

OSIJEK WASTEWATER NETWORK – OBSERVATIONS AND RAINFALL CHARACTERISTICS

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Osijek is the largest city in the eastern Croatian lowland region of Slavonia. Some specific stages have been observed in the development of its wastewater network. Over the past decade, a system of urban conglomerates has been established from a simple wastewater network. The basic concept and design elements of the wastewater network are based on characteristics of the local rainfall. Also, extreme rainfall events are particularly interesting for the system efficiency and management capabilities. Because of that, observations of rainfall events began at the end of the last century at five locations, with an automatic rain gauge. This paper presents rainfall measuring and certain problems in its implementation. The preliminary analysis of registered rainfall events indicates their characteristics. The analysis of the extreme rainfall events during the fifteen-year research season (1999–2013) reported in a form of one-minute rainfall events indicates a significant change in this century. Rain gauges recorded short-term rainfall events with amounts equal to the range of average monthly values. Finally, the paper points out the necessity of a more detailed analysis of rainfall events in the Osijek area because of urban flooding risks that could be mitigated by establishing a real time control system.

KEY WORDS: wastewater network, rainfall spatial distribution, extreme rainfall events, rainfall gauge, rainfall monitoring

SIEŤ ODPADOVÝCH VÔD V OSIJEKU – POZOROVANIE A CHARAKTERISTIKY ZRÁŽOK. Osijek je najväčšie mesto nížnej oblasti Slavónska na východe Chorvátska. V rozvoji siete odpadových vôd sa zistili niektoré špecifické etapy. V priebehu posledného desaťročia sa z jednoduchej siete odpadových vôd vytvoril systém mestských konglomerátov. Základná koncepcia a konštrukčné prvky siete odpadových vôd sú založené na charakteristikách miestnych zrážok. Tiež extrémne dažďové udalosti sú obzvlášť zaujímavé pre efektivitu a riadenie systémov. Z tohto dôvodu sa koncom minulého storočia začali realizovať pozorovania zrážkových udalostí na piatich automatických zrážkomerných staniciach. V článku je prezentované meranie zrážok a určité problémy pri jeho implementácii. V predbežnej analýze zaznamenaných zrážkových udalostí sú uvedené ich charakteristiky. Analýza extrémnych zrážkových udalostí počas pätnásťročného skúmaného obdobia (1999 – 2013), ktorá sa uvádzajú vo forme jedno-minútových zrážok, naznačuje významnú zmenu v tomto storočí. Zrážkomerné stanice zaznamenali krátkodobé udalosti zrážok s množstvami rovnajúcimi sa rozsahu priemerných mesačných hodnôt. Nakoniec dokument poukazuje na potrebu podrobnejšej analýzy udalostí zrážok v oblasti Osijeku z dôvodu rizík v mestách, ktoré by mohli byť zmiernené zavedením systému riadenia v reálnom čase.

KLÚČOVÉ SLOVÁ: sieť odpadových vôd, priestorové rozloženie zrážok, extrémne zrážkové udalosti, zrážkomerná stanica, monitorovanie zrážok

Introduce

One of the key features of development of urban centres is the state and the level of development of their wastewater networks. It is conditioned by topography; way of life and standard of population; industrial development, wider social relations, as well as by

climatic characteristics. Each environment has its own specifications, and the experience gained in each particular system can be useful for troubleshooting other wastewater networks.

The success of the wastewater network engineering solutions depends on the data quality of the rainfall in an area. The quality solutions are impossible without

data measuring. The measuring has to be theoretically well organized, properly and carried out continuously, and adjusted to the engineering needs.

The problems caused by heavy rain (i. e. intense rainfall event of a short duration) are more dangerous and harmful and, therefore, in the main focus of hydrologic interests in the engineering practices. These are intense rainfalls, mainly of a short duration from 10 minutes to 2 hours, which can therefore be measured only by automatic rain gauges. In order to get a good perception of the internal heavy rain structure (i. e. time and space, distribution intensity on the urban area), it is necessary to have automatic rain gauges with short intervals recording (5 minutes and shorter), and a dense network of their placing (approximately one instrument per couple of km²). Due to the fact that wastewater network expands over time; the network of rain gauges has to be expanded, too.

Material and methods

Osijek wastewater network

Osijek is the fourth largest city in Croatia and, the largest economic and cultural centre of the eastern Croatian region of Slavonia, as well as the administrative centre of Osijek – Baranja County. The city is located on the right bank of the River Drava, between river kilometre 16 and 25, upstream of the River Drava mouth into the Danube River. The current wastewater network covers the Osijek city area, municipality of Antunovac; southern Baranja area; municipality of

Čepin. The system is continually expanding and the final coverage will be reached within a few years, and will be directed to the single discharge point.

The system consists of the old, northern sewer main (6.633 m long) and the new, southern sewer main (12.746 m). Sewer mains are extended east to west and collect water from multiple mains located north to south. Sewer mains drain the wastewater east to the outlet in Nemetin. This location is also foreseen for the construction of a wastewater treatment plant. (Fig. 1) The northern sewer main was built in the last century, in the period from 1912 to 1914. The implementation of a large infrastructure project encompassing the construction of a new and the rehabilitation of the existing, northern sewer main started in 2014. At the northern sewer main were eight combined sewer overflows (CSO). Two of them, were removed during reconstruction in 2016. The construction of the southern sewer main lasted for 37 years, between 1969 and 2006. Once constructed, the southern sewer main substantially burdened the northern one. In addition to the southern and western part of the city of Osijek, suburban settlements located south and west of the city are also connected to the southern sewer main. The northern sewer main connects to the southern one in the east of Osijek, and the connecting pipe has been constructed since 1988. Regardless of the construction of the southern sewer main, the northern sewer main is still significantly hydraulically overloaded, primarily during the heavy rainfall events, once storm overflows are activated.

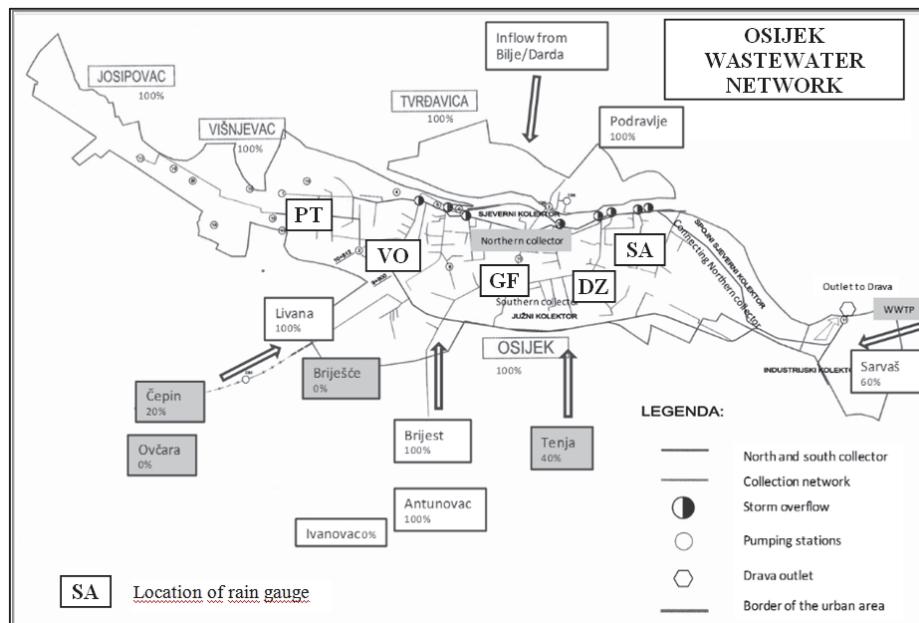


Fig. 1. Osijek wastewater network with locations of collector sewer (Northern and Southern), connection rate and approximately locations of rain gauges.

Obr. 1. Sieť odpadových vôd v Osijeku s miestami zbernej kanalizácie (severná a južná), rýchlosť pripojenia a približné polohy zrážkomerných stanic.

Wastewater treatment plant will have the capacity of 170,000 PE (population equivalents), and will have the third stage of wastewater treatment. The construction of WWTP has started in 2016, and should be completed by next year.

The Osijek wastewater network today comprises 370 km, 98 pumping stations and one discharge point (except combined sewer overflows) with a mechanical, rough bar screens. The wastewater is discharged into the Drava River at rkm 11 + 500. The wastewater network is partially combined (54%), and partially separated (46%). The inner part of the city is mainly covered by the combined system, while more recently connected areas, including the suburban settlements, are covered by the separate system. The southern sewer main mostly concerns a separate part of the network, while the old, northern sewer main concerns most of the combined part of the network. The Osijek wastewater network which includes the catchment area of the northern sewer main currently covers approximately 1050 ha. The inner city of Osijek is covered by the wastewater network almost 100%, while the coverage of suburban areas varies. (Fig. 1) The Osijek wastewater network, which includes the catchment area of the northern sewer main, currently covers most of the Osijek city area and the settlements Podravlje and Tvrđavica.

The big problem of the existing wastewater network of Osijek is its significant filling with sediment deposits. There are significant amounts of sediments along the entire northern sewer main line. The average height of the sediment filling (because of low sewer slope) in the northern sewer main is 45 cm, within the limit value range of 30 to 90 cm. Large amounts of sediment deposits are also present in the combined sewer overflows, resulting in overflowing of certain quantities of dry weather flows (domestic wastewater). This fact points out the sanitary and ecological unsustainability of the existing operational state of the northern sewer main with the associated catchment area.

Rainfall observation and related problems in Osijek

One of the activities conducted for the purpose of development projects of the Osijek wastewater network was monitoring of rainfall and flow (water level, velocity and geometry) in the drainage system. The Faculty of Civil Engineering from Osijek was chosen for that activity as a sub-performer. What was going to be measured, where and how was agreed with all for the project relevant clients.

By that occasion, the rain gauge network inside the city has been established first. It consisted of five automatic rain gauges. They were distributed along the city zone according to the placement options, secure operation conditions and the existing state of water gathered by the wastewater network. The distribution of locations of the rainfall observations in the city of Osijek can be seen in the Fig. 1. Digital rain gauges – rain gauges are

characterized by automatic work and continuous measuring. They enable the collecting of data about rainfall quantity in space and time. The used rain gauges digitally record time and growth of the total rainfall event in a form of rainfall impulses resolution from 0,1mm (volume of the measuring "buckets" mounted on a fulcrum, balanced like a see-saw).

The measuring was at first planned in duration of four months (only to connect rainfall, drainage and discharge in the wastewater network), but afterwards it was agreed to continue with measuring. In this paper we are presenting only some of gathered data analysis for the fifteen-year observation period, made with purpose to establish a space and time rainfall distribution over the city area. The analysed period includes the wet season (April-December), which is, in principle, used for the heavy rain analysis (Bonacci, 1994).

Basically this presents a rainfall data collection gathered at five locations along the city of Osijek in the period 1999-2013. These data are also complemented by other sequences (from other locations) in order to include a couple of the subsequent, in hydrological sense interesting years. The reason for this is the interruption of measuring at the starting, basic locations, but also the attempt to use and compare some other available data.

The measuring first started at two sites (marked as SA and GF), with the intention to gain experience in collecting and processing data on local rainfall and their properties. Soon after, three more locations (DZ, VO and PE) have been added in the framework of other hydrological measuring on the wastewater network of the city. As the main official rainfall measuring site of the National Hydro Meteorological Institute (DHMZ), Osijek-Čepin, and the new Osijek-Klisa and Osijek-Tvrđavica are located close to the city, our respective measuring covered the inner zone of the city.

Electronic rain gauges – ombrographs (SEBA Hydrometrie type RG-50) were installed for measuring purposes. They are characterized by automatic work, continuous measuring and simple connection to automatic data loggers (e.g. RDS-2). They enable the collecting of data about rainfall quantity in space and time. The basic parts of the measuring device (Fig. 2) are: aluminium housing, orifice – plastics hopper with collecting area of 200 cm², tipping bucket rain gauge sensor with resolution of 0,1 mm, impulse sensors and time memory. Instruments are not equipped with a funnel heating system, because the subject of the research was heavy rain which was not characteristic for the winter period. Therefore, during the cold winter months there were interruptions of measuring. That is the reason why we have some interruptions in measuring during the winter and cold months. The communication with the measuring instruments, memory and data reading, were done by a laptop.

When choosing a location for instrument setup, we tried to find spots not exposed to people's curiosity and possible impacts on measuring, or damages.

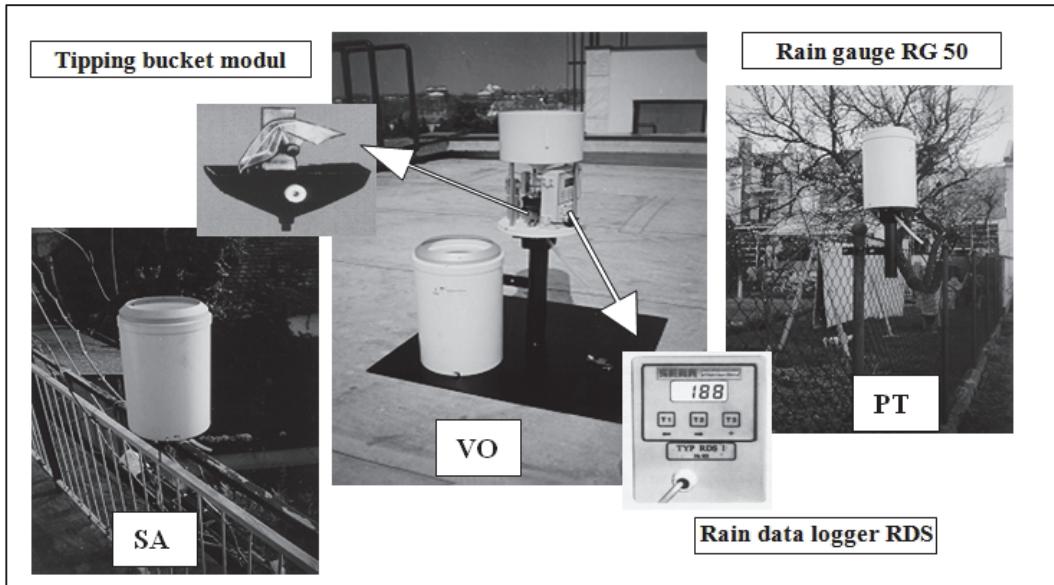


Fig. 2. Some tipping bucket rain gauge stations with in Osijek area (Patrčević et al, 2002).
Obr. 2. Niektoré stanice na meranie množstva zrážok v oblasti Osijeku (Patrčević et al, 2002).

Thus, two private houses (a terrace and a backyard) of public utilities employees, flat roofs of two public facilities (Dom zdravljia–DZ and Vodovod–VO) and a college skylight (at the Faculty of Civil Engineering, Drinska Street–GF) were selected. Besides benefits, there were also disadvantages, such as accessibility. In some cases it was necessary to announce the visit ahead and to be granted an access; sometimes the access was possible only with a help of a janitor, or an owner; and somewhere the access was hardly possible due to construction work on the spot. Surprisingly enough, during the measuring period, both flat roofs selected were subject to repair of the roof insulation; and the auxiliary storage facility was constructed just next to the backyard and a fence pole on which the rain gauge was set. It remains unknown to what extent have those facts effected the operation of instruments; at one of the roofs the instrument's base was wrapped into the said insulation, while on the other the equipment was being moved around. The warehouse roof was constructed too close to the instrument in terms of being sprinkled by rebound rain drops. The owners of private houses, who were interested in measuring, sold their properties so the new owners had to be convinced to cooperate in this matter. Thus, some instruments were not subject to a frequent, let alone a daily control. Occasionally, the rain gauges were found to be "clogged", whether the insects in the drought period occupied the drain hole of the funnel, or a seed, or other particle in the size of a drain hole; also there might have been an accumulation of compacted impurities (dust, airborne waste, etc.).

Calibration of instruments and commissioning was carried out every year, more than ones. Good batteries

and timer settings were essential at the start of each year. It takes skill to adjust timer, to each other and to the reference one. There were no settings to the winter/summer daylight saving time. Also, time periods set at the beginning of annual measuring and time synchronization were retained. This is what has to be considered when comparing these data to others, from different sources.

On some occasions, instruments were operating while the temperatures went down to a low level. Sometimes they were not shut down at the right moment, or properly protected, so there was freezing in the funnel, which consequently led to damage. The long-term exposure to atmospheric conditions has contributed to rupturing of plastic funnels, which then needed to be replaced by new ones or, appropriately patched. Fortunately, there were no other types of physical damage (to a protective casing or inner equipment). However, it can be noted that such damages are possible due to a sudden impact of a dropped down unidentified object, or an act of vandalism.

Data retrieval is done by using special software and it is possible in two forms, binary or numeric. The data retrieved in such a manner may be studied and processed into different standard forms (10-minute, 30-minute, hourly, daily, etc.). For this purpose, a laptop has been in use between 1998 and the end of 2002. It happened once that the data could not be read from RDS, so it was subject to a service check during a period of several days). After that, RDSs were read simply by downloading them by means of another (desk top) computer. Due to such unfortunate circumstances, and the loss of the first laptop, what was left were only the data

collected between 1998 and 2002, in a form of 5-minute rainfall. Unfortunately, the Faculty of Civil Engineering is no longer in possession of the old software for data processing, so the data collected after 2002 are available in numerical form, as they have been recorded. Such circumstances hampered the analysis of severe rainfall presented further in the text.

As outlined above, numerous circumstances influenced the collection of data on rainfall and, especially at the beginning; the staff of the Faculty were not well skilled in this activity so that the measuring and data collected additionally suffered from shortcomings that should be warned about. Therefore, getting acquainted with the potential problems occurring in the process of rainfall monitoring is set as an objective of this paper.

Among the recorded data, it is possible to notice the rare occurrence of double impulses or, timely very close (impossible) impulses. These are data generated during periods of low, mostly winter temperatures. Such data, considered as uncertain, should be excluded from the analysis.

Results and discussion

Collected data do not cover the entire calendar year, missing data concern periods of low temperatures (in winter); and particular moments of undesirable individual interruptions (most often due to clogging). Thus, during the measuring periods the data have not

always been collected at all locations. Even though, a respectable database was created encompassing the data from five model locations situated within the inner city and covered by the wastewater network. These data have surely included a large number of interesting showers which occurred in Osijek and overloaded a combined wastewater network during the 15-year period (from 1998 to 2013). At one of the locations (GF), measuring has been continued even in years to come, allowing a comparison with some other data from the surrounding metering locations. Only the most intense rainfall events were selected for the respective analysis. In this view, comparisons of 1-minute rainfall in real time were made. It can be seen that it is always about an individual, short rain event, lasting between approx. 10-15 minutes to 30-40 minutes. Some showers occurred separately, covering only a part of the city, and some affected the entire city, but with a very different intensity. During the period covered, records showed 107 such intense, single rainfall events, resulting in 230 location-specific records. It is about the rainfall events which 10-minute continuous duration resulted in at least 5 mm water depth (5 l.m^{-2}). This rainfall has been chosen since the reference literature marks it as the lower threshold rainfall, and implies secondary treatment (Table 1). The number of recorded short-term rainfall exceeding certain rainfall levels is shown in Table 2. Table 3 shows the maximum recorded rainfall events in the fifteen-year period.

Table 1. Heavy rain (storm) according to the practice in Croatia (Bonacci, 1994)

Tabuľka 1. Silný dážď (búrka) podľa postupu používaného v Chorvátsku (Bonacci, 1994)

Duration of rainfall event T (min)	The lower threshold rainfall		
	H (mm)	I (mm.min ⁻¹)	I (L.s ⁻¹ .ha ⁻¹)
10	5.4	0.54	90
20	7.4	0.37	62
30	8.4	0.28	47
40	9.0	0.225	37
50	9.6	0.192	32
60	10.5	0.175	29
120	12.0	0.1	17

Table 2. Observed rainfalls and a number of rainfall events exceeding the rainfall depth

Tabuľka 2. Pozorované zrážky a počet zrážkových udalostí presahujúcich vodný stĺpec

Duration of rainfall event	Rainfall depth (mm)	Number of rainfall event
10 min rainfall	5	107
	10	84
	11	69
	13	36
	15	22
	19	6

Table 3. Twenty maximum recorded extreme rainfall events in Osijek area**Tabuľka 3.** Dvadsať najväčších extrémnych zrážkových udalostí zaznamenaných v oblasti Osijeku

Nº	Year	Data	Hour	mm/10 min	Location
1	2013	11.05.	16	27.2	GF
2	2014	29.04.	14	24	GF
3	2010	21.06.	14	21.6	SA
4	2010	06.08.	20	20.7	DZ
5	2011	30.06.	14	20.1	DZ
6	2008	30.06.	12	19.3	VO
7	2013	11.05.	15	19	VO
8	2002	28.05.	16	18.7	PT
9	2007	17.06.	12	17.9	DZ
10	2007	10.08.	18	17.2	DZ
11	2007	10.08.	18	17.1	SA
12	2005	01.07.	19	17.1	PT
13	2002	14.07.	19	17	DZ
14	1999	04.06.	17	16.7	VO
15	2001	16.07.	19	16.7	DZ
16	1999	04.06.	17	16.6	PT
17	2002	14.07.	19	16.5	SA
18	2010	21.06.	14	16.3	SA
19	2003	04.07.	17	16.1	SA
20	2013	22.06.	23	15.9	VO

As shown in Table 3, the largest recorded short-term rainfall occurred on May 11, 2013 at GF site and was 27.2 mm (L.m^{-2}). This is also confirmed by newspaper articles issued on days around that date, focusing on the extent and consequences of that storm. The DHMZ's Annual Bulletin (Nikolić, 2013) stated that this particular storm resulted in rainfall that exceeded the 100-year 10-minute rainfall in Osijek. This event recorded at five locations, are shown in Fig. 3, where it can be seen that the shower lasted for 20 minutes. Contrary to that, the sixth (Table 3) rainfall is recorded only at the VO location (Fig. 4), while, for example the fifth recorded rainfall on the list (Table 3) occurred only in the eastern part of the city (Fig. 5). The time synchronization of events recorded at different locations should be considered with a certain reserve because the timers were not always most accurately synchronized (They differed in "several" minutes).

The data certainly point out the size of the rains and their hydrographical forms. What is interesting is the comparison with values determined according to various IDF curves. The traditional design of an urban storm drainage system is based on the storm intensity, which is estimated from Intensity-Duration-Frequency relations (IDF curves) based on historical rainfall data. One of the IDF curves applied to Osijek was based on data from the period 1957-1978; and the other was

based on the data from the period 1959-1991; in addition to the well-known data from the engineering practice, but also the one from the reference literature (Radonić, 2003). Essential values are shown in Table 4. In accordance with them, the limit values of 10-minute rain have been selected: in the amount of 5 mm (1-year return period, RP), 10 mm (about 2-year RP), 11 mm (RP 3-year) 13 mm (5-year RP), 15 mm (for 5-10-year RP) and 19 mm (for > 10-year RP). It can be stated that the urban wastewater network has experienced a much larger number of strong showers than it is indicated by the IDF ratios established so far. During the observed 15 years, there were 6 rainfall events in the city whose PP is assessed as a 10-year one, and 22 events should be of a 5-10-year return period. This should be taken into account in future engineering practice. This indicates a change in the IDF curve and the climate change that reflect the rainfall intensity many authors have already referred to (Cindrić, 2014; Hogg, 2010).

It is also necessary to be in possession and be able to analyse of 1-minute rainfall data. If the data are processed as 5-minute (or 10-minute) the differences may be significant, depending which of 5 or 10 minute interval are analyzed. The result of the maximum rainfall event analysis on Osijek area has shown that the result may vary to the large extent, for 10-minute event from 20.9 mm to 27.2 mm (Table 5).

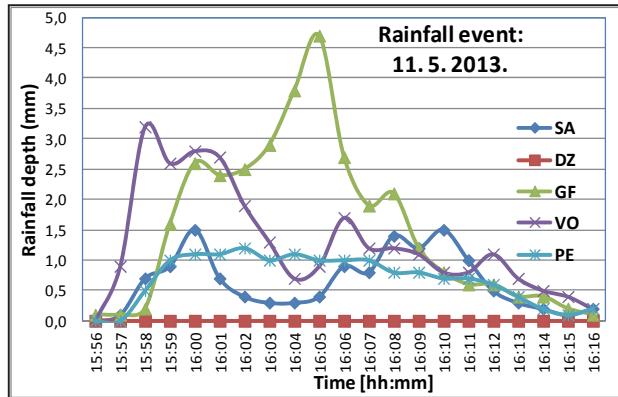


Fig. 3. Maximum rainfall event recorded in the city of Osijek in research period (1999–2013).

Obr. 3. Maximálne zrážky zaznamenané v Osijeku v skúmanom období (1999 – 2013).

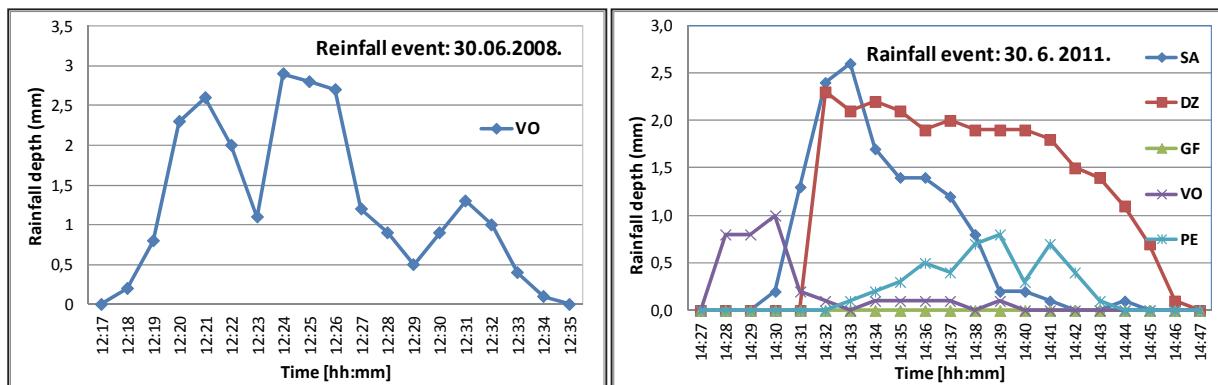


Fig. 4. Maximum rainfall event measured at one location in the city of Osijek – Vodovod (VO).

Obr. 4. Maximálne zrážky namerané na jednej lokalite v Osijeku – Vodovod (VO).

Fig. 5. Rainfall event measured in the eastern part of the city of Osijek.

Obr. 5. Zrážky namerané na východnej časti Osijeku.

Table 4. Characteristic values from the current IDF curves
Tabuľka 4. Hodnoty charakteristík z aktuálnych IDF kriviek

	DURATION			
	5 min		10 min	
	IDF CURVES (1957 - 1978)		IDF CURVES (1959 - 1991)	
	$l.s^{-1}.ha^{-1}$	mm/10min	$l.s^{-1}.ha^{-1}$	mm/15min
2-year	175	10.9	150	13.9
5-year	250	15	220	19.8
10-year	320	19.2	270	24.3
IDF CURVES (1959 - 1991)				
1-year	88	5.3	72	6.5
2-year	155	9.3	127	11.4
3-year	182	10.8	150	13.5
5-year	213	12.8	175	15.8
10-year	263	15.8	225	20.3
Recommendation for dimensioning - the Public Utility Company (Vodovod Osijek, 2015)				
5-year			188.93	17.0
Recommendations for dimensioning from literature sources (Radonić, 2003)				
5-year	245.0	7.35		

Table 5. Possibilities to choose data from rainfall database 11.05.2013. – Osijek (GF location)
Tabulka 5. Možnosti výberu dát z databázy zrážok 11.05.2013. – Osijek (GF poloha)

POSSIBILITIES TO CHOOSE RAINFALL DATA FROM DATABASE 11.05.2013. - OSIJEK (GF)									
Rainfall (mm)	Time	Static data		Chosen data data	Time	Static data		Chosen data	Real event
		5-min	10-min			10-min	5-min		
0.0	15:55:00	0			15:53:00				
0.1	15:56:00				15:54:00				
0.1	15:57:00				15:55:00	0			
0.2	15:58:00	4.6			15:56:00				
1.6	15:59:00				15:57:00				
2.6	16:00:00			20.9	15:58:00	9.3			
2.4	16:01:00				15:59:00				
2.5	16:02:00				16:00:00				
2.9	16:03:00	16.3			16:01:00				
3.8	16:04:00				16:02:00				
4.7	16:05:00		25.0		16:03:00	16.0			
2.7	16:06:00				16:04:00				
1.9	16:07:00				16:05:00	21.3			
2.1	16:08:00	8.7			16:06:00				
1.2	16:09:00				16:07:00				
0.8	16:10:00				16:08:00				
0.6	16:11:00				16:09:00				
0.6	16:12:00				16:10:00				

Conclusion

The improvement, reconstruction or development of the wastewater networks today is based on the modelling of flows in sewer system. In view of optimisation, the quantity and the quality of the input data are important for the value of the assigned model of the wastewater network, for the right decisions in the system managing and, for the technical procedures applied to system objects/structures/facilities. Considering all that, it is important to put the special emphasis on the quality of measuring the hydrologic parameters in the wastewater network. At the combined wastewater network, which is in the city of Osijek, the most important hydrologic parameters primarily include a rainfall event, a short-duration heavy rain in particular. Because of that, rainfall intensity must be measured. The right choice of the hydrometric equipment, properly distributed measuring locations in the city area, as well as the team for monitoring, servicing and control are very important for acquiring valuable input data for modelling. Every measuring is accompanied by some difficulties.

The performed monitoring has beyond any doubt established that the rainfall showed the difference along the elongated urban area of the city of Osijek, due to time and space asymmetry. For the longer observation period the amount of total rainfall in the city is the same. But, for the shorter period the differences on the

locations are evident. For the particular city heavy rainfall event, the local character is noticeable, which should be taken into account during a designing phase of facilities/structures in the framework of the urban wastewater network.

The heavy rainfalls of a short duration vary widely in the inner city area, and then it is expected that such differences may be even bigger in larger areas. Given that both settlements and the wastewater network are extending, it is necessary to increase the number of rainfall gauging stations. When IDF curve data from only one rain gauge station are used (as it is a common practice), it is burdened by randomness of events (local events), so a much longer series, or many more local regional structures should be considered. It is necessary to measure rainfall data on different locations which can be used in the sewer system flow simulation models – even with its spatial distribution. Contemporary sewer models allow that. It is necessary to investigate how errors of the input “rainfall” data, especially errors in spatial distribution, affect the modelling of sewer flow. It is, also, necessary to experientially define the areas of flood risks in the city. If the flooding occurrence in some area is too high, there are two possibilities, to increase the sewer system transport capacity or to decrease the rainwater inflow (infiltration, green infrastructure etc.).

Literature

- Bonacci, O. (1994): Oborine-glavna ulazna veličina u hidrološki ciklus (Precipitation – main input in Hydrological Cycle), Geing, Split.
- Cindrić, K. et al. (2014): Vremenske promjene kratkotrajnih jakih oborina u razdoblju 1955. – 2010. za Split i Varaždin (Temporal changes of short-term heavy precipitation in the period 1955–2010 in Split and Varaždin), Hrvatske vode, 89, 239–25.
- Hogg, W. D. and Hogg, A. R (2010): Historical Trends In Short Duration Rainfall In The Greater Toronto Area, Report for the Toronto and Region Conservation Authority (<http://trca.on.ca/dotAsset/105189.pdf>. 10.6.2017).
- Nikolić, D. (2013): Izvanredni meteorološki i hidrološki događaji u novinskim izvješćima u Hrvatskoj u svibnju 2013. godine (Extraordinary meteorological and hydrological events in news reports in Croatia in May 2013), Meteorološki i hidrološki bilten, DHMZ RH, 5, Zagreb.
- Patrčević, V., Maričić, S., Mijušković-Svetinović, T. (2002): The parameters determination problem of the sewage system function; XXIth Conference of the Danube Countries on Hydrological Forecasting and the Hydrological Basis of Water Management, Bucharest, Romania.
- Radonić, M (2003): Vodovod i kanalizacija u zgradama (Household installation), Zagreb
- Vodovod Osijek (2015): Opći i tehnički uvjeti isporuke vodnih usluga (General and Technical Conditions for a Water and Wastewater Connection Agreement, Osijek).

SIEŤ ODPADOVÝCH VÔD V OSIJEKU – POZOROVANIE A CHARAKTERISTIKY ZRÁŽOK

Osijek je najväčšie mesto nížnej oblasti Slavónska na východe Chorvátska. V rozvoji siete odpadových vôd sa zistili niektoré špecifické etapy. V priebehu posledného desaťročia sa z jednoduchej siete odpadových vôd vytvoril systém mestských konglomerátov. Základná koncepcia a konštrukčné prvky siete odpadových vôd sú založené na charakteristikách miestnych zrážok. Z tohto dôvodu sa koncom minulého storočia začali realizovať pozorovania zrážkových udalostí na piatich automatických zrážkomerných staniciach. V článku je prezentované meranie zrážok a určité problémy pri jeho implementácii a pozorovaní. Zdôrazňuje sa, že je dôležité zvoliť si kvalitné meracie zariadenie a vhodný tím pre servis meracieho zariadenia a rovnako je dôležitá dlhodobá kontrola meracích miest. V článku sú tiež uvedené poruchy, ktoré boli zaznačené pri monitorovaní zrážok v meste Osijek. Skúsenosti s monitorovaním zrážok

v sieti odpadových vôd v Osijeku ukázali, že je potrebné mať veľa zručností a šťastia na to, aby bola táto úloha dobre vykonaná. Predbežná analýza extrémnych zrážkových udalostí počas pätnásťročného sledovaného obdobia (1999 – 2013), ktorá sa uvádzajú vo forme jedno-minútových zrážok, naznačuje významnú zmenu v tomto storočí. Automatické zrážkomerné zariadenia naznačujú krátkodobé udalosti zrážok s charakteristikami rovnajúcimi sa rozsahu priemerných mesačných hodnôt. Analýza naznačuje zmenu krivky IDF a zmenu klímy, ktorá sa odráža na intenzite zrážok, o ktorej už mnohí autori referovali. Vútorálna štruktúra najdôležitejších silných zrážkových udalostí ukazuje ich veľkú priestorovú a časovú asymetriu. Dokument poukazuje na potrebu podrobnejšej analýzy udalostí zrážok v oblasti Osijeku z dôvodu rizík v mestách, ktoré by mohli byť zmiernené zavedením systému riadenia v reálnom čase.

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