

URBAN FLOODING EVALUATION FOR THE OSÓRIO CREEK SUB-BASIN VICINITY IN THE CITY OF MARINGÁ-PR, BRAZIL

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ABSTRACT: The main reason of urban flooding in the Brazilian cities is the deficient urban planning, which includes the design of the drainage systems and the occupation of the land in the watersheds. The urban floods are sources of socioeconomic problems to the local population. They can propagate diseases and offer risk to people's lives in the affected areas. The aim of this study is to develop a computational model to perform simulations of different flood scenarios. A case study was carried out for the district of Porta do Céu in the city of Maringá-PR, Brazil. Field data was collected and the inconsistencies were corrected. The model was implemented by using Bentley® SewerGEMS® v8i software. Three scenarios were analyzed and the results demonstrated that the current drainage network is underestimated. However, it is possible to execute structural and non-structural measures for flood mitigation in the region.

Key Words: Scenarios in urban drainage. Urban flooding. Structural control measures. Non-structural control measures. Computational modeling in urban drainage.

1. INTRODUCTION

The urbanization process has been occurring over the years, more steeply, thereby leading to the need to establish appropriate measures for the urban rigging to ensure the population a better quality of life.

With urbanization, issues also came to be resolved which did not exist before, such as urban drainage, since there is, in traditional urbanization, an increased rate of waterproofing, creating the need to transport the rainwater which traditionally filtered into the soil.

Pinto and Pinheiro (2006) point out that urban drainage should be understood as a system which collects, transports and makes the final release of surface water from the rainwater. The measures that comprise this system aim to risks reduction and losses arising from flooding.

This process, when it is not performed adequately, results in the occurrence of flood and flooding, generating social and economic losses in these regions.

Among the causes of urban flooding has the technical gap of professionals, the regulation lack of the impacts transfer within cities, the limited knowledge of decision-makers on the subject, the production of sediment transported during rainfall as a result of urbanization and occupation and allotment of risk areas (TUCCI, 1998, 2007).

Therefore, it follows that will always need an overview of the flooding, caused by urbanization in order to effectively fight its causes and consequences, since any action, when taken in an isolated way, have the desired effect regarding urban flooding (Pedrosa, 1996).

In the city of Maringá at Parana State, have been observed that the urban flooding increasingly frequent in certain areas. In the outfall stream called Osorio, comprising Porta do Céu allotment and its surroundings, there are serious flooding problems of which it is known, cause flooding of streets, erosions, ruins in structures and disposal of waste and dirt transported during rainfall. With this, the inhabitants of this region are more likely to contract waterborne diseases, in addition to all the economic and psychological damage.

One of the main indicators of urban development is the drainage density, while the main hydrological indicators of urbanization are the impermeable area and concentration time (TUCCI, 2007). Similarly, it is possible to measure qualitatively the importance of drainage systems and impermeable areas in accordance with the comparison of the magnitude of urban development indicators. The urban planning in the establishment of construction standards for district indirectly establishes these standards.

Small areas of study, the determination of impermeable areas from aerial photographs is more practical than most methods that use data from satellites (Sleavin et al., 2000 apud Esteves, 2006).

Another method emphasized by Esteves (2006) is the correlation coefficient, which is used coefficients of impermeability. These coefficients, determined from several accurate measurements of impermeable areas, are related to the use and occupation of the soil classes and indicate the average impermeability of classes. After the determination of the coefficients, the use of the method is practical, through the use of tables, and more work is restricted to determining the areas of each use and occupation of soil class. However, the use of these coefficients in areas with characteristics different from those where they were determined can cause significant errors. The Table 2.1 illustrates the choice of coefficients.

Table 2. 1 - Impermeability coefficients depending to the type of soil use (SCS, 1986)

Use and occupation of the soil class	Impermeable percentage (%)
Urban districts	
Commercial	85
Industrial	72
Residential districts, depending to medium size of the lots	
≤ 506 m ²	65
1012 m ²	38
1349 m ²	30
2023 m ²	25
4047 m ²	20
8094 m ²	12

Esteves (2006).

To Tucci (2007), the water balance changes in urban watershed due to waterproofing and channelling. The change of the balance can be observed in the volumes of the main hydrological processes of the hydrological cycle and in the hydrograph that characterizes the temporary dynamics of the flow output.

Tucci (2007) exemplifies the changing volumes of water balance in accordance with the following:

- Increased volume of runoff due to Soil sealing;

- Reduced groundwater recharge. With the reduction in infiltration due to sealing, the aquifer tends to decrease the groundwater level due to lack of recharge, reducing groundwater flow;
- Due to the replacement of natural hedge by impermeable areas occurs a reduction in evapotranspiration, as the urban area does not retain water in vegetation and does not allow the evapotranspiration.

The IDF equations are obtained by a series of data intense rains, sufficiently long and representative of interesting place.

Intense rain is an event where there are large rainfall volume in a relatively short time interval. For the definition of the IDF equations, are analyzed, through adjustments of extremes probability distributions, the maximum annual rainfall observed for each duration (Silveira, 2010).

The most representative work for different Brazilian regions in determining the intensity-duration-frequency relationships was presented by Pfafstetter (1957) for 98 weather stations throughout Brazil, based on partial series.

If there are no IDF equations, empirical equations could be used, as developed by Bell (1969) based on data from different countries or by Uehara et al. (1980), who used data obtained by Pfafstetter Otto (1957). Obviously, the accuracy of the results can not be compared to values obtained with observation data of study area. Therefore, serve as an estimate, since it was chosen to use the IDF curves.

The IDF equation of Maringá city is described in equation (01).

$$i = (2085 \times Tr^{0,213}) / [(10 + Td)^{1,09}] \quad [1]$$

Where:

i – intensity (mm/h);

Tr – return event (years);

Td – duration time(minutes)

Font: Fávaro et al (2000)

2. MATHEMATICAL MODELING

2.1 Concepts

According to Dourado Neto et al. (1998) and Detomini (2004) modeling is coming from an area of knowledge called systems analysis, and can be defined as an organization of particular interest attributes, which aims to conceptualize, integrate and generalize scientific knowledge through the simplification of reality, and that results in an auxiliary tool for simulations of various scenarios.

As pointed out by Jorgensen (1994) and Tundisi (1999), the use of models has played an important role in the planning and development of alternative scenarios that include the proper diagnosis of water systems in its structure, process and dynamics. From this point of view, Azevedo et al. (1997) affirm that the mathematical simulation models provide the response of a system to a set of input information, including decision rules, allowing the decision maker to examine the various scenarios consequences of an existing system or of a system design.

2.2 Gradually Varied Flow (GVF) – Rational (StormCAD)

The Gradually Varied Flow (GVF) model - Rational (StormCAD) used in SewerGEMS software characterizes network analysis and simulation using flow through the rational method. The simulation uses the subarea data on the basis of peak factor, the concentration time, size of the subarea, runoff coefficient and basin slope.

When the flows are determined, the hydraulic pressure is determined using methods of gradually varied flow.

2.3 Structural and non-structural measures

Control measures in the entire basin involve flood control through structural and non-structural measures, which are hardly dissociated. Structural measures involve costs that most cities do not have the resources to face and should be minimized. The politics of flood control can certainly reach structural solutions to some places, but within the overall vision of the entire basin, where it is rationally integrated with other preventive measures (non-structural) and made compatible with urban development (TUCCI, 2005).

To Filho et al. (2006), structural measures consist of physical engineering measures designed to deflect, hold, reduce or drain faster and lower levels of direct water runoff, thus preventing damage and disruption of activities caused by flooding. Involve, mostly, hydraulic structures with massive investment of resources. However, they are not designed to provide absolute protection, because these would be physically and economically viable in most situations.

For non-structural measures, the same author affirm that, as the name implies, do not use structures that change the waters flow regime of direct runoff. They are basically represented by measures to control the use and occupation of soil (in wetlands and basins) or to reduce occupants vulnerability of areas at risk from the effects of floods. In the latter search for ways for these people start to get along better with the phenomenon and be better prepared to absorb the impact of physical damage caused by the floods. The non-structural measures often involve, cultural aspects that can make it hard its implementing in the short term. Public involvement is essential to the success of this implementing (Filho et al., 2006).

3. METHODOLOGY

The design of Maringá urban structure derived from a modern urban project, designed by architect and urbanist Jorge Macedo Vieira, who identified with the "Garden City" and the "Athens Charter" guidelines, aiming at a harmonious development (MORO, 2003)

With the continuous occupation process in the city, the areas which until then weren't belong to the initial tracings of the city were being occupied. The urban perimeter increased, consequently it was no exception to the occupation of the stream Osorio (SESCO et al, 2010) basin. Thus, it was emerged existing neighborhoods in the stream basin Osorio, from the 1970s, intensified in this occupation from the year 2000, where it currently has almost entirely urbanized.

The occurrence area of problems described in this work is characterized by the early part of the outfall stream Osorio, reducing to an influence area of approximately 2.3 km² (Figure 1)

The red polygon highlighted in Figure 1 shows the boundaries of the sub-basin that influences the occurrence of floods in the study area. The blue circle is located in the central focus region of this research study.

Among the physical environment aspects of the region, the main soils that can be found in Maringá are red latosol and red nitosol, which have clayey to very clayey texture (EMBRAPA, 1999).



Figure 1: Influence area of region affected by floods

3.1 Study Definition

Data collection had initially implemented through research of the rainfall characteristics of Maringá region, proceeding by IDF equation (Intensity, Demand, frequency) of the city. It was performed the physical characterization of the river basin, with subsequent surveys upon the Municipality of Maringá, of the existing projects in this region.

After these surveys, it was proceeded to input of data step in an analysis and sizing software Bentley® SewerGEMS®. To validate a simulation was performed, in which all the characteristics described in the original drainage design, such as recovery time, infiltration coefficient, diameters, depths of the existing mesh, quantity and position of the catch basin were adopted. Then, It was observed that the drainage systems adopted in the project coincide with the simulation results.

Then it was proceeded to conduct hypothesis test, simulating scenarios, such as modification assessment of recovery times, reviewed the modification coefficients of infiltration, physical changes of pipes, and also a quantitative analysis of the runoff volume generated.

For the simulations it was taken into account the infiltration coefficient of 0.68, the same physical conditions of pipes (slope and depth of project) collection capacity in the catch basin fully opening and maximum flow in pipe 75% value diameters of the project.

Among the possible scenarios, it was restricted to just recovery times of 5 and 10 years, since it is known that these are the most useful for small networks modeling of urban drainage.

It is assumed that through checks made by satellite images and site visits of the study, there is a considerably higher percentage of impermeable area. By Tucci (2007) research, a region of the São Paulo city – Brazil was studied, with high level of waterproofing showed a ratio of approximately 70% impermeable. This data was used for the simulations, thus proposing a more unfavorable condition for the existing current situation.

4. RESULTS AND DISCUSSION

After initial simulations, to validate the model, it was possible to verify that the network upstream of this allotment could not sufficiently meet the region, thereby causing excess water during rainfall, drain for study allotment. As a solution, it was chosen to perform the modeling and possible solutions only of the allotment Porta do Céu by economic issues.

The simulated scenarios were:

- Scenario 1 – Recovery Time 5 years;
- Scenario 2 – Recovery Time 10 years;
- Scenario 3 – Retention of 10% in lots;

Both scenario 1 as the 2 had the same stretches of exceeding the capacity of the network flow. Figure 2a shows highlighted in red, the portions with higher flow. The excess flow in the upstream network, incorporated in A and B were 31.83 L.s^{-1} and 1511.72 L.s^{-1} respectively, for Scenario 1, and 94.37 L.s^{-1} and 2200.93 L.s^{-1} in respective points for Scenario 2.

Scenario 3 showed a reduction in flow due to the retention of flow part in lots, in the peak flows. The excess flow in the upstream network, incorporated in A and B were 34.06 L.s^{-1} at point A, while at point B was 1538.19 L.s^{-1} . Figure 2b shows highlighted in red, the upper stretches of the network capacity throughput in scenario 3.

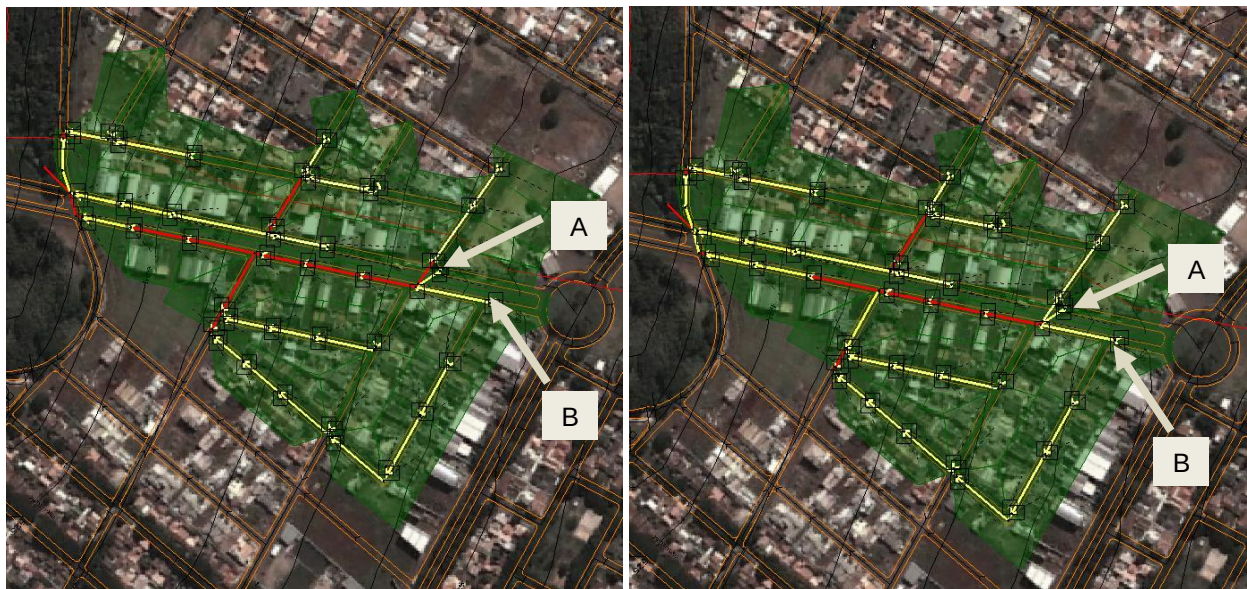


Figure 2a and 2b: Drainage network of the allotment Porta do Céu, in Scenario 1

After the simulations, it was also been possible to draw up profiles of parts with excess flow and check the energy grade and hydraulic grade line. Figure 3 shows the portions profile analyzed. Figures 4, 5 and 6 show the profiles of the main part affected by precipitation in simulations of scenarios 1, 2 and 3, respectively.



Figure 3: Portions main profile analyzed

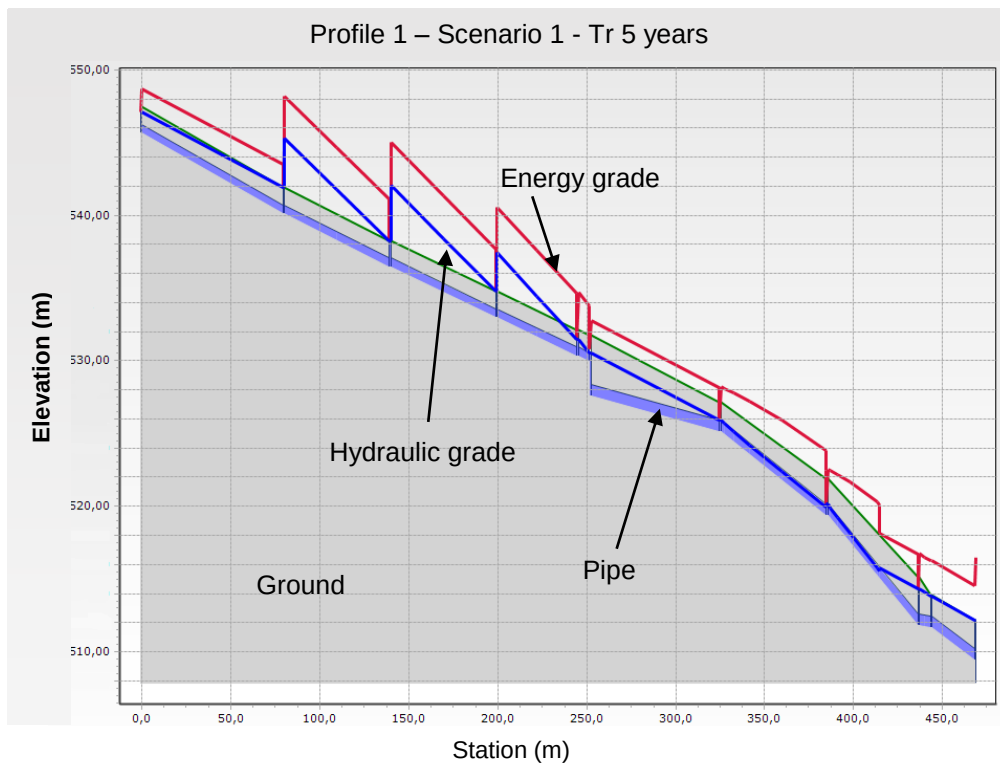


Figure 4: Profile generated in Scenario 1

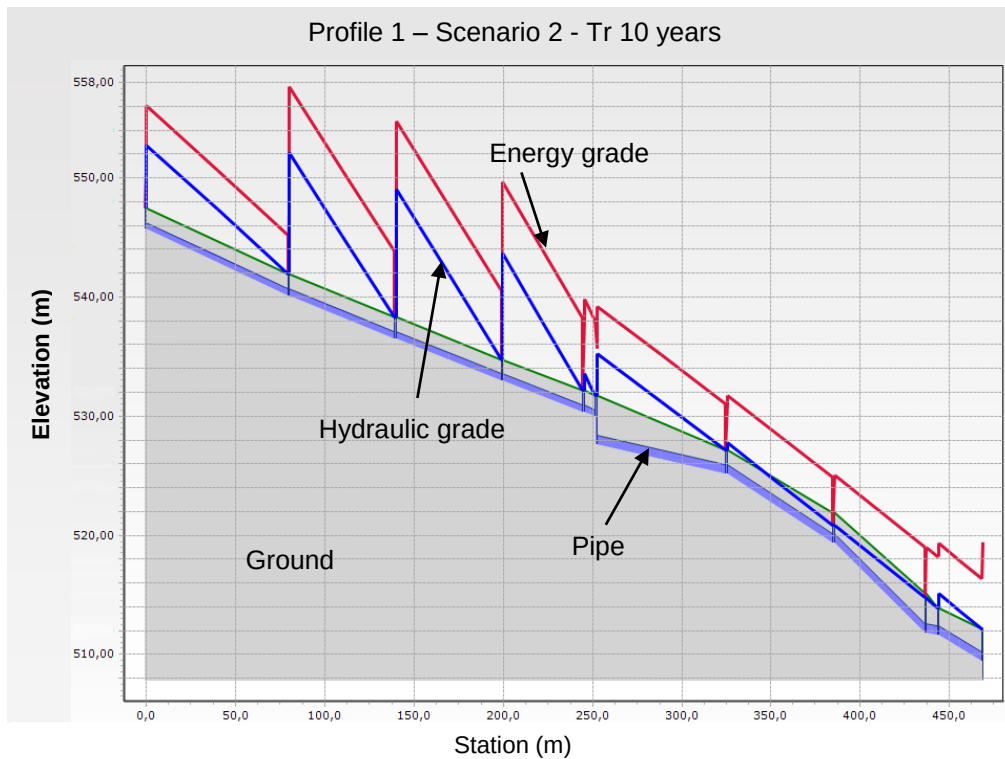


Figure 5: Profile generated in Scenario 2

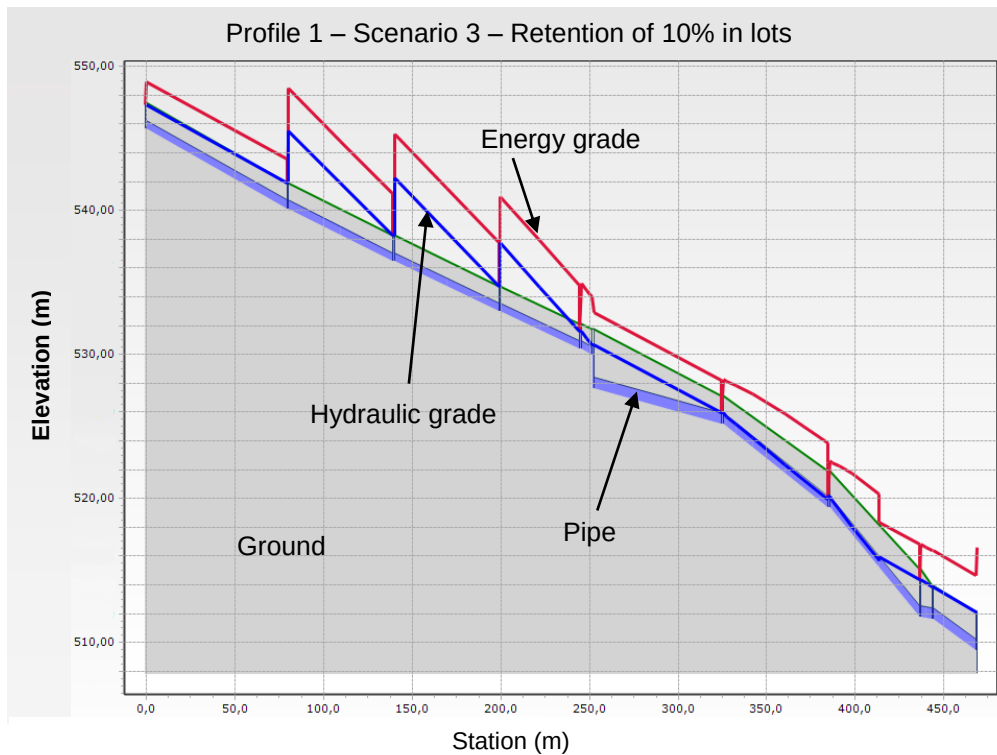


Figure 6: Profile generated in Scenario 3

After the analysis of scenarios 1, 2 and 3, it was possible to draw a surfboard design for each scenario with the necessary modifications. Scenarios 1 and 3, by having in the end of the simulations,

approximately equal flows and coincide with the diameters of their pipes, they were described in a single plank. A table (1) in which to benchmark changes the legs between simulated scenarios and the current situation was also prepared.

Table 1 - Comparison between the existing situation and proposed scenarios.

CURRENT SITUATION x SCENARIO 1 x SCENARIO 2 x SCENÁRIO 3							
Runnoff (C) - 0,68				CURRENT	SCENÁRIO 1	SCENÁRIO 2	SCENÁRIO 3
Conduit	Start	Stop	Length (m)	Diameter (mm)	Diameter (mm)	Diameter (mm)	Diameter (mm)
TR-27	PV-17	PV-81	11,6	400	800	800	800
TR-32	PV-80	PV-17	59,1	400	600	600	600
TR-37	PV-40	PV-41	4,9	400	600	600	600
TR-45	PV-31	PV-26	71	400	400	600	400
TR-53	PV-08	PV-31	48,5	400	400	600	400
TR-57	PV-21	PV-80	7	400	400	600	400
TR-63	PV-26	PV-99	29,3	400	600	600	600
TR-64	PV-83	PV-84	7	600	800	1.000	800
TR-65	PV-81	PV-90	101,5	600	800	800	800
TR-66	PV-34	PV-88	59,7	600	800	1.000	800
TR-68	PV-87	PV-83	45,7	600	800	1.000	800
TR-69	PV-88	PV-87	59,7	600	800	1.000	800
TR-72	PV-82	PV-51	4,6	600	1.000	1.000	1.000
TR-73	PV-46	PV-41	6,4	600	800	800	800
TR-74	PV-44	PV-82	6,7	600	800	800	800
TR-75	PV-48	PV-85	8,2	600	800	800	800
TR-76	PV-51	PV-86	23,5	600	1.000	1.000	1.000
TR-77	PV-53	PV-44	39,6	600	800	800	800
TR-80	PV-55	PV-53	50	600	800	800	800
TR-83	PV-41	PV-55	65,8	600	800	800	800
TR-84	PV-85	PV-46	70,7	600	800	800	800
TR-87	PV-93	PV-01	7	800	1.000	1.200	1.000
TR-88	PV-01	PV-92	24,7	800	1.000	1.200	1.000
TR-89	PV-92	Saída-13	39,9	800	1.200	1.200	1.200
TR-91	PV-95	PV-93	51,5	800	1.000	1.200	1.000
TR-93	PV-96	PV-95	60	800	1.000	1.200	1.000
TR-94	PV-86	PV-84	68	800	1.000	1.200	1.000
TR-95	PV-84	PV-96	72,8	800	1.000	1.200	1.000
TR-98	PV-99	PV-34	4,3	400	600	600	600
TR-99	PV-100	PV-101	4,6	400	600	600	600
TR-132	PV-136	PV-117	7,6	600	800	800	800
TR-134	PV-117	PV-137	34,7	600	800	800	800

Based on informations obtained in the Municipality of Maringá and with the information that the drainage network projects in allotments that are approved in the municipality must be designed to recovery time of 10 years, it was tested the model in order to ensure their validation.

The parameters adopted were recovery time of 5 years, duration time of 10 minutes and rainfall runoff coefficient of 0.50.

Thus it was investigated that for the calculation model, the diameters found corresponded to the same existing in the project. It is useful to remember that some diameters obtained were slightly lower, eg, diameter of 525mm. However, as this is commercially impractical size, it was adopted the nearest higher dimension, which is the diameter of 600mm, coinciding with the existing pipe.

Because it is a software in its student version, the number of tubes that can be analyzed and sized is limited, so the entire network has been divided into 2 parts. One part was characterized by the drainage network of the study allotment and the other part by the upstream drainage network, which has no interconnection. The volume of excess water drainage network upstream was added to the allotment studied. This methodology was applied to all scenarios studied.

5. CONCLUSIONS

In this simulation, it can see that the existing network, both upstream watershed, as in the allotment in question, are undersized, as the existing network was simulated as having been designed with C of 0.5, and verified at the time validation of the model, which is characterized as a region of 50% impermeable area.

Another important issue to make is over the initial sizing of these networks, therefore, because it is drainage systems installed decades ago, mainly chains upstream watershed, the recovery period adopted, according to the Maringá Municipality informations, it was a TR of 5 years, and it is possible to find, routinely, in the most recent projects, the adoption of 10 years for TR.

To solve the existing problem of flooding in this region, the adoption of 10% retention in lots proved to be technically feasible. Although no economic/financial analysis of the proposed scenarios has been performed, it may be noted that Scenario 3, adopting retention in lots, it was obtained results of identical diameters to Scenario 1, even having adopted TR of 10 years for scenario 3 against TR of 5 years for Scenario 1.

With the analyzes and comparisons in Scenario 3, it was possible to verify that the exchange of 1029 meters network should be necessary, corresponding to 34% of 3027 meters of allotment drainage network, it would be required to support all that demand, adopting for this retention 10% in lots.

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