

River Revitalization in the Context of Urban Stormwater Management: the Case of Acari River Basin, Brazil

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ABSTRACT

Acari River basin, in Rio de Janeiro city, Brazil, is an urban watershed densely populated with formal and informal settlements. The river basin suffers of environmental degradation, illegal riverine occupations, river banks erosion and siltation, which worsens flood consequences. Considering the concept of river revitalization, this work aims to propose a set of distributed measures over the urban landscape along Acari River, using a hydrodynamic computer model, to analyze the system behavior during the occurrence of floods and to forecast future scenarios, with flood control measures to revitalize river functions. Results showed frequent water levels higher than 0.50m for large areas in the present situation and, in the worst regions, extreme flood levels of 2.00m. Considering the introduction of revitalization measures, it was possible to see the damping of the flood peak in more than 1m. In various areas, the river stopped to overflow for the design rainfall. In this context, proposed revitalization measures showed satisfactory results in reducing the rates of flooding. However, they weren't enough to eliminate the negative impacts generated by urban floods. Larger areas for detention measures and relocation of people from risky areas are problems to be faced in the context of the basin revitalization.

KEYWORDS

River revitalization; urban storm water management; mathematical modeling; MODCEL

INTRODUCTION

Acari River basin, in Rio de Janeiro city, Brazil, consists of an urban watershed with a drainage area of about 107 km². Figure 1 shows a plan view of this basin, with an indication of the main river and its tributaries.

Acari River is one of the largest water courses of Rio de Janeiro. Its spring is located at Gericinó mountain and, together with Pavuna River, it forms São João de Meriti River, which flows into Guanabara Bay. The river crosses several significant avenues as, for example, Brazil and Automóvel Clube avenues and an important highway named President Dutra.

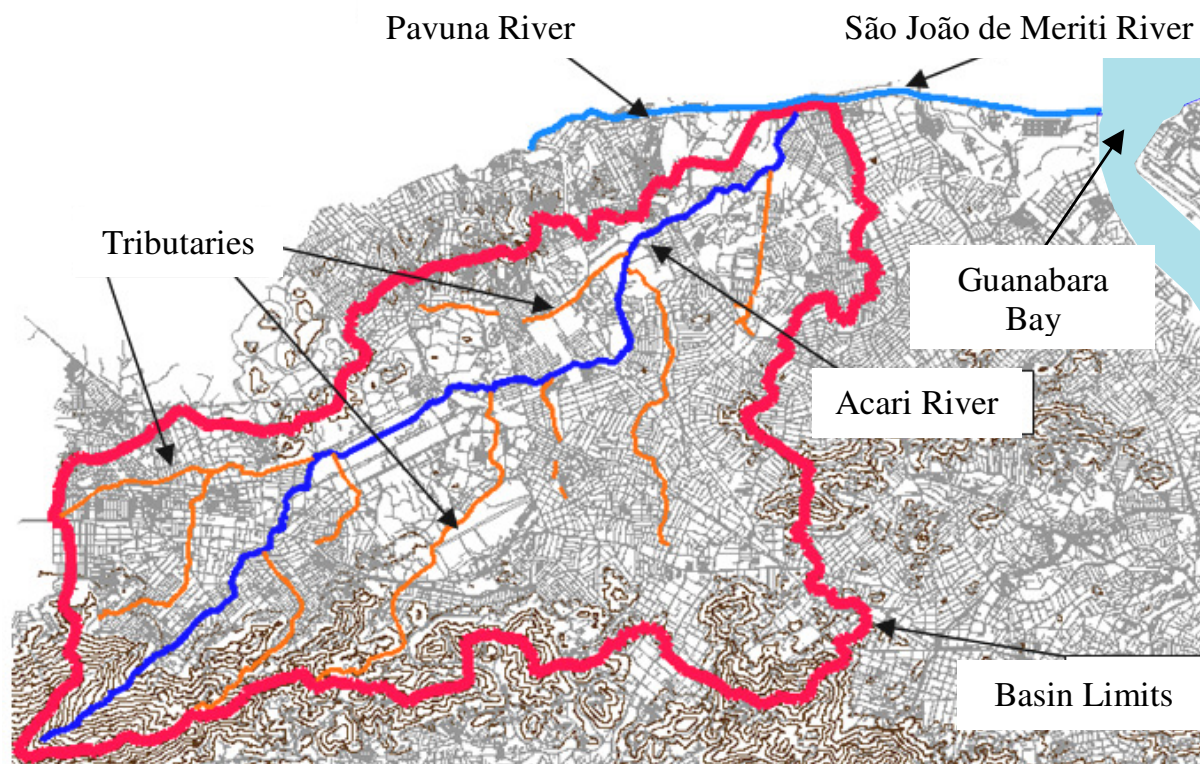


Figure 1: Acari River basin and the main drainage network.

Acari River plains are densely populated by medium and low-income people, with several informal settlements. The river basin suffers from severe environmental degradation, with illegal riverine occupations, lack of sanitation, river banks erosion and siltation, in several different places. This situation worsens flood consequences in the basin.

The growing interest in river revitalization motivates an emerging trend in river restoration programs worldwide. However, implementation of these programs to the specific case of urban rivers involves a greater complexity. The methods used, the learned lessons and the results of river restoration process in less disturbed regions, such as rural and natural landscapes, are not directly transferable to highly urbanized areas, where the surfaces are more impervious and there are considerable changes in their geomorphologic, hydrologic and ecologic characteristics (Herzog *et al*, 2010).

Considering the concept of revitalization of areas near water courses, this work aims to propose a set of distributed measures over the urban landscape along Acari River, in order to retard the peak flow, allow the groundwater recharge and try to restore approximately the natural flow conditions.

RIVER REVITALIZATION

It is known that self-sustaining river systems provide important ecological and social goods and services to human life (Postel and Richter, 2003 *apud* Palmer *et al.*, 2005). River revitalization is an issue that comes as a necessity to face the progressive deterioration of river ecosystems worldwide.

There are many definitions, from different authors, about river restoration. This study will adopt the one presented by González del Tánago & García de Jalón (2007). According to these authors, river restoration can be understood as being a set of activities directed to give back to the river its structure and behavior as an ecosystem according to processes and a dynamic that is equivalent to its natural conditions, or the one set as the reference of good ecological condition.

Although this discussion still has many uncertainties, there are several examples of European and American rivers that were submitted to revitalization. The results can be analyzed not only from the aesthetic viewpoint and to improve the environment, but also in terms of hydrologic and ecologic functioning of restored river reaches, increasing the quantity and quality of river resources and their potential use to riverine population (González del Tánago & García de Jalón, 2007). Some examples can be cited, as the Thames River, in England (Hill, 2010), the Isar River, in Germany (Arzet, 2010) and the Cheonggyecheon River, in South Korea (Noh, 2010).

In urban areas, river revitalization is more complex, because of the large modifications suffered by the riverine areas, with the construction of buildings and roads, which make it difficult to have the space needed to recover the natural processes of the river bed and its banks (González del Tánago & García de Jalón, 2007).

River revitalization in urban environments has its main focus on the restoration of the lateral connectivity with the river banks and its tributaries, the restoration of the river natural flow regime, as well as the increase of the degree of freedom of the river. Urban water courses restoration is a challenge for managers, researchers, experts and citizens.

The combination of Flood Risk Management (FRM) concepts with river revitalization measures can be a solution of efficient applicability in urban rivers, in comparison with traditional and localized drainage solutions (Jormola, 2008). Thus, what is expected is the creation of a self-sustainable natural river system, in order to maintain the flood control function after the flow patterns restoration.

The presented river revitalization concepts were used as an alternative to reduce the negative impacts of recurrent floods in areas near the Acari River.

METHODOLOGY

In the present study, it was used a hydrodynamic computer model, MODCEL (Mascarenhas and Miguez, 2002), to analyze the behavior of the system during the occurrence of floods and to forecast future scenarios, where flood control measures were proposed. These measures vary from linear parks, greenways, detention basins, combined in multifunctional landscapes, in order to revitalize river functions.

To evaluate the effectiveness of the proposed interventions, in terms of reducing the problems caused by flooding in Acari River basin, trying to restore the approximate natural flow conditions, the following steps were followed.

- (1) Diagnosis of the existing drainage system, using MODCEL.
- (2) Identification of the critical areas, not only in terms of flooding but also in terms of river degradation, with the definition of those that should receive revitalization measures.

- (3) Definition of revitalization measures to be installed.
- (4) Simulation of the modified scenario, with MODCEL.
- (5) Comparative analysis between the results of the simulated scenarios (current and modified ones).

After the evaluation of the present scenario of Acari River basin, and the critical areas, it was chosen a varied typology of urban parks, which focus on the adoption of green infrastructures as flood control measures.

The implementation of linear parks is an alternative for the traditional investment on programs of urban water courses canalization (Medeiros and Magalhães Júnior, 2009). The inclusion of these parks in urban areas may incorporate a set of revitalization measures along rivers, which mainly aim to reduce the incidence and effects of floods, the erosion, the sedimentation and to prevent the advance of irregular occupation of riverbanks.

Figure 2 shows the proposed revitalization interventions along Acari River.



Figure 2: Localization of the proposed revitalization interventions along Acari River.

The considered urban parks typology consists of different definitions of parks which have different functions (Carneiro, 2006):

- **Urban River Park** – Longitudinal parks with the purpose of protecting water course banks, also avoiding their irregular occupation by low income population.
- **Urban Flooding Park** – Longitudinal parks, purposefully deployed in areas with low elevations, to allow frequent inundation, which will help to laminate floods.

- **Urban Environmental Park** – Large parks, flat or not, with the purpose of environmental preservation and land use valuing, with the aim of minimizing runoff generation.

To better analyze the results, some control points were elected, as indicated in Figure 3 and detailed in Table 1. These control points were chosen to cover the spatial distribution of the flooded modeled area.



Figure 3: Control points and intervention sites along Acari River.

Table 1. Localization of the control points

Control Point	Localization	
	Site	Neighborhood
1	Cel Phidias Távora Avenue	Pavuna
2	Automóvel Clube Avenue	Pavuna
3	Arnaldo Guinle Street	Coelho Neto
4	Cajatuba Street	Honório Gurgel
5	Safiras Street	Honório Gurgel
6	Leocádio Figueiredo Street	Guadalupe
7	Luis Coutinho Cavalcanti Street	Guadalupe
8	Loasa Street	Deodoro

The recurrence time adopted for calculating the design rainfall was 20 years and the duration of the rain coincides with the concentration time for the Acari River basin. It was adopted different runoff coefficients: 0.2 in park areas, 0.5 for edifying areas and 0.7 for zones that are densely occupied. Flooding areas on the Urban Flooding Parks were lowered in 1.5m.

RESULTS AND DISCUSSION

Simulated results showed that most of the areas had water level higher than 0.50 m for the present situation, which is considered critical. Some regions had extreme flood levels,

between 1.50 m and 2.00 m (FUNDAÇÃO COPPETEC/UFRJ, 2006 and Miguez *et al.*, 2009). Figure 4 shows the peak flood obtained for both the current and the modified scenarios. The adopted measures can be an important tool to minimize the flood problem by reducing peak flows.

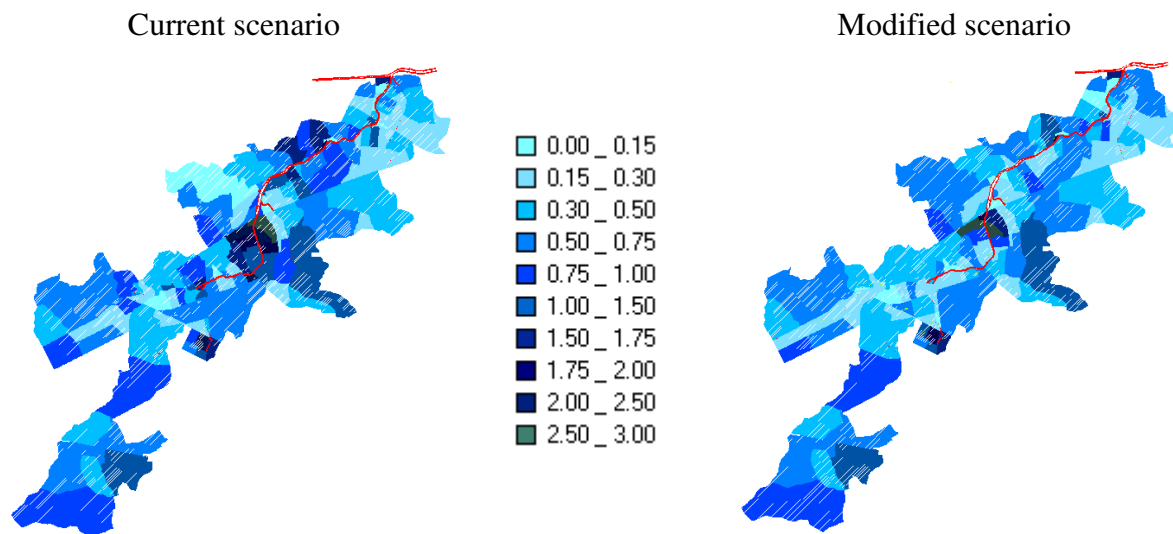


Figure 4: Flood map for current and modified scenarios at Acari River basin.

It was noted the improvement of the basin in general, resulting in flood reduction, with the introduction of green areas and flooding parks in different places over the entire basin. In some areas, it was possible to see the damping of the peak flood in more than 1 m in the water depths. In some other sites, the river did not overflow for the design rainfall considered.

Table 2 shows a comparison between the flood levels on the current and on the modified scenario, after the implementation of the revitalization interventions. This Table discriminates flood depths for each control point.

Table 2. Flood levels comparison.

Control Point	Localization	Flood depths (m)	
		Current scenario	Modified Scenario
1	Cel Phidias Távora Avenue	0,27	0,03
2	Automóvel Clube Avenue	1,54	0,68
3	Arnaldo Guinle Street	1,19	0,12
4	Cajatuba Street	1,16	0,43
5	Safiras Street	2,13	0,58
6	Leocádio Figueiredo Street	0,51	0,12
7	Luis Coutinho Cavalcanti Street	0,70	0,21
8	Loasa Street	1,31	0,31

It was observed, from the results, a good reduction of flood depths in areas that previously had a high level of flooding. Some areas, such as those represented by the control points number 5, 6, 7 and 8, had the maximum flood elevation reduced in approximately 70%. Some other areas had a reduction of more than 80% (control points 1 and 3).

Even with significant improvements, there are still important flooded areas in the basin. This may be due to the limitation to find larger amounts of storage areas in the basin, considering the great urbanization on this region. The worsening of the problem could lead to the need of the implementation of more drastic measures to protect the urban areas. In some cases, some communities located near the river, in risky areas, may need to be relocated. This could help to minimize damages and open more space for river and urban revitalization.

CONCLUSION

The proposed revitalization measures showed satisfactory results in reducing the rates of flooding at Acari River basin. However, they weren't enough to eliminate the negative impacts generated by urban flooding, as it could be expected. In this case, the critical urban problems, related to disordered and, sometimes, irregular land use and occupation need to be treated in a broad sense and the city itself has to be rethought.

For the realization of a complete revitalization process, in a broad sense and in accordance with the original concept, it would be necessary to remove many buildings and even infrastructure works that currently exist in the floodplains. This type of proposal, in general, will not be feasible for high urbanized areas, especially in developing countries with limited resources for investment. The river revitalization process needs to be discussed in a particular way for urban areas and a consensus solution between the natural landscape and the built environment must be found.

In highly urbanized areas of Acari River basin, the available areas for interventions are scarce, there are numerous socio-economic problems, which make the revitalization process very complex, because it involves the need of large riparian areas, in order to find space for the river recover its natural course and flooding areas. However, even if these riparian areas were restored to the original natural condition, the heavy modifications that the basin suffered over the time would probably lead to floods still happening. Thus, the space that would be required to recover the river course today is greater than the natural one. Actions in the basin have to be considered, to decrease the impermeability and to rescue superficial retentions, with the use of reservoirs.

The revitalization interventions proposed, however, even configuring an only partial revitalization, are important. In addition to reducing the peak flood, they help in the dissemination of this kind of techniques and provide a new perception about the existence of the river for the community involved. They also allow the river valuing and reintegration as part of urban landscape. Finally, it should be pointed out that any process of revitalization takes time to be fully developed and find itself complete. It is necessary to await the responses of the environment, regarding the "new" conditions to which it will be submitted. During this time, complementary actions, resulting from the monitoring of this evolution may and should be developed.

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