THE USE OF SWMM SOFTWARE FOR THE MANAGEMENT OF SUSTAINABLE URBAN DRAINAGE

A UTILIZAÇÃO DO SOFTWARE SWMM PARA A GESTÃO DA DRENAGEM URBANA SUSTENTÁVEL

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Abstract: The present work presents a study performed in the hydrographic basin of the Figueira Stream located in the city of Umuarama-PR, with the intention of reducing surface runoff and expanding the storage of urban waters to minimize the current environmental problems, such as silting and erosion. The main objective is to implement LIDs (Low impact development) devices known in Brazil as low impact urban development and with the help of the Storm Water Management Model - SWMM software, to simulate the behavior of urban waters considering the real situation and comparing them with the simulation with insertion of LIDs. As a methodology, an in loco survey was performed, followed by two simulations. The first simulation considered the data from the in loco survey. We observed that the basin is not prone to flooding, but there is a great possibility of erosion and silting. In the second simulation, we inserted three types of LIDs: filtration basin; porous pavement and infiltration valleys. The data was analyzed and the behavior of urban waters was compared. Our study observed an improvement in water balance and flow propagation. Finally, we understood that with the implementation of the LIDs the results generated were satisfactory, in the sense of providing solutions to improve the environmental problems installed in the basin, consequently promoting improvement in the quality of urban life.

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Keywords: Low Impact Development – LID. Simulation. Environmental Problems

Resumo: O presente trabalho apresenta um estudo realizado na bacia hidrográfica do Córrego Figueira localizado no município de Umuarama-PR, com intuito de redução do escoamento superficial e ampliação do armazenamento das águas urbanas para minimizar os problemas ambientais presentes, tais como assoreamento e erosão. O principal objetivo é implantar dispositivos LIDs (Low impact development) conhecido no Brasil como desenvolvimento urbano de baixo impacto e com o auxílio do software Storm Water Management Model – SWMM, simular o comportamento das águas urbanas considerando a situação real e comparando-as com a simulação com inserção dos LIDs. Como metodologia, realizou-se o levantamento in loco, seguida de duas simulações. A primeira simulação considerou os dados provenientes do levantamento in loco. Observou-se que a bacia não tem propensão a inundações, porém tem grande possibilidade de erosões e assoreamento. A segunda simulação, fez-se a inserção de três tipos de LIDs: bacia de filtração; pavimento poroso e vales de infiltração. Analisou-se os dados e realizou-se a comparação do comportamento das águas urbanas. Observa-se melhoria no balanço hídrico e propagação de fluxo. Por fim, compreendeu-se que com a implantação dos LIDs os resultados gerados foram satisfatórios no sentido de proporcionar soluções para melhoria dos problemas ambientais instalados na bacia, consequentemente promover melhoria na qualidade de vida urbana.


1 INTRODUCTION

This paper aims to analyze the characteristics of the Figueira stream hydrographic basin, located in the urban area of the city of Umuarama-PR, with the main objective of investigating environmental degradations, such as: erosion and silting. Using Storm Water Management Model - SWMM 5.0 software to simulate proposals for low-impact urban development (LID), in order to reduce the amount of runoff and increase the volume of storage and infiltration.

Due to the consequences of human actions on the environment, it is important to be aware that urban construction affects the natural water path, because this landscape is modified daily, such as the removal of vegetation that dramatically changes the hydrological cycle, increasing surface runoff. Other examples are disordered constructions and the factors of planned urbanization, such as paving streets and waterproofing the land by civil construction (SILVA, 2011).
Based on hygienist thinking, a consequence of the measures taken since the last century, in order to improve the cleanliness and hygiene of the urban environment, many plans were not concerned with the possible environmental problems that these actions could cause, mainly downstream. This fact is confirmed by the rates of erosion, silting and pollution of rivers, in addition to the frequency of floods. (TUCCI, 1997).

In view of the above, proper planning is needed to prioritize topographic issues, the water system, peculiarities of the urban environment and mainly to adopt a new way of thinking that uses sustainable development for the management of urban drainage.

This new thinking consists of conservationism, that is, it aims to conserve the maximum amount of water in the urban environment and direct it to filtration and infiltration, with the aim of reducing the volume of water from urban drainage sent downstream. Finally, minimizing environmental impacts, such as: silting, erosion, river pollution, among others (BAPTISTA, 2011).

In order to reduce the conflicting aspects caused in the environment through urbanization, it is suggested to work with applications of techniques of natural drainage systems. According to Souza et. al. (2012) this system is recognized as a low impact urban development method that has become a reference in America as LID (Low Impact Development); in Australia as WSUD (Water Sensitive Urban Design) and in the British bibliography as SuDS (Sustainable Drainage Systems).

2 NATURAL DRAINAGE SYSTEMS: LOW IMPACT URBAN DEVELOPMENT (LID)

Natural drainage systems with the term low-impact urban development (LID) began to be implemented from the 1980 in Seattle in the United States, as a management plan for stormwater, enabling the development of green infrastructure
through of bio-retention cells, which retain part of the rainwater that would be drained, for proper infiltration and filtration (SOUZA et al. 2012).

Canholi (2005) understands that this type of technique reserves the precipitated waters, typically used for residential lots and circulation routes, with the objective of reducing the peaks of the flows that propagate in the drainage network, creating the opportunity to recharge aquifers and in the case of cisterns, the possibility of reusing these stored waters.

In the view of Souza et. al. (2012) low impact urban development techniques (LID) provide an improvement in the quality of urban life and the environment, as they allow the improvement of the local microclimate, thus reducing the volume of surface runoff from precipitation, in addition to making spaces greener and more attractive urban areas.

The management of these natural drainage systems can be performed by the SWMM (Storm Water Management Model) software, which was used for the development of this work, using the low impact urban development term (LID), because the SWMM software also uses it that way.

2.1 SWMM software as an aid to urban drainage management

The Storm Water Management Model (SWMM) software was developed during 1969-71 by the U. S. Environmental Protection Agency (USEPA) for the qualitative and quantitative simulation of runoff from small basins. This software presents several tools, allowing the insertion of real data from a hydrographic basin and the simulation of the behavior of these rainwater and the possibility of flooding.

In recent years, SWMM has been the focus of studies that seek to reduce degradation in river basins and was translated into Brazilian language by the Federal University of Paraíba as an Urban Drainage Management Model.

Another important tool is Low Impact Device Control (LID), which, when deployed in the sub-basins, aims to store, infiltrate and evaporate the water from
urban drainage, thus reducing the volume of water that reaches downstream points. (USEPA, 2012).

3 METHOD

The studies developed in this paper served to verify the situation of urban drainage in the hydrographic basin of Córrego Figueira. Based on the methodology of Ronquim et. al. (2015) the paper was developed in 3 stages.

1° Stage - Characterization and delimitation of the study area: an on-site survey of the hydrographic basin of Córrego Figueira was developed, with the purpose of determining the physical characteristics of the basin, for insertion in the software.

2° Stage - delimitation and discretization of the sub-basins to carry out the simulation; two simulations were performed, aided by the SWMM 5.0 software: in the first simulation, the data obtained through the on-site survey (real data) were inserted and the possibility of flooding was verified; in the second, the following LIDS were inserted: filtration basin; porous pavement and infiltration ditches.

3° Stage - results: finally, the simulation was performed and the results were analyzed to verify the efficiency of the implanted LIDs.

4 RESULT AND DISCUSSION

4.1 Characterization and delimitation of the study area

The city of Umuarama is located in the northwest of the state of Paraná, with approximately 109,000 inhabitants, with a population density of 81.7 inhab./km² (IPARDES, 2019), being the 17th city in the state in terms of population based on the census of 2010 IBGE, this municipality has been consolidating itself as an important urban pole in the Northwest of Paraná.

Due to the growing population increase, the urban area and, consequently, the impermeable area are expanded, causing a significant increase in the volume of rainwater, which in turn quickly reaches downstream points, contributing to
environmental degradation, such as erosion, pollution, silting of rivers, among others.

In order to carry out this study, the area of analysis was considered to be one of the regions that receives the drainage from the city’s urban drainage. The research is limited to the hydrographic basin of the Córrego Figueira (Figure 1) (one of the headwaters of rainwater drainage planned since the initial route of the city) that passes through Lake Aratimbó, empties into the Pinhalzinho stream, and finally flows into the Goioerê River, one of the tributaries of the Piquiri River. This hydrographic basin has an elongated shape, and its drainage occurs as a ramification.

**Figure 1** - Figueira Stream Hydrographic Basin, located within the urban perimeter of the city of Umuarama-PR

![Location of the Figueira Stream Hydrographic Basin](image)

**Source:** Author, 2020

As physical aspects, the hydrographic basin of Córrego Figueira has a perimeter of approximately 12.59 km, an area of approximately 8.18 km² and its main bed is about 4.6 km. The altitude at the highest point of the basin is 490 meters and the altitude in the exutory is 361 meters above sea level, that is, the hydrographic basin has 129 meters difference in level. At the 410-meter level there is the presence of an artificial lake called Aratimbó lake, executed in the middle of the year 2000, with the main purpose of revitalizing a degraded area and receiving rainwater runoff.
The results indicated that the basin has a low probability of flooding, considering that the value found for the form factor was 0.39, which indicates a low propensity to flooding. After the on-site survey, it was found that the Figueira Stream and consequently the lake are silted up and upstream erosion is observed, in addition to the presence of turbid waters, as shown in Figures 2 and 3.

Considering that the study area presents serious environmental problems, such as: silting and erosion, it was decided to delimit the sub-basin with a new exutory in the Aratimbó lake. In order to mitigate the problems encountered, the SWMM software was used to assist in the management of urban waters, with the main interest of inserting LIDs devices in the sub-basin in order to minimize the amount of runoff. With the diagnosis it was observed that on rainy days there is overflow of the rain gutter, however there is no presence of flooding in the urban environment.

4.2 Simulations

4.2.1 Simulation 1: considering the data in loco

After delimiting the Figueira Stream sub-basin and creating the new exutory on Lake Aratimbó, it made the discretization in 11 sub-basins, as shown in Figure 4. Their respective zonings were analyzed. Then, the study area was modeled using the SWMM 5.0 software, as shown in Figure 5.

Source: Authors, 2020

Revista Mundi Engenharia, Tecnologia e Gestão Paranaguá, PR, v.5, n.7, p. 283-01, 283-14, 2020
DOI: 10.21575/25254782rmetag2020vol5n71117
In this paper, it was decided to insert three types of LIDs and because it is a microdrain study, the Return Time of 50 years was considered. The pluviometric data were selected from the formula of Intensity Duration and Frequency - rain IDF for Umuarama-PR (Equation 1), defined by Fendrich (2003), where the TR = Return Time (years) and t = rain duration (min).

\[
I = \frac{1752,27 \times TR^{0.14}}{(t + 17)^{0.840}}
\]  

(1)

The calculations were performed using the alternate block method to determine the design rain, with a time interval of 5 minutes. Then, the Hietogram graph (mm) for Umuarama-PR was generated, as shown in Figure 6. Among the various options to be configured for the simulation, the Dynamic Wave Flow and Green-Ampt
propagation model was selected for infiltration, and thus the first simulation was carried out.

Figure 6 - Project Hietogram for Umuarama-PR.

![Hietogram for Umuarama-Pr (mm)](image)

Source: Authors, 2020.

Table 1 presents the water balance data. It is observed that the water balance presents minimum storage and high amounts for runoff. Table 2 shows the continuity of the flow propagation, it is observed that the external effluent is the amount of water that flows out of each sub-basin.

<table>
<thead>
<tr>
<th>Table 1 – Water balance before LID implantation</th>
<th>Table 2 – Flow Propagation Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydric balance</strong></td>
<td><strong>Flow Propagation Continuity</strong></td>
</tr>
<tr>
<td>Before LIDs Implementation</td>
<td>Before LIDs Application</td>
</tr>
<tr>
<td>Volume $\times 10^4$ (m$^3$)</td>
<td>Volume $\times 10^4$ (m$^3$)</td>
</tr>
<tr>
<td>Height (mm)</td>
<td></td>
</tr>
<tr>
<td>Total Precipitation</td>
<td>Affluence Rainy Season</td>
</tr>
<tr>
<td>16,41</td>
<td>16,09</td>
</tr>
<tr>
<td>69,830</td>
<td></td>
</tr>
<tr>
<td>Infiltration losses</td>
<td>External Effluence</td>
</tr>
<tr>
<td>0,37</td>
<td>16,07</td>
</tr>
<tr>
<td>1,597</td>
<td></td>
</tr>
<tr>
<td>Surface runoff</td>
<td>Internal Effluence</td>
</tr>
<tr>
<td>16,67</td>
<td>0,00</td>
</tr>
<tr>
<td>70,910</td>
<td></td>
</tr>
<tr>
<td>Final Surface Storage</td>
<td>Storage Losses</td>
</tr>
<tr>
<td>0,02</td>
<td>0,00</td>
</tr>
<tr>
<td>0,077</td>
<td></td>
</tr>
</tbody>
</table>

Revista Mundi Engenharia, Tecnologia e Gestão Paranaguá, PR, v.5, n.7, p. 283-01, 283-14, 2020
DOI: 10.21575/25254782metg2020vol5n71117
There is a significant amount of surface runoff and the amount of the final stored volume is irrelevant. In view of the results obtained stored and in order to improve the water balance, it was decided to perform a new simulation with insertion of the LIDs.

4.2.2 Simulation 2: considering the applications of LIDs devices.

Based on the data obtained, it was decided to insert three types of LIDs: filtration basin, porous pavement and infiltration ditches. To determine the number of LIDs inserted in each sub-basin, the management instrument: Municipal Master Plan was searched for the amount of permeable area that each sub-basin should have.

According to the Umuarama Master Plan (2018) the zonings diagnosed in the study area and their respective permeable areas were: Trade and Service Zone 1 (ZCS1) and Trade and Service Zone 2 (ZCS2) has a permeability rate of 20 %; Residential Zone 2 (ZR2) and Residential Zone 3 (ZR3) have a 25% permeability rate.

After research in the Umuarama Master Plan, it was determined that each sub-basin would receive 3 types of LID, an average of 8% for filtration basin, 7% for porous pavement and 3% for infiltration ditches, totaling an average of 18 % of LIDs deployment. This percentage was stipulated to guarantee a greater amount of storage and infiltration.

Subsequently, checking all the data entered, it was possible to run the simulation and analyze the profiles and status reports. Thus, Tables 3 and 4 were created to present the data obtained by the state report, where Table 3 presents the values for Water Balance after the implementation of the LIDs. It can be seen that there were improvements in the results of the water balance, in relation to the runoff and there was a reduction of 17%. Table 4 shows the continuity of the flow propagation with the application of LIDs, in which there were also improvements in external effluent, with a reduction of 17%.
Table 3 – Hydric balance before LID implementation

<table>
<thead>
<tr>
<th>Hydric Balance</th>
<th>After LIDs implementation</th>
<th>Flow Propagation Continuity</th>
<th>After LIDs Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume x10^4 (m³)</td>
<td>Height (mm)</td>
<td>Volume x10^4 (m³)</td>
</tr>
<tr>
<td>Total Precipitation</td>
<td>16.41</td>
<td>69.830</td>
<td></td>
</tr>
<tr>
<td>Infiltration losses</td>
<td>1.38</td>
<td>5.873</td>
<td>13.32</td>
</tr>
<tr>
<td>Surface runoff</td>
<td>13.87</td>
<td>58.972</td>
<td>13.28</td>
</tr>
<tr>
<td>Final Surface Storage</td>
<td>1.28</td>
<td>5.443</td>
<td>0.04</td>
</tr>
</tbody>
</table>

A satisfactory result was obtained for flood control for rain with a 50 year return time. The nodes and conduits were not overloaded. It is observed that with the implementation of the LIDs controls there was an improvement in the water balance, a decrease in the surface runoff and an increase in the water storage.

In several cities there are studies on the management of urban drainage using the SWMM software, each with its specificities. As for example, the studies carried out by Ronquim et al. (2015) and Nunes et al. (2017) who managed the watershed, with application of LIDs, aided by the SWMM software.

The study by Ronquim et al. (2015) developed drainage management in the Rio Lajeado hydrographic basin in the municipality of Palmas-PR, in which macrodrainage was used, using storage and control units with LIDs in the simulations. Each sub-basin had an average of 20% next to the LIDs treatments, where infiltration ditches were used in the rural area, and in the urban area 10% with filtration basin and 10% with porous floors. This simulation generated satisfactory results for flood control and improvement in the river's water balance.
Nunes et. al. (2017) in his study of urban drainage management in the Rio Morto watershed in the municipality of Rio de Janeiro-RJ, he only appropriated the application of a green roof as an LID device and considered that the impact of the implementation of green roofs would have great benefits if the basin were densely urbanized.

In the hydrographic basin of the Córrego Figueira, an average of 18% of LIDs device control was inserted: infiltration ditches (3%), filtration basin (8%) and porous pavement (7%), thus opting for the same LIDs used in the study by Ronquim et. al. (2015). It was possible to observe that these controls provide satisfactory results, which help to improve the water balance. Unlike Nunes et. al. (2017), in this study there was no interest in working with green roof type LIDs.

From the virtual simulation with the application of 3 types of LIDs, it was observed that the reduction in runoff was 17% and that there was a significant increase in the amount of storage and infiltration. These techniques used for simulation are relatively simple and easy to apply, and can be implemented both in urban lots, as well as in circulation areas and free spaces to the public.

5 FINAL CONSIDERATIONS

The use of SWMM with the application of LIDs (filtration basin, porous pavement and filtration ditches) allowed an overview of the possibility of reducing runoff, expanding the amount of water stored and implementing these systems in urban life.

The interesting thing about this proposal is that it allows the stored water to infiltrate and filter naturally, with a tendency to recharge aquifers. These techniques allow urban waters to behave more closely to the natural. This is expected to reduce runoff, and also reduce erosion and siltation that plagues the watershed and degrades, not only streams and lakes, but also the environment of cities.
For future work, it is suggested that simulations be performed including other LID techniques, such as cisterns and green roofs. Finally, it is proposed that this study be associated with environmental education work with the general population, professionals and municipal management to understand and adopt these techniques in urban lots, in the circulation of pedestrians and public open spaces.

ACKNOWLEDGMENTS: Thanks go to the Federal Institute of Paraná (IFPR) Campus Umuarama for providing the opportunity to participate in the project entitled “Diagnosis of drainage management and urban landscape of the hydrographic basin of the Figueira stream in Umuarama-PR” financed by the CNPQ / IFPR scholarship.

REFERENCES


Edição Especial - I SISU (Simpósio Interdisciplinar de Sustentabilidade)
Enviado em: 24/02/2020
Aceito em: 10/11/2020
Editores responsáveis: Otávio Akira Sakai e Diane Belusso