AMERICAN JOURNAL OF HYDROPOWER, WATER AND ENVIRONMENT SYSTEMS

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AMERICAN JOURNAL OF HYDROPOWER, WATER AND ENVIRONMENT SYSTEMS

Editorial

We now come to the AJHPWS's fifth edition.

This publication is one of the actions undertaken by the Latin American Working Group of IAHR's Hydraulic Machines and Systems Committee.

The fight in searching new papers and prestige from scientific community is incessant. An effective contribution for sustainable development is one of our purposes.

All our researches have the potential to promote scientific knowledge and to support new policies aiming the development of new technologies from the technical, social and economic point of view, in addition to subsidize sustainable development and the quest for a better future.

Thus, dissemination of knowledge, methodologies and procedures of physical phenomena scientific modeling and solutions to reach technological development is one of the groups' goals and consequently, of this journal.

In this case, this journal gradually becomes an eclectic vehicle within the limits of water resources and environment, if there are, and in addition it is interesting for the academy, considering that most part of papers come from research groups of several universities and research centers distributed in Brazil and Latin America.

This edition addresses several subjects such as: the project and building of a small hydropower plant aiming to become a learning tool for teaching and training of engineering students; suitability of an existing reservoir to operate as a mini hydropower plant, according to regulatory environment of not centralized micro generation in Brazil; comparative studies of methodologies for hydraulics transient calculation and finally, studies addressing management issues of water resources.

We do hope to contribute in any way in this direction. We look forward you to appreciate reading of selected papers for this edition of AJHWES.

Yours faithfully,
Geraldo Lucio Tiago Filho
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American Journal of Hydropower, Water and Environment Systems

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INSTRUCTIONS FOR AUTHORS

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All papers must be submitted in English. In case the author wants to translate the article through the journal all costs for the translation will be charged on the account of the author.

1. Formatting articles

1.1. Article structure

1.1.1 Subdivision - numbered sections

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

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All text of the manuscript must be located within a 170 mm by 252 mm rectangle of a white A4 page or within 170 mm by 240 mm for the letter format. The margins are given in Table 1. An example of the page format is given in Fig. 1

[Table 1]: Page margin for manuscripts.

Margin Position	Top	Bottom	Left	Right
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All text should be single spaced, black and in 12-point type. "Times News Roman" or a similar proportional font should be used. Total length 15 pages in Word.

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State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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Provide sufficient details to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

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Results

Results should be clear and concise.

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This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

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The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

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Within the text, references should be cited in numerical order according to their order of appearance. The numbered reference citation within text should be enclosed in brackets.

After the second edition all papers must have at least one reference of the American Journal of Hydropower, Water and Environment Systems.

Example: It was shown by Prusa [1] that the width of the plume decreases under these conditions.

In the case of two citations, the numbers should be separated by a comma [1,2]. In the case of more than two references, the numbers should be separated by a dash [5-7].

List of References. References to original sources for cited material should be listed together at the end of the paper; footnotes should not be used for this purpose. References should be arranged in numerical order according to the sequence of citations within the text. Each reference should include the last name of each author followed by his initials.

(1) Reference to journal articles and papers in serial publications should include:

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Sample References

- [1] Ning, X., and Lovell, M. R., 2002, "On the Sliding Friction Characteristics of Unidirectional Continuous FRP Composites," *ASME J. Tribol.*, 124(1), pp. 5-13.
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- [9] Smith, R., 2002, "Conformal Lubricated Contact of Cylindrical Surfaces Involved in a Non-Steady Motion," Ph.D. thesis, <http://www.cas.phys.unm.edu/rsmith/homepage.html>

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A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

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Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and',

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Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention there, as well as in the footnote. Ensure consistency of abbreviations throughout the article.

Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

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Present simple formulae in the line of normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text).

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SOFTWARE FOR GENERATING FLOW DURATION CURVES VIA REGIONALIZATION

¹Cordeiro, Adria Lorena de Moraes ; ²Blanco, Claudio J. C.; ³Silva, Raimunda da Silva e; ⁴Pessoa, Francisco Carlos Lira

ABSTRACT

Due to the lack of streamflow data in isolated regions, regionalization models have been used, including the simulation of flow duration curves. In this context, the proposed work aims to apply the software GCPV (Generator of flow duration curves) to generate duration curves. The software was developed in a graphical environment called NetBeans 8.0.2. It was performed with morphoclimatic characteristics of watersheds and regionalization models available in the literature and referring to the state of Pará. Software tests revealed its ability to simulate duration curves when compared those observed duration curves. Thus, basins lacking flow data, through the GCPV software, have an option to simulate flow duration curves for multiple water use projects, such as: hydroelectric power plants, irrigation, water supply, sanitation, water quality assessment and navigation.

KEYWORDS: NetBeans, Multiple Regression, Cubic Model, Amazon.

1. INTRODUCTION

Knowledge of flow data in a river basin is important, because it serves as a basis for planning and management of water resources. According to Gontijo Junior and Koide [1], in order for the streamflow monitoring network to be efficient, gauge stations must be installed in such a way that their density and spatial distribution in the region allow the determination of hydrological characteristics of a Region. However, Brazil has continental dimensions with a vast hydrographic network, making the densification of streamflow gauge stations to be no easy. Thus, in order to fill this gap, in relation to flow duration curves, numerous works have been produced, for example: Mendicino and Senatore [2] analyzed the performance of seven models of regionalization of flow duration curves for 19 basins in southern Italy, known as Calabria. For the definition of the regional models, they used multiple regression analysis. The statistical models showed good reliability. Yasar and Baykan [3] studied 72 streamflow gauge stations in Kansas - USA. The authors proposed a model to simulate flow duration curves, called EREFDC - Estimation of Regionalized Flow Duration Curve. The model is based on linear and nonlinear mathematical equations capable of predicting curve parameters based on variables such as: drainage area, annual mean precipitation, soil permeability, latitude and longitude. Booker and Snelder [4] constructed flow duration curves for 379 streamflow gauge stations located throughout New Zealand to investigate how parameterization and generalization methods are combined for regionalization at sites with no flow information. Multiple regression equations were applied and the regional model of generalized probability distribution of extreme values was the one that best estimated the duration curves. Costa et al. [5] performed a regionalization study of flow continuity curves for rivers in the hydrographic regions of Calha Norte and Xingu in the State of Pará. The authors tested the fit of 5 mathematical models of regression (power, exponential, logarithmic, quadratic and cubic), similar to the method of Mimikou and Kaemaki [6], and concluded that for the Northern Channel basins, the cubic model was the best fit. For the Xingu region, it was the exponential model that adjusted better.

Currently, there are several softwares for hydrological regionalization, for example, HBV hydrologic model (Seibert

and Vis [7]) was implemented in Python. This software has flexibility, computational efficiency, proven effectiveness under a wide range of climatic and physiographic conditions in the world in several previous regionalization studies. The self-written program of the model IHACRES using MS - Excel is used for the process of regionalization of flows in India (Javeed and Apoorva [8]). Saboia and Lopardo [9] presented the software "Regionaliza 2014", capable of producing some hydrological parameters for any region of the state of Paraná, Brazil. The software development was done in Python 2.7, what allows the execution of the source code in many operations systems (Windows, Linux, Mac OS, etc.) without modifications. The computational system coordinated by Euclides [10] represented a milestone in the creation of software to carry out studies in the area of flow regionalization. The Águas de Minas Digital Atlas is a complete and up-to-date mapping of the surface water resources of the State of Minas Gerais.

Flow continuity curves are tools of great utility in the face of hydrological and environmental problems related to multiple uses of water, such as hydroelectric projects, irrigation systems and water supply; Water quality assessment, navigation systems, among others (Blanco et al. [11], Castellarin et al. [12]). With flow duration curves it is possible to determine the percentage of time at which flow is equalized or exceeded (Vogel and Fennessey [13]). Therefore, the elaboration of the GCPV software to generate flow duration curves from regionalization models to locations without data records appears as the main motivation for the work. The GCPV is registered with the INPI (National Institute of Industrial Property) under number BR512016001080-0.

2. MATERIAL AND METHODS

2.1. Data

Software input data are morphoclimatic characteristics of the watersheds. The drainage area, A (km²) and the mean annual rainfall, P (mm), were obtained through the Hydrological Information System (<http://hidroweb.ana.gov.br/>) of the National Water Agency (ANA); the length, L (km) and the head, H (m), which were obtained by means of GIS. These data are the

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independent variables used in the cubic models of regionalization of flow continuity curves defined by Silva [14] through multiple regression, with the flows, $Q\%$ (m^3/s), the daily dependent variable. These variables are represented in Figure 1. The clustering of streamflow gauge stations, the first step for the regionalization of flows, was elaborated, taking into account the dimensions of the drainage areas of the basins, originating three clusters of watersheds in the state of Pará (Figure 2).

2.2. Regionalization and Software platform

The clusters are as follows: I with area of 465 to 15000 km^2 , II with area of 15000 to 55000 km^2 , and Cluster III with area of 55000 to 764000 km^2 . These clusters are characterized by Equations 1-12 (Silva [14]), where the parameters a , b , c and d (defined for each cluster via multiple regression between Q , A , P , L and H) are positive constants.

• Cluster I

$$a = -24,24 + 0,01A + 0,02P + 1,6P + 0,31 H \quad (1)$$

$$b = -260,1 + 0,02A + 0,1P + 4,84L + 1,88H \quad (2)$$

$$c = 4,06 + 0,04A - 0,03P + 4,7L + 2,79H \quad (3)$$

$$d = 214,68 + 0,03A - 0,11P + 1,25L + 1,32H \quad (4)$$

• Cluster II

$$a = 2,29 \cdot 10^{-8} \cdot A^{1,68} \cdot P^{0,88} \cdot L^{0,15} \cdot H^{0,07} \quad (5)$$

$$b = 1,28 \cdot 10^{-6} \cdot A^{1,51} \cdot P^{0,83} \cdot L^{-0,02} \cdot H^{0,09} \quad (6)$$

$$c = 7,68 \cdot 10^{-5} \cdot A^{1,2} \cdot P^{0,94} \cdot L^{-0,24} \cdot H^{0,04} \quad (7)$$

$$d = 0,005 \cdot A^{0,79} \cdot P^{1,06} \cdot L^{-0,47} \cdot H^{-0,05} \quad (8)$$

• Cluster III

$$a = 0,18 \cdot A^{0,83} \cdot P^{0,07} \cdot L^{0,11} \cdot H^{-0,04} \quad (9)$$

$$b = 0,27 \cdot A^{0,77} \cdot P^{0,25} \cdot L^{-0,03} \cdot H^{0,09} \quad (10)$$

$$c = 0,47 \cdot A^{0,78} \cdot P^{0,27} \cdot L^{-0,33} \cdot H^{0,23} \quad (11)$$

$$d = 0,31 \cdot A^{0,97} \cdot P^{0,04} \cdot L^{-0,85} \cdot H^{0,52} \quad (12)$$

Thus, after selecting the cluster, A , L , H and P are required and necessary for the calculation of the flow rates and the generation of the duration curve via cubic model (Equation 13). This model was the best among those tried by Silva [14] that also tested the power, exponential, logarithmic and quadratic models. The Figure 3 summarizes the regionalization utilized in this study.

$$Q_{\%} = a - b \cdot D + c \cdot D^2 - d \cdot D^3 \quad (13)$$

Where D is the duration in %, being divided into intervals defined by the user of the GPCV.

Where:

1. Selection of the cluster (I, II, II) according to the drainage area of the river basin without flow data;
2. Insertion of A , L , H and P of the catchment area without flow data;
3. Determination of the parameters a , b , c and d through Equations 1-12;
4. Calculation of $Q\%$ (Equation 13) in function a , b , c , d and D .
5. Generation of the duration curve.

Based on Figure 3, the software was created through the graphical development environment called NetBeans 8.0.2 (Figure 4). NetBeans is a fast and easy development system for Java, mobile and Web desktop applications as well as HTML5 applications with HTML, JavaScript and CSS. NetBeans is free and open source, as well as a large community of users and developers around the world [15].

3. 3. RESULTS AND DISCUSSION

3.1. Software presentation

In the initial screen (Figure 5), the user must inform which cluster belongs to the river basin without flow data.

[Figure 5: GCPV initial screen.]

After choosing the cluster, the software will open a window (Figure 6), in which the user enters the input data: A, L, H and P, which should be known to calculate the parameters (a, b, c and d). Then, with the calculated parameters, the user reports the durations (D) between 0% and 100%. With a click on the Graph Curve button, in the next open window (Figure 7), the flow duration curve is determined by cubic model (Equation 13).

[Figure 6: Data entry screen.]

[Figure 7: Output screen with flow duration curve plotted.]

3.2. Software test

The data of the hydrographic basin, whose flow rate is measured by Fazenda Rio Dourado Station (Code ANA 18480000), can be found in Figure 2 through its geographical coordinates, Latitude: -8: 19: 37 and Longitude: -51: 27: 37. The morphoclimatic characteristics of the basin are: A = 6860 km²; L = 241 km; H = 250 m; And P = 1827 mm (Silva [14]). Thus, the range of the drainage area to be chosen is the first (465 to 15000 km²), characterizing cluster I (Figure 8).

[Figure 8: Window for selection of the Group, to which the basin belongs as a function of the drainage area.]

After this step, the morphoclimatic characteristics of the basin are reported to the GPCV (Figure 9).

[Figure 9: Window with the morphoclimatic characteristics of the selected basin.]

With the insertion of the morphoclimatic characteristics, which are applied to Equations 1-4 of Group I, parameters a, b, c and d are calculated (Figure 10).

[Figure 10: Window for calculating parameters a, b, c and d.]

With the parameters a, b, c and d, the flows are calculated through Equation 13, inserting durations 0 to 100%, in intervals of 20% or least (Figure 11). These data are arranged in a table so that the user knows the points that are presented in the graph. Finally, just click the Graph Curve button (Figure 6) and the flow duration curve is plotted (Figure 12).

D (%)	Q
0	544.0
20	280.1
40	139.671
60	81.878
80	65.883
100	50.85

[Figure 11: Window with the presentation of the durations and calculated flows.]

[Figure 12: Simulated and observed flow duration curves of Fazenda Rio Dourado gauge station.]

Figure 12 shows the simulated and observed flow duration curves of Fazenda Rio Dourado gauge station. In this case, the observed curve was edited on the figure to demonstrate the potential of the software to simulate the observed curves.

4. CONCLUSION

Proposed software was able to simulate flow duration curves, proving to be efficient in its use for generation of these graphs. Therefore, the application of the software is important in the data simulation for regions needing hydrological information. Thus, areas without flow data have an option through GCPV to estimate flow duration curves for projects of multiple water uses, such as: hydroelectric power plants, irrigation, water supply, sanitation, water quality assessment and navigation.

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