

Flood Damping Curve Modeling by Flood Routing Method Using Visual Basic for Applications-VBA

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Abstract- This work aims to present a design proposal for a flood damping reservoir located in an urban area. The issue arises when factors linked to disorderly urban growth, coupled with local geographic limitations and poor environmental habits in society, bring to light serious effects such as those already observed in urban floods.

The *flood routing* method aims to draw an attenuated reserve effluent flow curve using as premises the potential area of the reservoir, the type and size of the discharge device, in addition to a Triangular Unit Hydrograph (HUT). Other hydrological data are also important for the survey.

With the information in hand the method proves to be effective for the design of simulation of an adaptive reservoir in any urban area, especially in the regions often beset by floods generated by the six watersheds enclave which are hardly drained naturally in rainy times severe.

Keywords- *Urban Drainage, Flood Routing, Flood, Damping*

I. INTRODUCTION

In the last century, humanity has witnessed its own acceleration of growth. This population explosion reflects an endless series of positive and negative consequences in the field of society, technology and the environment.

The increase in frequency and intensity of urban floods, caused in large part by this growth, is notorious. The disorderly expansion of cities combined with society's bad habit of irresponsibly disposing of its solid waste, which ends up being deposited along the drainage stretches, generate events that affect society deeply, paralyzing business, increasing expenses and, above all, dredging lives.

The inclusion of retention basins, also called buffer reservoirs, carries a series of advantages due to their multifunctionality. In the focus of this study, the attenuation of the runoff peak is emphasized, but one cannot fail to comment on the positive points such as the prevention of flooding, degradation of the slopes of the runoff channel, in addition to the control of erosion and eventual contaminant loads.

In this context, Pizzo (2004) reports that urban planning is done in an integrated and multidisciplinary way. Ignorance of this aspect can lead to a late, expensive and inefficient formulation of the local drainage system. In addition, the zoning of urban areas and an effective building code contribute significantly to increased permeability, thus reducing surface runoff.

However, the chaotic scenario that the manager p ú PUBLIC find is very complex. How to mitigate the effects of urban floods in already established scenarios? How to carry out drainage projects in relatively confined areas of urban centers without the need to displace more population.

This work seeks to lead to one of these solutions, creating a flood damping system that can be feasible and at the same time minimally impact its surroundings.

Floods, whether urban or not, exist naturally and occur periodically, for them, classify them as natural, but there are those called anthropic, which can be those that are created or expanded, directly or indirectly by the action of man.

According to Pena (2020), floods can start at home, due to the population's lack of education in misdirecting their garbage, which is very often found blocking the street collection systems and the micro - drainage system. [1] (According to (IAP 2020), micro-drainage is the system of rainwater conduits used in the scope of streets, which provides the occupation of urban space by an artificial form of drainage, adapting to the road circulation system.)

In addition, Canholi (2015) reports that only in the last 25 years the development of more innovative systems with regard to drainage projects occurred. Such designs generally nature, aimed slow wave runoff increasing the concentration time (t_c) and reducing the maximum flow (Q).

For this, it was necessary to model a system based on the flood routing method, where the construction of a reservoir. This method, according Siebra (2021) analogously to the method known as Puls, is in summary form in assuming that there is a direct relationship between storage volume and its effluent flow rate Q_e and that, independent of the tributary flow Q_a .

Vendrame (2005) points out that the more sense effect by the urbanization movement is the increase in peak flow, thus, the development of this work seeks to pave the prerogative of that planning and execution of a project and accurate reservoirs of amortization can prevent, or at least mitigate, the urban flood disasters that are frequently reported .

Canholi (2013) highlights a series of studies focused on the chaos of urban floods, predominantly in the municipality of São Paulo, by the way, a great example since the high population and urbanization coefficients greatly accentuate the acute effects of floods, potentiating them with greater economic damage and, mainly, human losses. As an example, the Flood Control Reservoir – RCC on Avenida Pacaembu; Espraiada/Brooklin Water Complex, Cabuçu de Baixo Córrego Basin, among others.

II. METHODOLOGICAL PROPOSITION

This work intends to present one computational application, this is, this paper aims to suggest a model generic tank sizing for full control s that can be adapted to any urban reality before reasonably viable input variables to be calculated.

In general terms, it is intended to propose the development of a generic and adaptable application in VBA – Excel (Visual Basic for Applications). The choice of VBA was due to its wide distribution in the market and its wide and well diversified bibliography for consultation. Furthermore, as it is a very small and simple file to be manipulated, it can be easily distributed in the market, both academic and professional.

As this is an application focused on urban implementation, initially, the survey of flood data from a given location was highlighted.

However, it is necessary to contextualize the situation as a way to immerse yourself in the problem. The studied region is composed of several smaller courses, tributaries of the Damping Equations

The application offers two ways to calculate the dimensioning, one of these ways is calculated when the dam is provided by a single rectangular spillway and the other when it is provided with an orifice, in this case, the system allows a series of multiple orifices whose sums of all their diameters equal the diameter of a single hole.

Initially, the Continuity Equation in the reservoir is presented, represented in the derived form as:

A. Equations

1) Continuity Equation

$$\frac{dv}{dt} = Q_a(t) - Q_e(t) \quad (1)$$

Then, it is integrated by the finite difference method, dividing the result into sufficiently small intervals (or periods).

2) Integrated continuity equation

$$\frac{V_{final} - V_{inicial}}{\Delta t} = \frac{Q_{a,inicial} + Q_{a,final}}{2} - \frac{Q_{e,inicial} + Q_{e,final}}{2} \quad (2)$$

Equation 2 is continuity equation integrated with mean interval values.

The continuity equation can be split into two, one used in dams with rectangular spillways and the other for dams provided with a single or multiple orifices. However, it is necessary to perform a replacement process within the continuity equation. This process is necessary to calculate the routing equation with known variables without knowing the final period effluent flow (Q_{ef}).

3) Flow equation in rectangular spillways

$$Q = 2 \times L \times \sqrt{h^3} \quad (3)$$

4) Flow equation in orifices

$$Q = C_d \times A \times \sqrt{2 \times g \times h} \quad (4)$$

5) Routing equation for rectangular spills

$$\frac{\Delta t}{2} (Q_{a,i} + Q_{a,f} - Q_{e,i}) + V_i = V_f + L \times \frac{V_f^{0,5}}{A^{0,5}} \times \Delta t \quad (5)$$

Equation 5 is general equation for weirs.

6) Routing Equation For Orifices

$$\frac{\Delta t}{2} (Q_{a,i} + Q_{a,f} - Q_{e,i}) + V_i = V_f + 1,269d^2 \times \frac{V_f^{0,5}}{A^{0,5}} \times \Delta t \quad (6)$$

Equation 6 is general equation for orifices.

where:

Q_{ai}: Initial inflow of the interval [m3/s]

Q_{af}: Final inflow of the interval [m3/s]

Q_{ei}: Initial effluent flow of the interval [m3/s]

Q_{ef}: Final effluent flow of the interval [m3/s]

V_i: Initial volume in the range [m3]

V_f: Final volume in the interval [m3]

L: Spillway width [m]

A: Reservoir area [m2]

d: Diameter [m2]

Δt: Range variation [s]

7) Multiple Equivalent Orifices

For the calculation of multiple orifices, it is necessary to find the equivalent smaller diameters, for that the relation of equation 3 is used.

$$d = D_{eq} \times \sqrt{Q_o} \quad (7)$$

where:

d: Single hole diameter [m]

D_{eq}: Equivalent diameter of the smallest orifices [m]

Q_o: Number of orifices [unit]

B. Calculation Method

The formulas of the spillways are, both the orifices and the spillways, having in their unknown structures that do not have conventional arithmetic solutions, thus, it was necessary to use

numerical analysis methods to achieve the desired result. In this situation, the Newton-Raphson method, developed by Isaac Newton in 1671 and improved by Joseph Raphson in 1686, was used, being much more simplified and easier to apply than the first.

The purpose of this article is not to clarify the Newton-Raphson method; however, it is important to emphasize the mechanism developed. According to Teixeira (2021), it is, therefore, a method of approximation of the root of an equation, so that it can meet the desired solution within a previously defined approximation margin. As it is an indirect method of solving, Newton-Raphson needs consecutive logical iterations to reach the result, which could be chaotic if calculated manually. Teixeira, in a simple way, elucidates very well how the process takes place, and the VBA, with its logical-mathematical calculation tools and functions, allows the process to proceed in a fast way without gadgets. However, it is necessary to allow to be elucidated here, minimally its execution.

It is known that the model divides the base flood time into a number of user-defined equal intervals. As previously mentioned, Oakes (1961) suggests a ratio between concentration time and normalization time, in the order of 1:1.5, that is, for 4 periods in t_c , there are 6 periods in the influent flow normalization phase, totaling 10 consecutive periods of analysis. It is noteworthy that the user can enter as many periods as desired. The Oakes Model is shown below, like this:

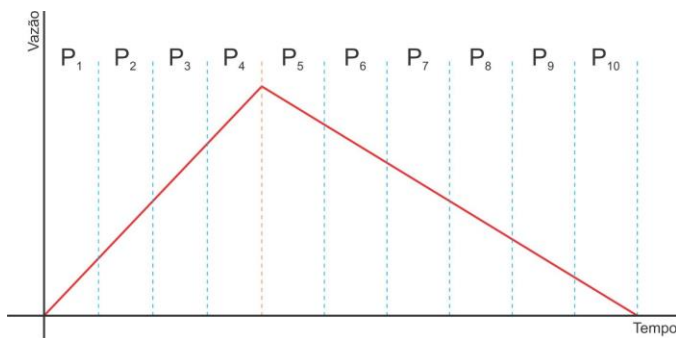


Figure 1. Division of the influent flow curve into periods

The principle of the damping model presented here is to define the final effluent flow in each period of time, however, for this it is necessary first to know the final volume (V_f), remembering that other quantities at the beginning of the calculation are known and system user-defined, such as:

- Period's initial influent flow (Q_{ai}): Defined as zero (0) in period 1.
- Final inflow of the period (Q_{af}): Defined through the Similarity of Triangles Theorem of Thales.
- Period's initial effluent flow (Q_{ei}): Defined as zero (0) in period 1

- Period initial volume (V_i): Set to zero (0) in period 1.
- Spillway width (L) or Orifice diameter (d): Defined by the project user
- Time interval: Defined by the system itself when dividing the number of periods.

Once the quantities are known, the appropriate equation for the type of spillway is chosen. The Newton-Raphson method requires that the equation be reduced to a single term, which is, set to zero. After this procedure, the first cycle of iterations starts where a first value and Final Volume of period (V_{f1}) is randomly indicated. This proposed model uses a specific routine to indicate an appropriate number according to the quantities existing in the calculated influent flow curve, however any value can be applied. The flowchart below, Figure 2, shows, in a simple way, the iteration process.

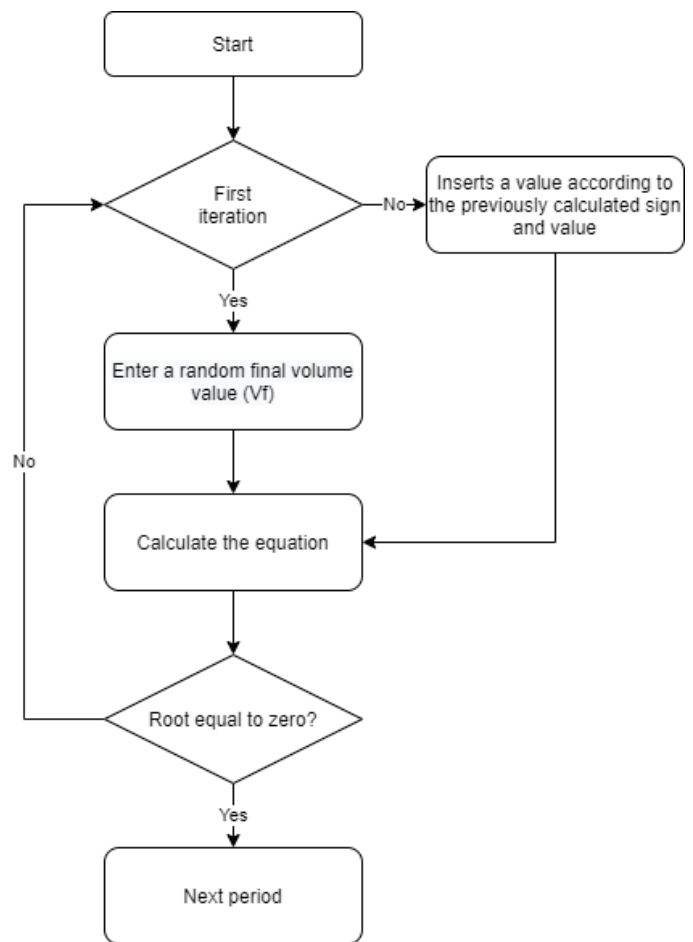


Figure 2. Newton-Raphson method iteration flowchart

Once the first cycle of iterations is finished, determining a volume with a root of zero, or a volume with a root close to zero, the application starts the second cycle of iterations, but with some observations. The main one is that the final values

of the previous cycle become the initials of the new cycle, exemplifying: $Q_{ef1} = Q_{ei2}$, $V_{f1} = V_{i2}$.

Once all the above-mentioned guideline has been carried out, the system enumerates the final effluent flow points (Q_{ef})

of each period and generates a graph relating the damped flow curve (Q_e) with the influent flow curve of the reservoir (Q_a).

Figure 3 shows the graphical result of one of these simulated dimensioning operations.

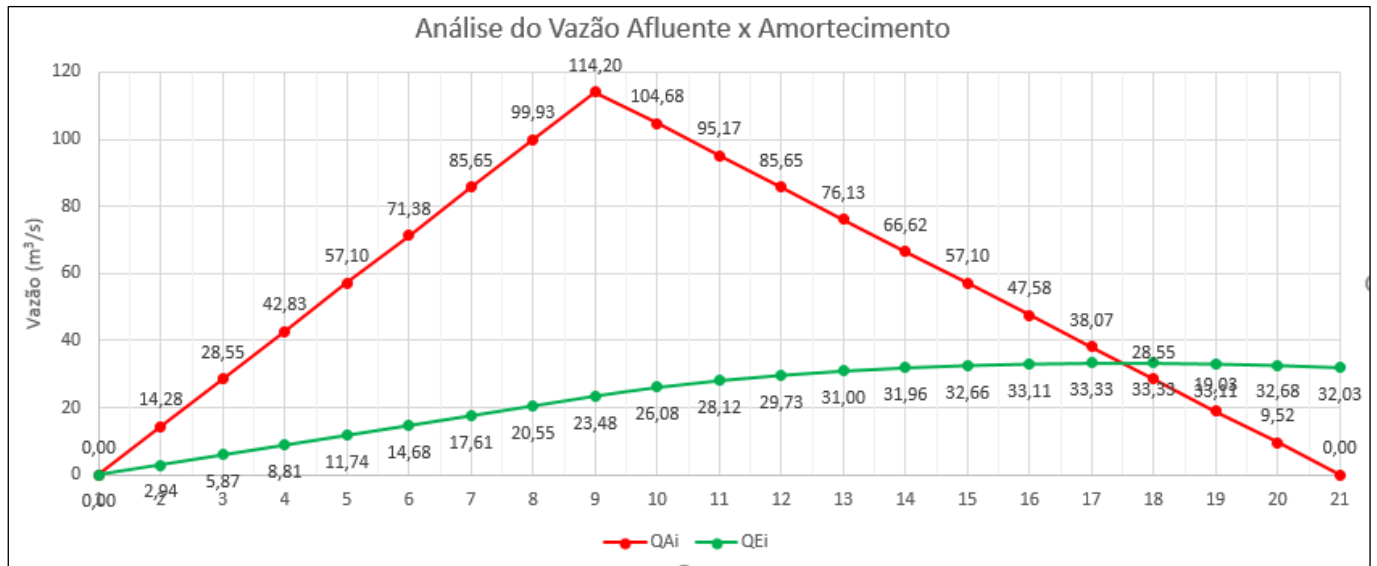


Figure 3. Graphical presentation of application output in VBA (red Q_a curve | Damped Q_e curve)

C. Equation and coding

According to Canholi (2013), it is necessary to determine the design rainfall, measuring the maximum flow peak that may flow into the thalweg, in addition, it is essential to capture the concentration times (t_c) in order to define two of the three points of the HUT (Triangular Unit Hydrogram). The author also mentions the survey of historical data for the preparation of IDF curves (intensity, duration and frequency) that help in the assembly of the HUT.

The third point, this determinant for the conclusion of the “triangle” is its base time, considered as the sum of t_c and the decay time of the influent flow curve (Q_a). This time is mentioned by Wilken (1978) and proposed by Oakes (1961) as the ratio of 1.5 of t_c .

Once determined the premises for determining the HUT, it becomes necessary to compile the mathematical code for a logical processing. In this aspect, Jelen and Syrstad (2014) found what many professionals experience in practice, that is, many programming languages are very complex or lack a series of logical libraries for the development of a functional code. In addition, there is a huge dependence of the technical and administrative areas on the information technology (IT)

sector for the preparation of reports based on data taken from large systems or with the manipulation of databases. In this regard, the authors raise major features of Visual Basic for Applications (VBA). Perhaps the main one is the intuitiveness in the elaboration of an efficient code, without depending on additional files or libraries for the operation. In addition, VBA brings other advantages such as an extensive and well-defined set of digital tutorials available for free on the internet; a large network of discussion forums where the exchange of experiences is really taken seriously; ease of distribution of the macro file due to the fact that it is a single file and the compatibility with the operating system, all originally Microsoft®.

At this stage, the application coding still needs some more information. In addition to peak flow (Q_p), base time and concentration time (t_c), the flood routing method needs additional data for its complete measurement. Therefore, a small Excel® spreadsheet was created (Figure 4) to capture input data such as the proportion number between the ascending and descending affluent flow, amount of ascending fractions, reservoir area (water mirror), type of discharge organ (which can be orifice or spillway), width of the spillway or, in the case of orifices, diameter and number of orifices.

| | A | B | C | D | E | F | G |
|----|---|-----------------|---------------------|---|---------------------------------|---------|---------------------|
| 1 | Cálculo da Capacidade do Reservatório de Amortecimento | | | | | | |
| 2 | | | | | | | |
| 3 | Dados de entrada | | | | | | |
| 4 | | | | | | | |
| 5 | Vazão de Pico (Q _p): | 114,20 | [m ³ /s] | | Capacidade de vazão do álveo: | 36,00 | [m ³ /s] |
| 6 | Vazão Afluente Inicial (QA): | 0,00 | [m ³ /s] | | Razão de Amort. Esperada (RA): | 31,5% | |
| 7 | Tempo de Concentração (tc): | 23:00 | [min] | | Altura máxima projetada: | 3,10 | [m] |
| 8 | Tempo de Base: | 1,5 | proporção | | Tempo de declividade de Qa: | 0:34:30 | [min] |
| 9 | Frações ascendentes: | 8 | | | Tempo total de cheia: | 0:57:30 | [min] |
| 10 | Área do Reservatório: | 30.000,00 | m ² | | Frações descendentes: | 12 | |
| 11 | Largura do vertedouro: | 2,00 | m | | Fração de tempo: | 02:53 | [min] |
| 12 | Tipo de descarregador: | Orifício | | | Fração de Q Ascendente: | 14,28 | [m ³ /s] |
| 13 | Diâmetro do orifício: | 0,80 | m | | Fração de Q Descendente: | 9,52 | [m ³ /s] |
| 14 | Quantidade de orifícios: | 12 | | | Altura máxima: | 2,92 | [m] |
| 15 | | | | | Vazão Máxima: | 33,33 | [m ³ /s] |
| 16 | | Rodar Simulador | | | Razão de Amort. alcançada (RA): | 29,2% | |

Figure 4. Data entry screen for running VBA

With all available assumptions, we proceed with the equation of the flood curve amortization, already calculated previously and demonstrated through the HUT.

III. CONCLUSIONS

The model proposed in VBA makes the entire sequence of cycles, one for each period determined by the user. Also, in its output data, it presents all the arguments used in the calculation of each cycle. Figure 5 shows some output values from one of the processes.

The algorithm model was calculated and compared with the mathematical calculations. The main output values present very

important information about: Influent/damped peak ratio; Fractional Influent Flow, Maximum projected height of the dam; Damped maximum flow. The model also compares the damped effluent flow with the alveo capacity and indicates if it still exceeds the drainage limit.

In addition, the model under tests proved to be efficient, adapting effluent flow to the desired capacity, in theory, preventing flooding.

In order for the model to be as competitive as possible with the real situations to be found, a routine for calculating equivalent diameters for multiple holes was included, in case a single hole proves to be inefficient or unfeasible.

| Fração | Tempo Inicial [s] | DT [s] | QA _f | QA _r | QE _i | V _i [m ³] | V _f | QE _f | K ₁ | K ₂ | Tentativa |
|--------|-------------------|--------|-----------------|-----------------|-----------------|----------------------------------|----------------|-----------------|----------------|----------------|-----------|
| 1 | 120 | 120 | 0,00 | 14,28 | 0,00 | 0,00 | 680,38 | 2,9353 | 6,75 | 856,50 | 22 |
| 2 | 240 | 120 | 14,28 | 28,55 | 2,94 | 680,38 | 2.721,51 | 5,8706 | 6,75 | 3.073,76 | 25 |
| 3 | 360 | 120 | 28,55 | 42,83 | 5,87 | 2.721,51 | 6.123,40 | 8,8059 | 6,75 | 6.651,78 | 26 |
| 4 | 480 | 120 | 42,83 | 57,10 | 8,81 | 6.123,40 | 10.886,05 | 11,7412 | 6,75 | 11.590,55 | 24 |
| 5 | 600 | 120 | 57,10 | 71,38 | 11,74 | 10.886,05 | 17.009,46 | 14,6765 | 6,75 | 17.890,08 | 25 |
| 6 | 720 | 120 | 71,38 | 85,65 | 14,68 | 17.009,46 | 24.493,63 | 17,6118 | 6,75 | 25.550,37 | 26 |
| 7 | 840 | 120 | 85,65 | 99,93 | 17,61 | 24.493,63 | 33.338,56 | 20,5471 | 6,75 | 34.571,42 | 27 |
| 8 | 960 | 120 | 99,93 | 114,20 | 20,55 | 33.338,56 | 43.544,24 | 23,4823 | 6,75 | 44.953,24 | 26 |
| 9 | 1080 | 120 | 114,20 | 104,68 | 23,48 | 43.544,24 | 53.703,55 | 26,0782 | 6,75 | 55.268,30 | 25 |
| 10 | 1200 | 120 | 104,68 | 95,17 | 26,08 | 53.703,55 | 62.442,59 | 28,1201 | 6,75 | 64.129,86 | 28 |
| 11 | 1320 | 120 | 95,17 | 85,65 | 28,12 | 62.442,59 | 69.820,22 | 29,73 | 6,75 | 71.604,38 | 27 |
| 12 | 1440 | 120 | 85,65 | 76,13 | 29,73 | 69.820,22 | 75.883,11 | 31,00 | 6,75 | 77.743,12 | 28 |
| 13 | 1560 | 120 | 76,13 | 66,62 | 31,00 | 75.883,11 | 80.670,38 | 31,96 | 6,75 | 82.588,17 | 28 |
| 14 | 1680 | 120 | 66,62 | 57,10 | 31,96 | 80.670,38 | 84.216,18 | 32,66 | 6,75 | 86.175,66 | 29 |
| 15 | 1800 | 120 | 57,10 | 47,58 | 32,66 | 84.216,18 | 86.551,31 | 33,11 | 6,75 | 88.537,77 | 27 |
| 16 | 1920 | 120 | 47,58 | 38,07 | 33,11 | 86.551,31 | 87.704,27 | 33,33 | 6,75 | 89.703,92 | 29 |
| 17 | 2040 | 120 | 38,07 | 28,55 | 33,33 | 87.704,27 | 87.702,07 | 33,33 | 6,75 | 89.701,69 | 25 |

Figure 5. VBA Output Analytical Report

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