ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

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OVERVIEW OF HEAVY RAIN DATA IN OSIJEK

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Keywords: *city of Osijek, collection of rainfall data, heavy rain, extreme rainfall events, rainfall distribution*

ABSTRACT

By definition, heavy rain is a short-term intense rainfall event which can often cause high-intensity flooding problems in urban areas. The properties of heavy rain depend on geographic determinants according to which the sewer systems are designed. This paper features the collection of data on rainfall and their statistical processing. It points out the differences that may arise during registration and processing of heavy rain data. Located in the eastern, lowland part of the Republic of Croatia, the area of the city of Osijek was used as an example. In the period between 1999 and 2012, the monitoring took place at five locations within the inner city, while in years to follow the data were obtained from several surrounding measuring locations.

While comparing the available data, what was observed were the characteristics of the local heavy rain, their occurrence by location, hydrographic forms, magnitude (quantity) of rain, and similar. The most commonly observed rainstorms in the area of Osijek were the episodes of rain (single, separated rain) in duration of 5 – 10 to 20 – 25 minutes, or less than 30 – 40 minutes respectively. The maximum magnitudes of 10-minute rainfalls were of 25 – 30 mm. In this century, the projected rainfall values with 2 – 10 year return period have been exceeded more than expected.

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1. Introduction

This paper presents a brief overview and continuation of the research of rain characteristics in the area of a city in the lowland part of Croatia. One of the main determinants of every urban environment is the drainage solution. Whatever that solution is, it is conditioned by the stormwater occurrences in that particular area. Thus, every engineering solution for drainage is based on rainfall data, obtained by long-term measuring [2, 5]. It is clear that valuable rainfall data and a good engineering approach to drainage allow better functioning and prosperity of the urban environment [13]. This paper also presents some of the experiences gained during the rainfall observation and measurement [13, 16, 17], collected data processing, as well as the engineering experiences in the Osijek area.

2. Observed Area and Issues

The city of Osijek is the center of Slavonia and Baranja, a northeastern region of the Republic of Croatia. It is a part of the Pannonian Basin, and it includes a wider area around the mouth of the River Drava in the Danube. This city with long and rich history is the fourth largest in the country. What is also interesting about it is the chronology of the development of its wastewater network, which even today is mainly of a combined type. However, the system's continuous upgrading and reconstruction requires many engineering solutions and adjustments. [12, 10].

The state-level ombrographic measurements have been established in the inner city area, and its surroundings, as well. Today, the measurements take place at several locations, with a particular location as the main one, being operational for the longest period. It is the Osijek – Čepin meteorological station which also determines the climatic characteristics of the area. The area concerned has a typical continental climate with the largest rainfall around June (over 80 mm), as well as in autumn (about 60 mm), with an annual average of about 700 mm. Average daily temperatures in winter can be below -4 °C and in summer over 28 °C [8, 9]. It is a strictly flat area, and the city is situated at the average of 90 m above sea level. The flat terrain itself imposes engineering solutions for drainage, and with the network extension the number of pumping stations in the system is increasing, as well [12, 10].

In the course of designing parts of the drainage system, IDF relations, obtained according to the Osijek main meteorological station, were applied. The previous papers established the differences among the entry rainfall data used in the engineering practice of regional designers [11]. These differences can be seen in Table 1, where a theoretical recommendation is provided, too [15]. Often, based on designers' personal experience, there are corrections (reductions) of this input rainfall value.

Table 1. Different values of the applied relevant rainfall data of Osijek

STATISTISTICS-PROBABILITY OF RELEVANT RAINFALL IN THE OSIJEK AREA – l/h/ha (mm/x-min)						
RP	**IDF (1957-78)**		**IDF (1959-91)**		**PRACTISE**	**THEORY**
duration	**10-min**	**15-min**	**10-min**	**15-min**	**10-min**	**5-min**
2 year	175 (10,9)	150 (13,9)	155 (9,3)	127 (11,4)		
5 year	250 (15,0)	220 (19,8)	213 (12,8)	175 (15,8)	188,9 (17,0)	245 (7,35)

Since extreme rainfall events also cause pressurized flow, or sewer overflow (Fig. 1), flooding and damage, the issue of relevant rainfall is always interesting. It is also a consideration of possible adjustments to the estimated climate change, with more intense precipitation. [4, 3] Thus, the Faculty of Civil Engineering in Osijek was also involved in the exploration of intensive rainfall in the area of its city [9, 8, 7, 11].

Figure 1. Overflow and flooding during heavy rains in Osijek (Sjenjak residential area)

There were 230 entries of individual intense rainy occurrences separated from the data collected at five locations around the city of Osijek in the 15-year period. More detailed description of this analysis is given in the paper [11]. The criterion for extracting the rainfall as extreme implied at least 10 mm of rainwater during a 10-minute long rainfall event, which corresponds to the rain of a return period of over one year. Among the selected events, there are almost 70 of those (i.e. 30%) with more than 11 mm of rain, which, however, corresponds to a three-year return period. The highest recorded rainfall of 27,2 mm is at the level of a 100-year return period. This rain is presented in Fig. 2, in the form of a diagram showing one-minute rain quantities.

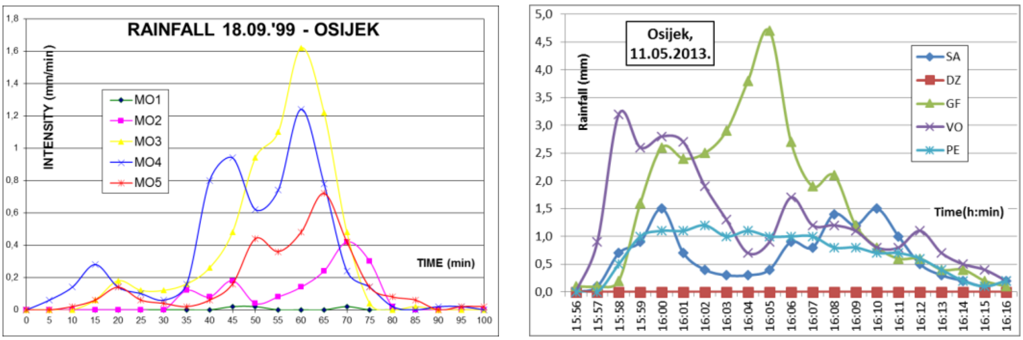

Figure 2. Two extreme rainfall events were recorded in Osijek during a 15-year observation period [11]

As early as the first research of rainfall in the area of Osijek [9, 8], done by the Faculty of Civil Engineering, there were spatial inequalities (rainfall variations by locations), shown by Fig. 2 in the form of average 5-minute intensities, because 5-minute rainfall events were observed, and those were selected based on time recorded by instruments.

In a later analysis [11], 1-minute rainfall events were selected from the records in order to make a comparison, as shown in Fig. 3. This approach enabled a more realistic overview of rainfall occurrences. In this way (by processing 1-minute rainfall data), the resulting basis on rainfall does not coincide with individual values of the previous statistical approach (5-minute rainfall). Below is an overview of this issue.

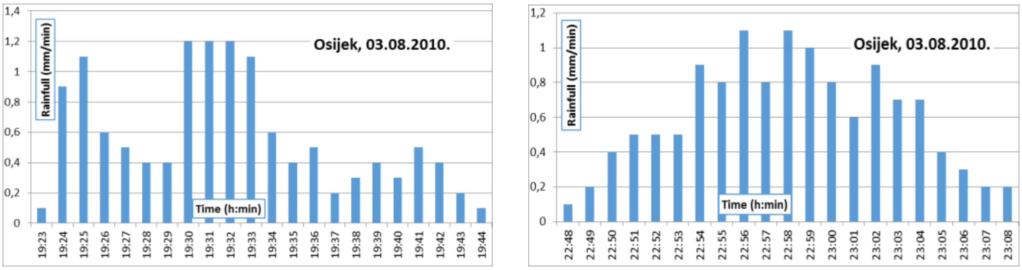

Figure 3. Two extreme rainfall events at GF (MO3) location, August 2010

3. Impact of a Measurement Method

Here one can give an overview of the interpretation of a rainy event from the judicial expertise perspective. According to the evidence provided by the court file, it was possible to establish the occurrence of the respective rainfall event that was suspected to have caused the flooding. For that purpose, stormwater and ombrographic data from the nearby hydrological stations were available.

By means of a rain gauge, the measuring included all the rain occurred from 7 a. m. (on the day subject to measuring) until 7 a. m. the next day (when the results were recorded for that day of reading). Continuous measuring was done by an ombrograph (when 0,1 mm of a collecting bottle was filled), then the total quantity of all the rainwater occurred within a day (from 0 to 24 hours) was made. This is why it is possible to have the same heavy rain attributed to the day one (by a rain gauge), as well as to the following day (by an ombrograph) – because it occurred between 0 and 7 o'clock.

Based on the hydrological data enclosed to the file, it was concluded that according to the rain gauge there were 35 l per square meter on the first day and 75 l on the second day, while according to ombrographical data there were 55 l for day one and 48 l for day two.

These quantities are not problematic if they are distributed equally throughout the day so that should have been determined by ordering a particular type of processing: according to hourly data. The latter have shown that the heavy rain which caused the flooding had two intense manifestations. Fig. 4 shows an approximate schematic overview of these hydrological data.

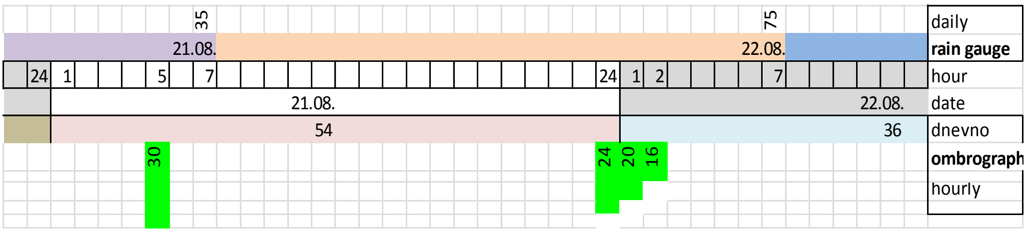

Figure 4. Example of displaying results according to different ways of measuring the rainfall

It is evident that the first heavy rain occurred in the morning of day one, around 5 p. m., when about 34 l/m^2 occurred in an hour or two. The second heavy rain happened during the night, between 11 p.m. and 2 a. m. the next day, with an amount of about 74 l/m^2. So, both rainfall events were of the same intensity (about 0,4 l/min on average). The first rain made the ground completely wet so that the other rain had significantly reduced evaporation and infiltration so nearly all the water became a runoff. (Flow rates increased in comparison to the usual, as well as the engineering-related ones).

The second rain with fewer losses (and a higher runoff coefficient) caused twice as much water in the runoff, i.e. it was even more dangerous because of the saturated (soaked) soil. In engineering terms: its maximum inflow to a certain site was increased in comparison to the one calculated according to the average data, which finally confirmed that the rain was causing the flooding in question.

4. Influence of the Time Component

For the respective analysis, and with no particular criterion, a one-month period of more rain was selected. This is the month of August 2010, the season that was marked by flooding problems. Already at the beginning of that period there were three heavy rainfall events: two in one day, and the third one two days later. In addition, the long lasting heavy rain was registered during the two days at the end of this month, as well. So, it can be said that there were four single rain episodes. In total, 83,7 mm precipitation was recorded during this summer month. This was above average and this month was classified as very rainy, while the whole year has been declared extremely rainy [14].

Among the three heavy rainfall events, the one that was registered on 6 August 2010 during the evening hours was especially heavy. Then, 2,2 mm of rainfall was recorded per minute. Fig. 5 shows that heavy rain in the form of minute precipitation. It is evident that within thirty minutes the rainstorm had two hits. The other two rainstorms (Fig. 3) were about 20 minutes long and of a half less rainfall minute intensity.

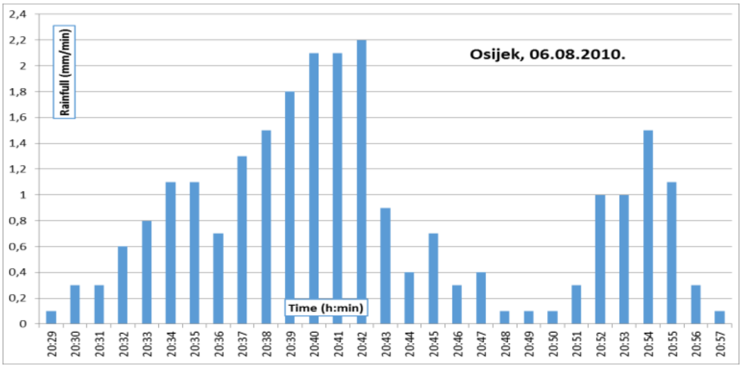

Figure 5. The largest rainfall event recorded at GF (MO3) site in August 2010

For the purposes of analysis, the rainfall events of August 2010 were reported as one-minute ones with regard to the time recorded by an instrument. The moment after a full hour has been considered as a start, while the first full minute as the end, and so on for the next few minutes. Then, by the same principle, they were grouped into 5-minute, 10-minute and 15-minute episodes. The maximum data was extracted over there, as they are used in statistical analyzes and probability estimates. For the analysis, it was assumed that the rain gauge timer was not accurate, so the minutes were added or subtracted to the time recorded by the instrument. That has resulted in various sequences of said rainfall events, .i.e. rainfalls of varying duration. Here it can be observed that, due to time shift, different grouping of rainfall data occurred, hence the reported maximum values are different. In the course of the analysis, what needed to be done were 15 shifts of 1 minute in order to check the changes of the 15-minute rainfall events. The obtained values are presented in Table 2.

Table 2. The maximum rainfall presentation obtained by introducing a time shift

Rain type	The first two maxima of rain a certain duration for a certan time shift (in minutes)														
	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
5 -min.	**8,8**	**7,4**	**7,7**	**9,1**	**9,7**	8,8	7,4	7,7	9,1	9,7	8,8	7,4	7,7	9,1	9,7
	4,9	6,3	6,4	5,7	5,0	4,9	6,3	6,4	5,7	5,0	4,9	6,3	6,4	5,7	5,0
10 -min.	**13,1**	**11,3**	**9,5**	**11,0**	**12,4**	**13,3**	**13,7**	**14,1**	**14,8**	**14,7**	13,1	11,3	9,5	11,0	12,4
	8,1	8,0	9,3	7,8	7,2	7,5	8,1	8,5	8,7	8,5	8,1	8,0	9,3	7,8	7,2
1 5 -min.	**17,6**	**17,6**	**17,2**	**16,9**	**16,0**	**13,8**	**12,2**	**13,2**	**13,5**	**14,0**	**14,3**	**14,7**	**15,7**	**16,7**	**17,4**
	9,3	12,7	12,6	7,5	12,3	10,4	11,7	10,1	10,6	10,8	11,1	11,3	11,3	10,8	10,2

Based on the data above, it can be stated that these are not small differences. The maximum rainfall range is as follows: for a 5-minute rain from 7,4 to 9,7 mm; for a 10-minute from 11,0 to 14,8 mm, and for a 15-minute rain from 12,2 to 17,6 mm. Consequently, there are 20 – 40% differences which can be caused by the time inaccuracy of an instrument – ombrograph.

5. Conclusion

Some conclusions may be drawn, as indicated in the paper, from the experience of the Faculty of Civil Engineering Osijek with measuring and processing of the rainfall data in the city area. The rainfall measuring itself is not too complicated, but when it comes to its organization and implementation, there are more problems. That is why it is necessary to point out these problems so that they can be avoided and removed more easily. The processing of collected data requires expertise and a serious approach because it has more specifics. The paper shows how the way of measuring and the reporting of results can affect the quality of information about a particular rainfall event, and thus on engineering solutions. The analysis of a random one-month period showed how many differences can be observed by adopting a different starting time when observing the rainfall events. All in all, it is evident that this issue requires further research.

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ПРЕГЛЕД НА ИНТЕНЗИВНИТЕ ДЪЖДОВЕ, РЕГИСТРИРАНИ В ГР. ОСИЕК

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Ключови думи: *град Осиек, набиране на данни за дъждовете, интензивни валежи, разпределение на валежите*

РЕЗЮМЕ

По дефиниция интензивен валеж е кратковременно интензивно валежно събитие, което често може да доведе до наводнения в градските територии. Характеристиките на интензивните валежи зависят от географските параметри, за които се проектират канализационните системи. Тази статия характеризира начина на събиране на данните за валежите и тяхната последваща статистическа обработка. В нея се изтъкват разликите, които могат да възникнат по време на регистрацията и обработката на данните за интензивните валежи. Град Осиек, който е разположен в източната равнинна част на Република Хърватска, е използван като пример в настоящото изследване. В периода между 1999 и 2012 г. е извършен мониторинг в пет станции, намиращи се в границите на града, докато в следващите години са събрани данни от няколко точки, намиращи се в съседство.

При обработката на наличните данни са отчетени появата на интензивни валежи в зависимост от местоположението, особеностите на релефа и количеството на валежите. Най-често наблюдаваните събития в района на гр. Осиек са с продължителност от 5 – 10 до 20 – 25 минути или съответно по-малка от 25 – 30 – 40 минути. Максималните стойности на 10-минутните валежи са от порядъка на 25 – 30 mm. През този век проектираните стойности с период на повторение 2 – 10 години са надвишени повече от очакваното.

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