# THE INTERNATIONAL CONFERENCE
# SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING
# SINARG 2023

# PROCEEDINGS

## VOLUME 2

# PROCEEDINGS OF THE INTERNATIONAL CONFERENCE SYNERGY OF ARCHITECTURE & CIVIL ENGINEERING SINARG 2023

## VOLUME 2

**PUBLISHED BY:**
FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ
SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ

**FOR PUBLISHERS:**
SLAVIŠA TRAJKOVIĆ, PHD
VLADA VELJKOVIĆ, PHD

**EDITORS:**
SLAVIŠA TRAJKOVIĆ, PHD
VUK MILOŠEVIĆ, PHD

APPROVED TO BE PRINTED ON 7TH SEPTEMBER 2023. BY THE DECREE OF TEACHING SCIENTIFIC COUNCIL OF THE FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ, NO. 8/181
APPROVED TO BE PRINTED ON 4TH SEPTEMBER 2023. BY THE COMMITTEE FOR MANAGING THE WORK OF THE SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ, NO. 1/23-159

**TECHNICAL EDITOR:** DUŠAN RANĐELOVIĆ, PHD

**COVER DESIGN:** LJILJANA JEVREMOVIĆ, PHD

**ISBN** 978-86-88601-81-8
**ISBN** 978-86-88601-82-5 (FOR PUBLISHING ISSUE)

**PRESS:** 100 COPIES

**PRINTED BY:** GRAFIKA GALEB NIŠ

**ORGANIZED BY:**
FACULTY OF CIVIL ENGINEERING AND ARCHITECTURE, UNIVERSITY OF NIŠ
SERBIAN ACADEMY OF SCIENCES AND ARTS - BRANCH IN NIŠ
SERBIAN ACADEMY OF SCIENCES AND ARTS - DEPARTMENT OF TECHNICAL SCIENCES

**IN PARTNERSHIP WITH**
SCIENCE TECHNOLOGY PARK NIŠ


*THE ORGANISATION OF THE INTERNATIONAL CONFERENCE*
***SYNERGY OF ARCHITECTURE AND CIVIL ENGINEERING - SINARG 2023***
*AND PRINTING OF THE PROCEEDINGS HAS BEEN SUPPORTED BY THE*
***MINISTRY OF SCIENCE, TECHNOLOGICAL DEVELOPMENT AND INNOVATION, REPUBLIC OF SERBIA***
*AND*
***SERBIAN CHAMBER OF ENGINEERS.***

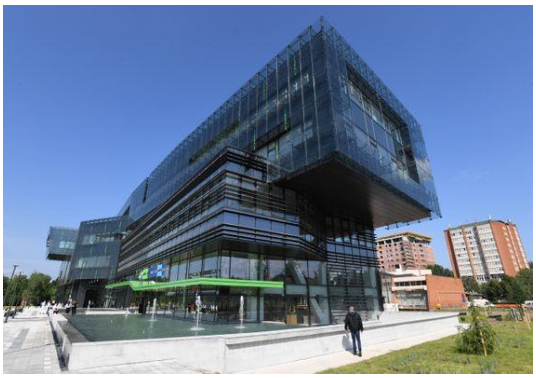
Ministry of Science, Technological Development and Innovation of the Republic of Serbia

ИНЖЕЊЕРСКА КОМОРА СРБИЈЕ

## CONFERENCE TOPICS

- ✓ *URBAN AND SPATIAL PLANNING*
- ✓ *PLANNING AND DESIGNING SMART AND RESILIENT CITIES*
- ✓ *URBAN AND ARCHITECTURAL DESIGN - THEORY AND PRACTICE*
- ✓ *ARCHITECTURAL DESIGN AND ANALYSIS*
- ✓ *ARCHITECTURE AND BUILT ENVIRONMENT*
- ✓ *BIOCLIMATIC AND BIOPHILIC ARCHITECTURE*
- ✓ *PRINCIPLES OF ECOLOGICAL DESIGN AND CONSTRUCTION*
- ✓ *BUILT HERITAGE PROTECTION AND MANAGEMENT*
- ✓ *BUILDING RENOVATION AND RECYCLING*
- ✓ *ARCHITECTURAL ENGINEERING*
- ✓ *BUILDING INFORMATION MODELING (BIM)*
- ✓ *STRUCTURAL ENGINEERING*
- ✓ *MATERIALS IN CIVIL ENGINEERING AND ARCHITECTURE*
- ✓ *ENGINEERING MECHANICS*
- ✓ *WATER RESOURCES MANAGEMENT*
- ✓ *HIGHWAY ENGINEERING*
- ✓ *GEOTECHNICAL ENGINEERING*
- ✓ *CONSTRUCTION ENGINEERING AND MANAGEMENT*
- ✓ *PROJECT MANAGEMENT*
- ✓ *CIRCULAR ENGINEERING*
- ✓ *ENTREPRENEURSHIP AND ENGINEERING*
- ✓ *TRANSPORTATION RESEARCH AND DEVELOPMENT*
- ✓ *CLIMATE CHANGE CHALLENGES IN ENGINEERING*
- ✓ *DISASTER RISK MANAGEMENT*

## CONFERENCE VENUE



sinarg 2023

International Conference

**Synergy of Architecture & Civil Engineering**

**Niš (SERBIA) - Science & Technology Park Niš - September 14-15, 2023**

# *PREFACE*

*The primary goal of the SINARG 2023 conference is to present contemporary achievements in the scientific and practical aspects of architecture and civil engineering. The organizers of the conference aimed to facilitate the participation of both national and international professionals in theoretical and experimental research related to the processes of design, project management, construction, and building maintenance within the construction industry.*

*Simultaneously, this scientific conference serves as a platform for exchanging experiences and information regarding innovations and advancements in planning, design, new materials, and construction and reconstruction technologies within the fields of architecture and civil engineering.*

*Therefore, this conference should serve as a forum where experts from civil engineering, architecture, and other related fields have the opportunity to present the results of their research. In that context, conference topics have been carefully selected to provide focus on current issues in the field and encourage productive discussion bringing fresh and original insights and concepts to the forefront.*

*More than 180 paper proposals have been submitted to the conference. A single-blind review process was used to assess the full papers. The reviewers are esteemed scientists holding PhD degrees in the same field as the paper's topic. There are more than 70 reviewers from ten countries who have significantly contributed to the scientific quality of the conference, and their names are printed in the proceedings.*

*A total of 142 full papers have been accepted for publication. Some of the papers have been selected for publication in our journals, with nineteen papers in Facta Universitatis: Architecture and Civil Engineering and nine in the Journal of the Faculty of Civil Engineering and Architecture. The conference proceedings consist of 114 papers divided into two volumes.*

*The total number of authors and co-authors accepted for publishing at SINARG 2023 exceeds 320. Out of this number, more than 80 authors come from abroad, representing 19 countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Greece, Hungary, India, Indonesia, Netherlands, North Macedonia, Montenegro, Oman, Poland, Romania, Serbia, Slovakia, Turkey, United Kingdom).*

*The editors express their gratitude to all the authors for their participation and to the reviewers for their valuable comments, which have contributed to the improvement of the original manuscripts and have enhanced the overall quality of the conference..*

*Niš, September 2023* *Editors*

# QUANTITATIVE CHARACTERISTICS OF HIGH INTENSITY RAINFALL IN THE VINCINITY OF THE CITY OF NIS

**Stevan Prohaska[1], Aleksandra Ilić[2], Ognjen Prohaska[3], Vladislava Bartoš Divac[4]**

**Abstract**

*The paper presents the analyses of heavy rainfall characteristics that are necessary for design purposes of water management facilities and systems on the small river catchment areas in the vicinity of the city of Niš. All analyzes were primarily completed within the monograph "Intensities of heavy rainfall in Serbia", published by the Institute for the Development of Water Resorces "Jaroslav Černi" from Belgrade in 2014, and results are explained and discussed within this paper for the area of the city of Niš. Official historical data from the Database of the Republic Hydrometeorological Service of Serbia are used for the period 1951-2008. In addition to the presented analyses, the rainfall episodes recorded at the main meteorological station (MS) Niš in recent years are analyzed separately. The paper is illustrated with graphical and tabular attachments with appropriate comments and conclusions.*

**Keywords:** *heavy rainfall intensities, rainfall duration, cumulative rainfall, rainfall distribution*

[1] Dr., retired full research professor, Institute for the Development of Water Resources “Jaroslav Černi”, stevan.prohaska@jcerni.rs
[2] Dr., Assistant Professor, Faculty of Civil Engineering and Architecture Niš, aleksandra.ilic@gaf.ni.ac.rs
[3] MSc., researcher, Institute for the Development of Water Resources “Jaroslav Černi”, ognjen.prohaska@jcerni.rs
[4] MSc., researcher, Institute for the Development of Water Resources “Jaroslav Černi”, vladislava.bartos@jcerni.rs

# 1. INTRODUCTION

In the water management system design practice in small catchment areas, the main interest is focused on the analysis of the intensity of short-duration rainfall (up to 24 hrs at most), which are the main cause of the catastrophic floods within those areas. With the aim of determining the structure of the formation of the heavy rainfall intensity, the Institute for the Development of Water Resources "Jaroslav Černi", in the cooperation with the Republic Hydrometeorological Service of Serbia, published the monograph "Intensities of heavy rainfall in Serbia", where, among others, relevant data from meteorological station (MS) Niš are presented [1].

Of course, the intensities of heavy rainfall which lasts less than 24 hours can be measured using different types of automatic precipitation measuring devices. There are only few that type instruments in Serbia compared to instruments (rain gauges) for measuring daily precipitation sums. Meteorological station (MS) Niš has measuring equipment for short duration rainfall since 1951, but the Republic Hydrometeorological Service of Serbia has jurisdiction over all precipitation measurements.

In the aforementioned monograph [1], the process of cloud formation and the occurrence of precipitation on the earth's crust is explained and the instruments for measuring precipitation are presented: pluviometers (rain gauges and totalizers) for discontinuous measurement of precipitation, pluviographs for continuous measurement of heavy rainfall and radars that are used to detect area that is affected by precipitation [2], [3]. Two procedures are applied for the pluviograph stripes processing, namely for constant one-hour time period and for different durations of rainfall, whereby the period in which the maximum rainfall depth was measured is considered within the rainfall episode. [4]

In the specific case, this paper shows the following characteristics of heavy rainfall in the vicinity of the city of Niš:

- Average intra-annual patterns of maximum daily precipitation sums and precipitation sums in the rainfall episode with the maximum annual precipitation sum;
- Hyetograph and cumulative line of the annual rainfall episode with the maximum amount of precipitation;
- Dimensionless cumulative lines of the annual rainfall episodes with the maximum amount of precipitation;
- Theoretical dimensionless cumulative lines of heavy rainfall for different probabilities of occurrence;
- Frequency of heavy rainfall;
- Theoretical values of the duration of heavy rainfall for different probabilities of occurrence;
- Frequency of occurrence time of heavy rainfall during the day;
- Dependence of the rainfall depth as a function of the duration and the probability of its occurrence;
- DDF-curves: rainfall depth as a function of duration and frequency;
- Reduction curves of heavy rainfall.

## 2. THE INTENSITY OF HEAVY RAINFALL PROCESSING FOR THE MS NIŠ

Input data can be found in [1].

### 2.1. Intra-annual presentation of the maximum annual precipitation sums with the maximum precipitation sums in the rainfall episode

Percentage of rainy days in year according to the measurements on the MS Niš rain gauge and pluviograph is shown in Figure 1.

The month with the most frequent occurrence of maximum rainfall in Niš is June. In more than 90% of cases, maximum rainfall occur in the period May-September, and the period without occurrence of maximum rainfall is December-January.

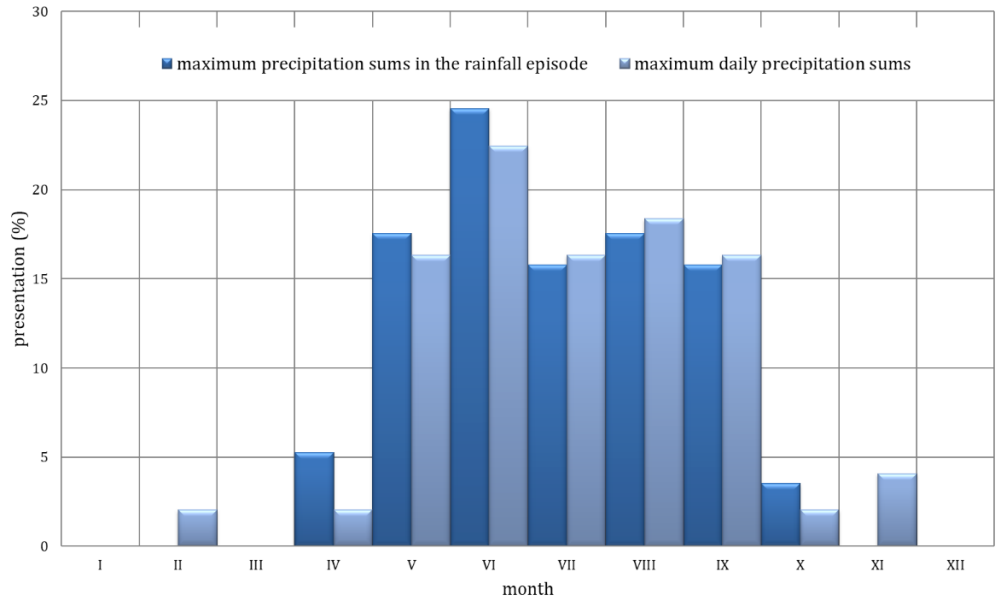



*Figure 1. Intra-annual presentation of the maximum annual rainfall amounts measured at the MS Niš rain gauge and pluviograph*

### 2.2. Hyetograph and cumulative line of the annual rainfall episode with the maximum amount of precipitation

The distribution character of the rainfall within episode is shown, for example, by hyetograph and cumulative line with the maximum registered precipitation on 12 June 1999 (5:50 pm – 11:00 pm).

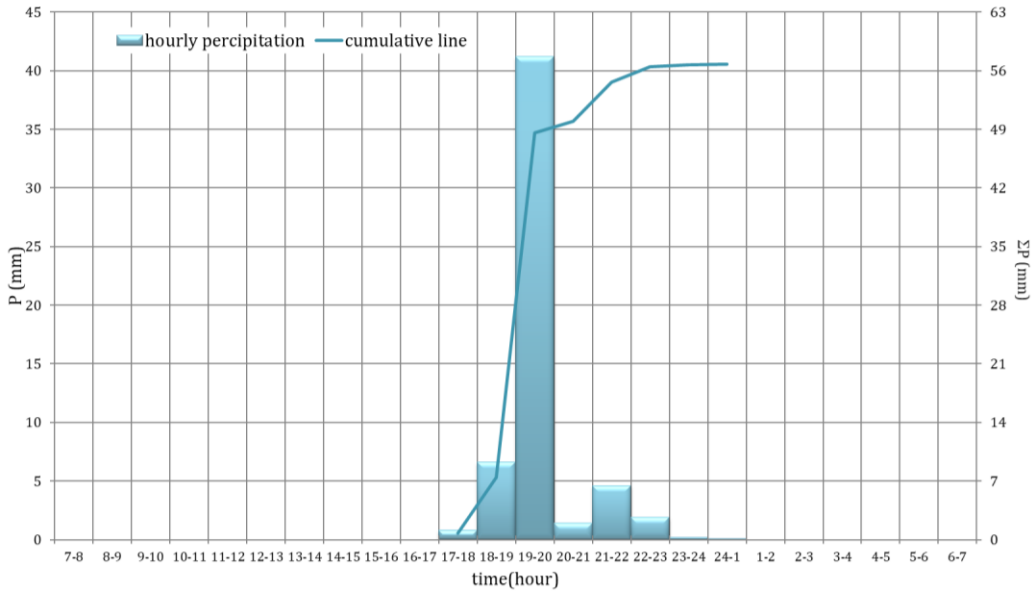



*Figure 2. Hyetograph and cumulative line for the rainfall episode with the maximum occurrence of rainfall*

### 2.3. **Dimensionless cumulative lines for annual rainfall episodes with the maximum precipitation sum**

In order to visualize the temporal distribution of rainfall during its duration, dimensionless cumulative lines were defined [5], [6], according to depth and duration. In the specific case, the coordinates of the dimensionless cumulative line are defined:

- Ordinate:

$$\eta_i = \frac{\sum_{j=1}^{i} P_j}{\sum_{j=1}^{Tk} P_j} \tag{1}$$

- Abscissa:

$$\theta_i = \frac{T_i}{T_k} \tag{2}$$

Where:

$\eta_i$ – ordinate of the dimensionless cumulative line,
$P_j$ – rainfall depth,
$i$ – the number of the characteristic point on the cumulative line ( $i$ = 1,2,3 .... $k$),
$j$ – the ordinal number of the rainfall variable,
$\theta_i$ – abscissa of the dimensionless cumulative line,
$T_i$ – rainfall duration for the characteristic point on the cumulative line,
$T_k$ – total rainfall duration.

The results of calculations for MS Niš are shown in Figure 3.

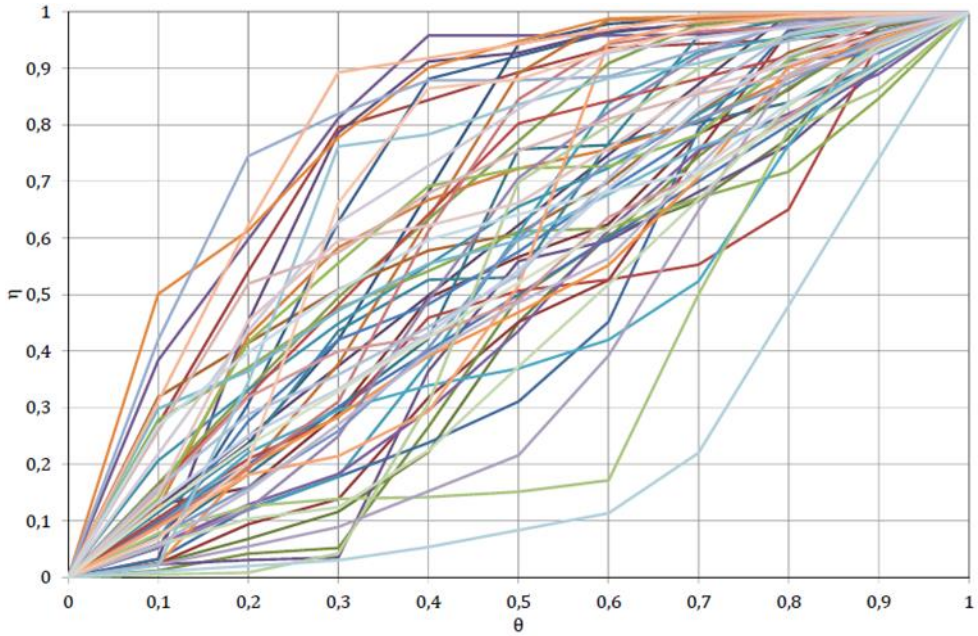



*Figure 3. Dimensionless cumulative lines for annual rainfall episodes with the maximum amount of precipitation on MS Niš*

Based on the graph shown (Figure 3), it can be concluded that in the area of the city of Niš, there is a great diversity in the character of the formation of rainfall within episode, from very sudden rainfall, to the occurrence of rainfall of moderate intensity, and rainfall with an abrupt ending.

### 2.4. **Theoretical dimensionless cumulative lines of heavy rainfall for different probabilities of occurrence**

Based on the defined cumulative lines of rainfall distribution within the episode, using the classic probabilistic procedure for each selected relative duration ($\tau_i$=0.1, 0.2... 1.0), theoretical values (Pearson III law of probability distribution) were calculated for the occurrence probabilities of 10, 20, 50, 80, and 90%. The results of these calculations for MS Niš are shown in Figure 4.

### 2.5. **Frequency of duration of heavy rainfall**

The next characteristic of heavy rainfall, very important for urban hydrology, is the duration and frequency of different durations ($T_k$) [5]. It is necessary to emphasize that the most frequent duration of heavy rainfall is significantly shorter than 24 hours, which can be seen in Figure 5, where the frequency of its occurrence in Niš is shown as a function of the duration of the rain.

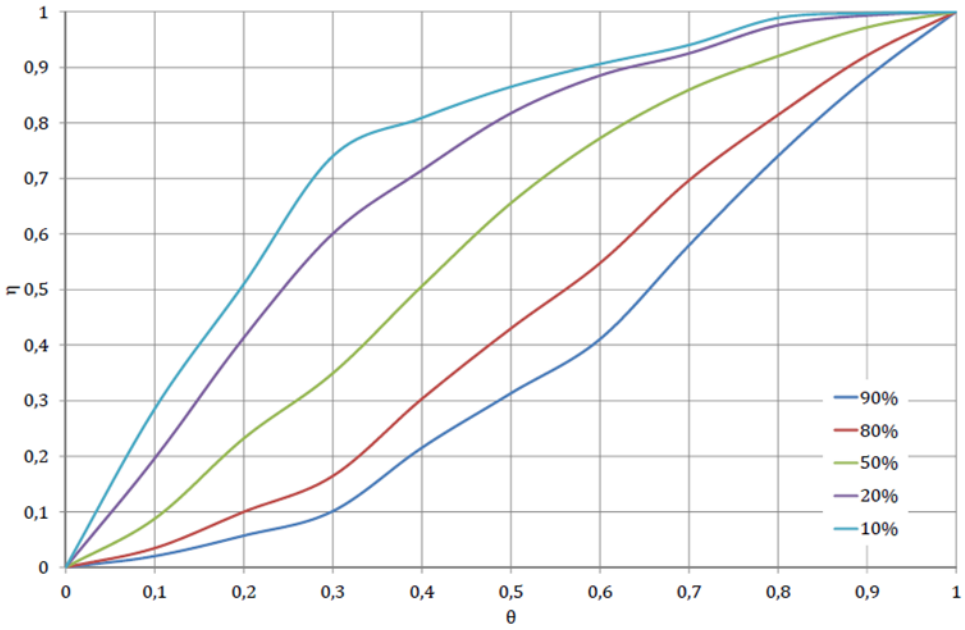



*Figure 4. Dimensionless cumulative lines of heavy rainfall for different probabilities of occurrence for MS Niš*

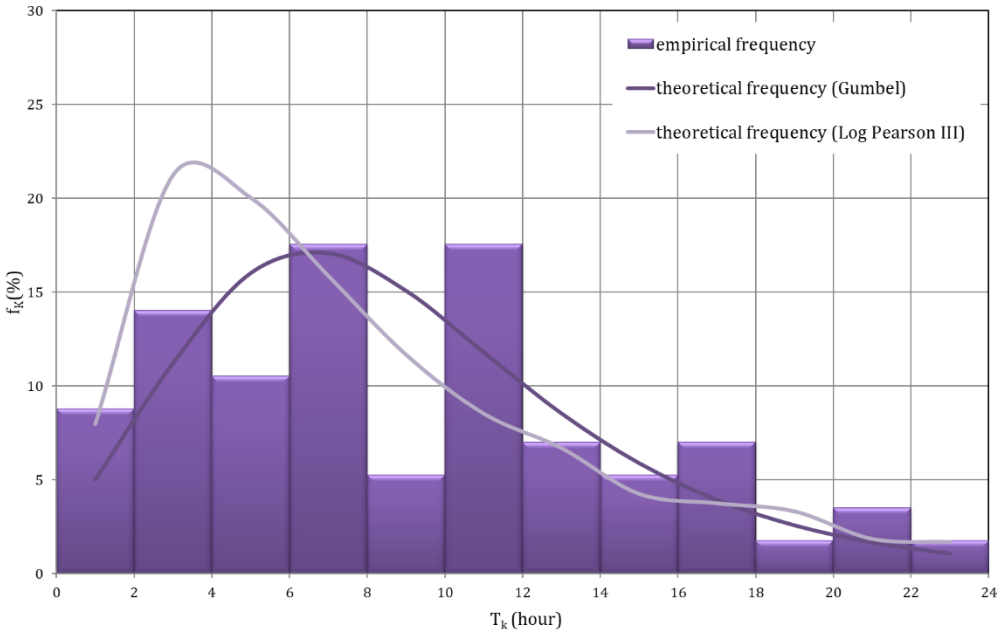



*Figure 5. Frequency of duration of heavy rainfall in Niš*

As shown in Figure 5, the most frequent duration of heavy rainfall in Niš appear in two periods, from 6 to 8 hr and from 10 to12 hr, and duration from 2 to 12 hr with a probability of over 60% can be expected.

## 2.6. **Probability of total duration of heavy rainfall**

The probability of occurrence of the total duration of heavy rainfall in Niš was analyzed applying several laws of probability distribution. The results of the calculation are shown in Figure 6.

Based on the presented results, following Gumbel law of probability distribution, it can be summarized that with a 100-year return period, heavy rainfall can be expected with duration of 29 hours, a ten year return period with 13 hours, and two year return period, heavy rainfall with a duration of 8 hours.

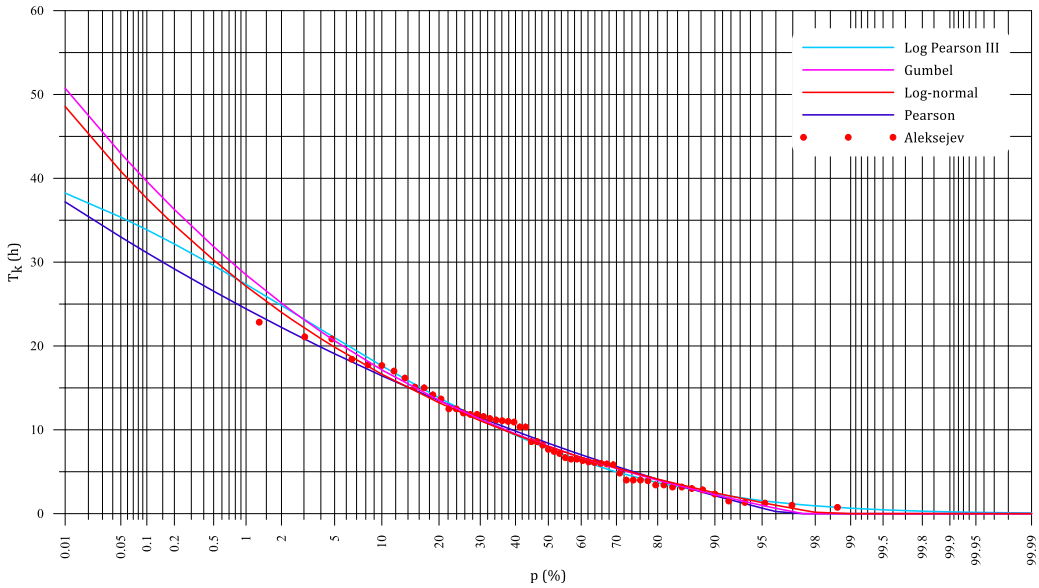



*Figure 6. Probability of occurrence of total duration of heavy rainfall in Niš*

## 2.7. **Frequency of occurrence time of heavy rainfall during the day**

One of the very interesting characteristics of heavy rainfall is the probability of heavy rainfall time of occurrence in one day (24 hours). For this purpose, an analysis of the frequency and probability of the occurrence time of rainfall during the day was performed using available hourly rainfall data of the maximum rainfall episodes registered [1], [3], [7]. The results of the calculation of the frequency of the occurrence time of heavy rainfall during the day for MS Niš are shown in Figure 7.

Based on these results, it can be concluded that heavy rainfall in Niš occurs between 7 pm and 9 pm. The rainfall will occur between 3 pm and 3 am next day with 70% of probability. The period with the least probability of heavy rainfall occurs from 7 am to 9 am.

## 2.8. **Dependence of rainfall depth as a function of rainfall duration and probability of occurrence**

The identification of heavy rainfall of shorter duration than a day, with the maximum amount of precipitation, is also carried out by the process of moving selected maximum amounts of rainfall for predefined periods of time, i.e. duration of rainfall [4]. The maximum annual intensities were processed for the 10, 20, 30, 60, 120, 360, 720 and 1440 minutes rainfall durations. The annual maximum daily precipitation sums are also included, registered on the rain gauge.

For the specified durations of rainfall, the probabilities of the occurrence of a rainfall depth and its intensity are calculated, using theoretical probability distribution curves. Applied goodness-of-fit tests showed that Gumbel distribution best fit. Based on these data, the dependences of the depth as a function of the duration and the probability of occurrence for MS Niš are shown in Figures 8 and 9.

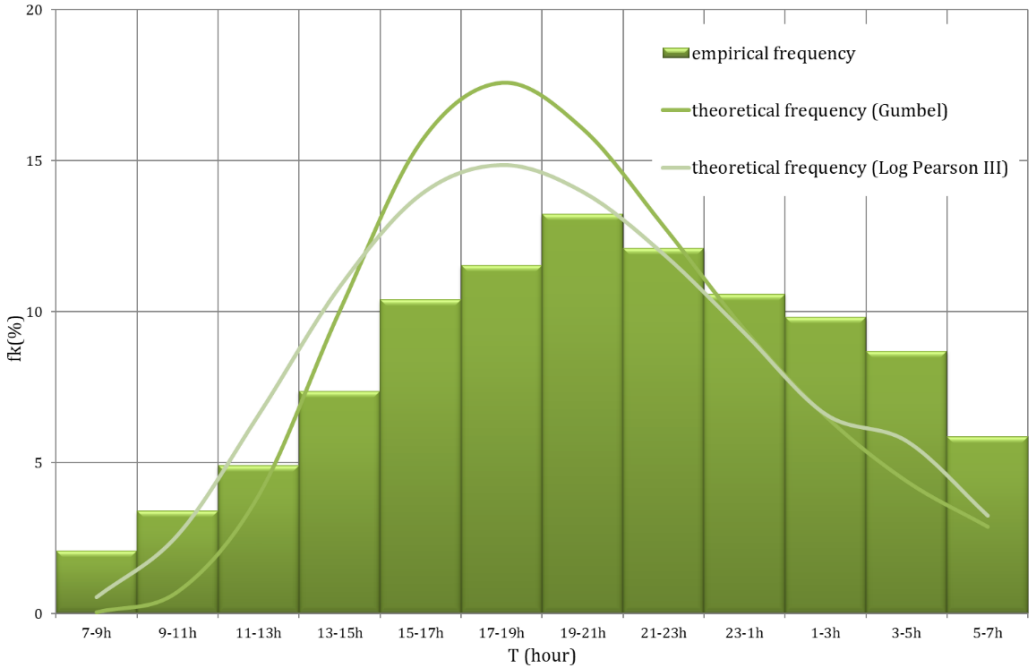



*Figure 7. Frequency of occurrence time of heavy rainfall during the day on MS Niš*

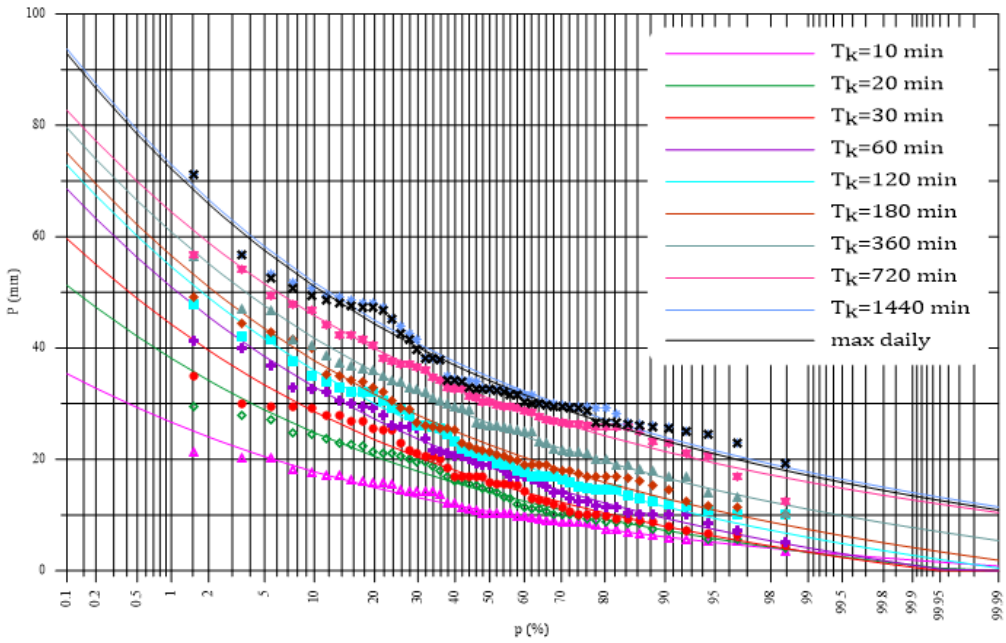



*Figure 8. Dependence of rainfall depth as a function of probability of occurrence and duration for MS Niš*

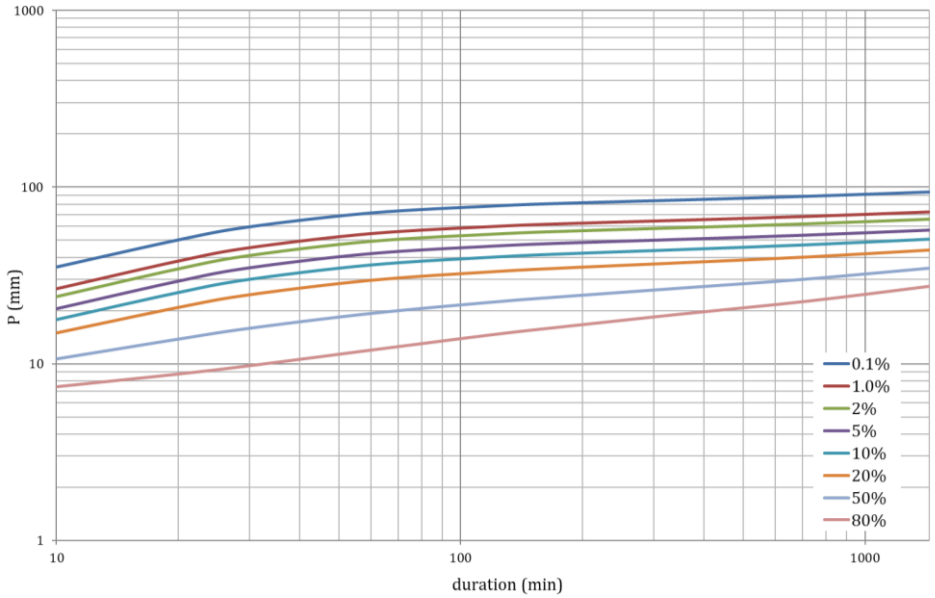



*Figure 9. Dependence of rainfall depth as a function of duration and probability of occurrence for MS Niš*

## 2.9. **Reduction curves of heavy rainfall**

The reduction curves of heavy rainfall $\psi(\tau)$, present the ratio of the maximum depth for any rainfall duration $\tau_i$ and the corresponding daily rainfall (24 hours duration) [5], i.e:

$$\psi(\tau) = \frac{P_{\tau_i}}{P_{24}} \tag{3}$$

Defined reduction curves of heavy rainfall for MS Niš are shown in Figure 10.

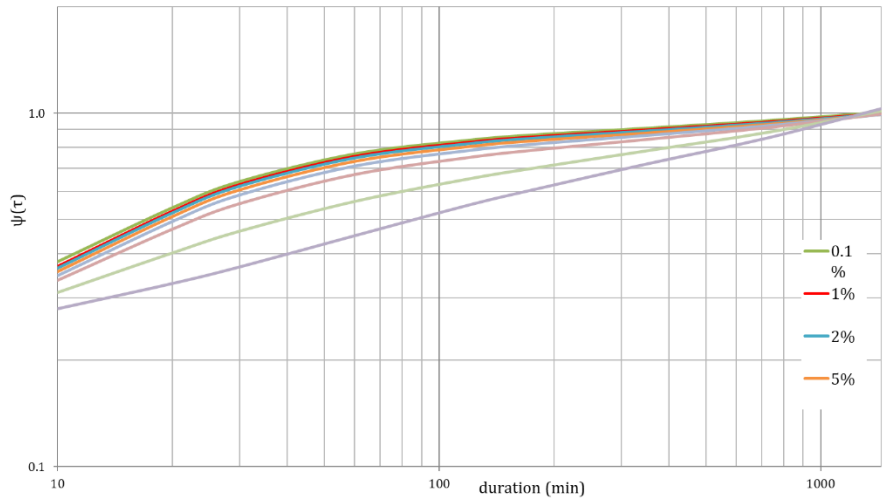



*Figure 10. Reduction curves of heavy rainfall for MS Niš*

The reduction curve is used to assess the amount of rainfall of any duration when only the probability of occurrence of 24hr rainfall is known.

## 3. CONCLUSION

The aim of this paper is to provide the basic characteristics of heavy rainfall, as a necessary basis for the design of water management facilities and systems on small catchments in the vicinity of the city of Niš. The presented results are given in Figures 1 to 10, while numerical values can be found in the monograph [1].

## REFERENCES


[1] Prohaska Stevan, Bartoš Divac Vladislava, Koprivica Ana, Đukić Dragan, Ilić Aleksandra, Ćatović Samir, Kapor Branka, Marjanović Srđan, Vukelić Vanja, Božović Nikola: **Inteziteti jakih kiša u Srbiji**, *Institut za vodoprivredu „Jaroslav Černi*“, ISBN 978-86-82565-40-6, str. 481, 2014. (In Serbian)

[2] Prohaska Stevan: 2003: **Hidrologija I deo**, *Rudarsko-geološki fakultet, Institut za vodoprivredu "Jaroslav Černi", Republički hidrometeorološki zavod Srbije*, Beograd, 2003. (In Serbian)

[3] Prohaska Stevan., Ristić Vakanjac Vesna: **Hidrologija kroz teoriju i praksu**, *Univerzitet u Beogradu, Rudarsko- geološki fakultet*, Beograd, 2002. (In Serbian)

[4] Prohaska Stevan, Kapor Branka, Ilić Aleksandra, Ćatović Samir., Marjanović Srđan, Bartoš Divac Vladislava., Koprivica Ana: **Kompleksna analiza pluviometrijskog režima jakih kiša kraćih trajanja na teritoriji Republike Srbije**, *Časopis „Voda i sanitarna tehnika“*, Vol. 41, No. 3-4, 2011., ISSN 0350-5049, str. 5-14, 2011. (In Serbian)

[5] Prohaska Stevan, Petković Tioslav: **Metode proračuna velikih voda**, Deo I, Proračun velikih voda na hidrološki izučenim profilima, *Građevinski kalendar*, Beograd, 1989. (In Serbian)

[6] Prohaska Stevan, Bartoš Divac Vladislava, Prohaska Ognjen: **Kvantitativne katakteristike kiša jakog intenziteta u okolini Palića sa aspekta projektovanja kišne kanalizacije**. *Konferencija „VODA 2023”*, 2023. (In Serbian)

[7] Janković Dragan: **Karakteristike jakih kiša na teritoriji Srbije**, *Građevinski kalendar*, Beograd, 1994. (In Serbian)

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

624(082)
72(082)

**INTERNATIONAL Conference Synergy of Architecture & Civil Engineering (2023 ; Niš)**
Proceedings [of] The International Conference Synergy of Architecture & Civil Engineering, SINARG 2023, Niš (Serbia), September 14-15, 2023. Vol. 2 / [editors Slaviša Trajković, Vuk Milošević] ; [organized by University of Niš, Faculty of Civil Engineering and Architecture [and] Serbian Academy of Sciences and Arts - Branch in Niš [and] Serbian Academy of Sciences and Arts - Department of Technical Sciences]. - Niš : University, Faculty of Civil Engineering and Architecture : SASA, Branch in Niš, 2023 (Niš : Grafika Galeb). - [12] str., str. 597-1187 : ilustr. ; 24 cm

Tiraž 100. - Str. [9]: Preface / Editors. - Bibliografija uz svaki rad.

ISBN 978-86-88601-81-8
ISBN 978-86-88601-82-5 (niz)

a) Грађевинарство -- Зборници б) Архитектура – Зборници

COBISS.SR-ID 123837961