companies currently operating. The Debrecen Regional and Innovation Industrial Park as a greenfield industrial park in the area of 40 hectares is now full; it has already been expanded by a 16.2 hectare area.

The University of Debrecen - Science, Technology and Innovation Park is currently a greenfield industrial site of the city, which lies north of the Western Industrial Park, in the periphery of Debrecen, on 25 hectares, and serves enterprises that have health and IT research facilities.

The Northern Industrial Park involves the Great Forest, the Teva Pharmaceutical Industries Ltd..

The city district of the Southwest Industrial Park includes the Kétútköz and the Basahalom units; moreover the wastewater treatment plant of Debreceni Vízmű Ltd. occupies a decisive part of its territory.

The Eastern Industrial District is considered the oldest industrial zone in Debrecen. This industrial area lies on a 25.7 ha area and comprises 21 operating companies. In case of industrial parks, high environmental pressures in water management have to be considered (mainly industrial profiles and in the case of high impervious surfaces), and at the same time big opportunities are given for a number of innovative solutions in the future.

In the southern part of the city, the Southern Industrial Area provides additional opportunities for future development processes with excellent logistic capabilities (Figure II.16.).

Figure II.16. Design plan of the Southern Industrial Park[19]

However, it also requires a complex solution with regard to water management and the airport, which will be discussed in more detail in relation to the Tócó creek watershed. In this industrial park, a significant number of free infiltration sites have been covered over a few years, where more local solutions could be applied to reuse rainwater, which would both improve water quality and provide a greener working environment.

Residential functions of industrial parks are negligible. In industrial park areas, economic developments are concentrated. At the same time, they exclude high-quality lands from production in significant areas. So the inclusion of brownfield investments in the eastern lower quality areas should be intensified. This also requires newly built Bypass Motorway in the eastern part of Debrecen. The location and development directions of the external roads determine the development of urban industrial parks and this will have an impact on the changes in urban hydrological processes, which should also be taken into consideration in the case of the town that is poor in surface water resources.

The Great Forest

Most important functions of the Great Forest are educational (University of Debrecen) and recreational (stadium, spa, amusement park, zoo). The Debrecen Sports Centre on 19 hectares is located here. Among the water management problems, the most important one is that there is a depression on the groundwater level and as a consequence of the gradual desiccation it threatens the Great Forest that needs intervention (see the CIVAQUA project). The reconstruction of the outdoor bath has already begun, where thermal water with high saline content causes a problem in urban hydrology.

Józsa

In the middle of the 1980s, the district of Józsa, which is located 6 km north-west of the city along the main road 35, was joined to Debrecen.. The town district has become popular in recent years among those wishing to move out of Debrecen, and due to this fact, the population growth is also significant at urban level. The problem of the town district is traffic, which is extremely overcrowded and dangerous in the morning and afternoon rush hour. The rate of private gardens here is high, therefore rainwater management could be important. The Tócó creek flows through Józsa, thus a significant green corridor could be implemented by an improvement process.

Peripheral settlement parts

Peripheral settlements are divided into the following two parts: on one hand they include other areas in the neighborhood of Debrecen (Nagymacs, Kismacs, Pallag, Bánk, Haláp, Nagycsere, Ondód and Hegy) and on the other hand also the town periphery (among them the most important residential areas are as follows: István Biczó Garden, András Bayk Garden, Halápi Suburb and Nagycserei Suburb). The rate of private gardens here is high, therefore rainwater management could be important. The main native vegetation of the Erdőspuszta involves oaks with lily of the valley (*Convallaria majalis*), which nowadays can only be found in smaller or larger patches. Lakes of Fancsika and Lake Vekeri provide opportunity for fishing and boating. However, these lakes were created by inland water collection, so occasionally they dry out entirely during drought periods. This requires action to be taken in order to solve continuous water supply, which could be provided by the CIVAQUA program.

Other zone

The Other Zone includes three not inhabited parts. However, these areas play a very important role in the city's life in different ways. The Debrecen Airport has become an international airport.. The drainage improvement has just started.

The Central Cemetery of Debrecen is located in the northern part of the city, along the main transport route No. 4, currently occupying 56.3 hectares and comprising 55,000 graves, 3,000 urns and 300 crypts in the nitrate sensitive area.
Nagyerdőtölgyes includes more or less natural (unspoilt) areas of Nagyerdő, which surrounds Debrecen from the north. The main problems are groundwater level depression and continuous fragmentation of this landscape, which conduces to spreading of invasive species.

Strategic planning and stakeholder roles in the planning process

Water in the city

Water demand in the city is highly dependent on population and age structure of the population. The total population of Debrecen is around 203,000 -207,000 people. Optimistic urban developing plans expect in the next decades the population to increase by 30-50 thousand people as of 2050.
The number of young people under the age of 15 has decreased by 2%, while the number of people over the age of 60 has increased by nearly 5%, so there has been a slow aging in the past decade, but this is still more than the change in the national average.
Based on the Hungarian City Development Plan (TEIR), the balance of migration in the city has not changed significantly. There is a significant difference between the permanent and migrating population of the city, which is attributable to a significant number of students travelling due to the high educational role and the number of commuters. The statistical number of the population does not correspond to the number of university students and academic staff of between 30 and 35 thousand, which also has a significant impact on water consumption.
Debrecen is an important tourist destination and during certain periods there is rapid increase in population numbers and water consumption, for example during the Floral Carnival on the 20th August, when the population is two times higher.
In this period regularly occurs a heat wave with higher environmental health risk for the young, ill and elderly population, but catastrophe management is prepared for these events.
In addition to the number of population, the number of dwellings in the urban area also affects the size of the built-in surfaces, which has increased significantly and this trend is increasing, and the demand for rented flats (students, workers, migrants) rises as well[20].
Along with the water consumption of households, the industrial-commercial water consumption is another major water demand.
Major companies operating in Debrecen could be fragmented into three major groups. These are the following: Enterprises with industrial activity, e.g. FAG, National Instruments Europe Ltd. TEVA Pharmaceutical Ltd. Zrt. FRIESLAND Campina Hungária Plc. Alföld Tej, Globus Cannery Factory, K-Frost Ltd., Pentafrost cold store factories. In the IT sector and financial service sector, there are, for example, IT Service Hungary Ltd., Ygomi Europe Ltd., British Telecom Global Services. Multinational trading companies include TESCO, INTERSPAR, AUCHAN, KIKA, PRAKTIKER. Companies with industrial activity have the highest effect on water consumption, but this group involves KEVIÉP Construction and Trading Ltd. which establishes water facility improvements. Most business activities are obliged to have an environmental impact assessment that includes environmental evaluation of water resources. However, usually it is cheaper to pay a penalty charge than to invest in water purification systems.
In the proximity to the airport, significant industrial park developments have started, which is a task to be solved in terms of drinking water and industrial water supply. There are three industrial parks on the western and southwestern edge of the city, the Agricultural Industrial Park, the Western Industrial Park and the Southern Industrial Park, where new investments are ongoing. The Tócó creek is also a recipient of rainwater

that drains from ever-growing covert areas. The water management situation of the airport and its surroundings is currently characterized by vulnerability. High intensity rainfall or spring snowfalls often cause flooding in the vicinity of the airport environment.

Links between the water cycle and other urban management sectors

The rate of green surfaces is significant in Debrecen with about 462 km^2, while the rate of surface water is only 1 % (Figure II.17.). Most parts of the interior area are already built in, while green surface is less than 1% of the total area only 160 hectares in total.

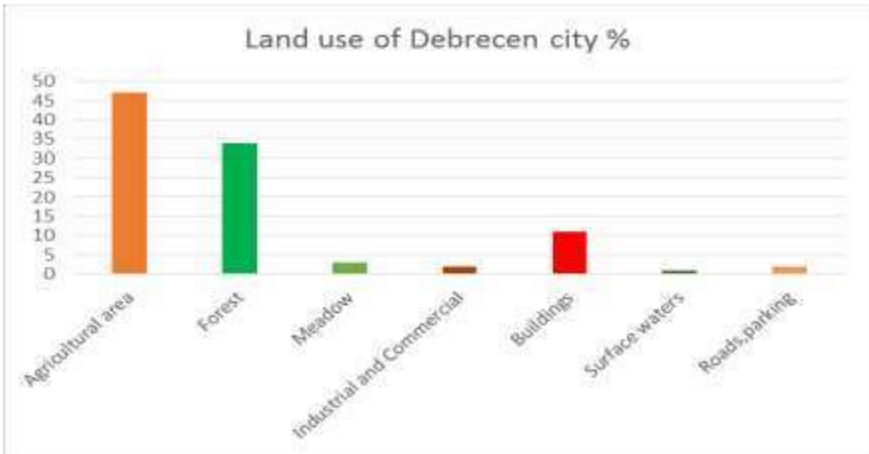


Figure II.17. Land use of the Debrecen City based on CORINE LC-100[21]

Based on plans, the areas of the city intended to grow are mainly divided into two main groups. In the eastern periphery of the city, there is an urban development zone, stretching from the Vámospércsi road to the Sámson road.

The other group is represented by economic improvement investments. This affects mainly the area of industrial park developments. The Határ street area is under continuous development, while the infrastructural developments in the airport area have just started. With regard to urban water management, these latter developments have a significant impact (Figure II.18.).

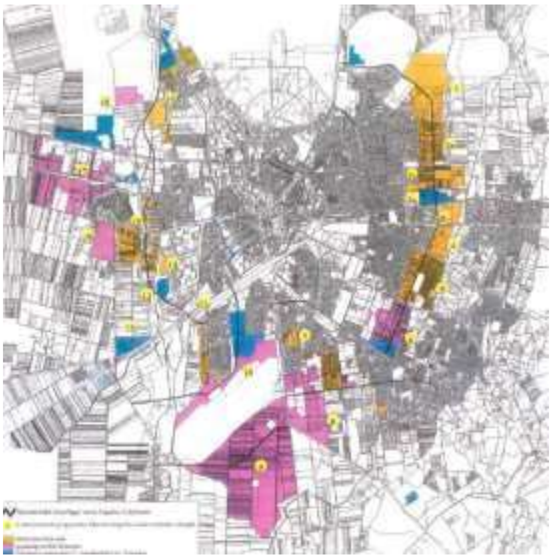


Figure II.18. Development plan – brown color indicates less and blue/purple indicates higher impact on water resources[22]

Negative effects of constructions are compensated by positive effects of green surface areas. In the region of Debrecen, forests with rich green surface areas associated with green corridors have to be joined to a whole coherent green surface system based on the Development Plan of Debrecen. To achieve this, the following purposes were declared[23]:

- Habitat green surface rehabilitation of the Tócó watercourse and the Kondoros watercourse have to be fostered
- Public parks of the city should be connected to the green areas bordering the settlement by planting trees, field parks and forests in the town;
- The gardens across the Kondoros watercourse in the eastern part of the city should be sustained like non-built-up areas, as they may function as a buffer zone between urbanization and natural areas;
- In garden suburban areas, a continuous surface needs to be provided for the green areas to ensure rainfall infiltration into the soil
- Around the southern sewage treatment plant and the waste disposal site, especially towards residential areas, to the whole buffer zone, a forestration must be carried out.

Value of green surface area per person should be raised at least close to the countrywide average. This is hindered by the fact that during urban development investments (road development, block restoration), many trees have been cut out. This resulted in a discontinuous green surface system.
A consequence of raising industrial areas is the loss of total green surface. In spite of this, there is a positive tendency in recent years of remarkable green surface developments and a reconstruction process has already started too. It includes twice as many trees tried to be planted after the trees are cut out due to developments by the local government. The number of woodcuts (487) and tree plantations (788 pieces) due to tree reconstructions and other urban development projects has shown a positive balance over the past five years. In addition, the number of trees planted was significant (1,112) in the frame of the park maintenance (Figure II.19.) during that period.

Figure II.19. The fountains play important roles not only in terms of urban landscape but also microclimate improvement in the Debrecen downtown (Photo: Tamas)

The strategic planning process for IUWM

The methodology of a strategic planning process provides the framework that facilitates a shift to more integrated policies, governance structures, practices and choice of technology for more sustainable water management[24]. The city needs have been determined by policy frameworks and urban planning tasks and were named the FŐNIX PLAN (2014-2020). Such an “analysis of the city needs” was based on legislation, expected development of the city and extended available information[25] (Figure II.20.).

Figure II.20. Hierarchy of the City' s Water Strategy and Policy[25]

The development framework for urban development of Debrecen is as follows:

European water policy: The EU WFD and Floods Directive, The EU Danube Macro-Region Strategy.[26]; EUROPE 2020 [27];
National water policy: The National Water Strategy (Kvassay Jenő Plan-KJT); The New Széchenyi Plan[28]; The Széll Kálmán Plan[29]; The National Rural Development Strategy.[30], The Darányi Ignácz Plan[31]; The National Environmental Program[32].; The National Framework Strategy on Sustainable Development of Hungary
Local water policy: The Municipality Decree No. 8 of 2003 (V. 23.) on the local building rules and regulation plan of the City of Debrecen; The Municipality Decree No. 24 of 2006 (VIII. 14.) on the protection of natural values of local importance
The Decree covers the administrative area of the City of Debrecen. The main aim of the Decree is to protect trees and especially valuable species, to conserve the potential habitat for flora and fauna. The rehabilitation concerns the non-protected area of Tóco within the administrative zone of the city. The Debrecen-Józsa Tóco-valley is protected as the Natura 2000 area (HUHN20122) and the site of community importance, where the goal is to protect and develop the area's water balance and natural conditions (aquatic and other communities, natural shoreline of the watercourse, etc.).

City water policy

Towns have a significant role in the successful adaptation of the EU 2020 Strategy. The aim of the next EU Cohesive Policy is to promote integrated town policy adaptation, which contributes to the performance of a sustainable town development and encourages the role of the towns in the Cohesive Policy area.
It is stated as a principle, that in favor of the sustainable urban development, such integrated strategies must be supported by the European Regional Development Fund for the period 2014-2020, which can treat urbanization related economic, social, environmental, climate problems. Urban water management is also involved in this strategical planning environment.
The strategic planning process consists of 3 main phases: baseline assessment document; conception of the urban development document; integrated urban development strategy document .
This process also includes monitoring and evaluation phases, where measuring and assessing the outcomes of implementation are important to make sure that the intended results are being achieved and, if necessary, to change the course of action.. The local strategic published urban development plan is called the Főnix Plan, which contains 3 main developing levels: vision-comprehensive goals; sub-goals; settlement development principles.
We would like to emphasize that urban water management, which is in correlation with horizontal development plans, does not contain a separate chapter of urban hydrology in the Főnix Plan. However, there are separated chapters related to environmental protection and sustainability, which include the following objectives and solutions:

- Thermal water medical institutes

- Debrecen Aquaticum Spa
- Established ecological network system in the town region
- Raised urban green surface areas to the whole system by development
- Civaqua regional development program
- Desalination of thermal water, disposal and treatment of effluent thermal water in Debrecen
- Development of a selective waste collection system
- Development of the Sustainable Energy Action Plan for Debrecen[33]

Stakeholders in urban water management

Debreceni Vízmű Zrt. (Debrecen Waterworks Ltd.) is a business organization with the water utility service license. According to the Water Utility Services Law, the permission license requiring activities for end user(s) like public utility drinking water supply and public sewage disposal and purification activities are provided in the frame of a public utility legal relationship by Debreceni Vízmű Zrt. Supplementary (secondary) activities include all the activities of the water utility service, which are not part of the public water supply service, carried out as a business activity. The activities of Debreceni Vízmű Zrt. are based on an accepted annual business plan adopted by the owner (local government), which is in close cooperation with the owner and other members of the group of the company.
Within the EU ISPA program, the public sewage disposal and purification service for 4 neighboring settlements (Ebes, Hajdúsámson, Mikepércs, Sáránd) has been taken over by Debrecen Waterworks Plc since 2014. The main objective of the project was to protect the surface and underground water sources of Debrecen and its agglomeration by the expansion of the sewage network and raising the efficiency of the sewage treatment plant.
The local government of the Debrecen City generally has a major responsibility for providing the space for water stakeholders to collaborate on better water management in a meaningful and effective fashion. Water authorities are usually more concerned with the technical side of managing an urban water system as key stakeholders in the strategic planning process (Figure II.21.).

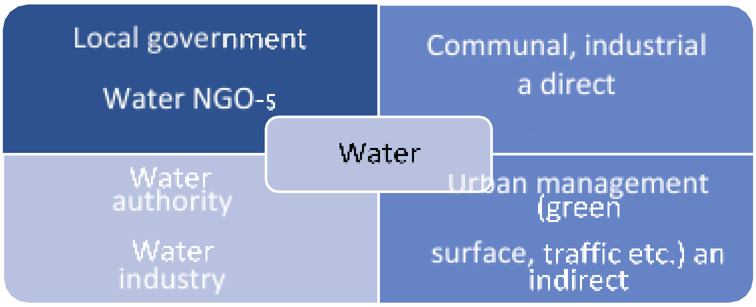


Figure II.21. Main groups of water-related stakeholders in Debrecen (based on [1])

Stakeholder categories in urban water management can be divided in different ways, but in the planning process there are two basic groups – a) this group is directly related to water (water supply, waste water treatment, stormwater management) and b) this group is indirectly related to water (land use planning, health service, parks and recreation, industry, commercial sector, etc.) (Figure II.22.). A good coordination within the local administration as well as professional facilitation of involving external stakeholders are key to achieving successful outcomes from the planning process.

Figure II.22. Detailed water stakeholder map (own source)

The stakeholder process needs to be equipped with clear and measurable goals and these have to be monitored and evaluated regularly. Given the ever-rising complexity of urban water issues, science and technology become increasingly important.

The highest level of social control in water sector is provided by the Trans Tisza Water Committee. The members have one vote per institution represented by the water, soil, natural protection authorities, local government, universities as well as non-governmental organizations.

The members of the Trans Tisza Water Committee evaluate the answer to the standard questions on a verbal yes-no-vote basis. This process is a social control on decisions of water resources. Before launching any water management project, the committee members should be consulted, and in case the project does not receive support from the members, it cannot be started.

For each project, the following questions have to be voted on:

1. The project manager of submitted water management endeavors to show the sustainability of water treatment and efficiency of water retention.
2. The technical content of the project fits into the local hydrological conditions, taking into account the regulations and standards related to urban water damage control plan and water framework directives.
3. When designing engineering structures, and determining the reference flow rate, have the requirements of the legislation and the relevant technical directives and standards, as well as the applicability of local settlement regulation been properly taken into consideration?
4. The designed project elements and technical solutions are appropriate and really cost-effective.
5. Are the planned drainage facilities available, are the appropriate recipients suitable?
6. Is the water infrastructure necessary for water quality management (e.g. sediment trapping, oil skimming, cleaning sump) properly planned?

IUWM and climate adaptation

The climate adaptation strategy is an important indirect milestone of the IUWM strategic planning process, since water management and climate change are closely connected. However, the main goal of the Climate Adaptation published in 2018 , the first county based strategy, is “to reduce greenhouse gas (GHG) emissions and vulnerabilities, building on local conditions, based on environmental and landscape values that contribute to moderate socio-economic differences by regional economic development and sectoral policy improvements.”

The aim of GHG emission mitigation of the Hajdú-Bihar county is to maintain the GHG emission at the level described in the national inventory until 2020 and foreseen GHG emission reduction level is at 6 % until 2030 and 43.6 % until 2050. Secondary mitigation reduction, adaptation of current impacts and preparation for predicted climate change effects give result in short term in terms of given conditions, as an opportunity. Impacts of mitigation improvements are profitable in the short term, while adaptation investments pan out in the short term as well.

The accepted IUWM-related mitigation goals are as follows:

- The application of local, environmentally-friendly building materials,
- The Urban Development and Landscape Planning Guide on how to adapt improvement methods to the settlement structure,
- Optimization of land use by adaptation aspects, set up pilot projects,
- Support of reforestation and forest renewal in the frame of close-to-nature forest management and implementation of water supply, carry out continuous forestation plan,
- Exploration of opportunities in water recycling and retention,
- Sharing good practices and corporate social responsibility,
- Climate protection and adaptation training,
- Definition and monitoring of climate strategy action related output indicators, goal-oriented result indicators[36]

The Urban Water Agenda 2030 identifies important water issues for cities, sets objectives for 2030 and proposes concrete actions to achieve these objectives as well as target values around the core areas that were evaluated in the following Table II.1.

Table II.1. Status of the New Urban Water Agenda 2030 Goals in Debrecen

Water efficiency	Target	Present situation	Trend	Remarks
Leakage reduction	less than 10%	higher	slightly positive	Partly estimated, Measuring
Consumption reduction	20% compared to 2015	higher	highly positive	if compared to 2000 or earlier this target is satisfied
Water reuse	50% of urban use	lower	slightly positive	in the future increase based on a new separate sewer network
Resource efficiency	**Target**	**Present situation**	**Trend**	**Remarks**
Energy efficiency of urban water systems	50% reduction	lower	highly positive	modernization of WWTP, renewable energy (biogas, solar energy)
Recovery of	75% of nutrients and	higher	highly positive	sewage sludge

materials from wastewater	50% of organic matter			composted; green waste composted
Water quality	**Target**	**Present situation**	**Trend**	**Remarks**
Safe drinking water to inhabitants	100%	satisfied	constant	
Treatment of wastewater	not available	satisfied	constant	
Treatment of storm/run off water	**Target**	**Present situation**	**Trend**	**Remarks**
Addressing emerging pollutants		not satisfied	constant	micro pollutants
Sustainability of urban water infrastructure	**Target**	**Present situation**	**Trend**	**Remarks**
Water pricing		constant price	highly positive	water price regulated by state
Investments		decreasing	negative	lower owner sources to invest
Flood/excess water prevention and nature based solutions	**Target**	**Present situation**	**Trend**	**Remarks**
Land use planning to prevent damages	impervious/impervious surface area ratio	decreasing	negative	High excess water risk, no flood risk
De-sealing/increasing infiltration	runoff	decreasing	negative	depend on urban sectors
Green infrastructure and storage of rainwater		moderate	slightly increasing	depend on urban sectors
Citizen involvement	**Target**	**Present situation**	**Trend**	**Remarks**
Raising awareness and empowering citizens	number of persons	increasing	positive	

Water Supply (drinking water, industrial/commercial water, irrigation, thermal water)

The water supply – sustainability problems

Since 95% of the total drinking water supply in Hungary and 70 % of the total drinking water supply in Debrecen city originates from subsurface layers, the significance of groundwater resources is outstanding. In this publication water located in the deposits near the surface is called (acc. to the specific Hungarian nomenclature) shallow groundwater (in other languages this terms stands usually for groundwater in general), water in deeper clastic sediments is called deep groundwater, while the deep groundwater of a temperature higher than 30 °C is thermal deep ground water, being a type of thermal water. (Remarks: The other main type of groundwater aquifers is the group of karstic rocks that can be found in almost half of the hilly areas covering one fifth of Hungary's territory). The upper layers down to the depth of 10 to 20 m are of fine-grained formations enabling only small discharges for local production. The majority of dug wells in the suburban areas of Debrecen produce water from such formations.

The groundwater balance, the levels and heads depend on the hydro-meteorological conditions, on infiltration and recharge and on the abstraction of water. In the 80's the high rate of water abstraction (Figure II.23.) coincided with dry weather, when a large withdrawal exceeded the reduced recharge for a long time, which led to a significant loss in the groundwater balance: water resources stored below the surface decreased leading to the fall of water levels. Quantitative risks stated in the EU Water Framework Directive were analyzed by the comparison of the monitoring and water abstraction data with available water resources.

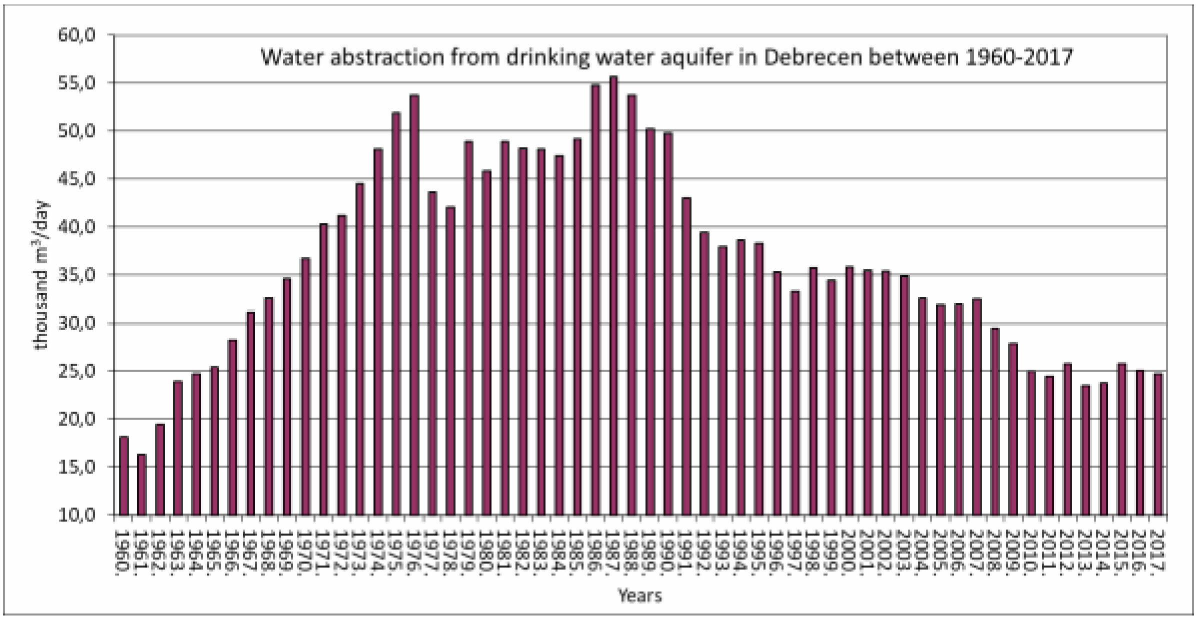


Figure II.23. Water abstraction from drinking water aquifer in Debrecen between 1960-2017 (Source: DEVIZ Rt.)

Quantitative risk (i. e. the risk of failing to meet good quantitative status by 2015 as stated in the Water Framework Directive) indicated the trend of increasing water levels and changes in groundwater flow detectable in the southern part of the Nyírség and the Hajdúság, which are wider geographical regions of Debrecen (Figure II.24.).

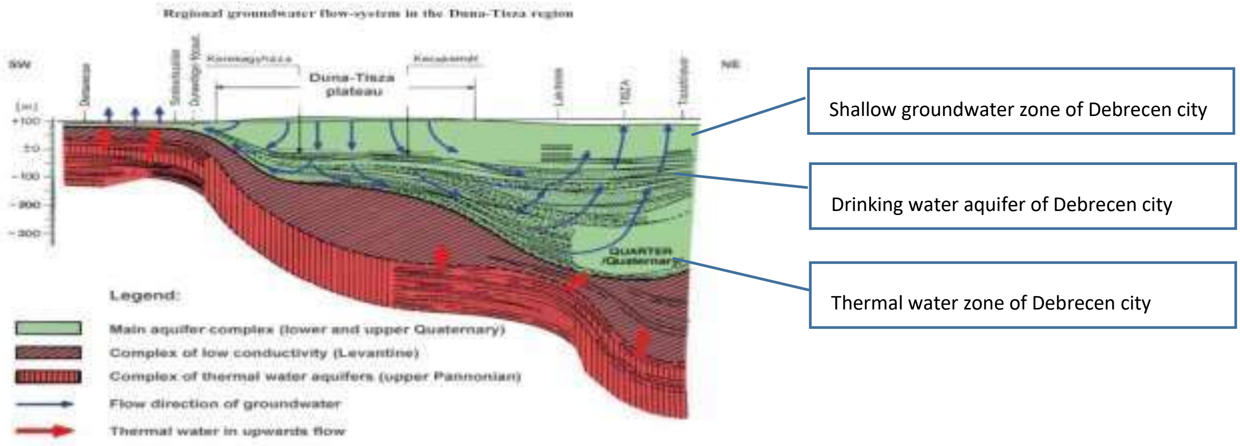


Figure II.24. Groundwater flow – system in the Danube-Tisza region[34]

The variations of shallow groundwater level depend mainly on precipitation: loss or surplus of infiltration accumulates for years. The change in flow conditions is caused by uncontrolled abstraction of shallow groundwater as well as by the (limited) hydraulic connection between shallow and deep groundwater. The lack of precipitation in dry seasons also seriously impacted excess water reservoirs in the eastern part of Debrecen.

These water reservoirs (Kati, Vekeri lakes) are very sensitive to rainy/dry weather fluctuations.

The quality of groundwater is determined mainly by an aquifer rock in which it is stored or where it is in movement. The original quality of water is highly influenced by the flow, by the travel time of water below the surface and temperature has a certain influence as well.

Water basin quality in catchment areas is different so it requires various water treatment solutions in the catchment area of the Tisza River. In Debrecen, sand, iron and manganese elimination, as well as filtering of methane is a daily operational task. Water treatment and purification plants are able to keep the limit values in drinking water. However, long water supply network with various technical status contributes to the additional hazard points. Therefore drinking water treatment costs could be 3-7 times higher , depending on water basin conditions.

Debrecen's drinking water supply is provided by two main water sources. One part of the drinking water arises from deep aquifer reservoirs beneath the city and the other part (32%) flows from the Tisza River, exactly from the Eastern main channel (Figure II.25.).

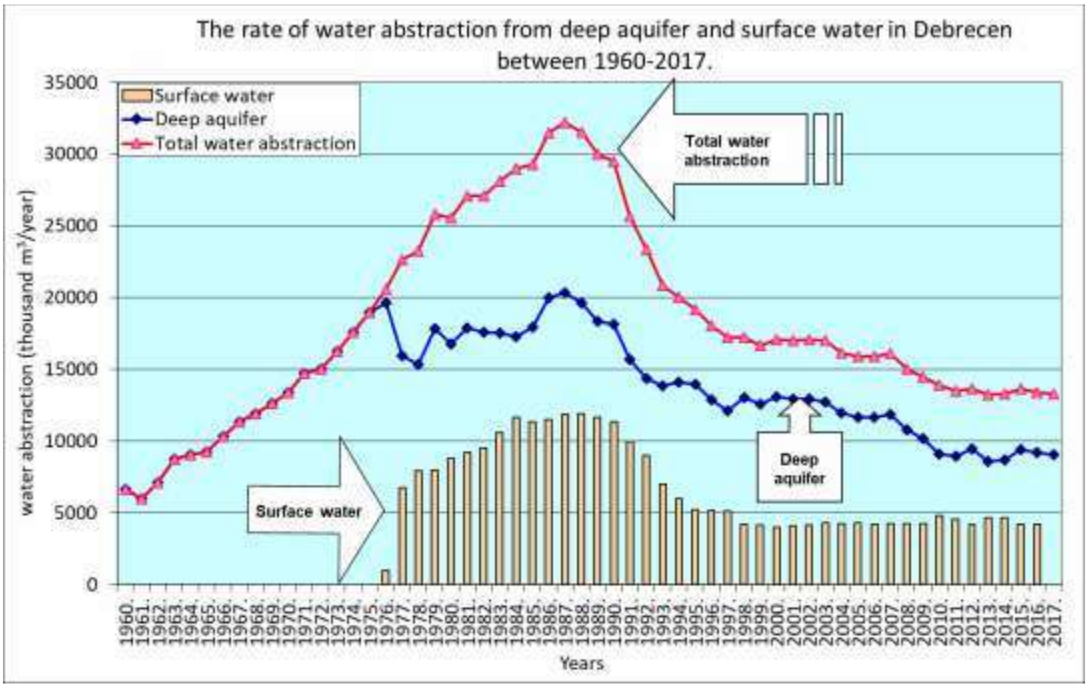


Figure II.25. The rate of water abstraction from the deep aquifer and surface water in Debrecen between 1960- 2017 (Source: DEVIZ Rt.)

Safe drinking water is supplied to households in a large percentage (Figure II.46.). Due to the significantly increased water prices, household water consumption since the 1990s has decreased , while in 2006 the annual water consumption per inhabitant in Debrecen was 33.3m^3 .

Table II.2.[1]National average and Debrecen's private water consumption data[35]

Categories	National average	Data of Debrecen Vízmű Ltd.. in 2015.	Data of Debrecen Vízmű Ltd. in regional settlements in 2015
Average annual water use per location	79.36	66.91	68.52
Monthly average water consumption per location	6.61	5.58	5.71
Average Daily Water Use per Usage	0.22	0.19	0.19

Based on the above mentioned database (Table II.2), it can be stated that data are below the national average. The drinking water consumption in the Hungarian region can be studied using an interactive web map as well[36]. The daily monitoring of drinking water quality is made in accordance with the daily test schedule of the Central Laboratory of Debrecen Vízmű Ltd., and the official inspection is carried out by the National Public Health and Medical Officer Service (NPHMOS) experts.

The differences in the parameters of the water temperature and taste at the consumers originate in the long water supply (pipeline) networks.

Risk evaluation of aquifers

The Debrecen water plant, as the European water service provider, has to implement the Preventive Drinking Water Risk Management (PRM), referred to in the WHO Guidelines as Water Safety Plans (WSP)[37]. The Guidelines are primarily intended for water and health regulators, policymakers and their advisors, to assist in

the development of national standards. The Guidelines and associated documents are also used by many others as the source of information on water quality and health and on effective management approaches.
The combined effect of the 3 components is highly emphasized for safe drinking water from catchment to consumers, starting with:

- an effective protection of resources designated for drinking water supply (groundwater, spring water, rivers, dams, and lakes), under the responsibility of the catchment authorities.
- drinking water intake, treatment and distribution, should be based on a professional management system related to codes of practices, due diligence and well-trained staff/operators,
- maintaining high quality of drinking water up to the consumers' taps needs their domestic installations to be properly planned, installed and maintained, according to the PRM approach, under the owners' responsibility[38].

The deep groundwater in Debrecen is suitable for drinking water supply; in the case of deep groundwater, the application of the proper water treatment technology is necessary, based on risk management. In the case of groundwater basin, it is required to determine three geological protection profiles:

- Inner Protection Zone: it is identified to protect against the transmission of rapidly degrading toxic chemicals and some water-borne diseases.
- Outer Protection Zone: protection against non-degradable, bacterial and other degradable pollutants;
- Hydrogeological protective zone or Source Catchment Protection Zone: protection against non-degradable pollutants, which must be assigned either to the entire water catchment area of groundwater abstraction or to a specified part of it[39].

In practice it is needed to highly emphasize the safety of drinking water from catchment/aquifers to consumers, starting with:

- an effective protection of resources designated for drinking water supply (groundwater, the Tisza river, Tisza lake), under the responsibility of the catchment authority and the water company.
- drinking water intake, treatment and distribution, should be based on a professional management system operated pursuant to codes of practices, due diligence and well- trained staff/operators,
- maintaining high quality of drinking water up to the consumers' taps needs their domestic installations to be properly planned, installed and maintained, according to the PRM approach, under the owners' responsibility[40].

The US EPA DRASTIC methodology was implemented to evaluate the pollution potential of hydrological setting of the Debrecen city[41]. These settings incorporate major hydrogeological factors, which affect and control ground-water drinking water zones[42]. The result of the standardized vulnerability map ranges from the most vulnerable to contamination to the least vulnerable around drinking water pumping stations. The measurement areas of 4 Debrecen zones were analyzed based on the following[43]:
The 1st aquifer water exploitation zone is in the western part of the city at the I. Exploitation Plan (EP), which exploits only from the lower Pleistocene layer with 36 pumps. The average elevation is 112.4 m. The depth of the deepest well is 163.8 meter and the shallowest is 122 meters deep. The permitted exploitation capacity is 15,000m^3/d. In the case of long shaft deep wells water the above limits for iron, manganese and ammonium and for methane content are observed. In the region, the groundwater and the shallowest aquifer are polluted. Based on soil and groundwater analyses, it can be established that the pollution originated from the lack of sewage network for the industrial and agricultural activity and inconvenient waste storage. In the water samples from certain locations, nitrogen derivatives, heavy metals, oil, organic matter, micro pollutants, and inorganic salts have been detected above the limits. Polluted groundwater has not yet reached the drinking water layers. However, due to the fact of vulnerability, there is a risk of endangerment in the longer term. Continuous monitoring must be carried out to monitor the state of this layer.

The 2nd aquifer water exploitation zone is in the northern part of the city and involves the Great Forest II. Exploitation Plan and its neighborhood. Nearby the deepest Pleistocene layer, the middle Pleistocene layer has a significant pressure, while exploitation from the shallowest layer is low, but it is notable. The deepest and most important level is operated by 40 wells. Most important pumps are the 32 pumps of the II. Exploration Plan, 3 pumps in the TEVA Pharmaceutical company and 3 pumps in the University of Debrecen Medical and Health Science Center. The average surface elevation in this zone is 126.3 meters. The depth of the deepest pump from soil surface is 187.2 m and the depth of the shallowest pump is 151.0 m. In the case of long shaft deep wells water the above limits for iron, manganese , ammonium and for methane content are observed. In the region, the groundwater and the shallowest aquifer are polluted. CH pollution at TEVA Rt. is achieved in deeper aquifer layers. Remediation of this area is in progress. The extension of pollution results in the necessity of a new water work development. Based on soil, groundwater and aquifer analyses, it can be established that the pollution originated from the lack of sewage network for the industrial and agricultural activity and inconvenient waste storage. In the water samples from certain locations, nitrogen derivatives, heavy metals, CH derivatives, organic matter, micro pollutants, and inorganic salts have been detected above the limits. Water basin is vulnerable so its safety must be managed and must be provided to keep safe.

The 3rd aquifer water exploitation zone (3rd. zone) is located at the Southern East industrial park of Debrecen. After a treatment, the water is used for industrial and social goals in significant quantity, using all three Pleistocene layers. Manufacturing and industrial activities are the most significant water users, which require water in adequate quantity and quality. A cannery, meat, tobacco and leather processing, beverage, MÁV vehicle repair and thermal power plant are operating in this zone. From the lower Pleistocene layer more than 3,000,000 m^3 water is exploited, which is almost a quarter of the annual aquifer water exploitation of the Debrecen Waterworks Ltd. (13,047,000 m^3). The average surface elevation is 118 m. The deepest layer is filtered by 22 wells, out of which 15 operate continually. The depth of the deepest well is 210 m and the depth of the shallowest one is 158 m from surface. In the northern parts there is one layer (e.g. Debreceni Vízmű Ltd.), while in the case of eastern wells there are 3 layers (e.g. Globus Cannery Ltd.) and the exploited depth is between 122 m and 202 m. The upper levels are exploited by a large number of companies, so the vertical use of the zone is the largest here.

The 4th aquifer water exploitation zone (4th zone): In the eastern part of the city, two parallel wells were built, handled by the 4. VÜ (Exploitation Plan). It is exploited from the lower Pleistocene layer by 26 wells. The depth of the shallowest well is 172.5 m and the depth of the deepest one is 220.7 m. The vertical extension of the layers is 142-214 meters from the terrain and their number varies (from one to four). The thickness of this layer is 26 m in its western part. However, 8 km from there to the east, it is 47 meters. The average terrain surface is 121.4 m. The upper Pannonian layer is exploited in 273.1 m depth by one well. Filtration takes place in two layers at the depth of 235.2-264.1 m. There isn't additional exploitation in Zone 4, although at Vekeri Lake there are two wells for the water supply to the resting center. These exploit from the lower Pleistocene layer, but their effect is not significant due to the distance and the annual production of 2000 to 3000 m^3. In 1963, four water level monitoring wells were also established.

In the examined area there is an eroded fluvial-acrylic, with a typical clay terrain with quaternary formations settling in the upper Pannonian part. The main particle size composition characteristic is small particle size sand fractions[44].

Depending on the morphological conditions, the level of the first groundwater zone is located 1.5-4.6 m under the surface. The maximum groundwater fluctuation in the area is approximately 1.7 - 2.0 m. In deeper locations, the maximum groundwater level is expected in the zone of soil surface. Aquifer supply analyses showed that in case of near flat surface, the amount of precipitation infiltrating to an aquifer is from 140 mm to 180 mm per year. With the groundwater depth of between 1 and 4 meters it is expected to be at around 100-120 mm. Based on the transmission model layer geostatistical analyses, it can be concluded that the lowest aquifer layer is vulnerable in all four zones. Based on the layers of territorial sensitivity analysis, it can be concluded that the lower Pleistocene layers are particularly sensitive to the infiltrated pollutants as all zones in the studied area are in the no. 10. category, which is the most sensitive category[1]. The function of the applied GIS model is to evaluate these separate data layers and data content together and to provide a new type of information to the user, therefore, it has proved to be particularly suitable for the vulnerability study. The additional advantage of the GIS model is that it contains commonly available measureable parameters on the entire water basin. In the case of the Debrecen's water basin, these completed GIS model sensitivity analyses confirmed the results of the GIS simulation model (Figure II.26.).

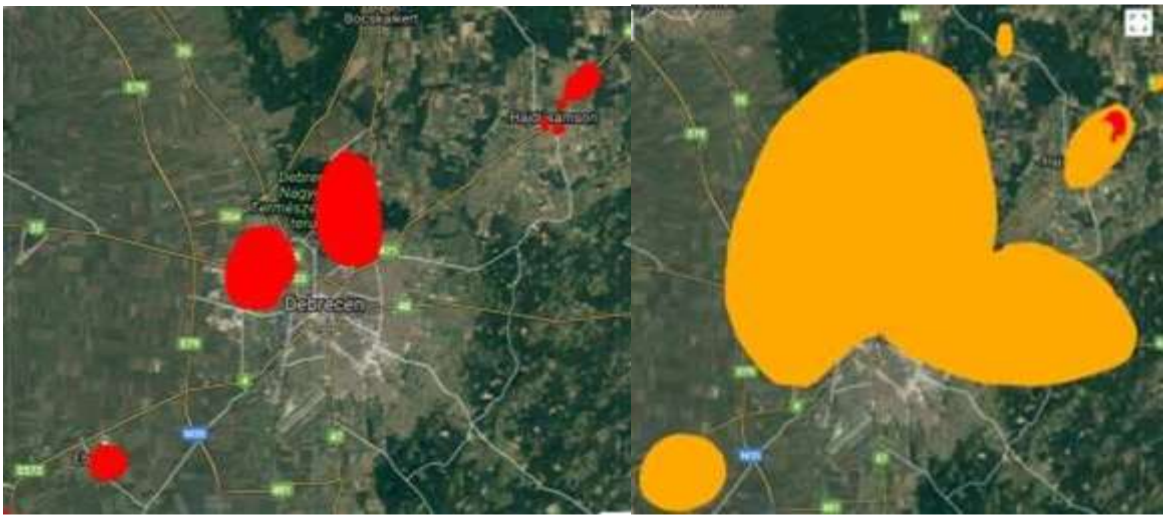


Figure II.26. 5 years travelling time water basin in the northern part of the Ebes and Hajsúsámson region, while in most parts of the town, the average travelling time is 75 years[45]

Water Safety Plan Applied in Debrecen

Hungarian Water Safety Plan (HWSP) and Water Safety Plan (WSP) of Debrecen treat the entire water network as a single system. However, four subdivisions are distinguished based on the following: the method of water exploitation, applied water treatment, quality of distribution network and consumer points. It is required to elaborate this method for all subparts: system description, hazards identification, risk assessment, action and control points, evaluation and monitoring measurements. The process of analyses, measured areas and applied documents are shown in the following Figure II.27.:

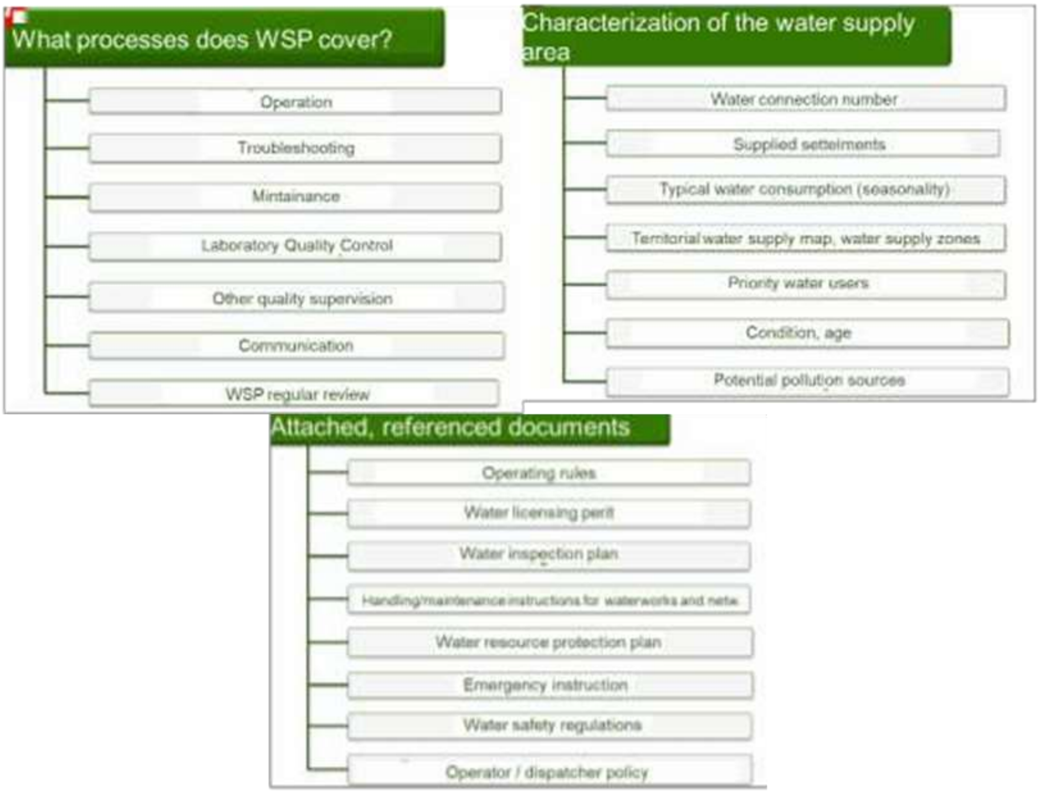


Figure II.27. The processes investigated, the test areas and the documents used for WSP (Source: DEVÍZ Rt.)

Hazards analyses method separates physical, chemical, biological, microbiological and radiological types evaluated on a 1-5 scale by frequency and severity indicators in 1 to 5 range. Both indicators (frequency and severity) describe together the vulnerability. Applied values are shown in the following tables (Table II.3., Table II.4.):

Table II.3. Applied scores of the water safety plan[46]

Probability of occurrence (frequency of occurrence of hazard)			**Consequence severity (probable effect of a hazard)**				
			Not signific.	**A bit signific**	**Moderate signific**	**Very signific**	**Catastrophe**
		Weight	**1**	**2**	**3**	**4**	**5**
Rare	**Every five years**	**1**	**1**	**2**	**3**	**4**	**5**
Low probability	**Yearly**	**2**	**2**	**4**	**6**	**8**	**10**
Medium probability	**Monthly**	**3**	**3**	**6**	**9**	**12**	**15**
High probability	**Weekly**	**4**	**4**	**&**	**12**	**16**	**20**
Almost always	**Daily**	**5**	**5**	**10**	**15**	**20**	**25**

Table II.4. Definitions of the effects [50]

Effect	Definition
Catastrophe	Lethal for large number of people
Very significant	Lethal for small number of people
Moderate significant	Lethal in special circumstances or unacceptable to a large amount of population or hazardous for large populations
Slightly significant	unacceptable to a small amount of population or hazardous for small populations
Not significant	No effect/ not detectable

Customers' and stakeholders' engagement are fundamental in order to achieve an understanding of mutual priorities and needs to develop WSP in the cities.

Thermal water

The geothermal gradient (indicating the increment of temperature (°C) per depth unit) is 5°C /100 m being about one and a half times higher than the worldwide average. This is partly due to the fact that in the Pannonian basin, where Hungary is situated, the earth-crust is thinner (only 24 to 26 km) than the worldwide average of 30 to 35 km. Moreover, the basin is filled up with well insulating clayey and sandy sediments. The measured values of thermal flux (i.e. the heat output coming from large depths) are high (90 mW/m^2 as an average) in comparison to the average of 60 mW/m^2 on the European continent. The mean temperature is approximately 10°C on the surface of the country.[47]
The thermal water is used mainly for balneology but in the recent years heating and hot water preparation was also preferred. Usually the temperature of the wells head is around 60-90 °C, so it can be used for heating various facilities or for different industrial or agricultural needs and processes (Figure II.28.). As the salt content of the Hungarian thermal waters is usually very high, the operation and maintenance of geothermal systems may be expensive.[48] Based on the Debrecen case study, it can be concluded that in case of a building, the energy need is variable throughout a year, but the highest values are registered in the winter period.

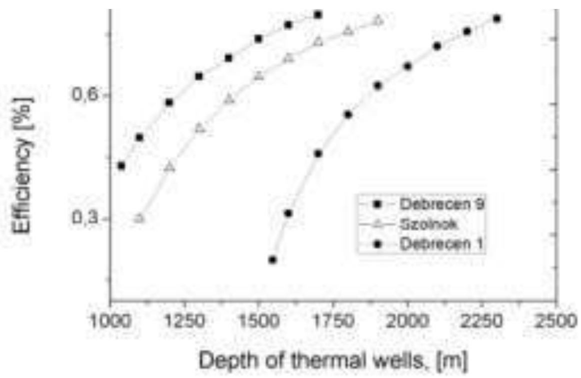


Figure II.28. Efficiency of absorption machines vs. depth of thermal wells[49]

The efficiency increases most rapidly for the Debrecen 1 geothermal well, the Debrecen 9 geothermal well provides higher temperatures and therefore, higher efficiency of thermochemical compressors for the same depth (Figure II.53.). The efficiency of utilization can be raised if the heat source is used during the entire year. This can be done if absorption machines are used for cooling with thermo-chemical compressors. The efficiency of absorption machines depends on the temperature of the heat source. There are two Spas in

Debrecen. Aquaticum Mediterranean – Thermal Bath is located in the Great Forest (Figure II.54.) and Kerekestelepi Spa in Debrecen. In both spas the temperature of thermal water pools is from 33.35 to 38 °C[50]. The high salt content of the treated thermal water effluent causes water quality problem in the Tócó creek.

Stormwater, excess water, flood, water storage

The water flow, water regime and water quality of the Tócó

The Tócó creek is the dominant surface water resource of Debrecen city. The watershed area of the Tócó creek (Figure II.29) is 173 km^2, the length of the watercourse is 25.940 m owned by: Water Directorate 0+000 –4+200 m; 24+500 – 25+940 m; the City of Debrecen 4+200 – 24+500 m. Important pressures affecting surface water bodies are identified in the RBMP. Important task is to solve the adequate water supply of the Tócó watercourse and to enhance water management related activities in local/urban and regional spatial planning and development in environmental, social and economic sense. As a part of the development concept, new blue spaces should be created in the urban environment improving the residents' quality of life. Plans targeting the environmental situation in the region include the creation of a 'green corridor' alongside the Tócó in Debrecen with water areas, forest belts reducing the dust pollution coming from the West while providing favourable conditions for the development of wellness and sports activities.

Upper city section of the Tócó creek from Route 35 to Kishegyesi Road (19+447 – 13+674 sections)

This is the former Kistócó Újgát to Buk-gát section with the Köntösgát in the middle of the section (today's Balmazújvárosi Road). In dry weather, the Tócó has no water supply at the urban section, over the sewage treatment works inlet (10 + 978) (Figure II.56.). There may also be inlets in the city water supply system during this period. Based on the data from the DEVÍZ Rt, of Debrecen, due to the activity of the Water Production Plant, the total annual volume of water leading into the Tócó is 59400 m^3/year. This quantity comes from repairs and renovation of wells, pool and electricity power line cleaning. During the regular network cleaning of the water network, 10,000 to 30,000 m^3 / year water is supplied to the Tócó.

Figure II.29. Dry course of the Tócó creek[51]

The first concentrated rainwater inlet in Józsa is the 184 l/s standard flow from the Józsa Center to the 22 + 450 section of the watercourse. The next significant inlet is the inlet of rainwater, from the Debrecen bypass section of the Route 4, into the 19 + 400 section of the Tócó. The standard inland excess water flow is 1.6 m^3/s. Oil and sand interceptors were built at PURECO inlet.

In addition to the current design and operation, the system is sensitive to water quality. Under any circumstances, pollution gets directly into the Tócó as a result of an accident or an emergency situation in the western part of the city. Relatively high quality precipitation cannot be deposited in this section, there is no water recharge or refreshment in dry conditions, so water cannot be managed.

Middle city section of the Tócó creek from Kishegyesi Road to purified sewage discharges (13+674 – 10+978 sections). There are both water quantity and water quality problems in the section below the Kishegyesi Road. The Kishegyesi Road urban drainage from the operating combined sewer system leads to a high volume of diluted sewage to the Tócó in case of precipitation with a certain intensity and duration.

The maximum and average discharge of urban drainage is not exactly specified. In each permit, the values given in calculations based on further sizing do not match. The "most authentic" values and the operation of the urban drainage are based on the investigations and analysis by János Ditrói, the chief of the sewerage industry from Debrecen Water Works Ltd.

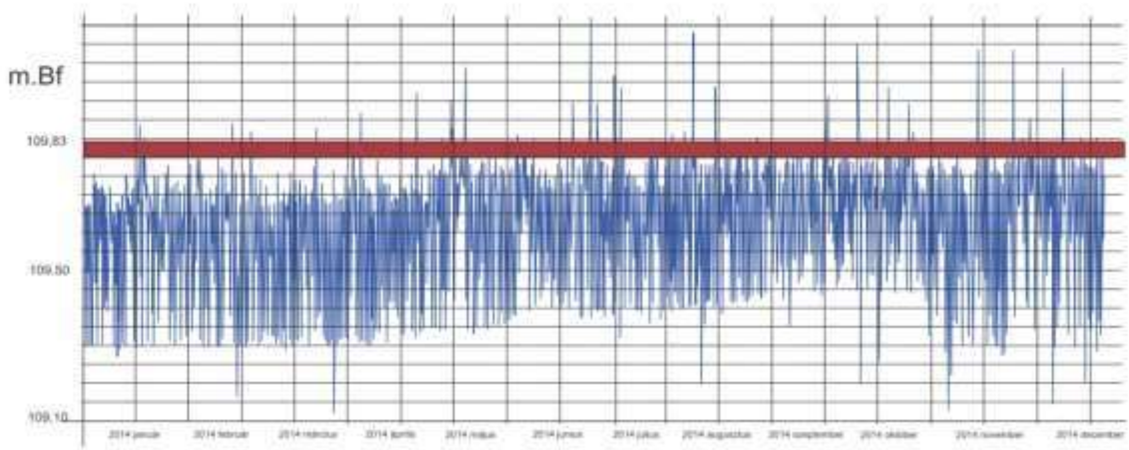


Figure II.30. The evolution of the measured water levels and the operation of the urban drainage of Kishegyesi Road in 2014.[51]

The 5-6 m^3/s corresponds to the hydraulic calculations of the MÉLYÉPTERV in historical data of the 90's, where the calculated value equals 5.5 m^3/s (Figure II.30.).

In rainy weather, in the cases where the urban drainage does not supply water to the Tócó, the operation features of canal are similar as described above. Apart from shorter sections, it is dry in a rain-free period.

The watercourse goes further south across the 4th highway and the Budapest-Záhony railway line, where the 11 + 720 section receives the occasional water from the Southern line stream. The operation of the Southern line stream is also based on DEVIZ Rt. report.

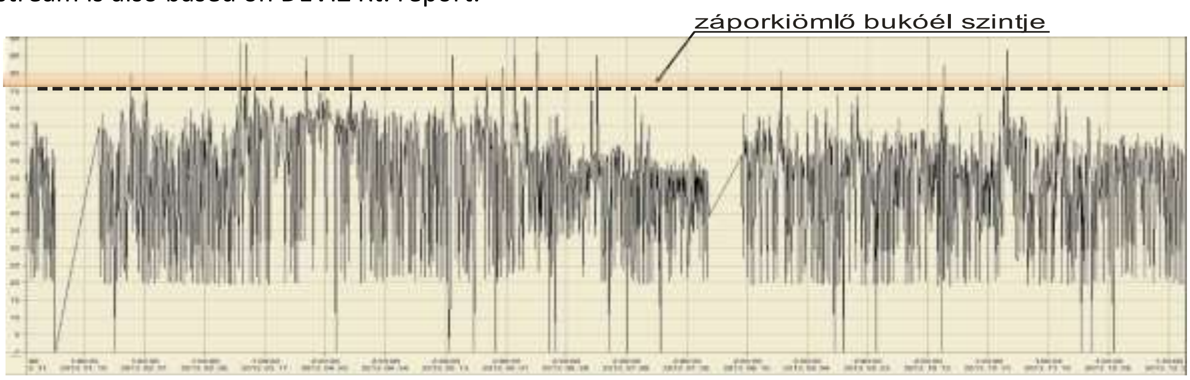


Figure II.31. The evolution of the measured water levels in the main basin and the operation of the Déli sor combined sewer overflow in 2013.[51]

South of the Déli sor street combined sewer overflow, approximately 750 m (10+978 section) away from the sewage treatment plant of the city, the point of inlet of purified sewage into the Tócó watercourse is situated. From this section to the recipient, the Tócó has a constant water discharge (Figure II.31). It means that the discharge and water quality of the dry season come from the purified sewage. In 2013, this average was 0.48 m^3 / s, in 2014 it was 0.43 m^3 / s water discharge, with average 53-58 mg / l KOIcr, 1-2 mg / l NH_4-N and 10 mg / l NO_3 qualitative values.

In the section, along with the water management deficiencies of the section over it, drain capacity shortages and quality problems also appear. The lack of capacity of the recipient is endangering the operation of the drainage system and sewage plant.

Lower city section of the Tócó creek, out of town section to the recipient (10+975 – 0+000): From the sewage plant inlet, the Tócó has a standard discharge of water, with a daily average of about 0.5 m^3 / s in dry weather. Passing along Debrecen's "waste belt area", it goes parallel with the Debrecen-Nagykereki railway line at a stage.

The precipitation from the city arrives to this section passing through the territory of the airport, or from the airport. The Tócó, and on its western side, runs parallel to the Mikepércs pond system from the former Lovász-zug reservoir, consisting of 13 built lakes. The Lovász-zug reservoir was recultivated in 2012 under a water license. Its original water surface was nearly 20 ha, its original reservoir volume was over 300.000 m^3. The total surface area of the Mikepércs pond system is 49.46 ha and its reservoir volume is 809.000 m^3 and the Tócó is merged with Kondoros in the 60 + 900 section of the Kösely, where the capacity of the received water is 9.5 m^3 / s. The environment of the two watercourses is one of the most endangered areas by floods in the area closer to the river, but both the Tócó and the Kösely have been repeatedly flooded in the last few years with persistent inland excess waters.

The role of the Tócó creek is not significant in Hortobágy-Berettyó surface water in current VGT (water basin management plan). However, such temporary water courses are of significant importance in urban water management system, although hopefully, the new VGT practice will also pay more attention to solve IUHM problems. By new revitalization process, a real fresh watercourse should be developed and can be applied to solve critical water scarcity (e.g. irrigation, industrial water).

The examined section of water deficiency in the sections above it, are no longer characterized by dry weather. Obviously, with the constant discharge of purified sewage, the utilization of its discharge is very limited. The limitation of the canal capacity of the basin, with the sections over it, is equally problematic. In some rainy periods, water drained from the city, from the airport, from agricultural land results increased backwater level in the canals. The lack of capacity and filling often causes flooding mainly in the vicinity of the estuary, especially when large water arrives at Kondoros, as the drainage capacity of the incoming Kösely watercourse, is only 9.5 m^3 / s. In case of high water level of the Tócó, it has an adverse and dangerous effect on the parallel railway structure.

The issues a conventional approach to storm water and excess water management is facing – balance in run off – Infiltration - Evapotranspiration

Preventive actions for hydrological adverse impacts are always more simple and cost effective compared to damage management actions.

Detention pond or retarding basin is a facility for temporary water storage to reduce the flood peaks. Detention ponds are usually constructed at natural depressions. The pond may be equipped with control gates and may be kept with a minimum storage to maintain aquatic life alive during low flow periods. The design of capacity is based on the runoff generated from the basin due to a storm. Sluices are designed to make control releases and spillway is provided to discharge the excess water as a prevention against the structure damage and inundation of the upstream in case of heavy storm.

Infiltration ponds are similar to detention ponds, but they are specifically provided to infiltrate the storm water routed there into the soil. Usually, no sluices for releasing water are provided. However, spillways and low level outlets for emergency operations are provided. The infiltration ponds are appropriate to places with pervious soils and deep water table. The disadvantage of these ponds is the possible odour problems, whereby they may become sites for mosquitoes in hot seasons.

Figure II.32. The grassed 2nd train line as a good example to improve infiltration (Photo:Tamás)

Wetlands are shallow ponds with growing aquatic plants constructed across streams at depressions for the removal of pollutants in water. They provide a detention time for the water to settle pollutants/sediments and for aquatic plants to uptake pollutants. A low velocity has to be maintained through wetland, whereby wetlands are effective at removing phosphorus, nitrogen compounds, metals and organic compounds, and sediments in water. However, the required surface area of the wetland is large, to treat high discharges of storm water runoff.

Infiltration trenches are provided to enhance the infiltration of storm water into the ground. A trench is excavated in the ground and filled with crushed stone. The top of the trench is covered with fabric to avoid sediments and debris entering the trench. Trenches trap storm water and facilitate infiltration of water into the soil and recharging the groundwater. Therefore, the runoff volume is reduced. It is important to provide suitable sediment traps or settling basins at the upstream of the trenches, so that sediment is removed from the water. Efficiency of an infiltration trench depends on the infiltration rate.

Figure II.33. These big containers cannot treat the runoff problems (Photo:Tamas)

These are the stripes of grassed soil surfaces introduced between the urban impervious surfaces and the storm drains to slow down and partially infiltrate runoff. This is possible when the storm water discharge can be spilled on to the strip and spread across the width of the grass strip. The velocity of the flow over the grass is small and part of the flow is infiltrated and the suspended particles in the flow are trapped within the grass strip. Grass strip should be of very mild slope and grass should be dense enough to avoid erosion and forming channels. However, the effect of grass filter strips in reducing flood peak is low. Grass swales perform similarly to grass filter strips when the slopes are small, less than 5 %.

Figure II.34. Different gardening methods to save irrigation water on walking street (Photo:Tamas)

Pervious pavements are permeable surfaces, where the runoff can pass and infiltrate into the ground. Pervious pavements facilitate peak flow reduction, ground recharge and pollution filtering. There are three types of pervious pavements: a) porous asphalt pavements b) porous concrete pavements c) garden blocks. The main difference to conventional pavement is that there is no fine aggregate in the mixture used in the construction. Porous layer is constructed on a granular base laid on the existing soil surface. These pavements not only reduce the flood peak but also abate the pollutants in the surface runoff.

Some pervious pavements require frequent maintenance and investment cost is higher. In Debrecen, AKSD Ltd. is responsible for public green surfaces as well as water management. AKSD Ltd. Is supposed to manage 3.2 million m^2 green surface handled by the local government. These areas are categorized such as downtown frequented areas, roadside greenbelt areas, larger housing estates which determine sustaining tasks in different issues. 80-86 % of the urban green surface is grass, lawn, park and 5,000 m^2 surface is covered with flowers. Pruning of trees, shrubs and vegetation is also managed by AKSD Ltd.

Linkages between storm and excess water – drought management, storage and recreation - CIVAQUA project

The Eastern Main Canal, which plays a decisive role in the water management of Debrecen's wider area, ~~it~~ was built in the middle of the century. The main target was to build a canal to provide irrigation. Since the mid-1960s, the irrigation clusters of Nagyhegyes, Hajdúszovát and Hajdúnánás were built, which enabled the irrigation of about 6 thousand hectares. Between 1976 and 1981, with a 7 km-pipeline built in the first phase of the Hajdúhátság Multipurpose Water System (HTVR), the water of the canal was made available for irrigation in other areas . HTVR would have initially allowed 30,000 hectares of irrigation, but the second and the third schedule were not built due to insufficient funds. The construction of the system was necessary, because the canal that runs along the edge of the Hortobágy cannot irrigate the higher Hajdúhát by gravity. In addition to satisfying the irrigation water demand, the waters of the Eastern Main Canal are used to partially supply drinking water to Debrecen, ensuring the region's other economic water demand, and to ensure the welfare functions.

New water source to Látókép water reservoir is the key to increase irrigation possibilities on good quality soils of the western part of the city.[52]

The blue networks of Debrecen, consisting of the Tócó and the Kondoros creeks, Kati, Vekeri, Fancsika lakes and other artificial bodies of water (Békás lake) in the city, can complete green networks. The green network potentially connects the green areas as a ring around the urban area, and the blue network aims at improving the ecological conditions of the rivers and associated wetlands. The key element of these methods to optimise water quality and quantity in urban watershed is time. The critical drought and wet period of urban hydrology can be solved with more alternative water recycling or/and locally stored water resources. Till now this network is rather fragmented, not really a flow and we have to improve the resilience of urban water ecosystem.

The CIVAQUA project includes ensuring the possibility of irrigation of the area of 30,000 ha, the partial water supply to lakes built near Debrecen, the creation of recreational areas, the degradation of the Great Forest and other green areas, the improvement of their water management features, the improvement of Debrecen microclimate, the provision of water supply to the Tócó and the Kondoros Canals, the storage of surface water resources, their increased utilization, onthe improvement of the water management features in the Erdőspuszta region, the detention of inland waters in reservoirs, thus reduction of inland peaks and the development of complex water management.

The main objectives of CIVAQUA project:

- To improve Debrecen Great Forest water management status
- To provide water supply of Erdőspuszta wellbeing systems of lakes
- To provide irrigation development opportunities
- To improve sport and recreation opportunities Expected water demand based on project:

- The Tócó water storage and ecological water demand: 70 ha x 0.8 m = 560,000 m^3 + water outlet ~ 640,000 m^3 = 1.2 million m^3/year
- Water withdrawal of Nagyerdő 2 million m^3
- Water withdrawal of Erdőspuszta lakes: 213 ha x 0,8 m = 1.7 million m^3
- Water withdrawal of irrigation 22,550 ha x 150 mm = 33.8 million m^3/year
- Total water demand: kb. 39-40 million m^3/year

Waste water – water recycling, alternative water source

The conventional approach to waste water management – waste water treatment

The facility for wastewater drainage from Debrecen urban areas is generally provided in two ways: a separate sewer system for wastewater from storm sewers or as a combined sewer system. In separate sewer systems, wastewater is collected and treated separately. Afterwards, treated water is sometimes discharged to surface water bodies. In combined sewer systems, wastewater and storm water are drained together and released after treatment to the Tócó creek. In many cases the amount of precipitation has moderate, but significant effect on the amount of waste water (Figure II.35.). Even though an overflow under extreme conditions is directed to main storm water drains bypassing the treatment facilities.

In case of a separate sewerage network system, generated waste water and rainwater are collected and transferred to waste water treatment plant by sewerage network in two different ways. Benefits of the system: economical efficient channel size can be applied, - waste water treatment plant has equable operation, - the runoff is more favorable due to the higher slope, - rain water can be an alternative water source. Disadvantages of the system: - two networks are required (one for rainwater, one for waste water), - the network has a large space requirement causing many difficulties during placement, - the cost is higher.

The 85 % of households are connected to the sewerage network. As the agglomeration area of the city is sparsely populated and scattered over large areas, sewage collection is carried out in some cases in economically efficient way by sewer replacement structures. The waste water is then treated in the central

waste water treatment plant (WWTP). Treated waste water quantity is decreasing. The main reasons are decreasing water use, spreading of water saving solutions.
However, the total amount of contaminants in generated waste water has not decreased yet. So pollutant concentration is higher, which requires more expensive cleaning technologies. Based on the dataset of the DEVIZ Rt. (responsible for waste water treatment plant in Debrecen), the amount of treated water is constantly decreasing, whereas the rate of the produced sewage sludge is increasing. (Figure II.77.). The changes reflect that the city produces less amount of, but more concentrated and polluted waste water than before.

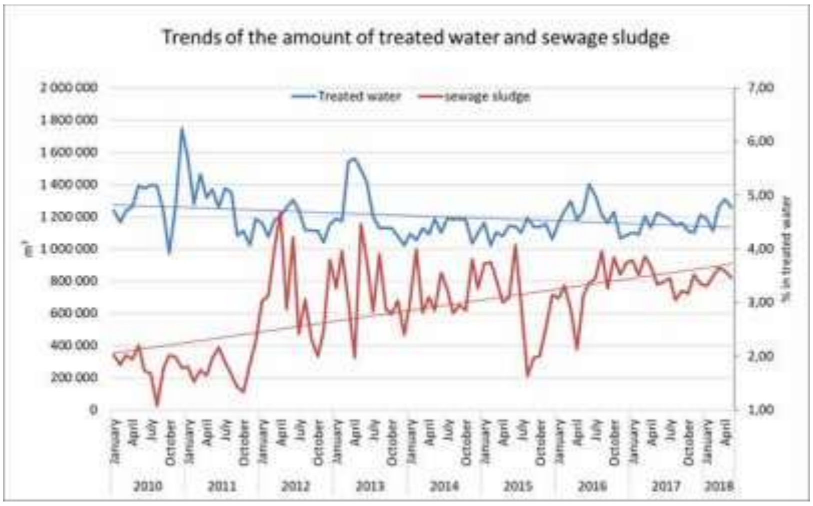


Figure II.35. Trends of produced treated water and sewage sludge based on the data of Debreceni Vízmű Zrt.

More concentrated sewage also causes problems in the sewer network because of the sedimentation risk. The anaerobic processes in the sedimentation can be associated with odour impact during the summer time. In WWT plants with larger capacity, the cleaning of 1m^3 wastewater unit cost is lower because of higher constant costs of WWTP (Figure II.78.). Cleaning capacities must be built and operated, even if there are quantitative and qualitative fluctuations in the cleaning cycle of WWTP over a 15-25-year-life cycle. Increasing efficiency was the goal of increasing the waste water treatment capacity in Debrecen as well.
Based on the data in the Table II.5. below, the wastewater production in Debrecen is below the national average and it shows water safety and environmentally friendly water management.

Table II.5. Generated waste water data on the national level and in Debrecen[53]

Content in m^3	National average	Data of Debreceni Vízmű Ltd. in 2015	Data of Debreceni Vízmű Ltd., regional settlements in 2015
Average annual generated waste water per household	86.05	68.12	76.95
Average monthly generated waste water per household	7.17	5.68	6.41
Average daily generated waste water per household	0.24	0.19	0.21

Remarks: 60 g/d COD or 120 l/D equal to 1 PE

From chemical aspect, the chemical hazards in wastewater can include a wide range of substances that naturally occur or of those of anthropogenic origin. They include industrial chemicals, chemicals used in households, chemicals excreted by people, and chemicals used or formed within wastewater and drinking water treatment processes.

Content of generated waste water shows seasonal differences, depending on the operation of two main industrial plants. TEVA Pharmaceutical Ltd. could generate waste water affected by antibiotics, while cannery factory generates waste water with higher organic content and N content during sweet corn production process period. In recent years, sewage treatment plant is immediately informed about any kind of environmental hazard situations to change the daily operation of its modern biological treatment (period of residence time in an anoxic space, aeration, etc.)., thus environmental damage can be prevented. In the near future, WWTP will also face a big challenge to remove organic micro-pollutants (metabolites and hormone-depleting substances).

Effect of applied sewage treatment technology on water quality

40,000-45,000 m^3/day waste water is generated every day in the city and surrounding settlements, and is treated by the WWTP. Waste water stays in the WWTP for more than a day. During this day, waste water is treated by a three-stage technology called primary, secondary and tertiary treatment. This cleaning process produces treated waste water, whereby its quality is better than required by the relevant environmental standards. This treated water discharges into the Tócó creek near Debrecen. Sewage sludge coming from the sewage treatment is utilized by modern technology.

Mechanical treatment of waste water: raw waste water arrives at WWTP by gravity flow, where raw mechanical pollutants (floating contaminants, solid objects) are filtered by two 15 mm bar screens (Figure II.79.). The screens remove mechanical objects, press and collect them in dumpsters and dispose them in landfills. Two bar screens and the collector have the capacity of 6000 m^3/h, filter wastes with particle size more than 3 mm, filter and help to collect filtered waste. After filtering, an online monitoring station measures the following parameters: COD value, pH, NH_4-N, PO_4-P, suspended matter, temperature.

Waste water flows by gravity into two compartments of the aerated sand filters deployed in parallel, where sand and fat are sedimented. Removed sandy sludge is placed into two parallel established grit washers, the clean grit is removed through a classifying screw, statically dewatered and discharged into a container. While removed fat is placed into 1-1 storage tank with the size of 3 m^3.

The temporary storage capacity for urban runoff (storm water) is 15,000 m^3, which gives a possibility to store rainwater when the amount of input waste water is higher than cleaning capacity of the WWTP. Typical feature of climate change, mainly in the summertime, are heavy rainfalls occurring more frequently, which can exceed storage capacity. After the grit removal, raw waste water gets to two Dorr sedimentation tanks with diameter of 40 meters. Separation of sewage sludge and water phase is managed here. The waste water is transferred in pipelines of the treatment plant by gravity and pumping.

Biological treatment technology: Biological nutrient removal is provided by 1-1 anaerobic tanks with 500 m^3 capacity called anaerobic I. (pre-sector) and II. 1-1 anaerobic pool with 1000 m^3 capacity (Figure II.36.). Anaerobic polls are activated sludge reactors with continuous mixing in a form like horse racing track. Task of pre-sector is to reduce nitrate content of the recirculating sludge. Pool II. increases the efficiency of phosphorous removal of waste water.

Figure II.36. Biological waste water treatment of Debrecen WWTP (Photo: Tamas)

After an anaerobic treatment, the sewage water flows by gravitation into so called anoxic pools with the capacity of 2,500 m^3 playing an important role in nitrogen removal process. Anoxic mixers are continually mixed in activated sludge reactors with horse racing track like shape, which is the place of de-nitrification in waste water treatment plants. However, there is a possibility for simultaneous operation.

From the anoxic spaces, after de-nitrification, the active sludge suspension flows into the aeration pool with 4000 m^3 volume kept under continuous aerobic conditions. Each aeration pool contains 9696 numbers of Flyght Sanitaire membrane diffusers. This is an advancement in aeration technology, delivering high oxygen transfer, while minimizing system headloss, for an overall superior aeration performance compared to other high efficiency aeration devices. Sewage treatment plant uses centrifugal pumps to transfer the nitrified mixed liquor from the aeration zone to the anoxic zone (tanks) for denitrification. These pumps are often referred to as Internal Mixed Liquor Recycle (IMLR) pumps. Biological cleaning process is called aerob oxidation, which is carried out in aeration tanks. Nitrification itself is a two-step aerobic process. Organic materials are reduced through the biological oxidation. Within this process, ammonia (NH_4) is oxidized to nitrite (NO_2) as a result of nitrification, and then nitrite is oxidized to nitrate (NO_3). In aeration tanks these processes require 1.8-2.0 g/m^3 dissolved oxygen concentration conditions. The air supply is provided by 7 Aerzener and by 4 HV turbo blowers.

The active sludge is extracted from the purified sewage in 4 Dorr type sedimentation tanks with 40 m diameter and 2 Dorr sedimentation tank with 55 m diameter (Figure II.37.). A part of the sedimented material, the sludge itself, is returned to the head of the aeration system to inoculate the new wastewater entering the aeration tanks. This fraction of the sludge is called return activated sludge. The surplus activated sludge is transferred to the sludge treatment zone by flow pumps.

Figure II.37. Solar energy panels (left upper part), sedimentation tanks (center part) sludge composting plant (right upper part) (Photo: Tamas)

Monitoring of the quantity and quality of purified water is carried out in measuring well. Treated waste water parameters in the measuring well are continuously monitored by online measuring station consisting of several measuring probes. These are the following: Chemical Oxygen Demand (COD), Temperature, NH_4-N, pH, PO_4^- P, Floating Agent, NO_3-N. Due to an unfavorable composition of incoming sewage, it could be necessary to add excess carbon sources (methanol) to mechanically purified sewage. Iron (III) sulphate is added when biological phosphorus removal cannot provide the 5 mg / l threshold for phosphorus in the treated waste water.

The capacity of pre-treatment and waste water storage tanks is 300 m^3/day, and is suitable for waste water storage coming from domestic scale collection systems collected by vacuum trucks. The task is to prepare input waste water for treatment process with communal waste water. After decanting, the waste water is transferred to grids and to the bar screen. The task is to filter, remove and dewater solids and large objects from the wastewater. The task of the sand filter is to remove the sand content from the waste water, while pre-aeration tank is used to prevent harmful sedimentation.

High-capacity aerobic WWTP produces a large amount of sewage sludge, so it is time to manage it efficiently in the future.

Sewage sludge treatment: With the development of WWTP, higher amount of sewage sludge is generated thus, energy utilization of the sludge came into priority, instead of agricultural utilization. In case of agricultural utilization, the demand was less than continuously generated sewage sludge. In addition, there are many strict rules and regulations for soil protection. Due to strict food safety regulations and rules, farmers have started to protect their products from potential risks of sludge. At the same time, sludge after digestion is composted and improved a new product at the compost site of AKSD Ltd. by aerobic composting. Biogas production: In case of biogas production, dry matter concentration must be raised by dewatering method. Dry material content of sludge is raised within the sludge treatment technology by compression centrifuges, providing 4-5 % dry material content of sludge. The compressed sludge is placed in 50 m^{-3}capacity homogenizer. Intense mixing is ensured in the homogenization tank, and then the homogenized sludge transferred into digesters.

Sludge digesters are subjected to anaerobic fermentation of the pre-condensed sludge in a mesophilic temperature range (+ 35 °C) to stabilize the sludge, to improve its dewatering and to recover the maximum biogas amount. The capacity of the three fermentation towers is 2*4,500 + 6,000 = 15,000 m^3 (Figure II.38.). Within a Q_d = 400-600m^3 / d daily input, the hydraulic retention time (HRT) is approx. 19-25 days, depending on which digestion towers are in operation at the same time.

Figure II.38. Sewage sludge digestion tower in Debrecen WWTP (photo by DEVIZ)

The stabilized sludge flows from digestion towers to 2 gasification infrastructure, which is continuously mixed to homogenize the sludge. After adding polyelectrolyte to the sludge of 400-600 m^3, stabilized sludge with 2-3 % dry matter content is transferred to the dewatering centrifuges every day.
The by-product of anaerobic fermentation is biogas, which mainly contains methane (CH_4) 58-62 %, carbon dioxide and other gases under 1 %. An average of 4000-5500 Nm^3 of biogas per day is generated from the decomposed organic material. The fuel value of the biogas is 23.2 MJ / Nm^3. Biogas is stored until the use in a 1,000 m^3 gas bag and in a 1,000 m^3 double membrane gas storage tank. In operation, biogas can be used in gas furnace or in gas engine. Digestive tank and sludge are heated by heat exchanger. Gas boiler should provide heat for digestion process. 2 THERMOPRESS built in:

- Boiler 1 output: 550 kW
- Boiler 2 output: 300 kW.

Biogas utilization technology by gas engines
During anaerobic fermentation, biogas is generated with 40-55 % methane content and is utilized by gas boilers. However, utilization of biogas in gas engines is more efficient:

- produces electricity
- generates utilizable heat energy.

Generated electricity is used in a water treatment plant and heat energy is utilized to heat up the sludge. Thermal energy utilization is almost exclusively based on biogas during the summer months, while the average natural gas consumption in the winter months is just around 20 % of the total gas utilized (Figure II.39.).

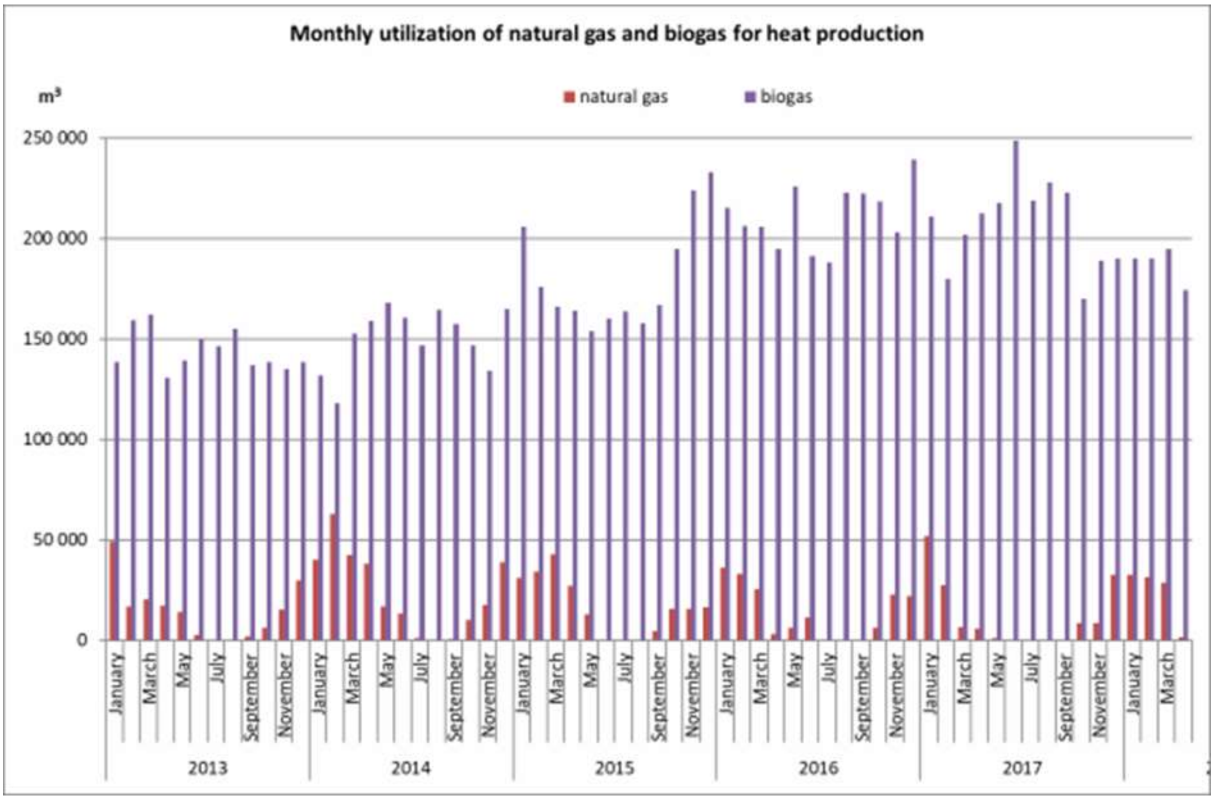


Figure II.39. Monthly utilization of natural gas and biogas for heat production of waste water treatment plant in Debrecen (Source: DEVÍZ Rt.)

Utilization of generated biogas is carried out by 2 JES 208, 1 JES 316 gas engine and JM 312 gas engine. Gas engines have the following technical parameters (Table II.6.):

Table II.6. Generated energy based on the three engines

Type	Electrical Power (KW)	Heat Production (KW)	Biogas consumption (Nm^3/h)	Natural gas consumption (Nm^3/h)
JES 208	253	404	120	77
JES 316	659	997	314	
JMS 312	625	700	260	

Because of the protection and within the life time of gas engines, the H_2S out of the biogas must be removed or reduced. Therefore, a desulphurisation system is built in the biogas network which provides the reduction of Sulphur content of biogas. More than 250 ppm S content could damage the gas engines and cut down their lifetime period. On one hand, biogas utilization generates electricity by the means of gas engines, on the other hand, it ensures heat energy for waste water treatment plant. Gas engines generate electricity output (2*253+659+625 kW) utilizable in electricity network for waste water treatment plant at the same time. The electric energy produced on the gas engines does not cover the total electricity demand of the waste water treatment plant, so biogas production can cover 75 % of the plant's electrical supply, 25 % of the total electrical energy has to be consumed (Figure II.40.).

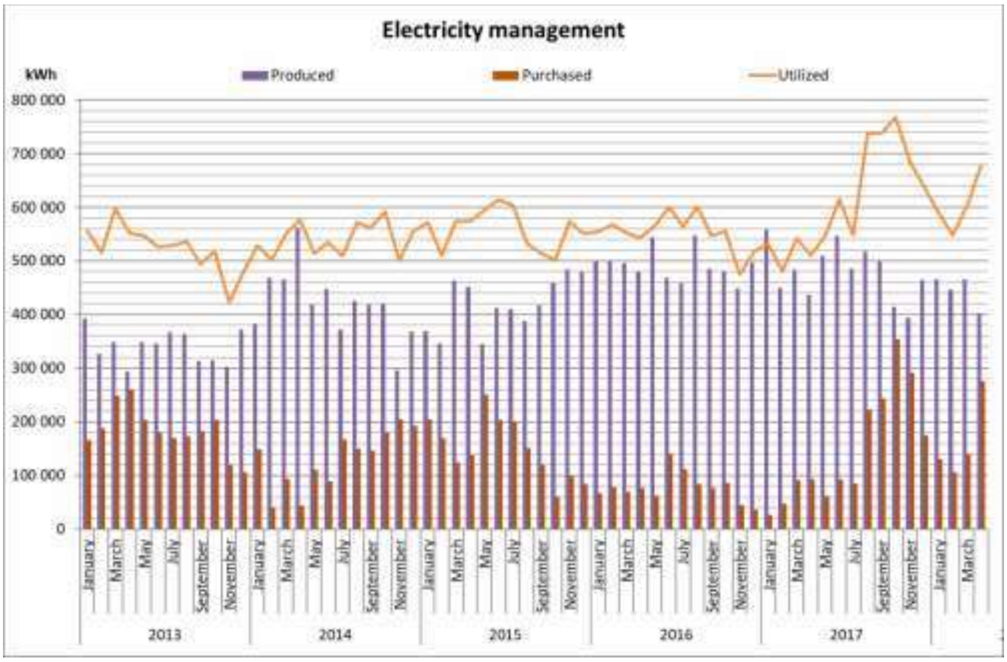


Figure II.40. The utilized electricity of the Waste water treatment plant in Debrecen (Source: DEVIZ Rt)

Residual heat generated by cooling engines, lubricating system and intermediate refrigerator, is suitable for heating the recirculated water in a heat exchanger. During summertime, the residual heat generated by sewage sludge technology, is transferred to the heat center of Debreceni Hőszolgáltató Zrt. for hot water supply of house estates.

It can be concluded that sewage treatment has a key role in water quality protection. However, it must be emphasised that the process starts with prevention and not with 'end of pipe' technology. So, the following challenges must be met in the future:

- WWTP should be prepared for variable hydrological and pollution loads due to climate change
- Content of waste water is permanently changing, depending on public habits and industrial participants.
- Waste water treatment technology has to be well prepared for new sources of pollution (organic micropollution).
- In case of warmer wastewaters, dissolved oxygen content decreases, hydrogen production is increased, higher aeration is necessary.
- Manage the improvement of salt content.
- Implementation of the phosphorus content (struvite) utilization.

Dry material content of biogas outlet is raised to 23 % by dewatering centrifuges. Dewatered sludge is collected in 6.5 m^3 containers, than it is transported to the composting plant. Annual amount of the dewatered sludge utilized for composting is 30,000-35,000 m^3. The sewage sludge is placed in huge prisms and mixed with chopped plant residues – grass, pruned branches and buds – and cellulose degrading bacteria communities are added and degradation process starts. Compost is created after a two–month-period, when the compost is applicable in arable land or horticulture (except fresh vegetation).

Waste water management and urban agriculture utilizing grey water and treated water

In the western part of Debrecen, remarkably fertile soils are under agricultural use, where regular water scarcity is a barrier in the development activity. So, properly cleaned waste water could be supplied to these areas. In this region, the water scarcity is at around 200-250 mm/year and only 2 % of agricultural land is irrigated in Hungary. In a 10 years' period 2-3 years are affected with drought, while 2-3 years of excess water (frequently in the same year).

Consequently, 6-8 years of irrigation would be necessary in a 10 years' period. In addition, in 3-4 years, the irrigation would bring extra profit. Water charges (water cost) are less than 5 %, which is relatively cheap, in comparison to investment and operation costs (mainly electricity). However, it is expensive due to its long-term financial return. Total salt content of thermal water is more than 1500 mg/l with salinity impact, so it is not suitable for irrigation. Tourism should generate the cost of cleaning the thermal water. The quantity of water will be transported to the area in the framework of CIVAQUA program, which will improve the water quality, also through its dilution effect.

In case of calculation with 50,000 m^3 properly cleaned waste water within 6 months of irrigation period, 9 million m^3 treated water could be utilized for irrigation and thus, could provide the irrigation of 9,000 ha agricultural land calculating with 1000 m^3/ha (100 mm/ha) utilization intensity. This is 10 % of total irrigated area of Hungary. Additional rise of up to 15-17 % could be achieved by storage capacity investments. However, these water storage capacities could fulfil recreational and fishing purposes. Currently available and currently missing irrigation water could contribute to a more intense and more profitable vegetable and fruit farming in parallel with higher employment rate. In addition to water quality problems of irrigation, lack of capital in agriculture, fragmentation of fields, lack of professional human resources are the barriers of irrigation development. To achieve these goals, water use reform, development and reuse are required in an integrated hydrological approach.

3. Case study for Oradea city

Introduction of the city of Oradea

Oradea (Figure III.1.), currently the capital city of Bihor County, is one of the important economic, social and cultural centers of north-western Romania. Oradea is located on the banks of the Crișul Repede River near the eastern Hungarian border in the north-western part of Romania. This region is also called Northern Transylvania. Oradea played an important industrial role in its region on the turn of the 19th century. The city is today an important center of economic, social and cultural life in the western part of Romania and it is also the core city of its region. Nevertheless, the number of inhabitants has slightly decreased in recent years and currently stands at around 200,000. The core city area is 11,598 ha, and larger urban zone area 753,25 km^2[54]. The population was 196,367 inhabitants in 2012 in the core city and 210,851 inhabitants in larger urban zone. Public recreational green space per capita is 4.46 m² for inhabitants in the core city (2006). The per capita green space is 25 m² (2012) in the city, which is somewhat lower than the EU average, but far more than the Romanian average, that is why the city won the title of ”Green Capital of Romania” in 2011.

Figure III.1. The crest of Oradea

Urban climate

Biogeographically, Oradea belongs to the Pannonian region. The climate is a transitional temperate continental type with the Mediterranean influence. The annual mean temperature in the Oradea area is 10.2 °C. The absolute maximum temperature recorded being +39.4 °C. (August, 1952), while the minimum absolute temperature achieved -30.4 °C (December, 1961). The climate is driven by winds from the West and is temperate-continental, with an average annual temperature of +10.40 °C. July average temperature does not exceed 21 °C, while in January, there is an average of -1.4 °C. Rainfall is closely related to humidity and cloudiness. Thus, in plain sites of Oradea the average annual rainfall is between 500-700 mm, in hills from 700 to 1000 mm. The wettest period is from August to October (82.4 mm) and the driest in March-April (13-32 mm)[55]. The role of the heat island is also significant (Figure III.2.)

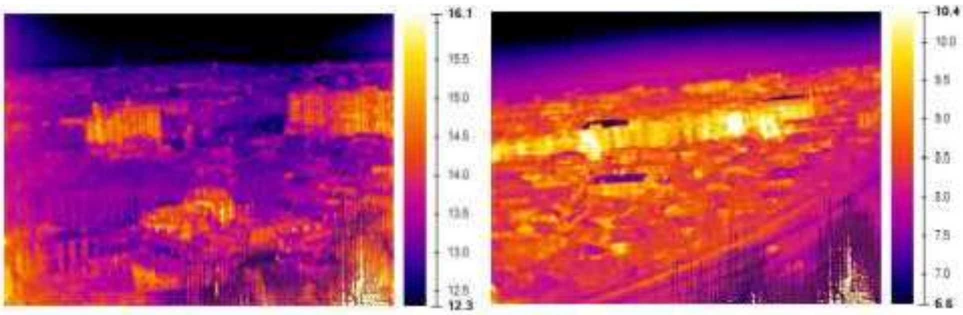


Figure III.2. Thermal image heat island, downtown Oradea City in winter (Photo: Nagy)

The meteorological data and products are collected from sensors and sent to the Regional Weather Forecasting Services and the National Weather Forecasting Center to be validated, and process them. In the National Meteorological Administration of Romania, there is already a reliable infrastructure for the

operational management and dissemination of the geospatial meteorological data and products within the framework of the National Integrated Meteorological System (SIMIN)[56]. SIMIN integrates five WSR-98D S-band radars, and one of them was installed in Oradea, whereby it can cover large area of the Tisza watershed.
The WSR-98D S band Weather Radar System can generate products for flash flood.
Rainfall Accumulation products generated by the Nexrad Precipitation algorithm. (One Hour, Three Hours and other useful products: composite reflectivity with rectangular grid (2x2, 4x4 km; Storm Tracking Information; Storm Structure Mezo cyclone detection; Hail Index).
TBSS special radars signature is an important warning tool in the supercell of storm (severe hail and tornado), but correct validation also cannot be ignored.[57]
The ALADIN project (1991) for the development of the ALADIN model, especially designed for meso-scale phenomena simulation and input for hydrological models within the DESWAT project as well specialized forecast for different customers.
New numerical forecasting models COSMO coupled with the pollution dispersion models (IMPUF)[58]. The study related to torrential rains from Oradea shows that the highest frequencies of heavy rains are with the average intensity between 0.32 and 0.4 mm/min (19.2-24 mm/hour) and belong to the 50.2 – 79.5 min. class period by Wussow.[59]
Radars provide good opportunity to measure high energy hail and tornado storms. The maximum number of storms recorded in one day was 1502 on July 22, 2008 with duration 22 minutes. The highest activity was recorded between 1 and 7 p. m. (55 % of the total), whereby 4 p. m. was the peak.[60]

Urban hydrology

The main rivers cross the Criș Plain in bulk from the East to the West, down the mountain area, mainly the Western Carpathians. Namely the Barcău, the Crișul Repede, the Crişul Negru, the Crişul Alb. In network towards tributaries, local rivers are much smaller but permanent flow. The lacustrine units fall into the category of limited scope. Among the best represented lacustrine, stand ponds, located nearby the channels of the Criș. Ground water is found in sand and gravel stationary in the meadows, dejection cones, terraces and even blades of the two steps of the silt plain. Unlike the ground, the deep waters are stationed in Mesozoic sedimentary formations, Miocene and Quaternary permeability is generally appropriate and of significant thickness. Existing major aquifer systems in the basement area are stationed in the corresponding deposits Holocene, Pleistocene – Pliocene upper Lower Pontian, Lower Cretaceous and Triassic, the last three aquifers have water systems hyperthermia.
The relief to the Western Hills area, a type of subbasement Carpathian and Pannonian was covered by sedimentary deposits of Badenian, Sarmatian, Pannonian and Quaternary ages, hydrographically always shifted to the West, against the withdrawal shoreline of Lake Pannon, geographic ultimate unit in western Romania, respectively.
The Criș Plain is the central component of the western rivers of the country focusing on the Barcău and the Criș rivers, with altitudes ranging from 90-180 m, dominating those below 140 m. It presents the most branches, penetrating deep in the hills, especially on the Barcău, the Crişul Negru, the Crişul Alb and on the Cigher. This important unit is formed with the east-western profile, in two steps relief well highlighted, or one high and one low, respectively.
High level, with elevations of 100-170 m consists, in a part from the Western Hills, from a series of slops.
Low level, overall with altitudes below 100 m consists of plain ramble, low tab plains and plains on drained swamps.
The Criș Plain regionalization Condition of the Plain Quaternary of the Criș evolution contributed to the genesis of two main orographic stages, positioned from the East to the West as follows: one high, the aprons, towards hills and other low alluvial to the West, in the first stage bringing the literature into question, the presence of

hilly plains and another deposits tabulated.
High plains, except for Carei-Valea lui Mihai Plain, are located towards the hills, then standing out the plains Pirului (from Tășnad to Târgșor), Biharia (between Barcău and Crișul Repede), Miersigului (Crișul Repede-Crișul Negru) and Susagului (Crișul Negru-Crisul Alb). Low plains have much wider extension (about 65 %) than high, they are developing from the North to the South, from Corridor Ier and Plain Santaului up to the Crișul Alb and Teuzului area. Low plains can be highlighted by the following territorial components: Corridor Ier, Plain Borș, Plain Salonta, Plain Crișul Negru, Plain Teuz, Plain Crisul Alb.[61]
Oradea city is nestled among hills that divide and unify the Crișana Plains and the hill-like limits of the Apuseni Mountains in a harmonious way. Located on the Crișul Repede River, which divides the city into almost equal halves. Located about 10 km from Borș – the highest border point on the western border – Oradea covers an area of 11,556 ha. The city lies at an altitude of 126 m above the sea level, at the mouth of the Crișul Repede valley towards the low plain area, in the contact zone between extensions of the Apuseni Mountains and the extended Banato-Crișan Plane. It is a transitional area, from hilly terrain (The Western Hills, The Oradea Hills and The Gepiş Hills) to the Pannonian plain.[62]

Urban structure – urbanization

Oradea is a middle-sized city in the northwest of Romania. The spatial planning system of the city is organized to different levels: the national level provides the legislation background; the county level has a right to provide an opinion on land use planning of the city based on the Spatial Plan of the County and also provides guidelines for spatial planning in general. The metropolitan level does not have an authority concerning the spatial planning, it rather provides a loose framework for economic development and large scale infrastructure development.[63]
After 1989 the industrial life of Oradea experienced multiple changes, the most significant ones being related to the closure of large factories and plants and the appearance of many private companies with a wide field of production activities (Figure III.3.).

Figure III.3. At the edge of the city, red mud cassettes of abandoned industrial sites where remediation is very costly and time consuming task (Photo: Google Earth)

In Romania there are four levels of administration with urban spatial planning competencies: national, county, metropolitan and city level. The metropolitan level, called Zona Metropolitană Oradea (ZMO) consists of the city of Oradea and a voluntary group of 11 settlements in its region. The ZMO was established in 2005 to promote its development potential by integrating various local approaches in a broader planning process. At the present, cooperation in water supply, purification and waste management are two key areas of interest.

The organizational form of this cooperation is an inter-community development association, a quasi-public body with multiple competences. The most important instruments guiding land use at the city-level are the following three: General Urban Plans, Zonal Urban Plans and Detailed Urban Plans (Figure III.4.). The most important instruments that define green space protection and enhancement are legally binding documents such as the three land use planning instruments mentioned above, 429/2009 Local Decree on Organization, Development and Maintenance of Green Spaces and the Green Cadastre of Oradea, the latter of which lists and categorizes the different green spaces of the city.[64]

Figure III.4. The grasslands of the Oradea parks positively affect the infiltration of the precipitation into the soil.[65]

GREEN SURGE project was a trans-national research project funded by the European Union's 7th Framework Programme and summarized in the next part of this case study. The important achievements are mainly related to the creation of new green space in the city (Figure III.10.). For example, Parcul Linişti and Parcul Seleuş are the parks built on former cemeteries. Another important achievement was created by the Green Cadastre of Oradea, which contains information about the 663 hectares of green spaces inside the city.[66] Unfortunately, for many projects, there is no further resource at the end of the project to continue with the results.

According to green space officials in the municipal government, there is a gap in data and information providing a basis for the development of good strategies, and there is a lack of cooperation with urban development officials. They consider this cooperation important to find a good balance between construction and green spaces. Oradea has developed its green space extensively in the last decades mainly by converting brownfields into new public parks.

In Oradea the quantity of green spaces accessible to the public has increased significantly in the last ten years, just as their quality for recreation and as a wildlife habitat. The political leaders of the city aim at providing all citizens with good-quality green space within a five-minute walking distance from their residence. Accordingly, the important achievements are mainly related to the creation of new green space. For example, Parcul Linişti and Parcul Seleuş are the parks built on former cemeteries. The vegetation of the city is mostly deciduous forest, dominated by oak (Quercus robur) and beech (Fagus sylvatica), but in the meadow area belonging to the Crişul Repede River, we find hydrophilic and higrophilic trees, such as: willow (Salix alba), weeping willow (Salix L.), poplar (Populus nigra, Populus alba, Populus tremula) and alder (Alnus glutinosa). Herbaceous vegetation is dominated by grasses. Fruit trees are found both, in the heart of the town as well as in the surrounding area. Oradea has an important horticulture and viticulture tradition thanks to the presence of slopes with southern and western solar exposure.[67]

Stakeholders in the city

The essential stakeholders regarding the green space planning in Oradea are currently the municipality and, to some extent, business actors. In addition, homeowners' associations, schools and civic organizations play an increasingly important role in forming the urban green areas. Due to insufficient financial resources and/or due to democratic considerations to involve different actors in city development and management, the city has developed a kind of institutionalized solution, a local decree for regulating processes, which can be used to empower different actors (businesses, inhabitants, institutions) to take the responsibility for maintaining certain pieces of green spaces.[68]

Business actors are involved in the process in two ways: (1) private businesses “adopt” pieces of public area for planning, implementing and maintaining the green space interventions and they can promote their companies in these spaces in return; or (2) other private businesses implement the municipal green space policy based on public procurement processes. Further, the City helps homeowners’ associations to implement green space plans and supervises housing associations to maintain a specific area around the housing blocks (also see below). The City Hall of Oradea has concluded 800 partnership contracts with homeowners’ associations, basically including all multi-family buildings within the city. The associations can request a change or major transformation regarding their close surrounding green areas, or they can ask the municipality to create new green areas, if there are none available in the surroundings. Today, the number of non-governmental organizations is low, their influence is limited, and they formulate very few proposals, even though political decision makers would consider their proposals. There is also a lack of civic interest, which seems to be a general phenomenon in Oradea. This missing civic involvement is a cultural challenge which may need decades to improve. Oradea does not have any long term or short term strategic type of plan concerning green spaces. It rather has a political vision about the developments and practical technical plans for daily operations with regard to the maintenance of green spaces.[69]

The city officials acknowledge the importance of biodiversity and the maintenance of an ecological network. This is reflected by the network of large-scale green areas situated mainly along the rivers and streams that characterize the city. However, in terms of biodiversity, native species are not preferred over non-native, resistant ones.

The most significant place regarding biocultural diversity is the river Crișul Repede that crosses the city, providing both, recreational areas and natural habitats. The river is mainly framed by city parks, while some river stretches run between dams. The parks and river banks can only be used by pedestrians; cars are not allowed.

Besides the river banks, several parks are designed with statues or are used for cultural events. For example, in the December Park, there is a statue commemorating a Romanian soldier, and sometimes religious groups gather in the park to sing. The city aims at creating green areas resistant to challenges of the urban environment and also available and accessible for all of the city’s inhabitants. These are the main features characterizing green space policy in Oradea. These features are also reflected in of the city’s handling of biocultural diversity: native species are not favoured over non-native, resistant ones, and cultural diversity is overwritten by the importance of accessibility for all inhabitants.[70]

Flood and storm water management

Hydromorphological situation

The Crisul Repede section of Oradea is modified, so the migration of aquatic animals is limited. The weirs affect local species negatively, limit the free longitudinal fish migration, if they are not equipped with functional passage systems. More studies were dedicated this problem. There are many hydrotechnical facilities along the Crișul Repede River, including spillway sills. In the city of Oradea, there are sills located at the CFR Bridge, the City Hall of Oradea, the Dacia Bridge and many others. These spillway sills negatively affect the connectivity of the Crișul Repede River, strongly reducing its biodiversity and intrinsic ecological value. The need for longitudinal connectivity of rivers represents an essential condition of the Water Framework Directive approved by the European Union and, therefore, should be applied to all streams containing migratory species.

The CFR Velenta Bridge study area weir is located on the Crişul Repede River on the eastern side of Oradea and represents a barrier for fish fauna migration upstream of the Crişul Repede River. This weir is placed on the Crisul Repede→Bonor – border (RW3.1.44_B7), classified as a single heavily modified water body with many obstacles (11 weirs). In this area, the Crişul Repede riverbed width is 70 m beside the weir, the flow rate is 23.1 m^3 /s, and water velocity is 0.4 m/s. The average elevation of the terrain is 130.2 m beside the weir. The water temperature is 18 °C, the pH – 8.11, and the turbidity is 371. The characteristic migratory fish species of this fish zone are the following: the nase (*Chondrostoma nasus*), barbel (*Barbus Barbus*) and zarte (*Vimba vimba*).[72]

In the study area 12 fish species were identified in total, from which three species are migratory: nase, barbel and bream, the latter two being the most numerous. The general ecological status of the Crisul Repede river water in the period 2006-2011 is a good one, but a potential point pollution source was wastewater outlet with dominant industrial wastewater. The main purpose of the weir is to stabilize the riverbed beside the railway bridge and water catchment. The analyzed weir comprises: crest weir, stilling basin, fixed and mobile resberme and is 3 m high with a 2 m drop (Figure III.5.).

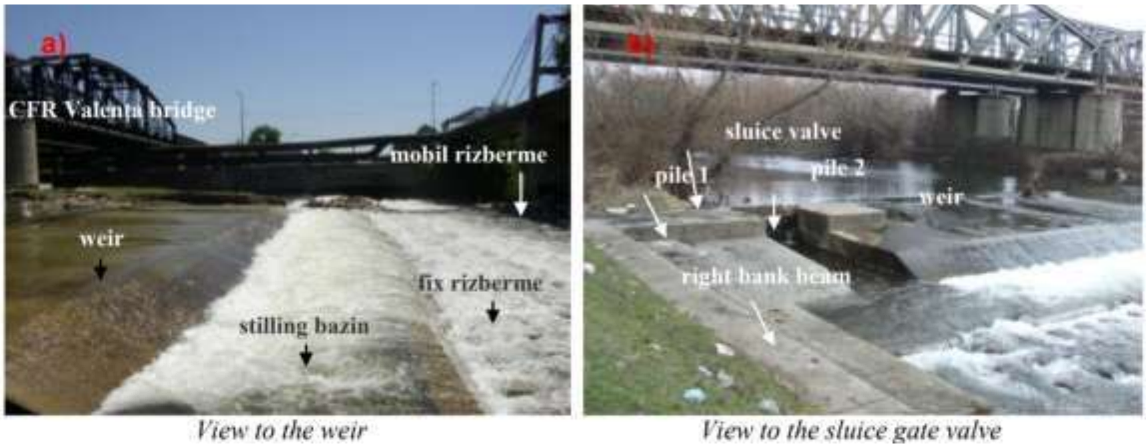


Figure III.5. The weir close to CFR Valenta Bridge [73]

The solution was developed during the elaboration of the research study Bioengineering techniques of ecological restoration of water courses – support for environmental objectives set by the Water Framework Directive, accomplished to National Institute of Hydrology and Water Management in 2013[74] (Figure III.6.).

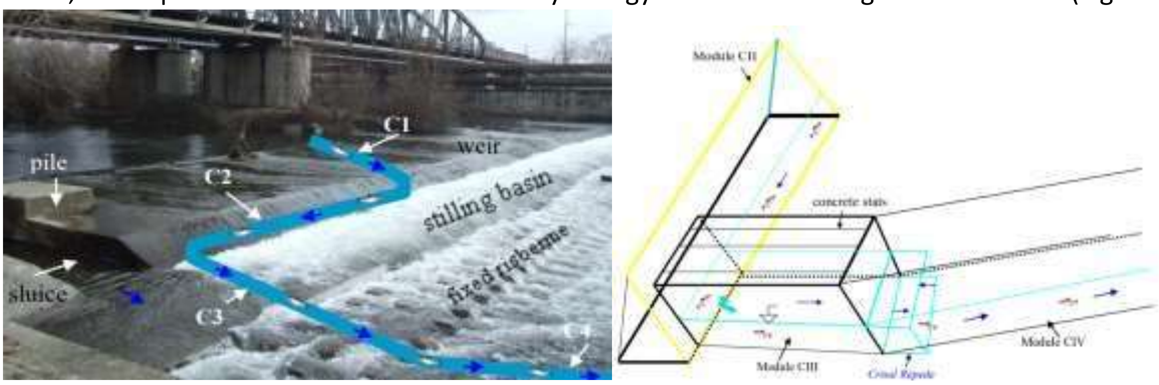


Figure III.6. The planned fish pass on Crisul Repede[75]

The conclusion of the study was that the proposed technical solutions to facilitate fish migration upstream the weir, placed downstream the railway bridge, is a technically feasible measure for longitudinal connectivity restoration and comes in supporting and completing the concerns of central and local authorities related to the reconstruction of the Crisul Repede River, biodiversity conservation of the local aquatic ecosystems and increase of the tourist attractiveness of the study area (Figure III.7.).[76]

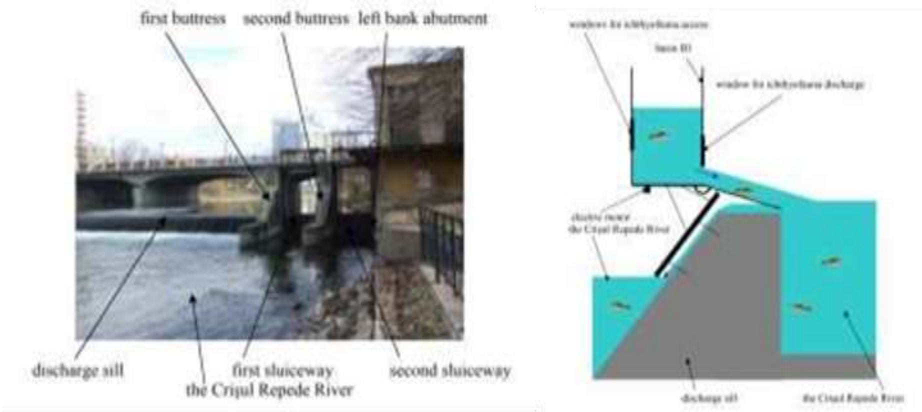


Figure III.7. Dacia Bridge and a potential solution to help connect the fragmented blue corridor[77]

Other study prepared a more technical (mechanical-electrical) solution to ichthyofauna migration upstream – downstream of the discharge sill in the neighborhood of Dacia Bridge (Figure III.8.), the city of Oradea.[78] This solution is automated but more expensive than the traditional hydrotechnological method and requested more adaptation investment, if applied on other river.

Figure III.8. The buffer strips around the river can play important role to filter surface runoff water (Photo: Google Earth)

Flood Management

The territory of the town is included in the drainage basin of the Crișul Repede River, with a rich network of rivers and streams, tributaries, which concentrate in its catchment area.

It crosses the city right through its center, creating a meadow in the historical center and conferring natural beauty to the entire area. Traversing Oradea, we also have the Peța thermal stream and Paris, Sălbatic, Adona brooks, all tributaries to the Crișul Repede River. From Romania perspective, floods are among the most hazardous natural disasters in terms of human suffering and economic losses (Figure III.15.). Major floods occurred in 2000, 2005, 2006, 2008 and 2010, the worst ones in more than 40 years, affected large regions of Romania: in the Timis county (April 2005) over 1,300 homes were damaged or destroyed, 3,800 people were evacuated and about 30,000 hectares of agricultural land flooded; in five counties situated in eastern Romania (July 2005) 11,000 homes were inundated, 8,600 people were evacuated, 20 people were killed, 53,000 hectares farmland flooded, 379 bridges damaged or destroyed; in 12 counties along the Danube (April,2006) 3,077 homes were affected (1,049 completely destroyed), 16,000 people evacuated, 5 people killed, 144,000 hectares of land flooded; in six counties from the north-eastern part of Romania (July 2008) 3,985 houses were affected (over 300 totally destroyed), 15 834 people evacuated and 35,084 hectares of agricultural land inundated.[79]

Further project aims were to provide an efficient and powerful flood-monitoring tool to the local and river authorities, as well as to other key organizations, which is expected to significantly improve the efficiency and effectiveness of flood defence action plans.
In terms of hydrography, there is a marked difference between the high rates of mountain runoff and the low runoff rates in the plains. Thus, runoff flood waves form quickly in the Romanian part of the basin and move rapidly to the plains in the Hungarian part of the basin, which is characterized by relatively slow flows and a potential for inundation.
Flood management includes pre-flood, flood emergency and flood recovery activities. The pre-flood activities are: flood risk management for all flood causes; disaster contingency planning; building flood defence infrastructure and implementing forecasting and warning systems; maintenance of flood defence infrastructure; land-use planning and management within the whole basin; discouragement of inappropriate development within flood-prone plains; public communication and education on flood risk and actions to take in a flood emergency. The flood risk impacted area is relatively small in comparison to other rivers (Figure III.9.).

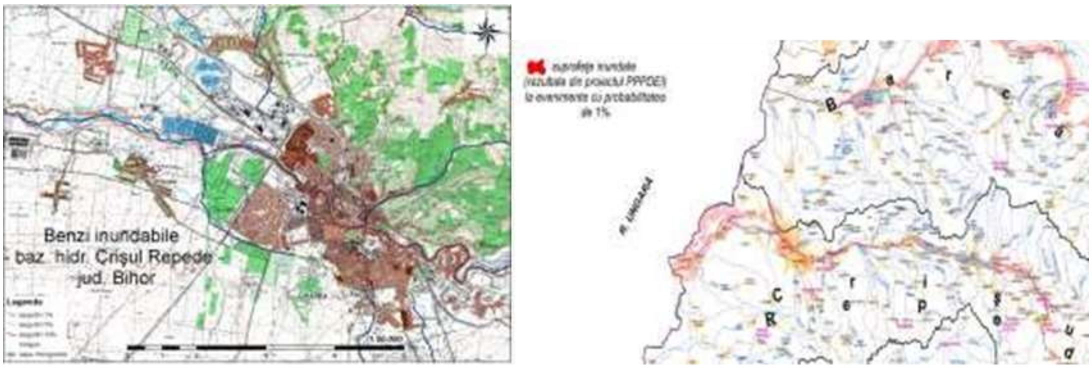


Figure III.9. Flood risk map of Oradea (p=1%) and the Crisuli repede river (Oradea in central position)[80]

Operational flood management includes: detecting the probability of a flood; forecasting future river flow conditions from hydrological and meteorological observations; warnings issued to the authorities and the public on the extent, severity and timing of the flood; response to the emergency by the public and the authorities.[81] Post-flood activities are: relief for the immediate needs of those affected by the disaster; reconstruction of damaged buildings, infrastructure and flood defense; recovery of the environment and economic activities in flooded areas; review of flood management activities to improve planning for future events in the area. Various processing techniques (classification, geo-referencing, filtering, and photo interpretation) should be used to combine the optical and radar images and map the flooded areas.[82]
Within the framework of flood surveying, satellite images can provide up-to-date geographical information helpful during different phases of the flood.
Mayor of Oradea and Head of the Crisu Water Directorate concluded a cooperation agreement in 2011 according to which the two institutions will jointly work on the upgrading of the Nagyvárad section of the Crisul Repede. The purpose of the agreement is to make the Oradea section of the Crisul Repede more beautiful landscape and to mitigate the flood risk of the riverbank. The Convention specifies that the municipality will clean the river bank of the Crisul Repede Oradea area. At the same time, the Crisu Water Directorate has undertaken to clean up the river bed, the Decebal Bridge boundaries and carry out environmental campaigns in order to the awareness of the population regarding the importance of environment protection.[83]
In relation to reconstructing the banks of the Adona Stream, there are two important aspects: to reduce the flood waves in the stream, and to find solutions to the ecological problems of the area.[84]
Flood-risk analysis needs to make use of, and integrate, many sources of ground and remote sensing information. This approach is more demanding in case of a transboundary river. Apart from ground

information on the occurrence and risk evaluation of floods, EO data supplied by the satellite orbital platforms (SPOT, IRS, LANDSAT-7, NOAA/AVHRR, RADARSAT, QUIKSCAT, EOS-AM "TERRA" and EOS-PM "AQUA"), in the optical and microwave spectral domains, substantially contribute to determining the flood-prone areas.

The satellite-based products will contribute to a preventive consideration of extreme flood events by elaborating plans for flood mitigation, building infrastructure in flood-prone areas, and by optimizing the distribution of spatial flood-related information to end-users.[85]

Flood related product:

- Non-real-time flood mapping
- Maximum flood extend mapping
- Flooded area classification
- Flood evolution mapping
- Damage assessment maps & reports
- 2D Animations
- 3D Flythrough

National Water Administration "Apele Române", together with the National Institute of Hydrology and Water Management elaborated a Catalog of potential national measures on flood risk management. The types of proposed measures are clustered in five areas of key action: Prevention, Protection. Flood risk awareness; Rebuilding / Reconstruction and Training with 23 measuring types. Flood Risk Management Plans include all measures and actions that must be taken by all those involved in flood risk management (Ministries, IGSU, ANIF, prefectures, local governments of Oradea, Bihar county councils, etc.). Flood Risk Management Plans take into consideration more relevant aspects, such as: flood impacted areas; areas for potential water storage from floods (such as major natural retention basin); the environmental objectives in accordance with Article 4 of Directive 2000/60/EC (Water Framework Directive); integrated soil and water management; spatial planning; land use; conservation, the environment, etc.).[86]

The Structure and Content of the Flood Risk Management Plan:

- The recommendations of the Plan Flood Risk Management,
- The minimum requirements must be developed
- Concerning the different types of measuring based on a catalog of potential measures, where promoting nonstructural – green infrastructures
- The methodology indicates structural and nonstructural measures via the step by step method with prioritized a multi-criteria (MCA) cost – benefit analysis.

Natural Water Retention Measures[87], [88] aim at restoring and maintaining water related ecosystems by natural means. They are Green Infrastructures intended to maintain and restore landscape, soils and aquifers in order to improve their natural properties, the environmental services they provide, and to favour climate change adaptation and reduced vulnerability to floods and droughts.[89]

Water Supply (drinking water, thermal water)

Drinking water supply

Drinking water quality management policy of is as follows:

- To provide the best quality and affordable water and wastewater treatment services;
- Promote respect and transparency through the equal and non-discriminatory treatment of all its clients.
- To achieve a high level of professionalism by continuing training of staff to treat them with respect

and without discrimination;

- To ensure the continuity, stability and sustainable development of the company through competitive management;
- To build an integrated corporate identity and structure linked to the operating area, while promoting institutional accountability;
- To upgrade and expand the operating system under conditions of real protection and preservation of the environment.

The need for water supply of Oradea is satisfied partly from ground water and partly from surface water of the river Repede, which is collected by five pumping stations with a total design capacity of 2,100 l / s.
The raw water is captured from the underground by drains.
The applied drinking water technology allows the use of surface water abstracted from the Crisul Repede river in Oradea city by 5 Water Treatment Plants – WTP (Water Company of Oradea S.C. COMPANIA DE APĂ ORADEA S.A.) Plants 1-4 obtain water from the water drains through the water table which in turn are fed from the enriched pools of infiltration. 5th WTP use surface water source from the Crisul Repede. The river is intended basically as a backup solution that can provide drinking water. This system completes the construction and specific objects (food pipe, manholes, valves, flow management). Actual plants are equipped with pumping equipment, flowmeter instrumentation and automated treatment plants.[90]
The five drinking water stations are located on both sides of the Crisul Repede River, in the north-east of the city, which has a total capacity of installed pumping 2,100 l /s. Raw water is abstracted from aquifers through drainage network located in the vicinity of the Repede River. To enrich an underground water layer using a total of 23 wells (15 on the right and 8 on left banks of the river) the Crisul Repede is fed through a culvert system from two catchments located upstream behind the dam Fughiu. The entire water supply system consists of Oradea catchments, water connection pools, enrichment field's infiltration, water plants are within a protection zone with a total area of approx. 280 ha.[91]
On the right bank of the 1st Water Treatment Plan (WTP) surface, water is abstracted through two pipelines from Ø1000 mm socket capture caisson type. Through these pipes, water abstracted is directed through a desilting on two longitudinal concrete clarifiers (140 m x 40 m) provided with inlet baffle. After passing through clarifiers, water reaches the 13 groundwater basins enrichment layer, placed on two parallel rows (8 + 5 pools) with Crişului bed. The tanks have dimensions of 200 m x 40 m water depth is approximately 1.5 m between the two rows of basins and between basins and Crisului, two drains are placed to capture groundwater that feeds 1st WPT. Drains have a total length of 4,200 m, are pictured at a depth of about 6 m and diameters that increase progressively with proximity to plant one (Ø400 - Ø1000 mm). Through these drains, water from aquifers is captured and directed toward gravity caisson to plant one. There are a total of 27 drainage manholes located on their route, visible in the field. Power filters are made with raw water directly from capture, through a pipeline Ø 600 mm, the water turbidity is low and if water has high turbidity, the last pool enrichment, after previously passing through desilting, decanters and pools, just ordered the coarse dirt trail in the water to settle by gravity.
The 2nd WTP is physically located on the right, but pumping network on the left bank of the Crisul repede River has a rate of 250 l/s. It uses only groundwater abstracted via a drain (Ø600 mm, l = 960 m).
Enriching layer drain groundwater supply is via two pools fed by the river enrichment of 1st WPT. Cheson the plant 2nd is cylindrical, with a diameter of 3 m and a depth of 9 m.
3rd WTP is still on the right located downstream of the 1st plant and is designed with pumping capacity of 150 l/s. The supply of water is through a drain from a Ø300 mm, a length of 560 m and with a Ø250 mm caisson pipe 1st WTP. The discharge pipe 3 feeds 2x10,000 m^3 to 2,000 m^3 tank located at a higher rate of 2,000 m^3 tank provides water in the area surrounding the tanks of 10,000 m^3, and the water escapes through the pipe from the pump 1st WTP the city. The 4th WTP is located on the left bank of the Crisul Repede river with design capacity of 500 l / s. It uses only groundwater abstracted through drain. To enrich the phreatic layer, there are 8 pools

rich with dimensions of approx. 40 mx 300 m, water depth is about 1.5 m water supply watershed is the Crisul Repede gravity of the two pipes. The 8 pools enrichment are located approximately perpendicular to the Crisul Repede bed.
PWIN – Modflow[92] hydrogeological studies indicate that alluvial aquifer of 5-8 m in an area with variable permeability zones (filtrate coefficients kf = 30 m / day in the South and 120 m / day in the North, with intermediate values between the two limits in the remaining value territory).[93]
At the operational area of water supplying, there are 8 treatment plants for potable water abstraction, the transport and distribution network length 1,186 km. Water distribution to consumers is ensured through 131 pumping stations and 44,800 water connections (out of which 26,000 branches are in Oradea).
Water Company Oradea manages approx. 45,000 company-owned measuring points (installed in the distribution system), of which 18,000 points are radio controlled.

Thermal water

The mineral resources (including Geothermal Energy) make the exclusive object of public ownership and belong to the Romanian government. The right to conduct exploration operations and mining activities (including harnessing of Geothermal Energy) is granted by concession agreements, concluded with the National Agency for Mineral Resources (NAMR) and approved by Governmental Decision. Next strategic goals are: to develop efficient methods for use of geothermal heat for direct use and/or electricity production by environmentally friendly use in particular concerning the protection of underground drinking water resources, emissions, etc. The typical geothermal heat flow values observed in the Pannonian basin (80-120 mW/m^2) are considerably higher than the continental average, and this shows that the Pannonian basin, in general, is a promising area for geothermal energy utilization. Geothermal exploitations in Romania are located in Oradea, Borș, Ciumeghiu, Otopeni (North Bucharest) and Căciulata-Călimănești (Olt Valley) (Figure III.10.).

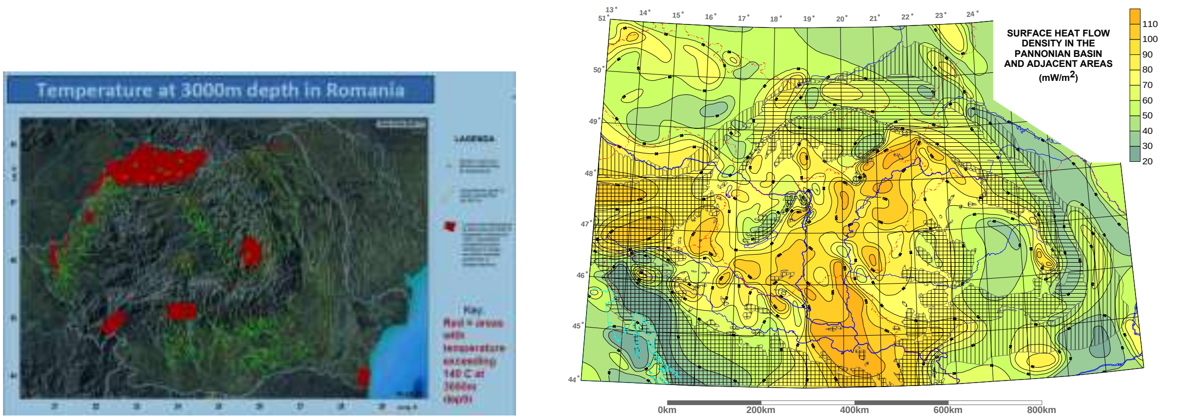


Figure III.10. Geothermal energy map of Romania and the Carpathian Basin [94]

The Oradea geothermal reservoir is located in the Triassic limestone and dolomites at depths of 2,200 – 3,200 m, on an area of about 75 km^2 and it is exploited by 13 wells, of which one is used for reinjection. Well head temperatures range from 70 to 105°C. There are no dissolved gases, and the mineralization is lower than 0.9-1.2 g/l. The water is of calcium-sulphate-bicarbonate type. The water is about 20,000 years old and the recharge area is in the northern edge of the Pădurea Craiului Mountains and the Borod Basin. The natural recharge rate was calculated at 300 l/s based on the only interference test by now, carried out in 1979 (Paal, 1979) (Figure III.11). The Oradea aquifer (Triassic) is hydro dynamically connected to the Cretaceous aquifer Felix Spa (shallower and colder) and are part of the active natural flow of water.
The Bors geothermal reservoir is situated about 6 km north- west of Oradea. This reservoir is completely different from the Oradea reservoir, although both are located in fissured carbonate formations. The Bors

reservoir is a tectonically closed aquifer, with a small surface area of 12 km. The geothermal water has 13 g/l TDS,5 Nm^3/m^3 GWR, and a high scaling potential (Figure III.12.) (Table III.1.).

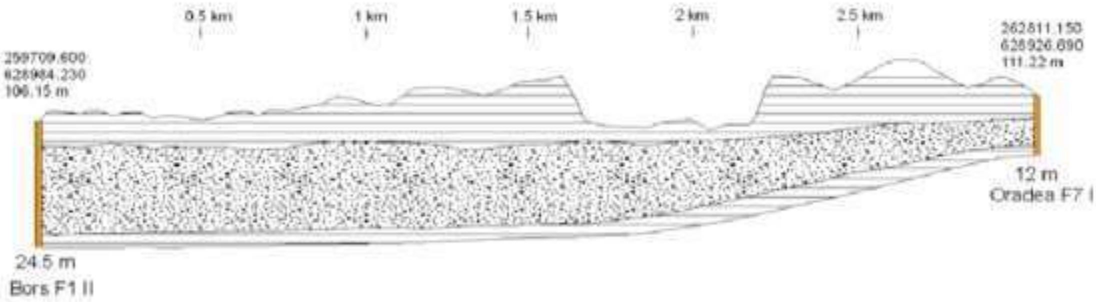


Figure III.11. Types of aquifers' lithology in the Cris Plain[95]

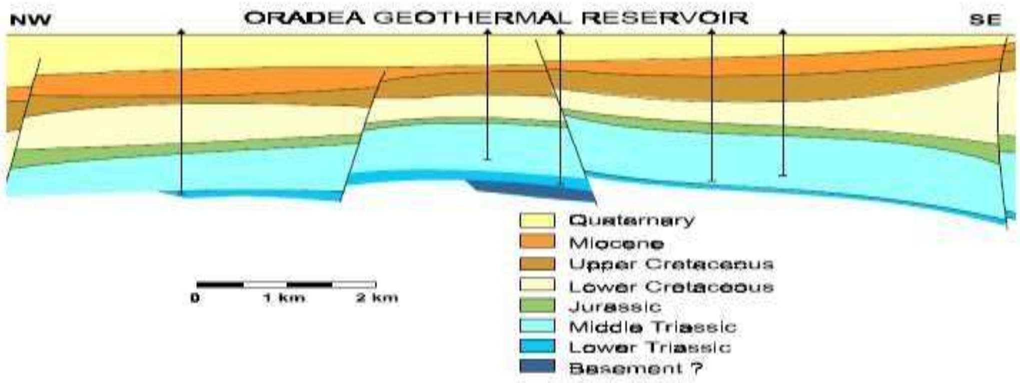


Figure III.12. Cross section through the Oradea reservoir[95]

Table III.1. The characteristics of the main geothermal aquifers in Oradea region

Parameters	U/M	Oradea	Bors	Western Plain
Area	Sqkm	7	12	2500
Depth	Km	2.2-3.2	2.4-2.8	0.8-2.1
Drills wells	Total	14	6	88
Well head temperature	°C	70-105	115	50-85
Temperature gradient	°C/100	3.5-4.3	4.5-5.0	3.8-5.0
TDS	g/l	0.8-1.4	12-14	2-7
Exploitable reserves (for 20 years)	MW/day	570	110	4,700
Flow rate	l/s	4-20	10-15	4-18
Total installed power(with existing wells)	MWt	58	25	210

The reservoir temperature is higher than 130 °C in the average depth of 2,500 m. Production of four artesian wells can only be maintained by reinjection of the whole amount of extracted geothermal water. In the past, three wells were used to produce a total flow rate of 50 l/s, and two of the other wells are used for reinjection, at a pressure that did not exceed 6 bars. The geothermal water was used for heating 12 ha of greenhouses. The dissolved gasses were partially separated at 7 bars, which was the operating pressure, and then the fluid passed through heat exchangers before being reinjected.

The Beius geothermal reservoir is situated about 60 km south-east of Oradea. The reservoir is located in fissured Triassic calcite and dolomite at 1,870–2,370 m deep. The first well was drilled in 1996, down to 2,576 m. A line shaft pump was set in this well in 1999, now producing up to 45 l/s geothermal water with 84 °C wellhead temperature. A second well was drilled in early 2004, and a line shaft pump was installed soon after completion. The geothermal water has a low mineralization (462 mg/l TDS), and 22.13 mg/l NCG, mainly CO_2 (0.01 mg/l of HS). At present, the geothermal water from the first well is used to supply district heating to a part of the town of Beius.

Direct geothermal energy is used to heat housing. The geothermal reservoir located under the city supplies currently 2.2 % of the total heat demand. By generalizing the reinjection, the production can be increased to supply about 8 % of the total heat demand, without and significant reservoir pressure or temperature decline over 25 years.[96]

According to Rosca study for a combined natural gas and geothermal district heating system, the best economic performance in Oradea. The best option is to use geothermal energy only for culinary water heating in a larger number of substations, in 5 doublets located in city districts, with space heating of blocks of flats being supplied by natural gas-fired boilers. In this case, the system is also more simple and easier to operate. A fourfold increase in production from the Oradea geothermal reservoir is possible without any adverse effects if at least 70 % of the extracted geothermal fluid is reinjected. As natural gas and geothermal water are the least expensive and the least polluting energy sources, the Municipality of Oradea has decided to develop them in the near future[97].

One of the best uses of geothermal energy is the bath where it can be used for balneological treatments or for recreational purposes. However, in terms of water quality, the high salt content of the effluent is problematic, but in case of Oradea enough diluent water is available (Table III.2.).

Table III.2. Water quality in the Felix-1 Mai spa.

pH	SiO_2 mg/l	Cation (mg/l//m.mol(l))					Anion (mg/l//m.mol(l))		
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Fe^{2+}	SO_4^{2-}	Cl^{-}	HCO_3^{-}
7.7	48.75	263.74 / 13.26	67.33 / 5.54	19 / 0.83	8 / 0.2	2.82 / 0.1	827.85 / 17.23	7.09 / 0.19	157.2 / 2.8
6.8	60.33	252.92/12.62	34.53 / 2.81	31 / 2.84	10.8 / 0.27	1.28 / 0.04	652.61 / 13.58	18.12 / 0.51	185.9 / 3
7	58.28	212.22 / 10.59	29.56 / 2.43	40 / 1.74	11.5 / 0.29	1.23 / 0.04	507.33 / 10.56	18.12 / 0.51	247.9 / 4
6.7	59.94	249.13 / 12.43	41.46 / 3.41	33 / 1.43	11 / 0.28	1.5 / 0.05	695.22 / 14.47	14.18 / 0.39	2.71.1 / 2.8
6.6	76.58	196.99 / 9.83	18.68 / 1.53	42 / 1.82	10 / 0.25	3.6 / 0.13	434.54 / 9.05	18.12 /0.51	247.9 / 4

Waste water - water recycling, alternative water source

Waste water treatment

The operational area of the Oradea Water Company (Figure III.13) has progressively widened so that the public services of water supply and sewerage have been taken over from the following localities: Sânmartin (Sânmartin, Baile Felix, Baile 1 Mai, Rontău, Haieu, (Nyorid, Leş, Livada), Oşorhei (Oşorhei, Fughiu, Alparea, Cheriu, Felcheriu), Giurşu de Gîrbediu, Gîrbedu Negru, Rîpa, Sîntandrei (Sântandrei, Palota) Criş (Girişu de Criş, Tărian), Beius (Beiuş, Delani), Hidişel (Hidişelu de Sus, Hidişelu de Jos, Mierlău, Sântelec), Drăgeşti (Drăgeşti, (Tileciş, Poşoloaca), Vârciorog (Vârciorog, Fasca), Olcea (Olcea, Călacea, Ucuriş), Ineu (Ineu, Husasău de Criş), Copăcel, Lăzăreni (Lazareni, Calea Mare).

Figure III.13. Waste water treatment plan of Oradea (Photo, Google Earth)

The main activities of S.C. Water Company Oradea S.A. involve:

- water withdrawal, water supply, raw water treatment and pumping of drinking water;
- the transport and distribution of drinking water and the collection and transport of wastewater and rainwater;
- sewage sludge treatment and discharge of treated water into the river.

The resident population is 250,565 inhabitants on the entire operating area - of which: water supply: 239,319 inhabitants (95.52 % of the resident population) and sewerage: 197,052 inhabitants (78.65 % of the resident population)
In Oradea - a resident population of 184,461 inhabitants - of which: water supply: 183,322 inhabitants (99.39 % of the resident population), sewerage: 171,730 inhabitants (93.10 % of the resident population). Oradea Water Company, with more than 120 years of experience in water supply, currently operates the following capabilities:

- Pumping stations – treatment and pumping of drinking water: 8 stations of which are in Oradea - 5 stations with a total capacity of 2,100 l/s capture-treatment-pumping potable water;
- Water transport and distribution networks – 1,186 km, out of which: 683 km – in the urban area (606 km – Oradea) and 503 km – in the surrounding
- Water connections: 44,800 pieces, from which: 28,510 units – in the urban area (25,784 units – Oradea) and 16,290 units – in rural areas
- Potable water pumping stations: 131 stations, of which 82 hydropower stations for drinking water in Oradea;
- Household Channel Networks 660 km, out of which: 514 km in the urban area (475 km – Oradea) and 146 km in the countryside
- Canal networks 362 km – Oradea, 16 km – Beius, Sinmartin – 5 km. Household canal connections: 30,649 pieces. 25,169 units in the urban area (22,634 units – Oradea), and 5.480 units in the countryside.
- Pumping stations in the sewage system: 93 stations of which in Oradea: 29 wastewater pumping stations and 8 pumping stations. Sewage treatment plants – 4, of which one is the Oradea wastewater treatment plant with a 2,200 l/s wastewater mechanical-biological wastewater treatment capacity.

Collection and transportation of wastewater and rainwater

The waste water and rainwater are collected by partly mixed and partly separate sewer network system. Oradea sewerage network's length is 462 km. Municipal wastewaters in the lower areas of the City are

collected and pumped by 29 wastewater pumping stations into gravity canals to reach the gravity way of the treatment plant. At the total operating area, the Company operates 100 pumping stations (93 wastewater pumping stations and 9 rainwater pumping stations), of which 39 stations are in Oradea (30 pumping stations for domestic water and 9 pumping stations for rainwater). The rest of the stations operated by the Company are located as follows: Beius – 8, Tinca – 6, Sanmartin – 11, Ineu – 3, Tileagd – 2, Nojorid – 6, Osorhei – 25.
The Wastewater Treatment Plant is located on the right bank of the Crisul Repede River close to the Industrial Park and the Crisul Repede river and the red sludge dump of the Chemical Sinteza enterprise. The station is connected to the two main collectors, where pipe diameter is 70 / 105cm and 165 / 260cm collecting domestic and industrial wastewater. The Wastewater Treatment Plant (WWTP) treats domestic and industrial wastewaters in Oradea and some neighboring areas. The WWTP is mechanical-biological and tertiary type and the effluent of the station is disposal into the Crisul Repede River. The treatment capacity was planned for a capacity of 2200l/s (7920m^3/h), where the mechanical phase can take Q=4000 l/s (14400 cm/h) flow rate, with Q = 2200 l/s (7920m^3/h) capacity.[98]
The Paris Stream has been troublesome for many years for the local government because, due to the level difference and the waste water emitted by the streams, this stream has always endangered the Crisul Repede and polluted the river (Figure III.14.). The Paris Stream is managed by the Crisul Water Directorate, and parallel to the works, the Water Directorate will set up a canal and rainwater drainage system.[99]

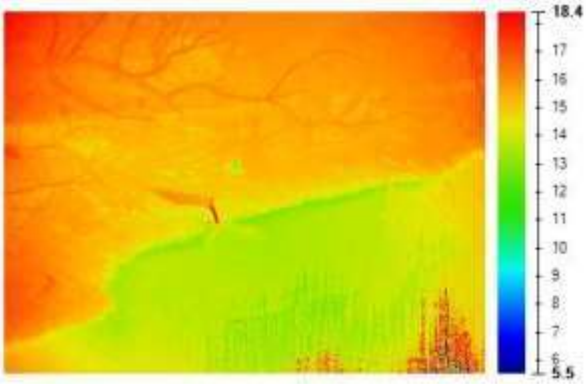


Figure III.14. Thermo-image of water outlet into the Crisul-Repede river in the middle of the Oradea winter season (Photo: Nagy)

Water quality of recipient

The measured typical water quality indicators at the Oradea monitoring station: - thermal regime and acidification (RTA); - oxygen regime (RO); - nutrient regime (NUTR); degree of mineralization (salinity) (SAL); natural specific pollutants (PTSON); - Other relevant chemical indicators: phenols, detergents, AOX (AICR); chemical and biological condition (Figure III: 30, Figure 31). The measuring frequency of 6 times per year for the physical-chemical indicators and 2-4 times for the biological elements, depending on the monitored indicators.
At the Crisuri basin in Oradea monitored on the surface waters used for drinking according to GD 100/2002, modified by GD 567/2006 where Coliformi fecali; Coliformi totali; Strep Tócóci fecali were A2 class. The most parameters do not exceed the value of the threshold but some chemical parameters were critical (sulphate content was 607 mg/l, Na content 360 mg/l, phenol 16 µg/l).[100]

4. Spatial decision supporting in urban hydrology

Critical Knowledge on Spatial Decision Supporting in Urban Hydrology

From the decision support point of view, approach of Share Vision, presented in the JOINT Tisza project was the baseline. The methodology is described in detail by US ARMY CORPS ENGINEERING, Institute for Water Resources.[101]

The goal of Shared Vision Planning is to improve the economic, environmental and social outcomes of water management decisions. Shared Vision Planning facilitates a common understanding of a natural resource system and provides a consensus-based forum for stakeholders to identify tradeoffs and new management options according to the next steps:

1. Develop an understanding of decision support systems and how they can be used.
2. Define collaborative modeling, including Shared Vision Planning, and when and how it can be applied.
3. How Shared Vision Planning has been used in a specific context.
4. Use a data set and model to test alternative options given a set of objectives.
5. Share model findings and work together towards a solution.

There are a lot of different methods presented, but based on the above mentioned list, a short description of an optional solution is given here.

Firstly, an understanding of *spatial* decision support systems and how they can be used needs to be developed. Urban hydrology planning is most fundamentally linked with the spatial dimension, and the scale of the decision.

Secondly, *collaborative modeling* needs to be defined, including Shared Vision Planning, and when and how it can be applied. Obviously, hydrological decisions involve many intangibles that need to be traded off. To do that, they have to be measured alongside tangibles whose measurements must also be evaluated as to, how well, they serve the objectives of the decision maker. The Analytic Hierarchy Process (AHP) is a theory of measurement through pairwise comparisons and relies on expert judgements to derive priority scales.[102] These are the scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgements representing, how much more, one element dominates another with respect to a given attribute. The judgements may be inconsistent, and the AHP's task is to consider, how to measure inconsistency and improve the judgements, when possible, to obtain better consistency.

In the case of Debrecen, as an example, available surface and ground water resources are limited from different reasons, which require trade off solutions, based on summarized aspects, described in the next table (Table IV.1.):

Table IV.1. Potential conflict between two important drinking water resources of Debrecen

DRINKING WATER RESOURCES	Surface water from the Keleti main canal	Ground water- from deep aquifer
Advantages	Unlimited water source	Water quality risk lower Good water quality, Treatment cost moderate Owner the local government More preferred by local settlements
Disadvantages	Water quality risk higher, Treatment cost higher Temperature problems Owner is not influenced by the local government Less preferred by local settlements	Limited sustainable source

The similar water conflicts can be identified in the next cases on the Debrecen city area:

- Untreated thermal water quality versus surface water quality in the Tócó
- Old problematic tree cutting versus microclimate and landscape changing
- Fishing versus water quality/quantity in the eastern part of the city
- Dust health problem in spring and quick drainage solutions in the city and western arable land

Spatial Uncertainty and Decision Rule in Urban Hydrology

To meet a specific Hydro Urban objective, it is frequently the case that several criteria will need to be evaluated for stakeholders. (Voogd, 1983[103]; Carver, 1991[104]). With conflicting different objectives of water usage, competition occurs for the available natural, economic and social resources since it can be used for one objective or the other. For example, we may need to resolve the problem of land allocation for green/blue corridor and new industrial park. Clearly, the two cannot coexist in traditional decision environment. In cases of complementary objectives, multi-objective decisions can often be solved through a hierarchical extension of the multi-criteria evaluation process. For instance, we might assign importance to each of the water related objectives and use these, along with the suitability maps developed for each, to combine them into a single suitability map. This would indicate the degree to which areas meet all of the objectives considered (Voogd, 1983).

With conflicting objectives, it is sometimes possible to sequence the objectives and reach a prioritized solution. In these cases, the needs of higher ranked objectives are satisfied before those of lower ranked objectives are dealt with. However, this is often not possible, and the most common solution for conflicting objectives is the development of a compromise solution. Undoubtedly, the most commonly employed techniques to resolve conflicting objectives are those involving optimization of a choice function such as mathematical programming[105] or goal programming.[106] The concern in both is to develop an allocation of the land that maximizes or minimizes an objective function subject to a series of constraints.

Decision rule uncertainty arises from the manner in which criteria are combined and evaluated to reach a decision. A very simple form of decision rule uncertainty relates to parameters or thresholds used in the decision rule. A more complex issue is related to the very structure of the decision rule itself. This is sometimes called specification error,[107] because of uncertainties that arise in specifying the relationship between criteria (as a model) such that adequate evidence is available for the proper evaluation of the hypotheses under investigation.

Because of the different scales upon which hydrological criteria are measured, it is necessary that factors be standardized before weighting combination using and that they be transformed, if necessary, such that all decision factors maps are positively correlated with suitability. Standardization equitation:

$$x_i = \frac{(R_i - R_{min})}{(R_{max} - R_{min})} * standarzided\ range$$

where R= raw score.

A critical issue in the standardization of factors is the choice of the end points at which set membership reaches either 0.0 or 1.0. The method implemented in TerrSet is that of pairwise comparisons developed by Saaty [108] in the context of a decision making process known as the Analytical Hierarchy Process (AHP).

In our case, 7 Debrecen Urban Hydrology decision factors maps were prepared in IDRISI-TERRSET GIS environment: DRINKINGWATER, GROUNDWATER, RAINHARVESTING, SURFACEWATER, THERMALWATER, URBANGARDEN, WASTEWATER.

In the procedure for Multi-Criteria Evaluation using a weighted linear combination outlined above, it is necessary that the weights together equal one. In Saaty's technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pairwise comparisons between the Urban Hydrological criteria. The comparisons concern the relative importance of the two criteria involved in determining suitability for the stated objective. Ratings are provided on a 9-point continuous scale. For example, if one felt that proximity to SURFACEWATER quantity was much more important than WASTEWATER quality in determining suitability for BLUE/GREEN corridor, one would enter a 7 on this scale. If the opposite was the case (SURFACEWATER was very strongly more important than WASTEWATER), one would enter 1/7 (Table IV.2.).

Table IV.2. Importance rank table

extremely not important	very strongly not important	strongly not important	moderately not important	equally important	moderately important	strongly important	very strongly important	extremely important
1/9	1/7	1/5	1/3	1	3	5	7	9

In specifying the importance, each stakeholder group compares every possible pairing and enters the ratings into a pairwise comparison matrix. Since the matrix is symmetrical, only the lower triangular half actually needs to be filled in. The remaining cells are then simply the reciprocals of the lower triangular half. Note that where exists empirical evidence about the relative efficacy of a pair of factors, this evidence can also be used. The procedure then requires that the principal eigenvector of the pairwise comparison matrix be computed to produce the best fit set of weights (Figure IV.1., Table IV.3.). In case of TerrSet, an offer a special module named WEIGHT has been developed to calculate the principal eigenvector directly. Note that these weights will equal one, as required by the weighted linear combination procedure.

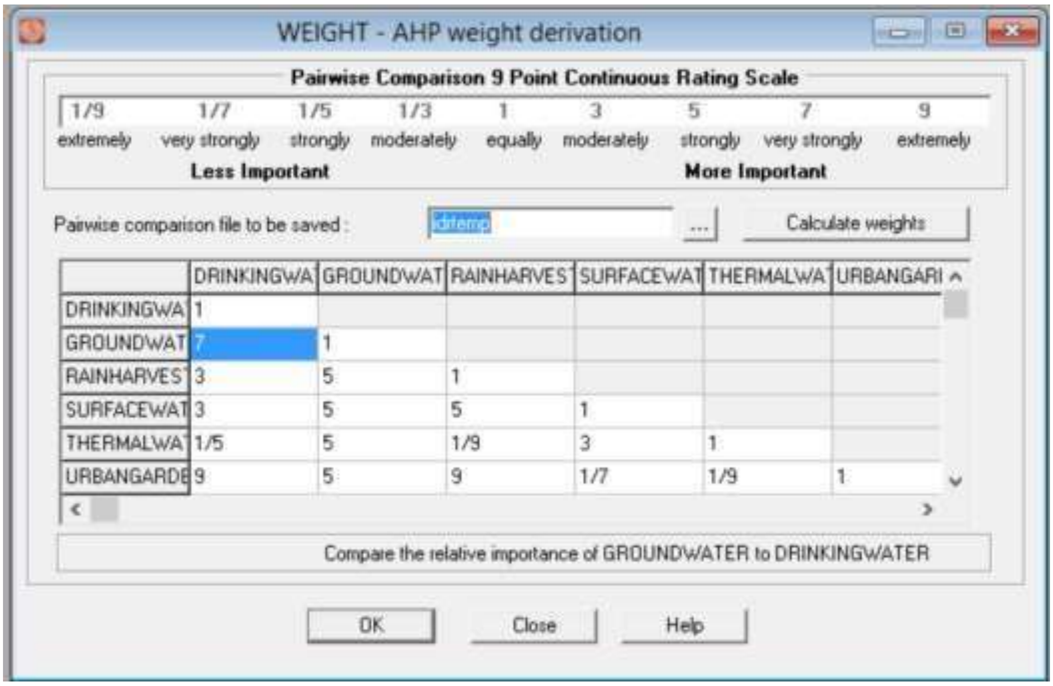


Figure IV.1. Weight – AHP table for one scenario

Table IV.3. The result of the decision eigenvector of weights

Sector	Eigen
DRINKINGWATER	0.0669
GROUNDWATER	0.0402
RAINHARVESTING	0.1356
SURFACEWATER	0.1751
THERMALWATER	0.1811
URBANGARDEN	0.2286
WASTEWATER	0.1726

In this case the decision consistency ratio = 1.24 (low), so re-evaluating the matrix should be taken into consideration. In the following consistency matrix, values close to zero show good consistency. Higher absolute values indicate comparisons that should be reconsidered.

Since the complete pairwise comparison matrix contains multiple paths by which the relative importance of criteria can be assessed, it is also possible to determine the degree of consistency that has been used in developing the ratings. Saaty[116] indicates the procedure by which an index of consistency, known as a consistency ratio, can be created. The consistency ratio (CR) indicates the probability that the matrix ratings were randomly generated. Saaty indicates that matrices with CR ratings greater than 0.10 should be re-evaluated. In addition to the overall consistency ratio, it is also possible to analyze the matrix to determine where the inconsistencies arise. This has also been developed as a part of the WEIGHT module in TerrSet.

Sustainable Urbanizing Landscape Development Tool

SULD is another method for stakeholders in urban hydrology modelling. The SULD (Sustainable Urbanizing Landscape Development) GIS based decision support tool facilitates participatory planning and scenario development, creating confidence in and knowledge of the model and its outputs. It enriches public discussion and adds transparency to the urban planning processes. So, it encourages stakeholders to reflect about their reality and future possibilities – effectively engaging them in the design of urban development plans where the value of water and green spaces assume a forefront position. Earlier chapter refers to the Debrecen case study (Figure IV.2.).

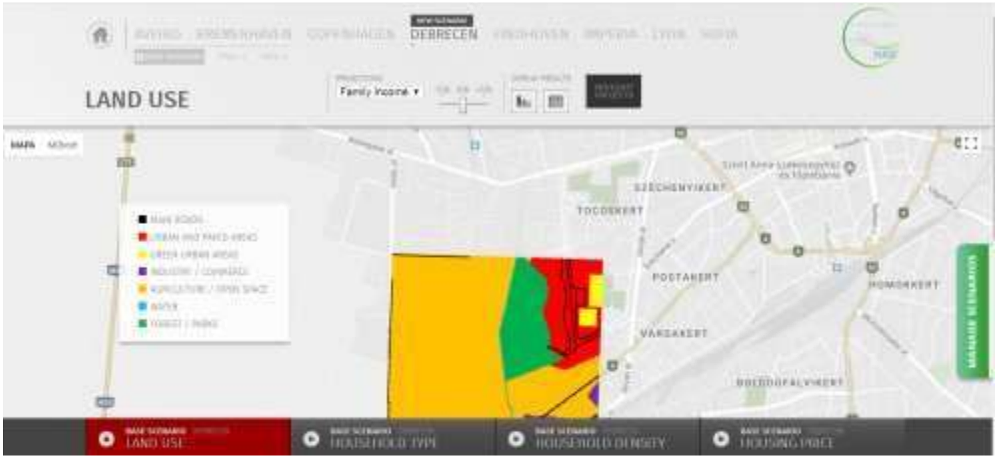


Figure IV.2. Interactive SULD Scenario analysis of Debrecen on WEB site [109]

GIS/RS data and technologies in modelling the urban water cycle

Urban hydrology analyses are basically influenced by precise, digital urban models in 2D and 3D. Remote sensing technologies (image processing) are able to cover large urban areas at cheap price and provide a quick solution for an area. Products for processing are partly or entirely automated, made by this remote sensing method. Their disadvantage is that interpretation requires time and professional knowledge. When the products comply with any GIS standards, based on generated indices, different urban hydrology related performance monitoring indicators are comparable. Another advantage is cloud computing data service of smart measurement devices, which allow a much more effective evaluation of water resources. Hopefully, SMART CITY practice will be expanded to water management like in case of public transport. However, these solutions are currently under development, but experience is encouraging. During description, the goal is not to define thematic issues, because they are different in all cities. At the same time, we would like to describe the framework of the implementation of spatial thinking conception of urban hydrology practice. Many tools still haven't been used directly in the field of applied hydrology. However, these tools are general decision supporting tools and input data models entirely adaptable in GIS based environment.

Available RS and GIS based databases in urban modelling in the reference cities

Internet based Facility Management (eKÖZMŰ)

The purpose of the single electronic public utility register (e-public utility) system is to ensure access to publicly available data of public utilities and trails such as water supply, sewage network construction services. Based on background legislation, organisations operating public utilities are responsible for electrical data providing.

Collected and serviced information connect designers, service providers and population concerned (Figure IV.3.).

Figure IV.3. Water supply network, property management layers about Debrecen, and Agricultural Campus of Debrecen University on WEB based information site[110]

The water-based online data processing system was implemented as a further development of the TESZIR-WEB server module, where the consumers can be informed about maintenance and operational repair work.

National Development and Territorial Development Information System

The National Regional Development and Territorial Information System, which has been in operation since 1998 and contains data about demographic, socio-economic, and built-in, landscape and natural environments. So it provides extremely complex spatial analysis.[1] Additional data sharing contributes and supports sustainable urban water management.

Land Cover Urban Maps

The CORINE Land Cover Urban Map is provided for 2006 and 2012. This vector-based dataset offers comparable land cover and land use classes where population is higher than 100,000. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The European Urban Atlas (Figure IV.4.) provides reliable, inter-comparable, high-resolution land use and land cover data for 800 Functional Urban Area (FUA) for the reference year 2012 in the EU and EFTA countries. The spatial data can be downloaded together with a map for each FUA covered and a report with the metadata for the respective area. Data resource Locator: http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012/view.

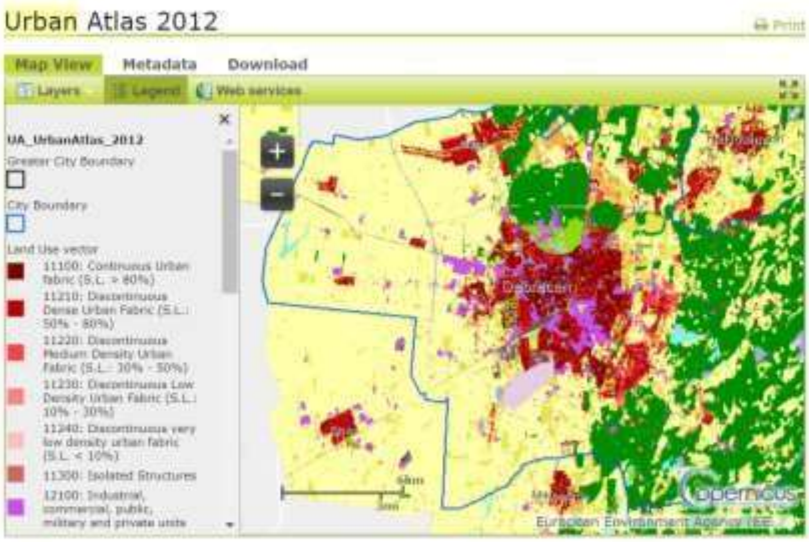


Figure IV.4. Urban map of Debrecen city (Source: Urban Atlas – COPERNICUS EEA)

The Urban Atlas is based especially on the combination of (statistical) image classification and visual interpretation of Very High Resolution (VHR) satellite imagery. Multispectral SPOT 5 & 6 and Formosat-2 pan-sharpened imagery with a 2 to 2.5 m spatial resolution is used as input data. The built-up classes are combined with density information on the level of sealed soil derived from the High Resolution Layer imperviousness to provide more detail in the density of the urban fabric. This information can be converted to hydrological pedotransfer data related to infiltration and runoff by actual or planned urban development plan.
Finally, the Urban Atlas product is complemented and enriched with functional information (road network, services, utilities etc.) using ancillary data sources such as local city maps or online map services. Data accuracy minimum mapping unit: Class 1: 0.25 ha, Class 2- 5: 1 ha and minimum mapping width (for example road) width: 10 m.

Carpatclim – Climate of the Carpathian region

The Climate of the Carpathian Region Project (CARPATCLIM) contributes to the availability of a set of homogeneous and spatially representative data to prepare relevant climate change studies in the region. The main aim of CARPATCLIM is to improve the climate data source and data access in the Carpathian Region for applied regional climatological studies such as a Climate Atlas and/or drought monitoring, to investigate the fine temporal and spatial structure of the climate in the Carpathian Mountains and the Carpathian basin with unified methods. The target area of the project partly includes the territory of the Czech Republic, Slovakia, Poland, the Ukraine, Romania, Serbia, Croatia, Austria and Hungary. 415 climate stations and 904 precipitation stations are used. The CARPATCLIM is a ~10 × 10 km resolution homogenized and gridded dataset on daily scale for basic meteorological variables and several climate indicators, 37 in total, on different time scales from 1961 to 2010.[111]

Sentinel 2 data products in UH

The Global Monitoring for Environment and Security (GMES) programme is a joint initiative of the European Commission (EC) and the European Space Agency (ESA) established a European capacity for the provision and use of monitoring information for environmental and security applications. ESA's role in GMES is to provide the definition and the development of the space and ground-based system elements. The GMES Sentinel-2 mission ensures the continuity of services that rely on multispectral high-resolution optical observations over global terrestrial surfaces. The mission objectives are to provide systematic acquisitions of high resolution multispectral imagery with a high revisit frequency, to ensure the continuity of multispectral imagery provided by the SPOT series of satellites, and to provide observations for the next generation of operational products such as land-cover maps, land-use change detection maps and geophysical variables. Consequently, Sentinel-2 contributes directly to land monitoring, emergency response and security services. Sentinel 2 possesses 13 spectral bands ranging from the visible and near-infrared to the short-wave infrared. The spatial resolution varies from 10 m to 60 m, depending on the spectral band, with a 290 km field of view. This unique combination of high spatial resolution, wide field of view and broad spectral coverage represents a major step forward compared to other multispectral missions. In urban hydrology Sentinel 2 can be used for assessing land cover, land use and land-use change detection maps.[112]

Digital elevation models – Shuttle Radar Topography Mission

The Shuttle Radar Topography Mission produced the most complete, highest resolution digital elevation model of the Earth. The project was a joint endeavor of NASA, the National Geospatial-Intelligence Agency, and the German and Italian Space Agencies. The new data increase the detail to 30-meter (98-foot) pixel spacing, now revealing the full resolution of the world's landforms as originally measured by SRTM. The data aid in better understanding, predicting and responding to runoff, flooding from severe storms and the threats of inundation.[113]

The soil data in UHM

Soil hydrological properties have important role in agronomic and urban hydrologic models, which have wide ranges of application. However the required data on soil hydrological properties to operate these models are often not available or difficult to measure, therefore, are often predicted. Special maps can be used to characterize the water retention of soils. Due to difficulties to prepare soil water retention maps based on direct measurements, it is convenient to estimate these properties from soil map information available, or easy to produce. In Hungary 1:10,000 detailed soil maps are available for more than half of the arable land area. These maps contain categorical (ordinal and nominal) type information on basic physical and chemical soil properties such as organic matter content, texture, calcium carbonate content and pH for non-salt affected soils. These maps also include soil taxonomic information, but lack data on hydrological properties.
The availability of newly developed Hungarian Detailed Soil Hydrophysical Database (Hungarian acronym: MARTHA) makes the investigations possible. The MARTHA database includes both, measured soil water retention information and data on basic soil physical, chemical properties and taxonomic classes, with a rich coverage from diverse soil types and geographical locations of Hungary.[114]

Advanced Urban Structure Measuring – LIDAR

An airborne LIDAR systematically scans from side to side, transmitting a very high density of pulses, and then records the pulse reflections back to the instrument. As the light pulses are received, the sensor records the time required for each pulse to leave, reflect, and return.[115] After the cloud segmentation of all individual objects (trees, house, electricity etc.) can be treated in virtual reality model to evaluate urban hydrological environment (Figure IV.5.).

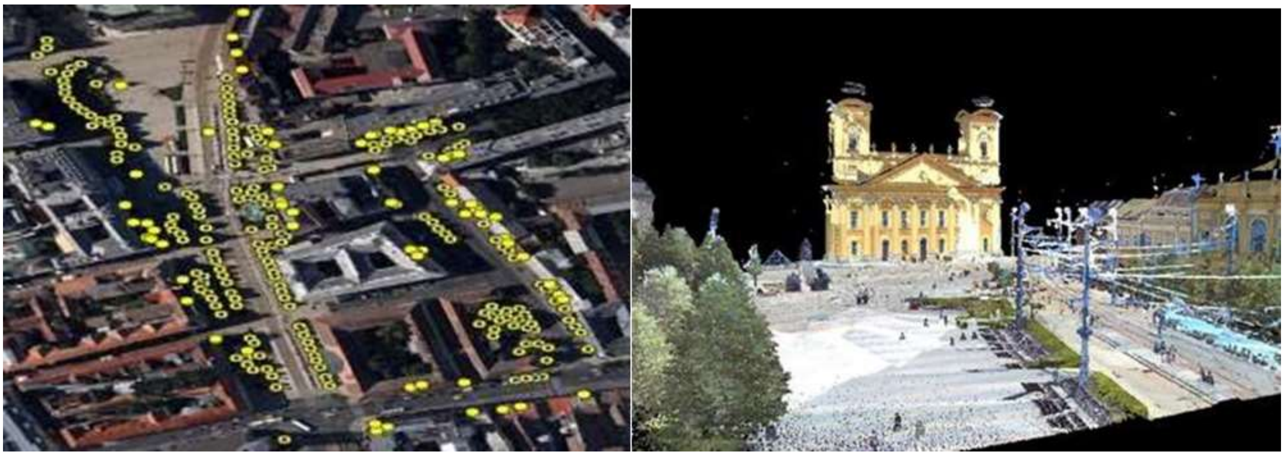


Figure IV. 5. 2D (left) and 3D (right) LIDAR based tree cadaster of Debrecen main square (Photo: Tamas)

The level of detail concept of the OGC standard CityGML 2.0 is intended to differentiate multi-scale representations of semantic 3D city models. The concept is in practice basically used to indicate the geometric detail of a model, primarily of buildings and the important basic input data of Urban Hydrology.[116]
In case of Debrecen, it is done by airborne LIDAR scanning with resolution of 15-20 point/m^2 (Figure IV.9.).

Figure IV.6. 3D Point clouds of Nagyerdő green urban area – left point clouds data, right segmented spatial objects from point clouds: houses, trees (Photo: Tamas)

After processing, it can be seen on the above image that individual objects are well separated and applicable for hydrology modelling. Results are shown in next figure, which covers Great Forest test site (Figure IV.6.).

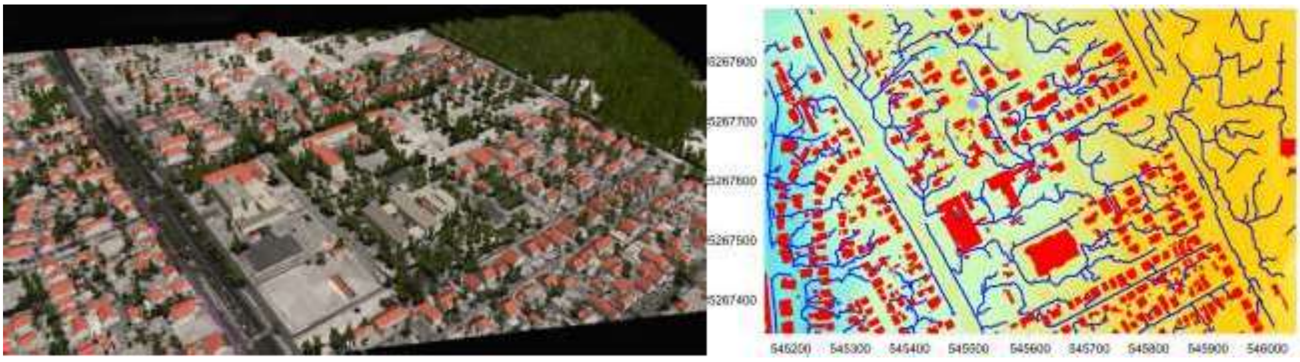


Figure IV.7. Virtual reality model of Nagyerdő pilot area (left image) Run off model of pilot area (right image) (Photo: Tamas)

On above Figure IV.7 on the left, red colour marks the area covered by buildings, local small water basins and their pattern of confluence shown in blue colour. The result of the analyses makes it possible to optimize the placement and the capacity of urban water gullies.

Spatial decision supporting tool in urban water balance modeling

According to the definition of runoff, the basic concept of this part of the study is that runoff is originally derived from the rainfall, notedly it is the water amount which is not infiltrated, evapotransporated or gathered into reservoirs without outlet. In addition, it is important to calculate with water delivered to the surface by human activities (i.e. irrigation) potentially increasing runoff.
The main aim of the present study is not to give the accurate runoff model of a certain area, we were rather focusing on Debrecen and Oradea (see below), but to investigate spatial factors affecting runoff in urban lands. Moreover, the factors can be further differentiated depending on how much they effect runoff that is the strength of the factor. In urban areas this task is even more complex due to various land cover and land use types. Moreover, urban areas are spreading and changing relatively fast.
Modelling the urban water balance enables the understanding of the interactions of water within an urban area and allows better management of water resources. Water supply in urban areas has a strong influence on the available water resources in the urban catchments and vice versa.
Water balance calculations were carried out on the examples of Debrecen and Oradea, both are situated within Tisza Catchment Area. Therefore, precipitation, evaporation, infiltration, drainage characteristics and runoff were studied.
In this part, the concept and the factors, the relevant spatial technological, data mining and data management applications and tools are presented. A Multi Criteria Evaluation method was developed in order to support decision making systems of developers and stakeholders. In addition, this method can be a basis for different scenario (“what if”) future plans, and with integration of archive data trend calculations can be undertaken.
The general model concept we developed to calculate the Urban Water Balance states that runoff can be predicted by (1) estimating the amount of effective evapotranspiration and infiltration, watershed areas and its amount, water intake/outlet from urban water infrastructure system and activities and (2) extracting them from the amount of precipitation (Figure IV.8.).

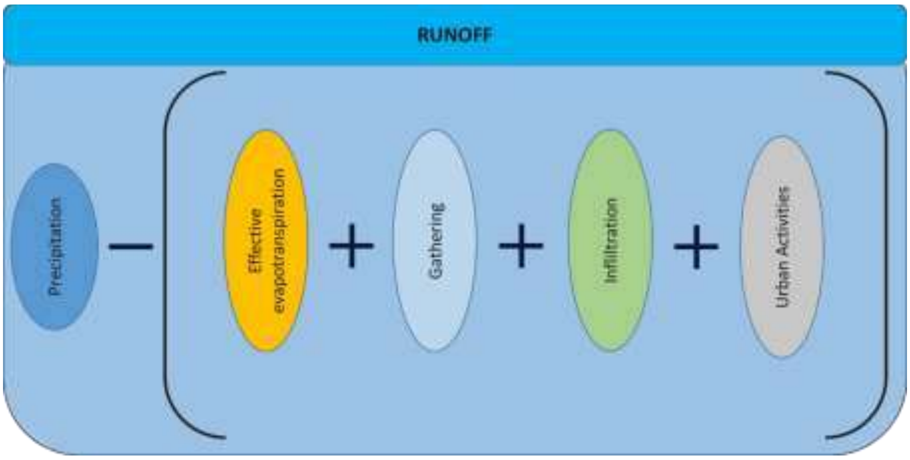


Figure IV.8. General model concept of the Urban Water Balance Calculation

To solve this equation, we have to calculate and at the same time also to spatially define each part of the summation. Therefore, we applied the following dataset types: potential evapotransporation, urban land use, land cover, digital elevation model (DEM), surface water reservoirs without outlet, geology, soil characteristics, groundwater outlet and urban water infrastructure (Figure IV.9.).

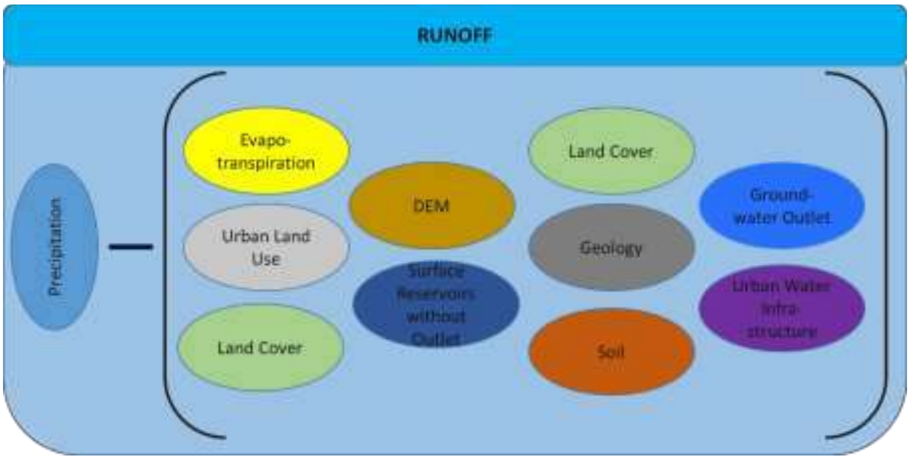


Figure IV.9. Input dataset types of the general model concept of the Urban Water Balance Calculation

Evaporation:

During our calculation to define precipitation and potential evapotranspiration, we downloaded the relevant data from CarpatClim data base (http://www.carpatclim-eu.org/pages/atlas/). In many cases there is greater difference between effective evapotranspiration (EET) and potential evaportrasporation (PET) values, and calculation of EET can be quite complicated by taking into account the land cover and land use properties. (i.e. ratio of vegetation and built up areas) and modification of evapotranspiration values may be advisable. In order to define surface cover features, it may be useful to apply remotely sensed data sets and the related data management tools. In the present study we recommend to use Sentinel2 datasets and to calculate vegetation indices e.g. Normalized Difference Vegetation Index. By having and comparing NDVI values of a certain area at different times (e.g. before vegetation period, middle of vegetation period, after harvesting) we can divide built up areas, arable lands, forests, gardens, tree rows, parks or even roads from each other. After reclassing, areas with high ET values are represented by higher values in the model, while high cover ratio means lower values. Place of intense water release to surface represents high values.

Gathering:

Gathering of surface water is strongly related to topography. For this reason DEM of study area was created based on the SRTM by clipping with the target area based on which, slope map, watershed division map, surface water flow direction map can be generated (Figure IV.10.).

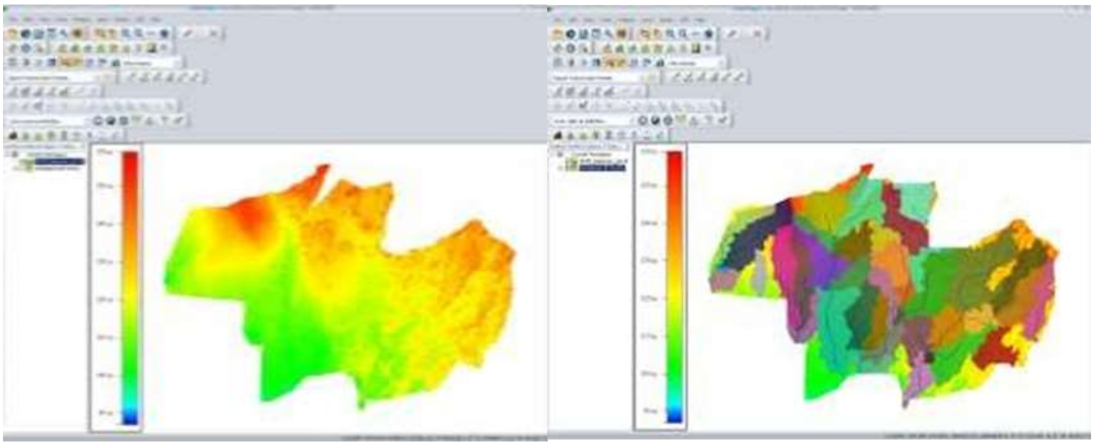


Figure IV.10. SRTM and watershed generation in GlobalMapper software environment (Photo: Bodi)

Surface water bodies without outlets have a special role in urban water balance calculations. These surface water bodies are actual reservoirs storing water and in addition, these areas have an effect on

evapotranspiration. Moreover, they are not only water resources but also can be involved in water management actively, in case of both extreme water loss (e.g. drought) and water surplus (e.g. storm water, snow melting). Therefore, in runoff models these areas should be handled specifically in decision making processes.
Consequently, high slope angle means lower ratio in the model and surface water reservoirs are represented by high values.

Infiltration:
For infiltration calculations geological and soil properties are required as basic input data.
While geological characteristics cannot be changed easily, soil characteristics, especially in urban environments, are usually modified due to landscaping and constructions resulting in new soil characteristics and new soil types i.e. urbanosoil, technosoil. These are seldom described on soil maps and their hydrologic properties cannot be defined easily due to the fact that these soils are a mixture of different materials. They mean difficulty on infiltration calculations in uncovered urban, areas where potentially infiltration can happen. However, since we have had no opportunity so far to map our study areas, the modified soil characteristics are not implemented into it. In our model examples four categories were created: zones with infiltration coefficient values of 5 %, 10 %, 15 % and 20 %. For example, saline and silt, clayey areas have low infiltration characteristics, loess and sand have higher (Table IV.4.).

Table IV.4. Estimated infiltration coefficiency values of the listed soil physic types

Soil type	Infiltration coeff. (%)
loess	15
loess, silt	10
sand, silt	15
silt, loess	10
sand	20
silt	10
lime silt	10
saline	5
sand, silt clay	10
silt, clay	5

Regarding the infiltration, it is important to highlight that fine dust transferred originally by wind but also by water, can modify infiltration properties of an area because where a thin layer of fine graded material is sedimented as a fine aquitard crust, infiltration decreases. Compaction of soil, caused by transportation, landscaping etc., has also decreasing effect on infiltration since due to compaction effective porosity of soil, material decreases.
Defining cover type and land cover ratio of a certain area is crucial since built-up covered areas, which is the most decisive feature of urban area, show wide spatial heterogeneity. Even within one type, greater differences can be measured. For instance, residential areas built up from high block houses and residential areas with gardens differ from each other from hydrological aspects as well very much. In the first case lower infiltration is expected.
Applying NDVI maps can be useful to estimate cover type of urban areas. It is quite popular and well-known and applied index, in this study calculated the data from Sentinel 2. On the example of Debrecen we can

distinguish covered areas by calculation the difference between NDVI values of February and May (2018) in Debrecen and according to our interpretation where within the inner areas of the city there is a low change between February and May and most likely covered surfaces are to be built up (Figure IV.11.). In outer areas of Debrecen where the difference is high (western parts), arable land is in the beginning of the vegetation period (e.g. maize fields).

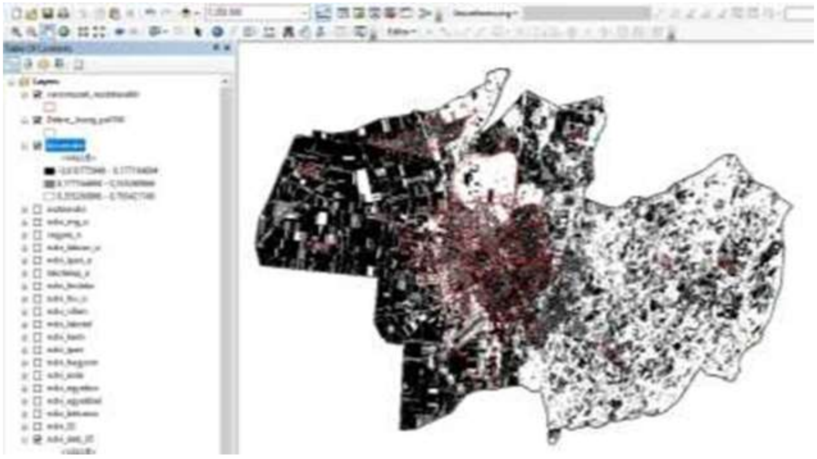


Figure IV.11. Difference between NDVI values of February and May (2018) in Debrecen (black color represents lower differences, white color represents greater differences) (Photo: Galya)

High cover ratio means low values in model running. Areas where the soil and bedrock features have high infiltration and high hydraulic conductivity properties, are reclassed with higher values in the model.

Urban activities:

There are different human activities affecting water balance of urban areas both, directly and indirectly. During some specific human activities related to specific land use types, we can count with significant amount of water surplus (e.g. irrigation and watering from groundwater reservoir, thermal water extraction and utilization). Not all these sources can be defined accurately, but most of them can be estimated by detection of the areas where these activities occur, for instance in the suburbs using the water exploited by smaller pumps from the shallow groundwater aquifers. By this activity, vegetation, evaporation, soil moisture content, soil chemistry and hydrologic properties of the blocks above the first aquitard layer are modified. This is difficult to implement to a model, but this factor should be considered.

Structure and technical condition of the urban water infrastructure, which traditionally comprise drinking water system, sewage network, rainfall drainage system and waste water treatment, has an influence on urban water system.

Artificial gathering methods by rainfall drainage system decrease runoff, therefore, these areas are represented by higher values in the model, while areas where water is outlet to the surface, are given lower values. It is important to mention that there are more and more losses in urban water infrastructures over time in form of slower leakage or intense water loss due to breaking the pipes. This amount of water can increase runoff.

In case of Oradea, the complex model comprises as seen on Figure IV.12. Input datasets and the main steps of data processes (clippings, rater calculations, reclassings, etc.) are described.

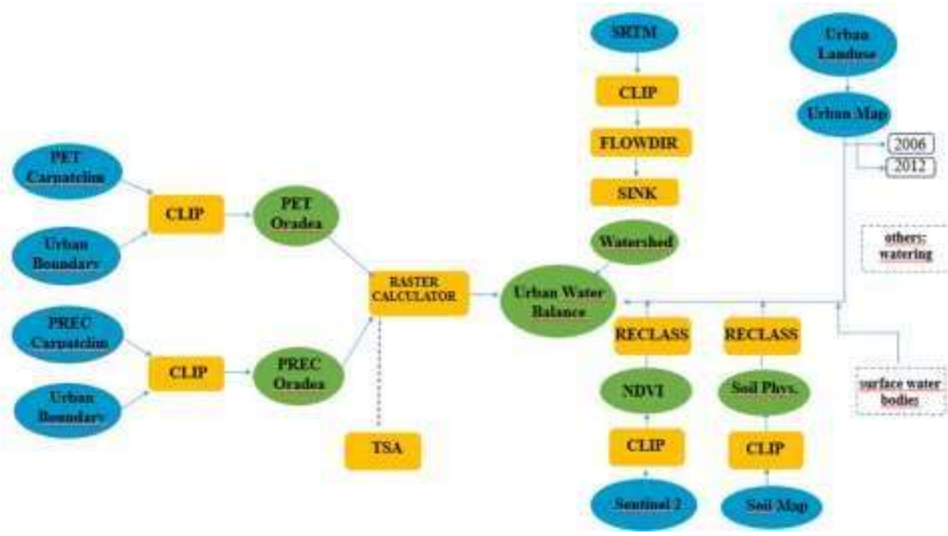


Figure IV.12. Applied model detailed for Oradea (Photo: Galya)

Closing Message

Having adequate and deliberate models is very important in sustainable water management considering the almost unpredictable changing environmental conditions and social requirements of the last decades and the future, as we saw it and as it is expected, respectively. By applying the presented modelling methods, water balance can be estimated within certain watersheds, urban areas (whether for entire cities or for smaller scale e.g. for districts) ensuring adaptability to the changes mentioned above.

Based on such estimation studies and development plans can be carried out to achieve a more integrated and conscious resource and waste management related to water helping for city administrations, developers and stakeholders in their decision processes.

Although spatial resolution of the macro and meso scale databases is usually low, using them to define spatial factors can be advantageous in case of regional models and from the aspect of comparability. It is important to note that reliability of the applied model is strongly affected by data quality and success of data harmonization. However, there are regions where not all of the applied datasets are available (or having inadequate quality), or the mentioned factors have different strength in the decision support process simply due to the area's properties, thus we can declare that the presented method can be a good example or a starting base, but not the only solution.

5. Summary

Involvement of stakeholders is indispensable in the optimization of local and urban water management opportunities in the future in a more extensive way without considerably hindering the decision-making processes. In the decision-making process, the significant risk and uncertainty of the climate change must also be taken into consideration. It is easy to accept that urban water catchments successfully meet the requirements of the Water Framework Directive. Urban water management will contribute greatly to the decrease of the existing problems of the entire river basin, such as point pollution, organic matter, nitrogen and phosphorus inputs.
To achieve integrated solutions the followings are recommended to be involved:

1. Institutional integration in the planning. Integrated urban water management requires holistic, integrated approach to fill the gap between urban planning and water management and even between different water sectors, to understand the different interests, aspects of water planners in a city. Out of several tools, the Share Vision Planning process uses in US and fits to 'open planning' applied by EU WFD, and seems to be appropriate for the development and implementation of a flexible strategy that holistically considers all areas of the urban water cycle and assures its linkages to other urban management sectors.
2. Diverse solutions (technological and ecological) and new management strategies are recommended to encourage coordinated decisions between water management, urban design and landscape architecture. Application of *green infrastructure* including soils, vegetation and other natural systems is favourable for urban ecosystems especially in the case of Oradea. Development of urban green infrastructure can enhance not only the urban landscape and natural habitats providing recreational opportunities, but also can mitigate the effect of CC and reducing the adverse effect of urban heat island. Options to *reduce water demand* – especially in cities with no significant surface water bodies, such as Debrecen –, and providing alternative sources, harvest rainwater and reclaim waste water (e.g. pollution control at the source and natural pre-treatment techniques) are suggested to be given priority as new resources. Storm water should be considered as a resource that *can be harvested for water supply* and retained to recharge aquifers, feed waterways and biodiversity with water. Human *waste water* can also be identified as a *potential resource* for energy generation and nutrient recycling. Grey and black water is more favourable to collect separately and manage close to the source and locally reuse the treated effluent for non-potable water supply purposes (industrial, irrigation, etc.). Efforts are needed to provide water of potable quality only for uses that require it. Leakage detection and repair complex thinking on leakage reduction using best technologies are desirable in both cities taking into consideration the economic, social and environmental factors. It is also an option to charge users based on tariff systems that account for different volumes of use, purpose of use, season, etc. Application of smart metering, raising awareness of water management can also help in demand reduction.
3. In future scenarios uncertain the environmental and social aspects, and CC is also suggested to concern. Future water demand is also recommended to forecast for analysing the future end- uses in different sectors and should be calculated with their uncertainties. Urban hydrology analyses can be fostered by precise digital urban models in 2D and 3D. Though spatial uncertainty and decision rules in urban hydrology need to be addressed. Remote sensing technologies (spectral image processing) are able to cover large urban areas at very preferable price and provide a quick solution for an area. Products processing can be partly or entirely automated, made by these remote sensing methods. Disadvantage of them is that the interpretation requires more time and professional knowledge.

4. In the future, more efforts would be needed and the work shall be done to implement an integrated UWM according to country-based specifications which are harmonized with local organizational and legislative background on the language of the given country in order to find the best fit of IUWM in urban planning and decisions in all TRB countries.

Abbreviations

AHP	Analytic Hierarchy Process
AICR	Other relevant chemical indicators: phenols, detergents, AOX
ALADIN	Aire Limitée Adaptation dynamique Développement InterNational
CGPP	co-generation power plant
CH	hydrocarbon
COD	Chemical Oxygen Demand
CR	consistency ratio
DEM	digital elevation model
DST	Decision Support Tool
EC	European Commission
EET	effective evapotranspiration
EFTA	European Free Trade Association
EO	earth observation
ERDF	European Regional Development Found
ESA	European Space Agency
EU	European Union
EU ETS	EU emissions trading system
FUA	Functional Urban Area
GIS	geographical information system
GMES	Global Monitoring for Environment and Security
HDI	Hungarian Drought Index
HTVR	Hajdúhátság Multipurpose Water System
HWSP	Hungarian Water Safety Plan
IDF	Intensity-duration-frequency
KJT	Kvassay Jenő Plan
LIDAR	Light Detection and Ranging
MÁV	Hungarian State Railways
MCA	multi-criteria analyses
MODIS	Moderate Resolution Imaging Spectroradiometer
NAMR	National Agency for Mineral Resources
NDGDM	National Directorate General for Disaster Management
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
NPHMOS	National Public Health and Medical Officer Service
NUT	Nomenclature of territorial unit
NUTR	nutrient regime
OGC	Open Geospatial Consortium
OHP	One Hour Precipitation
OMSZ	National Weather Service (Hungarian)
PET	potential evapotranspiration
PRM	Preventive Drinking Water Risk Management
PTSON	natural specific pollutants
REMO	Regional Climate Model
RO	oxygen regime
RS	remote sensing
RTA	thermal regime and acidification

SAL	degree of mineralization (salinity)
SIMIN	National Integrated Meteorological System
SPOT	Satellite Pour l'Observation de la Terre
STP	Storm Total Precipitation
SULD	Sustainable Urbanizing Landscape Development
SVP	Shared Vision Planning
THP	Three Hours Precipitation
UHI	Urban Heat Island
UHM	urban hydrology management
VHR	Very High Resolution
WHO	World Health Organization
WSP	Water Safety Plans
WTP	Water Treatment Plants
WWTP	Waste Water Treatment Plant
ZMO	Zona Metropolitană Oradea

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To find proper and the most relevant studies on these topics, various search engines were used, in particular Google Scholar, Digital libraries of ScienceDirect, SpringerLink, ResearchGate, Open Access. Each list of references was also thoroughly examined for every study that proved to be a useful material for this urban hydrology literature practise and research oriented paper.

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